# STABILITY INVESTIGATIONS ALONG THE ORDU PERIPHERAL HIGHWAY (KM: 21+000 – KM: 40+114)

**A THESIS SUBMITTED TO**
**THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES**
**OF**
**THE MIDDLE EAST TECHNICAL UNIVERSITY**

**BY**

**EVRİM SOPACI**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF**

**MASTER OF SCIENCE**

**IN**

**THE DEPARTMENT OF GEOLOGICAL ENGINEERING**

**DECEMBER 2003**

Approval of the Graduate School of Natural and Applied Sciences

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## ABSTRACT

### STABILITY INVESTIGATIONS ALONG THE ORDU PERIPHERAL HIGHWAY

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December 2003, 652 pages

The Eastern Black Sea Region of Turkey accommodates indecent residence conditions for people owing to ground conditions comprising mainly of volcanics and concurrent flysch, and its related irregular geomorphology. One of the important difficulties in this region is transportation. Accordingly, the Ordu Peripheral Highway which encompasses various structures such as, open-cuts, bridges, viaducts and junctions and double tubed tunnel sections which will be driven in these geological and geomorphological conditions is planned to be constructed.

In regional scale, volcanics, pyroclastics and flysch deposits often intertongue with each other even over very short distances. The accurate determination of the shear strength parameters of these lithologies is vital for the assessment of portal slope stability and support design in regards to tunnel design. Rock mass classification systems, namely, RMR, NGI Q system and GSI, have been employed to obtain the rock mass shear strength parameters. Stress analysis around the tunnel openings has been executed through employing 2D finite element analysis in an attempt to design tunnel support. The results of the finite element analysis have been correlated with the results obtained from the empirical methods. The overall analyses and interpretations led to the determination of the support systems to be employed during tunnel construction.



KEYWORDS: Black Sea Region, Tunnel, Volcanics, Flysch, Rock mass, Rock mass classification.

# ÖZ

## ORDU ÇEVRE YOLU BOYUNCA DURAYLILIK İNCELEMELERİ

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Tez Yöneticisi: Prof. Dr. Haluk Akgün
Aralık 2003, 652 sayfa

Türkiye'nin Doğu Karadeniz Bölgesi, zemin koşullarının volkanik kayaçlar ve bunlarla eş yaşlı flişlerden oluşması ve bunlarla ilişkili olarak düzensiz yerşekilleri barındırması nedeni ile insan yaşamı ve yerleşimi için pek de uygun olmayan bir durum sunar. Bölgedeki önemli sorunlardan biri olan ulaşımı çözmek amacı ile yapımı düşünülen Ordu Çevre Yolu yarma, köprü, viyadük ve kavşak gibi kimi yapıların yanısıra yukarıda sözü edilen jeoloji ve yerşekilleri koşullarında açılması gereken, her biri iki tüpten oluşan iki tünel bölümünü de içermektedir.

Bölgesel ölçekte volkanikler, volkanik çökeller (pyroclastics) ve flişler çok kısa aralıklarda bile birbirlerine sık geçişlidirler. Tünel tasarımı açısından bu biçim karmaşıkların dayanım parametrelerinin doğru olarak belirlenmesi tünel giriş-çıkış şev duraylılığı ve tünel destek tasarımı değerlendirmeleri için çok önemlidir. Bu gerçek doğrultusunda RMR, NGI Q Sistem ve GSI kaya sınıflamaları yapılmış, birbirleri ile deneştirilmiş ve kaya kütlesi bağlamında yorumlanmıştır. Bu sınıflama ve yorumlardan elde edilen dayanım parametreleri tünel giriş-çıkış şev duraylılık analizleri ve tünel destek tasarımı için veri olarak kullanılmıştır. 2D sonlu elemanlar çözümleme programı ile de tünel açıklığı çevresindeki gerilme çözümlemeleri yapılmış ve sonuçlar görgül (ampirik) yöntem sonuçları ile deneştirilmiştir. Sonuç olarak tüm hesaplamalar ve yorumlar ışığında yapım aşamasında uygulanmak üzere tünel ve portal kesimleri için destek tipleri geliştirilmiştir.

ANAHTAR SÖZCÜKLER: Karadeniz bölgesi, Tünel, Volkanik kayaçlar, Fliş, Kaya kütlesi, Kaya kütlesi sınıflaması.

**ACKNOWLEDGEMENTS**

Many people, directly or indirectly, have contributed to the development of this thesis. I profoundly appreciate those people who have lent me helping hand.

I am thankful to all my instructors who have supported me through my thesis studies. I especially appreciate the assistance and support of Prof. Dr. Haluk AKGÜN; P. E. and Research Assistant Mustafa Kerem KOÇKAR.

In the name of TEMELSU International Engineering Services Inc., I would like to thank Mr. Mustafa AKINCI for sharing his vast experience and his guidance at every stage of my engineering career and my thesis. In addition, I appreciate the support of Mr. Ömer ARDIÇ, Mr. Yavuz KURDOĞLU, Mr. Yavuz KARAGÜMÜŞ and Mr. Hasan ÖZKAN.

I am grateful to my family and my “little kitty” for their endless assistance and support regarding my life.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| 2D | Two Dimensional |
| $a_h$ | Earthquake acceleration in horizontal direction |
| BSI | British Standards Institution |
| c | Cohesion |
| cm | Centimeter |
| CSIR | South African Council for Scientific and Industrial Research |
| Cu | Copper |
| $E_m$ | Static Modulus of Deformation |
| ESR | Excavation Support Ratio |
| g | Ground Acceleration Coefficient |
| F.S. | Factor of Safety |
| GPa | Giga Pascal |
| GSI | Geological Strength Index |
| KGM | General Directorate of State Highways of Republic of Turkey |
| KM | Kilometer |
| kN | Kilo Newton |
| kPa | Kilo Pascal |
| m | Meter |
| $m^3$ | Cubic meter |
| $m_i$ | Hoek-Brown constant of intact rock |
| $m_b$ | Hoek-Brown constant of rock mass |
| mm | Milimeter |
| MM | Moment Magnitude |
| MN | Mega Newton |
| MPa | Mega Pascal |
| M-RMR | Modified Rock Mass Rating |
| NATM | New Austrian Tunneling Method |
| NGI-Q | Norwegian Geotechnical Institute – Q System |
| NW | Northwest |
| NX | Nominal core size |

| | |
|---|---|
| Pb | Lead |
| $Q_c$ | Corrected Q value |
| RMR | Rock Mass Rating |
| $RMR_p$ | Rock Mass Rating at portals |
| RQD | Rock Quality Designation |
| s | Hoek-Brown constant of rock mass |
| $s_i$ | Hoek-Brown constant of intact rock |
| S | Sulphur |
| SRF | Stress Reduction Factor |
| UCS | Uniaxial Compressive Strength |
| Zn | Zinc |
| $\phi$ | Internal Friction Angle |
| $\sigma_\theta$ | Tangential Stress |
| $\sigma_1$ | Major Principal Stress |
| $\sigma_3$ | Minor Principal Stress |
| $\sigma_C$ | Unconfined Compression Strength |
| $\sigma_{ci}$ | Unconfined Compression Strength of intact rock |
| $\sigma_h$ | Field stress in horizontal direction |
| $\sigma_v$ | Field stress in vertical direction |

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**APPENDIX – I** **FINITE ELEMENT ANALYSES RESULTS**

# CHAPTER I

# INTRODUCTION

## 1.1 Methodology

The increase in traffic load from day to day on Black Sea Highway brings some problems for the settlements situated along the highway. Together with the traffic congestion, air and noise pollution contribute to the disturbance of casual life of people in these districts. To get rid of this annoyance in Ordu, which is situated along the Black Sea Highway, the peripheral highway is planned to be constructed, and the stability considerations of this peripheral highway constitute the objective of this thesis.

In the scope of stability investigations along the Ordu Peripheral Highway, there exists various structures such as open-cuts, bridges, viaducts, junctions and tunnels. In this thesis, however, the main emphasis is tunnel design including portals. Therefore, every step and methodology used in tunneling will be comparatively described. Every stage before and during tunneling will be attempted to be explained in detail.

The geology and tectonics of the tunnel forming rock mass will be the first to evaluate. Mostly being disregarded or not employed effectively during tunnel studies, the importance of the geology and especially tectonics will be mentioned. Importance of the synthesis of geology and tectonics in constructing a geotechnical model will be emphasized.

The next step is establishing a meaningful connection between the geotectonical model and the design parameters as a geological engineer. These design parameters are generally the engineering properties of the rocks. Gathering of these parameters and tunnel support categories accomplished by rock mass classification systems will be comparatively

presented. The methods of investigation to obtain each individual item in the rock mass classification systems will be presented in detail.

Being different than other ordinary designs, a newly adapted rock mass classification, namely, A-RMR, will be introduced to obtain more precise results. Moreover, A-RMR values will be reassessed at portals on the base of NGI-Q System and "tunnel portal" concept. Recent developments about heterogeneous rock mass strength determination will be applied primarily in tunnel support design.

Both kinematical and analytical tunnel portal slope stability calculations will be executed in order to verify the accuracy of the cut slope angles.

At the end, the overall tunneling support design and calculations, most of which are empirical, will be checked by finite element analyses.

## 1.2 Purpose and scope

The Ordu Peripheral Highway Project comprises of various superstructures such as open-cuts, bridges, viaducts, junctions and tunnels. The main emphasis in this thesis is to design the tunnels of this highway. Accordingly, the stability investigation of portals and the tunnel support determination through rock mass classifications constitute the primary purpose of the study. For the purpose of assessment of the stability of tunnels, namely, Boztepe (T-1) and Öceli Tunnels (T-2), each of which consists of two tubes, the following issues have been carried out:

- Elaborate literature survey for theoretical background about tunnel and portal design,
- Assembling, correlating and interpreting of previous studies for the project area to comprehend geological conditions,
- Characterization of rock masses along the proposed route for tunnels by international classification systems as Geomechanics Classification (RMR, Rock Mass Rating), NGI (Norwegian Geotechnical Institute) Q-system and Geological Strength Index (GSI).

In recent years, there is an increasing trend in the application of NATM (New Austrian Tunneling Method) in Turkey. Therefore, the bases of NATM, which is able to be integrated with rock mass classification systems mentioned above, will be also described.

## 1.3 Organization and Investigation Teams

The following technical staff carried out the geological and geotechnical works:

Drilling works

B. Caner KANDEMİR (Geological Engineer/TEMELSON)
H. A. TİRYAKİ (Geological Engineer/TEMELSON)
Mustafa AKINCI (Geological Engineer/TEMELSU)

Field Studies

Mustafa AKINCI (Geological Engineer/TEMELSU)
Evrim SOPACI (Author, Geological Engineer/TEMELSU)

Lab Testing

The rock mechanics laboratory testing of the removed samples have been tested by The General Directorate of State Highways, Directorate of Soil Mechanics and Tunnels of Technical Research Department.

Office works

Mustafa AKINCI (Geological Engineer/TEMELSU)
Evrim SOPACI (Author, Geological Engineer/TEMELSU)

## 1.4 Project area

The Ordu Peripheral Highway deviates from the Bolaman-Ordu Highway at KM: 21+500. Prolonging with open-cuts and fills, the proposed route enters Boztepe Tunnel (T-1) at KM: 23+015. Coming out to the surface at KM: 26+323 at the left bank of the Karadere Valley, it reaches up to a length about 3310 m. Just at the right bank of the same valley, the route enters into the about 2035 m long Öceli Tunnel at KM: 26+458 and daylights at KM: 28+4692 near Pirahmetli district. The total length of the area occupied by the highway project reaches up to 20 km, approximately (Figure 1.1).

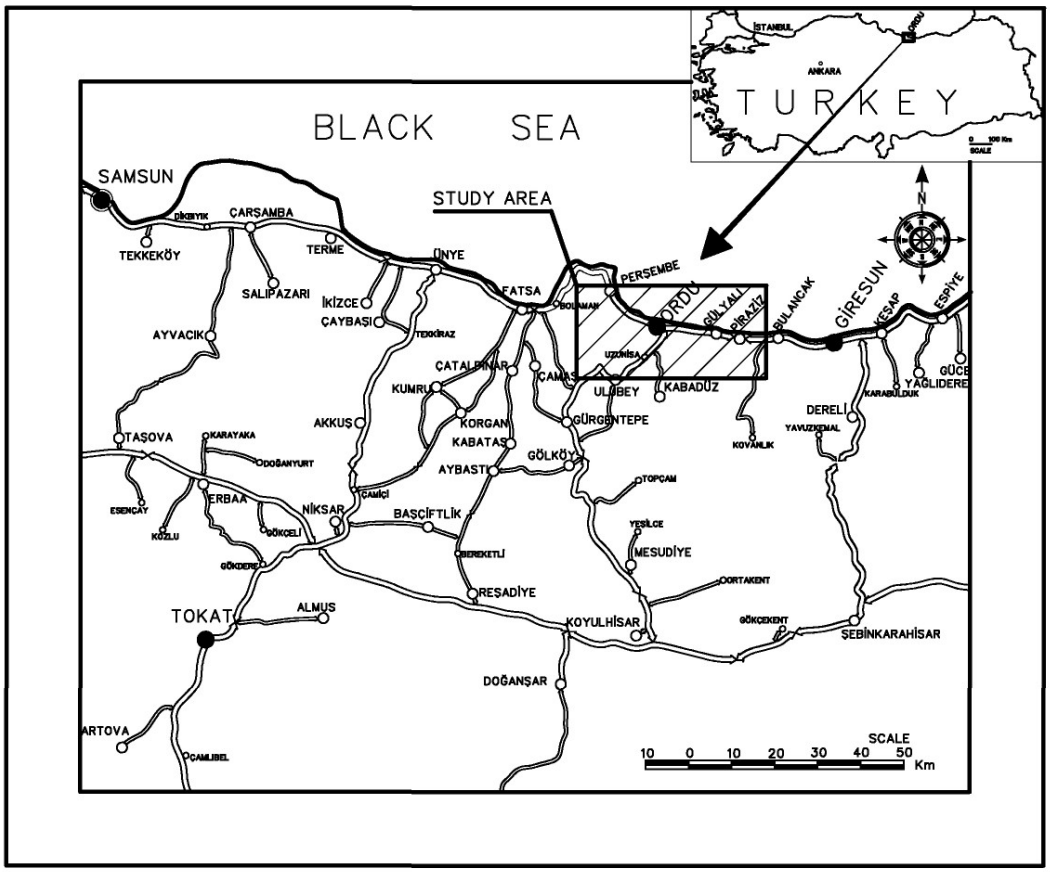



Figure 1.1 Location map of the project area.

## 1.5 Previous studies

The study area and its near vicinity have been examined and investigated by several scientists and engineers in both regional and small scale. Mainly, most of the studies were related to mining activities and to the tectonics of the Black Sea Region. The engineering geological investigations have been limited to the projects pursued, such as highway construction.

Schultze – Westrum, (1959), carried one of the earliest noteworthy studies for mine exploration in the vicinity of the study region. They, basically, studied the relations between lithologies and tried to explain their mode of occurrences nearby Giresun and Espiye.

Again, in the mine exploration sense, Erler (1975), worked out between Gölköy and Ordu. This study, during which simple lithology differentiation was made, had the purpose of gathering information about Pb-Zn bearing lithologies.

Terlemez and Yılmaz (1980) performed a stratigraphical study between Ünye – Ordu – Koyulhisar – Reşadiye and correlated the formations with the ones pinpointed by Schultze – Westrum (1960) and Seymen (1975). The facies change of volcanics and sedimentary rocks has been observed by the authors. They have found out five volcanism activities in different times, three of which are submarine and the remaining is plateau basalt.

Şengör and Yılmaz (1981) constructed a plate tectonic model in order to establish the relation between stratigraphy and tectonics of Turkey. This model is also applicable in the study area. By the help of this model, the realization of the tectonic history and the formation conditions of the lithologies in the study area becomes more obvious. These two properties, tectonic history and formation conditions, are effective tools in the estimation of rock mass behavior, especially with tunneling depth. Bektaş, et al (1987) studied Jurassic volcanism and related geotectonics in the Eastern Pontides. In this research, typical sections from different parts of the Eastern Pontides were correlated by means of geochemistry and a geotectonic model regarding Jurassic volcanism was constructed.

Tüysüz (1992) executed a case study for the evaluation of geochemical data from the region of Ordu – Ünye – Fatsa – Aybastı. In this study, a multivariate statistical technique was applied to the volcanics of the Eastern Pontides for gold exploration. The author has detected the anomalies especially in three main districts, Fatsa-Zaviköy, Fatsa-Tepeköy and Korgan regions. At the end of the study, it has been concluded that the formation of gold occurs in three phases. Keskin et al. (1995) have studied the stratigraphy of the Eastern Pontides in northeastern Turkey in six time intervals starting from Paleozoic. They have made a compilation study of the existing studies and they have put some recent information thorough their observations. They have differentiated and described the formation characteristics at the each time interval.

A detailed geological engineering study in the scope of Ünye-Piraziz State Highway, especially for the Hapan tunnel, was performed by Temelsu International Engineering Services Inc. (1997). An assessment of the geological and geotechnical conditions along the highway and the tunnel was made by means of geotectonical model construction, geological mapping and rock mass classification. Nowadays, the project design has been applying to real life and the Hapan tunnel has been excavating successfully without any problems.

# CHAPTER II

# GEOLOGICAL SETTING

## 2.1 Introduction

The project area regarding its geological characteristics can be included in the central part of the Black Sea Region. While the eastern portion of the Black Sea Belt is mostly represented by volcanic rocks, the western part is dominated by sedimentary rocks. In this frame, the project area accommodates volcanic rocks together with contemporaneous sedimentary rocks (Terlemez and Yılmaz, 1980). The geological units in the area are firmly connected with the tectonic movements that have occurred. The presence of volcanic rocks juxtaposed to sedimentary rocks in the project area can be explained by submarine volcanism. More precisely, the geological units derived from island arc volcanism of regional scaled tectonic movements characterize the Ordu region and its province (See Appendix - A).

In regional scale, various facies of Middle Jurassic – Pliocene age interval outcrop in the area. Middle – Upper Jurassic and Lower Cretaceous aged limestone of these forms the basement. Tuffite, andesite flows, agglomerate, limestone and sandstone alternation of Cenomanian – Campanian age cover the limestone with an angular unconformity. This unit is cut by dacite and syenite particularly near the Gölköy and Ulubey districts. Tuffite-argillaceous limestone alternation at north and arenaceous-argillaceous limestone alternation at south overlies the former unit. These two sequences of Maastrichtian age are thought to have lateral interfingering below younger units. Paleocene aged tuffite, agglomerate and limestone with coal seams, argillaceous limestone and sandstone alternation are deposited as a continuation of the units of Maastrichtian age. Limestone and at some locations basalt cover these units with an angular unconformity. Then, agglomerate and andesite flows and sandstone with agglomerate beds have been deposited. These units are of Eocene age.

Various basaltic formations were developed during the Miocene – Pliocene period, followed by young alluvium and debris flows.

## 2.2 Stratigraphy

In this section, the geological units will first be grouped according to the time of occurrence and then the stratigraphical descriptions of each formation will be provided separately.

### 2.2.1 Mesozoic (Jurassic – Cretaceous)

#### 2.2.1.1 Zinav limestone

Middle-Upper Jurassic aged Zinav limestone constituting the oldest autochthonous unit in the region is observed at the slopes of Zinav Pass towards NW of Reşadiye. The typical section gathered from this province reveals a 300 m thickness for Zinav limestone (Terlemez and Yılmaz, 1980).

The dominant color of the unit is whitish, light gray to dirty gray when it is altered. The bounding upper and lower parts of this unit are either massive or very thick bedded, whereas the middle section is thick bedded. Zinav limestone, deposited in a shallow sea environment, is highly fractured. The fractures are filled with calcite with a fine-grained, monotonous and sometimes oolitic texture.

Seymen (1975) also studied this unit under the name of Hankırıntepesi limestone and assigned Upper Jurassic – Upper Cretaceous age accepting the conformity and continuity of the units from Jurassic to Paleocene. On the other hand, Terlemez and Yılmaz (1980) claim an unconformity between Middle – Upper Jurassic – Lower Cretaceous aged Zinav limestone and the overlying units. Being mostly recrystallised, Zinav limestone will not be crossed along any tunnel alignment.

#### 2.2.1.2 Mesudiye formation

Mesudiye formation, posing its most typical section near Mesudiye, is comprised of agglomerate, basic lava flow, limestone, tuffite, mudstone, siltstone and sandstone. The

description of this formation was first made by Terlemez and Yılmaz (1980). Upper Cretaceous aged Mesudiye formation is the oldest lithostratigraphic unit near the project area and its lower bound can not be observed. The inferred thickness of this formation is about 1000 m.

Within the formation, pyroclastics are more dominant than interlayers of fine sandstone, claystone, tuffite and lenses of pelagic red limestone (Keskin et al., 1998). Agglomerates of the Mesudiye formation are dark gray, brownish colored, massive and sometimes very thick to thick bedded. The size of the andesitic and basaltic clasts varies from gravel to block. These clasts are angular and poorly sorted. The andesitic and tuffic cement of this agglomerate is either weak or tight. The clast contact is absent in case of weak cementation.

Tuffite is generally dark gray, gray, green and brown in color, thin to medium bedded but sometimes massive or thick bedded. Some limestone, basic flow and agglomerate clasts are observed in the matrix of tuffite.

The basalt and andesite member of this formation have calcite and zeolite infillings. Due to hydrothermal alteration, this member displays gray-black, light green and greenish gray color (Keskin et al., 1998). Basic flow generally is of andesitic character and rarely is basaltic and spilitic. Also, it has fractures with different orientations and is filled with calcite. Being dark gray, brownish, greenish and purple, it has fine-grained flow texture. The texture of this medium to thick bedded and sometimes massive rock is not obvious (Terlemez and Yılmaz, 1980).

The limestone member possesses gray, green and claret red color in the form of lenses or interlayers. Bed thickness varies from thin to medium. The fractures are various in orientation and filled with calcite and silicate, which are fine crystalline and rough without texture.

The grains of the scarce sandstone have completely originated from volcanic rocks. This thin to medium bedded member is greenish, gray, reddish and dirty yellow in color.

Mesudiye formation accommodates andesite, basalt and dacite dykes. The most observed one, however, is andesite dyke. Terlemez and Yılmaz (1980) observed the contact between the dacite dyke and Mesudiye formation towards the east of Ulubey where they

noticed weathering at the contact and tuff fragments of Mesudiye formation in the dacite dyke. Hence, they observed that the Mesudiye formation was cut by dykes.

Mesudiye formation is the product of an arc volcanism related with the subduction of the northern branch of Neo-tethys. The sedimentary component of this formation, nevertheless, has occurred under the circumstances where submarine volcanism ceased.

The most striking feature of the Mesudiye formation is its Kapanboğazı member consisting of red, pink and claret red colored, thin to medium bedded limestone, marl, mudstone, claystone, sandstone and tuff either in the form of lenses or interlayers. This member can also be traced as a key bed (Keskin et al., 1998).

Both tunnel alignments will be mostly cut by the Mesudiye formation.

#### 2.2.1.3 Tirebolu formation

In the vicinity of the project area, the formation constituting of trachy-andesite, andesite, rhyo-dacite, tuff-breccia, bentonized dacitic tuff and bentonite is named as Tirebolu Formation (Keskin et al., 1998). The thickness of the Campanian aged formation ranges between 350 m to 750 m.

Cu, Pb, Zn and S ore mineralizations through hydrothermal processes are well developed in Trachy-andesites. The green vitric tuff and the red crystalline tuff in trachy-andesites form light colored bentonite. Quartz, volcanic rock and glass fragments are included together with the clay matrix in vitric tuff similar to the crystalline one.

Dacite is yellowish, white, pink, light green and gray in color and is observed in the form of lava flows having columnar-joint structure. The matrix of dacite is mainly glass that was transformed into clay minerals with flow texture. Alteration can be observed locally in dacite which leads to the formation of bentonite at these particular parts. Beside alteration, the rock mass is highly weathered with dark gray color according to Terlemez and Yılmaz (1980).

Trachy-andesitic rocks lay on over the Santonian-Campanian aged Mesudiye formation. Tirebolu formation has occurred under submarine volcanism conditions. Whenever the volcanic activity had a break, red limestone, sandstone and marl was deposited.

This formation can be correlated with the dacite of Terlemez and Yılmaz (1980) and will not be crossed along any tunnel alignment.

#### 2.2.1.4 Akveren formation

Akveren formation is formed by sedimentary rocks such as limestone, sandy limestone, marl, siltstone and sandstone alternations. Some tuffite interlayers have also been reported around Kumru, Korgan and Fatsa where the formation outcrops extensively (Keskin et al., 1998). The cumulative thickness of the formation reaches up to 750 m. The same formation can be correlated with the Fatsa and Gölköy formations of Terlemez and Yılmaz (1980).

Limestone of the Maastrichtian aged Akveren formation is gray, white, reddish and medium to thick bedded. Some clay interlayers are observed. Since the limestone is hard and resistant to weathering, it constitutes ridges.

Clayey- sandy and tufficeous limestone is usually gray, bluish and light yellow, thin to medium bedded and forms a more gentle topography than limestone. Tuffite is gray and light yellow, thin bedded and highly weathered. It contains little clay and sand. Sandstone is gray and greenish, fine grained and medium bedded. The origin of most of the grains is volcanic. Thin sandstone layers are rarely observed in the formation. Agglomerate, having a thickness of 0.5 m, is massive and contains angular and unsorted andesite gravels within the weak tuff cement. The conglomerate is mostly observed at the lower bound of the formation. It is massive and comprises of volcanic, gray limestone, clayey limestone and claret red limestone gravels. The cement is generally weak and sometimes is firm. This conglomerate includes fragments from both the formation itself and underlying units, so it is different than basal conglomerate. Akveren formation being conformable with the Mesudiye and Tirebolu formations is mostly deposited in a deep sea environment whereas after a while shallow sea conditions might have become dominant where reefal limestone has been deposited. According to the fossil findings, the age from Maastrichtian to Paleocene can be assigned to this formation.

The initial portion of the Boztepe tunnel will be driven through Akveren formation which may be correlated to Fatsa formation of Terlemez and Yılmaz (1980).

### 2.2.2 Cenozoic (Tertiary)

#### 2.2.2.1 Kozmandağı limestone

The massive and sandy limestone near the vicinity of the project area is referred to as Kozmandağı limestone. This unit starts with dark gray, massive sandy limestone and claystone alternation from the bottom. Towards the upper parts, it continues with claystone and sandstone interlayered sandy limestone. The Upper Paleocene (Thanetian) aged Kozmandağı limestone, 150-200 m thick, is overlain unconformably by Lower-Middle Eocene aged Kumru formation.

This limestone, displaying reefal limestone characteristics, is most probably deposited in a relatively shallow environment of the basin.

This formation will not be crossed along any tunnel alignment.

#### 2.2.2.2 Kumru formation

Lower-Middle Eocene aged Kumru formation is formed by the alternation of sandstone, sandy limestone, marl, siltstone and carbonaceous sandstone.

About a 1.0 m thick conglomerate, consisting of 0.5 – 3.0 cm diameter volcanic and sedimentary rock gravels, is observed at the bottom of the formation. The cementing material is mainly calcite and to a lesser extent limonite. Moreover, some carbonaceous sandstone interlayers are present.

The limestone member of the Kumru formation comprises of gray, medium to thick-bedded massive limestone and sandy limestone whose bed thickness ranges between 1.5-2.0 m. Above this massive limestone – sandy limestone deposition, yellow claystone-clayey limestone alternation is present. Another massive, thick-bedded, sandy, yellow-pink colored and fossilliferous limestone is observed over this repetitive alternation (Keskin et al., 1998). This sequence ends with a siltstone-claystone alternation.

Kumru Formation can be correlated with the Yeşilce Formation of Terlemez and Yılmaz (1980) and will not be crossed along any tunnel alignment.

#### 2.2.2.3 Tekkeköy Formation

Tekkeköy formation comprises of andesite-basalt lava, pyroclastics and sandstone, siltstone, marl and tuffite interlayers. This Maastrichtian-Palaeocene (Thanetian) aged formation, being in transition with the Kumru formation, unconformably overlies Kozmandağı limestone (Keskin et al., 1998). The sandstone member is medium to thick bedded and the rock mass is weathered. Some large and small andesitic and basaltic dykes were observed to cut the sandstone. Agglomerate is massive, very fractured, hard and strong. The clasts are generally of basalt and andesite origin.

The presence of volcanic rocks and sedimentary rocks at the same location is an indication of submarine volcanism. This situation suits well with the island arc volcanism by Eocene aged subduction. According to the information gathered from the researchers, lavas are generally calc-alkaline and sometimes alkaline in composition. Tekkeköy Formation can be correlated with the Yeşilce Formation of Terlemez and Yılmaz (1980) and will not be crossed along any tunnel alignment.

### 2.2.3 Cenozoic (Quaternary)

#### 2.2.3.1 Recent Alluvium Deposits

In the project area and its vicinity, the alluvium deposits whose grain size ranges from clay to gravel are observed along the stream channels. The 10-15 m thick alluvium deposits usually have cross-bedding structure. The grains of the alluvium are mostly derived from volcanic rocks.

The alluvium deposits will not be crossed along any tunnel alignment.

#### 2.2.3.2 Slope Debris

Mineralogically unstable day-lighted volcanic rocks are prone to weathering as they are exposed to the surface. Both chemical and mechanical (physical) weathering processes cause them to be broken apart. Especially, along the skirts of the mountains in the project area and its vicinity this kind of debris material is observed. This loosened material contains grains from clay size to the block size in some places. The thickness of this slope wash material varies between 2.0 to 15.0 m in the region.

The slope debris will not be crossed along any tunnel alignment but might be observed as a thin cover especially at portal locations.

## 2.3 Tectonics

Generally the Eastern Black Sea Region of Turkey and specifically the project area and its vicinity comprise of the formations controlled by island arc volcanism emerging from the subduction zones (Şengör and Yılmaz, 1981). In the following sentences, this regional tectonics will be summarized:

- During Upper Cretaceous, one of the northern branch of Neo-Tethys, Intra-Pontide Ocean, commenced its closure. This convergent tectonic movement resulted in the following consequences below:

*Sakarya continent began to subduct from south to north beneath Eurasia along the Intra-Pontide Ocean. In relation to this subduction, first, island arc volcanism started at the continent part and then, at north, the Black Sea developed through continuous compressional tectonic movement.

*The products of this subduction zone at the project area and its neighborhood are the Upper Cretaceous volcanic rocks and their concurrent flysch type sedimentary rocks.

- Before Maastrichtian, the Intra-Pontide Ocean was closed and along this suture zone the Sakarya Continent crushed into the Rodoph-Pontide Continent.

- During Paleocene, Izmir-Ankara Ocean, another branch of Neo-Tethys, commenced closing up through which Anatolide-Tauride Platform began to subduct northward beneath the Rodoph-Pontide Continent. This period is represented by Eocene island arc volcanism resulting in volcanic rocks and their concurrent flysch type sedimentary rocks.

## 2.4 Structural Geology

Being the products of the subduction zone, Upper Cretaceous volcanics and sedimentary rocks inevitably display transitions with each other. Accordingly, they often

alternate with each other at some levels. The most well developed bedding planes are included within the sedimentary rocks. The most distinct property of the agglomerate is its massive structure. The bedding planes equivalent to the plane of deposition are scarcely observed. The average bedding plane dip direction/dip amount is measured as 210/15° whereas the average dip direction/dip amount of the joints are 010/80° and 120/70°, respectively.

The emplacement of the project area into a tectonically highly active region gave birth to the development of folds controlled by compressional forces along the tunnel alignments. In this regard, the change of the characterization of the folds over short distances is a challenge to design tunnel support.

## 2.5 Geomorphology

The regional geomorphology is controlled by Paleo-tectonics, namely, compressional tectonics. In this regard, the river or surface waters dug the earth's surface as rapid uplift of the region continued. The geomorphological model for the region dominated by the recent and young erosional forms is represented by the erosional flat plains in the valleys. Therefore, the drainage pattern, geological structure and the lithological characteristics of the rocks have determined today's morphology.

# CHAPTER III

# GEOTECHNICAL ASSESSMENT OF THE STUDY AREA

## 3.1 Introduction

In this chapter, the procedures for determining the geotechnical parameters of the rock masses are described. In this context, these procedures were divided into three categories as surface investigations, subsurface investigations and laboratory tests.

In the surface investigations, the properties of the discontinuities of the rock masses, which control the rock mass behavior, were investigated. Their spacing, aperture, persistency, roughness and the weathering conditions along with groundwater conditions are all vital for the assessment of the rock mass strength.

On the other hand, the aim of the subsurface investigation is to determine the rock mass geotechnical condition at the tunneling depth, which is not possible to observe during the surface investigations. Subsurface investigations by means of the drillings executed along tunnel alignments also reveal the groundwater conditions.

The laboratory tests, as a last stage, were performed on samples recovered from the drillings. The cores obtained from these drillings were preserved providing minimum disturbance and then taken to the laboratory for testing. The intact rock parameters were determined through these laboratory tests.

The geotechnical description of the rock masses is presented through integration of rock mass properties and intact rock properties (BSI, 1981). In this regard, the field findings representing rock mass properties and the drilling results coupled with laboratory tests

reflecting intact rock properties are interpreted to complete the geotechnical description of the rock masses.

### 3.2 Surface Investigations

In engineering geology, as in other areas, there is a need for clear and effective communication between individuals with diverse training. This communication problem is compounded by the fact that the engineering geologist is dealing with a material that is difficult to define due to its complex nature.

Before going any further, there is a need to clarify the difference between classification and description. In classification, a system and order are followed with information being recorded in a prescribed manner. In description, although all the complicated technical terms are recorded, essentially the individual puts down whatever he or she feels is important.

When one deals with the rock masses, rock material and rock mass concepts should be well known. The classification of rock material, a continuum or polycrystalline solid consisting of a natural aggregate of minerals, used by geologists requires a detailed consideration of mineralogy and petrography which may be of interest to engineers only in special circumstances. Engineering properties of rocks are not included in, and cannot be inferred from this type of geological classification. The important indices required in a description of a rock material are color, grain size, texture and structure, state of weathering, rock name, strength and the other characteristics and properties. However, the description of rock mass, a discontinuum consisting of rock material rendered discontinuous by planes of weakness or discontinuities, requires information additional to the description of the rock material. A rock mass should be well described first as a rock material, followed by additional information about discontinuities and other features of engineering significance (BSI, 1981). The descriptive indices of discontinuities written below for the rock mass classification can easily be gathered from the field observations:

- Type
- Location and orientation
- Weathered and altered state
- Infilling
- Aperture or separation of discontinuity surfaces
- Number of discontinuity orientations
- Frequency of spacing between discontinuities
- Persistence and extent
- Nature of surfaces

Here, in this chapter, the field descriptions of rock masses would be made on the basis of BSI (1981) to provide a common communication platform. Thus, these descriptions would form the basis of rock mass classifications presented in the following chapters.

### 3.2.1 Surface Investigation of the Upper Cretaceous Volcanics (Mesudiye formation)

As it was emphasized in the previous sections, the Upper Cretaceous volcanics being the product of the subduction zone are present in lateral and vertical transition with concurrent sedimentary rocks. (See Figure 2 in Appendix – A) In this respect, at some levels, volcanic and sedimentary rocks alternate so often and hence the differentiation of these two is difficult. Therefore, the descriptions made below are presented in the frame of this geological fact.

**a) Volcanic Rocks**

Displaying transition in both lateral and vertical directions itself, volcanic rocks can be grouped into the following members by field observations via unaided eye:

- Andesitic tuff and agglomerate
- Basaltic tuff and agglomerate
- Basaltic lavas

Volcanic rocks showing similar mass strength parameters along both tunnel alignments are the andesitic and basaltic agglomerate. The differentiation between basaltic and andesitic agglomerates by unaided eye is only possible through their colors. The rock mass characteristics of them do not vary so much, hence the engineering parameters of these are given in the subtitle entitled “agglomerates”.

Light-dark gray, greenish and blackish agglomerate is formed by lapilli (4.0-64.0 mm) and volcanic bomb (>64.0 mm) sized fragments within the matrix of andesitic and basaltic tuff and volcanic ash. The 1.5-2.0 m thick uppermost part of this unit comprises of block sized rock fragments owing to mechanical and organical weathering. In spite of this particular zone, agglomerates are slightly weathered and fresh in general. According to the rebound of the hammer when hit the rock, agglomerates are usually moderately strong (UCS, uniaxial compressive strength, is between 12.5-50.0 MPa) and sometimes strong (UCS is between 50.0-100.0 MPa). The most striking property of the agglomerates is their massive

structure. Scarce bedding planes were observed. The joints and bedding planes having a general orientation of 115/15º are discontinuous, undulating and irregularly rough. The spacing of the discontinuities is between 200-600 mm revealing RQD (Rock Quality Designation) =50-75%. The 1.00-5.00 mm opened (aperture) discontinuities are slightly altered and filled with non-softening, non-cohesive rock mineral or crushed rock filling.

Some layers of andesitic and basaltic tuff compared to the agglomerates serve poorer conditions regarding grain size, weathering and strength parameters. In this frame, the moderately weathered sections of the tuff are moderately strong (UCS is between 12.5-50.0 MPa) to weak (UCS is between 1.25-5.0 MPa), and the slightly weathered and fresh sections are moderately strong (UCS is between 12.5-50.0 MPa). These sections are highly fractured where RQD value ranges between 25-50% together with the average joint spacing of 60-200 mm.

Basaltic lavas can easily be distinguished by their dark gray and blackish colored outcrops. Being mostly fresh and slightly altered, they exhibit moderately strong (UCS is between 12.5-50.0 MPa) character. The aperture of the discontinuity is between 1.00-5.00 mm. The discontinuity walls are coated with iron-oxides at the surface. Having a spacing of 60-200 cm, basaltic lavas have the RQD value between 75-90%.

**b) Sedimentary Rocks**

Displaying lateral and vertical transition with Upper Cretaceous volcanic rocks, sedimentary rocks mostly show typical flysch character. These sedimentary rocks of deep-sea environment consist primarily of claystone, sandstone, marl, limestone, siltstone, and conglomerate.

Relatively, the best quality rocks among the flysch members, namely light gray-white colored, fresh limestone and sandstone, are strong (UCS is between 50-100 MPa). The average percentage of sandstone and limestone in flysch composition is about 20% and 5%, respectively. Both sandstone and limestone have bedding planes with a general orientation of 120/20º and 3-10 m persistency together with the undulating and irregularly rough surfaces whose aperture size is between 1.00-5.00 mm. These surfaces are slightly altered and sometimes coated with calcite fillings. Having a spacing between 60-200 mm, sandstone and limestone have RQD value between 25-50%.

Dirty white and light gray colored claystone and marl comprising of 60% and 10% of the flysch composition, respectively, are slightly to moderately altered, moderately weak (UCS is between 5.0-12.0 MPa) to moderately strong (UCS is between 12.5-50.0 MPa). Being moderately persistent (3-10 m), the bedding plane surfaces are undulating, irregularly rough, slightly altered and are filled with non-softening, non-cohesive rock mineral or crushed rock filling.

The bedding planes of the sandstone, limestone and conglomerate members of the flysch are effective in the slope stability considerations of the tunnel portals whose detailed information has been described in Chapter VI.

### 3.2.2 Surface Investigation of the Maastrichtian - Paleocene Sedimentary Rocks (Flysch; Akveren formation)

Brown, greenish and dirty white colored alternation of claystone, sandstone, marl and limestone displays its typical characteristics in the vicinity of the Boztepe Tunnel (T-1) entrance. The percentages of the lithologies are similar to that of mentioned Upper Cretaceous sedimentary rocks. This flysch type formation has gone through extensive tectonic processes through which some levels of this mass have been highly weakened.

The greenish marl and brown claystone, which are the weakest components, are highly weathered and their strengths are very weak to weak (UCS is between 1.25-5.0 MPa). The bedding planes are moderately persistent (3-10 m) together with undulating and irregularly rough surfaces whose aperture size is between 1.00-5.00 mm. These surfaces are slightly altered and sometimes coated with calcite fillings. Having a spacing between 60-200 mm, claystone and marl have RQD value between 25-50%.

The limestone, however, alternating with them is slightly weathered to fresh and moderately strong (UCS is between 12.5-50.0 MPa). It has bedding planes with a general orientation of 120/20º of 3-10 m persistency together with the undulating and irregularly rough surfaces whose aperture size is between 1.00-5.00 mm. These surfaces are slightly altered and sometimes coated with calcite and quartz fillings. Having a spacing between 200-600 mm, limestone has RQD value between 50-75%.

The dirty white sandstone is slightly to moderately weathered and moderately strong (UCS is between 12.5-50.0 MPa). The coarse and angular grains are mostly derived from volcanic rocks and limestone. Bedding planes with a general orientation of 120/20º are moderately persistent (3-10 m). Their surfaces are undulating and irregularly rough with the aperture size between 1.00-5.00 mm. These surfaces are slightly altered. Having a spacing between 200-600 mm, sandstone has RQD value between 50-75%.

### 3.3 Subsurface Investigations

In order (a) to establish the general nature of strata along the tunneling elevation, (b) to determine the vertical and lateral variations of the rocks, (c) to set the groundwater conditions, (d) to allow in-situ tests to be performed and (e) in order to obtain samples for tests, a total length of 2154 m drilling has been performed. Sixteen boreholes with a total length of 1497 m for the Boztepe Tunnel (T-1) and twelve boreholes with a total length of 657 m for the Öceli Tunnel (T-2) have been executed. The brief information of the boreholes whose locations, logs and core box photos are presented in Appendices A and B, respectively, is presented below Table 3.1.

Being the most critical part of the tunnels, the portals have been explored by the drillings T1-SK5, T1-SK6, T1-SK17 and T1-SK18 for the Boztepe (T-1) tunnel and T2-SK5, T2-SK6, T2-SK11 and T2-SK12 for the Öceli (T-2) tunnel. The first 5-10m of these drillings has crossed Akveren formation. As it can be noticed from the core box photos, these parts are mostly composed of brown to greenish brown claystone, sandstone and marl. All have grains of volcanic origin due to their mode of occurrence. They are moderately to highly weathered hence their strengths are very weak to weak (UCS is between 1.25-5.0 MPa). Their RQD value ranges between 25% and 50%. Therefore, these sections at the tunnel portals will be treated as soil rather than rock in the slope stability analysis. Accordingly, circular failure analyses will be performed at these particular sections of the tunnel portals.

The information provided from the remaining of the drillings will be handled in the characterization of the rock masses at the tunneling elevation. The rock masses of the similar lithologies and the shear strength parameters will be grouped into the same structural domains. Thereupon, these structural domains will be treated as homogenous rock mass sections in order to assign unique support system for each domain. In this frame, these structural domains are presented in Table 3.2.

Table 3.1. The summary of Borehole Data

| DRILLING NO | KM | LITHOLOGY | GROUND ELEVATION (m) | TUNNEL ELEVATION (m) | DEPTH (m) |
|---|---|---|---|---|---|
| T1-SK3(1) | 23+100 | Flysch (Marl+Clst+Lst) | 117.00 | 82.0 | 50.00 |
| T1-SK4(1) | 23+250 | Flysch (Marl+Clst+Lst) | 125.00 | 85.0 | 55.00 |
| TI-SK5(1) | 23+030 | Flysch (Clst+Marl+Sst) Volcanics (Agglomerate+Tuff) | 98.00 | 71.00 | 32.00 |
| T1-SK6(1) | 23+000 | Flysch (Clst+Sist+Sst) Volcanics (Agglomerate+Tuff) | 98.00 | 71.00 | 47.00 |
| T1-SK7(2) | 23+450 | Flysch (Clst+Marl+Sst) Volcanics (Agglomerate+Tuff) | 148.00 | 80.00 | 83.00 |
| T1-SK8(2) | 23+625 | Flysch (Clst+Marl+Sst) Volcanics (Agglomerate) | 148.00 | 84.00 | 79.00 |
| T1-SK9(2) | 23+915 | Volcanics (Agglomerate) | 185.00 | 91.00 | 109.00 |
| T1-SK10(2) | 24+250 | Flysch (Clst+Lst+Sst) Volcanics (Agglomerate+Tuff) | 190.00 | 97.00 | 108.00 |
| T1-SK11(3) | 24+450 | Flysch (Clst) Volcanics (Agglomerate) | 216.00 | 103.00 | 143.00 |
| T1-SK12(2) | 24+750 | Flysch (Clst+Marl+Cong) Volcanics (Agglomerate) | 244.00 | 110.00 | 148.00 |
| T1-SK13(2) | 25+225 | Flysch (Clst+Sist+Sst) Volcanics (Agglomerate+Tuff) | 274.00 | 120.00 | 169.00 |
| T1-SK14(2) | 25+600 | Flysch (Clst) Volcanics (Agglomerate+Bslt) | 280.00 | 130.00 | 165.00 |
| T1-SK15(2) | 25+950 | Flysch (Clst) Volcanics (Agglomerate+Bslt) | 256.00 | 137.00 | 134.00 |
| T1-SK16(2) | 26+200 | Flysch (Clst+Sist+Sst) Volcanics (Agglomerate+Bslt) | 209.00 | 142.00 | 82.00 |
| T1-SK17(2) | 26+300 | Volcanics (Agglomerate+Bslt) | 175.00 | 142.00 | 48.00 |
| T1-SK18(2) | 26+100 | Flysch (Clst) Volcanics (Agglomerate) | 172.00 | 142.00 | 45.00 |
| | | | | **TOTAL** | **1497** |
| T2-SK1 | 28+400 | Flysch (Clst) Volcanics (Agglomerate+Tuff) | 146.00 | 126.00 | 35.00 |
| T2-SK2 | 28+250 | Flysch (Clst) Volcanics (Agglomerate+Tuff) | 150.00 | 125.00 | 40.00 |
| T2-SK3 | 28+080 | Flysch (Clst) Volcanics (Agglomerate+Tuff) | 149.00 | 129.00 | 35.00 |
| T2-SK4 | 27+875 | Flysch (Clst) Volcanics (Agglomerate+Tuff) | 158.00 | 133.00 | 40.00 |
| T2-SK5 | 26+480(1) | Volcanics (Agglomerate+Tuff) | 171.00 | 145.00 | 41.00 |
| T2-SK6 | 26+480(1) | Flysch (Clst+Marl) Volcanics (Agglomerate+Tuff) | 180.00 | 145.00 | 50.00 |
| T2-SK7 | 26+675(2) | Flysch (Clst) Volcanics (Agglomerate) | 206.00 | 143.00 | 68.00 |
| T2-SK8 | 26+975(2) | Volcanics (Agglomerate+Tuff) | 210.00 | 138.00 | 87.00 |
| T2-SK9 | 27+280(2) | Flysch (Clst+Conglomerate) Volcanics (Agglomerate+Tuff) | 193.00 | 127.00 | 81.00 |
| T2-SK10 | 27+550(3) | Flysch (Clst) Volcanics (Agglomerate+Tuff) | 183.00 | 125.00 | 88.00 |
| T2-SK11 | 28+450(1) | Flysch (Clst+Sst+Marl) Volcanics (Agglomerate+Tuff) | 137.00 | 107.00 | 45.00 |
| T2-SK12 | 28+450(1) | Volcanics (Agglomerate+Tuff) | 139.00 | 107.00 | 47.00 |
| | | | | **TOTAL** | **657** |

(1) Drillings whose depth is 15.0 m below the tunnel design elevation are at portal along the axis of the single tube.
(2) Drillings reaching to 15.0 m below the tunnel design elevation are located along the axis of double tube.
(3) The depth of the pilot drilling is designed to penetrate 30.0 m below the tunnel design elevation.

Clst: Claystone Sst: Sandstone Lst: Limestone Sist: Siltstone Bslt: Basalt

Table 3.2 Domain characterizations of the Boztepe (T-1) and Öceli (T-2) tunnels.

| **BOZTEPE (T-1) TUNNEL** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **DOMAIN NAME** | T1-Pn (Entrance) | T1-1 | T1-2 | T1-3 | T1-4 | T1-5 | T1-Px (Exit) |
| **KM CHAINAGE** | 23+015<br>23+050 | 23+050<br>23+375 | 23+375<br>24+000 | 24+000<br>25+000 | 25+000<br>25+775 | 25+775<br>26+290 | 26+290<br>26+323 |
| **DRILLINGS INCLUDED** | T1-SK5 (RQD:50)<br>T1-SK6 (RQD:62) | T1-SK3 (RQD:56)<br>T1-SK4 (RQD:36) | T1-SK7 (RQD:94)<br>T1-SK8 (RQD:98)<br>T1-SK9 (RQD:97) | T1-SK10 (RQD:69)<br>T1-SK11 (RQD:67)<br>T1-SK12 (RQD:59) | T1-SK13 (RQD:67)<br>T1-SK14 (RQD:52) | T1-SK15 (RQD:69)<br>T1-SK16 (RQD:74) | T1-SK17 (RQD:52)<br>T1-SK18 (RQD:57) |
| **LITHOLOGY IN TUNNEL** | Tuff<br>Agg.<br>Clst. | Clst<br>Sst.<br>Marl | Agg. | Clst.<br>Agg.<br>Tuff | Clst.<br>Tuff | Bslt.<br>Clst.<br>Agg. | Agg. |
| **ÖCELİ (T-2) TUNNEL** | | | | | | | |
| **DOMAIN NAME** | T2-Pna* (Entrance) | T2-Pnb (Entrance) | T2-1 | T2-2 | T2-3 | T2-4 | T2-Px (Exit) |
| **KM CHAINAGE** | 26+453<br>26+550 | 26+453<br>26+550 | 26+550<br>26+800 | 26+800<br>27+050 | 27+050<br>27+375 | 27+375<br>27+750 | 27+750<br>28+492 |
| **DRILLINGS INCLUDED** | T2-SK5 (RQD:67)<br>T2-SK6 (RQD:64) | T2-SK5 (RQD:67)<br>T2-SK6 (RQD:64) | T2-SK7 (RQD:67) | T2-SK8 (RQD:86) | T2-SK9 (RQD:68) | T2-SK10 (RQD:77) | T2-SK1 (RQD:69)<br>T2-SK2 (RQD:68)<br>T2-SK3 (RQD:53)<br>T2-SK4 (RQD:64)<br>T2-SK11 (RQD:50)<br>T2-SK12 (RQD:67) |
| **LITHOLOGY IN TUNNEL** | Agg.<br>Tuff | Agg.<br>Tuff | Agg. | Agg. | Agg.<br>Clst. | Tuff<br>Agg.<br>Clst. | Agg.<br>Tuff |

* Domains entitled in the form of "T# - P" indicates the tunnel portals where "n" denotes entrance and "x" denotes exit. Similarly, "a" denotes left tube and "b" denotes right tube in the order of km increase.

Agg: Agglomerate
Bslt: Basalt
Clst: Claystone
Sst: Sandstone

### 3.4 Rock Mechanics Laboratory Tests

The rock mechanics laboratory tests on the samples, removed from boreholes and taken to the laboratory, were executed in three different categories as;

- Unit weight determination,
- Uniaxial compression test for the determination of uniaxial compressive strength, Young's modulus and Poisson's ratio,

- Indirect tensile strength (Brazilian) test, and triaxial compressive strength tests for the determination of cohesion and internal friction angle.

In order to explore the conditions for Boztepe Tunnel (T-1); 25 samples for unit weight determination, 20 samples for uniaxial compressive strength determination, 11 samples for indirect tensile strength determination and 6 sample trios for triaxial tests were experimented.

Likewise, to explore the conditions for Öceli Tunnel (T-2); 21 samples for unit weight determination, 30 samples for uniaxial compressive strength determination, 6 samples for indirect tensile strength determination and 3 sample trios with one sample quartet for triaxial tests were experimented.

All these rock mechanics laboratory tests were held at the rock mechanics laboratory of the "Directorate of Geotechniques and Tunnels Department" of General Directorate of State Highways. The test results are presented at Table 3.3, 3.4 and 3.5.

These test results would not be directly included into the tunneling design process since they represent the rock material properties. On the other hand, they would be evaluated as one of the components in the assessment of the rock mass classifications. The question immediately arises as to how the rock material is related to the rock mass. In answering this question, one must note, first of all, that the importance of the properties of intact rock material will be generally overshadowed by the properties of the discontinuities in the rock masses. Nevertheless, this does not mean that the properties of the intact rock material should be disregarded when considering the behavior of the jointed rock masses. After all, if discontinuities are widely spaced or if the intact rock is weak and altered, the properties of the intact rock may strongly influence the gross behavior of the rock mass. Furthermore, a sample of a rock material sometimes represents a small-scale model of the rock mass, since they both have gone through the same geological cycle. However, in general, the properties of the discontinuities are of greater importance than the properties of the intact rock material (Bieniawski, 1989).

Table 3.3. Uniaxial compression test results.

| BOZTEPE TUNNEL (T-1) | | | | | ÖCELİ TUNNEL (T-2) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample No** | **Depth (m)** | **Uniaxial Comp. Strength (MPa)** | **Young's Mod. (GPa)** | **Poisson's Ratio** | **Sample No** | **Depth (m)** | **Uniaxial Comp. Strength (MPa)** | **Young's Mod. (GPa)** | **Poisson's Ratio** |
| T1 SK3 | 31.00-31.23 | 73 | 17.0 | 0.38 | T2 SK1 | 19.80-20.00 | 76 | - | - |
| T1 SK3 | 46.75-47.00 | 41 | 21.5 | 0.07 | T2 SK1 | 29.65-30.00 | 8.4 | - | - |
| T1 SK4 | 50.57-50.72 | 33 | 10.5 | 0.13 | T2 SK1 | 29.65-30.00 | 6.82 | 0.7 | 0.32 |
| T1 SK6 | 26.27-26.53 | 44 | 11.5 | 0.21 | T2 SK2 | 35.73-36.00 | 12 | 2.5 | 0.18 |
| T1 SK7 | 60.19-60.49 | 33 | 10.7 | 0.22 | T2 SK3 | 18.40-18.75 | 61.0 | - | - |
| T1 SK8 | 59.72-59.97 | 22 | - | - | T2 SK4 | 26.28-26.52 | 2.2 | - | - |
| T1 SK9 | 75.71-76.00 | 45 | 12.3 | 0.13 | T2 SK4 | 31.20-31.54 | 17 | - | - |
| T1 SK9 | 86.00-86.37 | 39 | 12.3 | 0.17 | T2 SK4 | 38.77-39.10 | 13.79 | 8.15 | 0.12 |
| T1 SK9 | 101.17-101.50 | 26 | - | - | T2 SK5 | 25.48-25.72 | 11.65 | 4.4 | 0.41 |
| T1 SK10 | 82.35-82.57 | 24 | 30 | 0.23 | T2 SK6 | 28.33-28.50 | 91.0 | 22.75 | 0.14 |
| T1 SK10 | 92.81-93.09 | 67 | 41 | 0.3 | T2 SK6 | 38.00-38.29 | 64 | - | - |
| T1 SK11 | 113.27-113.42 | 20 | 10 | 0.44 | T2 SK6 | 38.00-38.29 | 63 | - | - |
| T1 SK12 | 136.00-136.23 | 28 | 7.3 | 0.38 | T2 SK7 | 42.75-43.00 | 17 | - | - |
| T1 SK14 | 159.81-160.00 | 62 | - | - | T2 SK7 | 42.75-43.00 | 15 | - | - |
| T1 SK15 | 27.66-28.00 | 33 | - | - | T2 SK7 | 58.03-58.30 | 22 | 2.25 | 0.09 |
| T1 SK15 | 100-100.24 | 25 | 10 | 0.26 | T2 SK7 | 58.03-58.30 | 23.6 | - | - |
| T1 SK15 | 116.20-116.46 | 95 | - | - | T2 SK8 | 62.00-62.25 | 28 | - | - |
| T1 SK16 | 49.52-49.73 | 6.5 | 6.2 | - | T2 SK8 | 70.56-70.80 | 1.05 | - | - |
| T1 SK16 | 63.85-64.14 | 54 | 37 | 0.24 | T2 SK9 | 47.30-47.60 | 8.4 | - | - |
| T1 SK17 | 22.00-22.21 | 97 | - | - | T2 SK10 | 61.30-61.50 | 16 | 1.7 | 0.20 |
| | | | | | T2 SK10 | 66.09-66.27 | 7.10 | - | - |
| | | | | | T2 SK10 | 69.25-69.60 | 11.3 | - | - |
| | | | | | T2 SK10 | 69.25-69.60 | 11.8 | - | - |
| | | | | | T2 SK11 | 30.33-30.54 | 17 | 3.0 | 0.17 |
| | | | | | T2 SK11 | 36.09-39.33 | 12.63 | - | - |
| | | | | | T2 SK12 | 14.60-14.84 | 10.9 | - | - |
| | | | | | T2 SK12 | 14.60-14.84 | 39.3 | - | - |
| | | | | | T2 SK12 | 21.28-21.50 | 5.0 | 1.6 | 0.36 |
| | | | | | T2 SK12 | 21.28-21.50 | 2.46 | - | - |
| | | | | | T2 SK12 | 26.97-27.36 | 3.5 | - | - |

Table 3.4. Results of the triaxial compressive strength tests of the core samples.

| Sample No. | Depth (m) | Lithology | Lateral Stress $\sigma_3$ (MPa) | Axial Stress $\sigma_1$ (MPa) | c (MPa) | $\phi$ ( ° ) |
|---|---|---|---|---|---|---|
| T1 SK7 | 48.00-48.33 | Volcanics (Agglomerate) | 10 | 74.2 | 11.6 | 32 |
| T1 SK7 | 48.00-48.33 | | 20 | 109.1 | | |
| T1 SK7 | 48.00-48.33 | | 30 | 139.7 | | |
| T1 SK9 | 66.65-67.00 | Volcanics (Agglomerate) | 10 | 45 | 6.8 | 27 |
| T1 SK9 | 66.65-67.00 | | 20 | 85 | | |
| T1 SK9 | 66.65-67.00 | | 30 | 99 | | |
| T1 SK9 | 75.71-76.00 | Volcanics (Agglomerate) | 10 | 78 | 15.7 | 27 |
| T1 SK9 | 86.00-86.37 | | 20 | 107 | | |
| T1 SK9 | 86.00-86.37 | | 30 | 132 | | |
| T1 SK10 | 82.35-82.57 | Flysch (Limestone) | 10 | 51.4 | 6.7 | 29 |
| T1 SK10 | 75.25-75.50 | | 20 | 81.4 | | |
| T1 SK10 | 75.25-75.50 | | 30 | 109.3 | | |
| T1 SK16 | 63.83-64.14 | Volcanics (Agglomerate) | 10 | 80.8 | 13.5 | 31 |
| T1 SK16 | 70.50-70.82 | | 20 | 109.2 | | |
| T1 SK16 | 70.50-70.82 | | 30 | 144.1 | | |
| T1 SK18 | 14.48-14.70 | Volcanics (Agglomerate) | 10 | 42.9 | 13.5 | 33 |
| T1 SK18 | 14.48-14.70 | | 20 | 81.4 | | |
| T1 SK18 | 20.56-20.81 | | 30 | 111.4 | | |
| T2 SK2 | 35.73-36.00 | Volcanics (Agglomerate) | 10 | 66 | 8.9 | 33 |
| T2 SK4 | 31.20-35.54 | | 10 | 61 | | |
| T2 SK1 | 14.16-14.42 | | 30 | 111 | | |
| T2 SK1 | 14.16-14.42 | | 30 | 128 | | |
| T2 SK3 | 18.40-18.75 | Volcanics (Agglomerate and basaltic tuff) | 10 | 175 | 35.8 | 35 |
| T2 SK5 | 14.00-14.26 | | 20 | 206 | | |
| T2 SK6 | 23.22-23.45 | | 30 | 248 | | |
| T2 SK8 | 70.56-70.80 | Volcanics (Agglomerate) | 10 | 35 | 1.8 | 28 |
| T2 SK8 | 67.54-67.83 | | 20 | 60 | | |
| T2 SK8 | 67.54-67.83 | | 30 | 91 | | |
| T2 SK12 | 26.97-27.36 | Volcanics (Agglomerate and basaltic tuff) | 10 | 85 | 16.4 | 30 |
| T2 SK12 | 26.97-27.36 | | 20 | 120 | | |
| T2 SK12 | 26.97-27.36 | | 30 | 145 | | |

Table 3.5. Indirect tensile strength (Brazilian) test results.

| BOZTEPE TUNNEL (T-1) | | | | ÖCELİ TUNNEL (T-2) | | | |
|---|---|---|---|---|---|---|---|
| **Sample No** | **Lithology** | **Depth (m)** | **Indirect Tensile Strength (MPa)** | **Sample No** | **Lithology** | **Depth (m)** | **Indirect Tensile Strength (MPa)** |
| T1 SK3 | Limestone | 31.00-31.23 | 6.85 | T2 SK4 | Agglomerate | 38.77-39.10 | 1.94 |
| T1 SK3 | Limestone | 46.75-47.60 | 5.05 | T2 SK5 | Tuff | 25.48-25.72 | 0.55 |
| T1 SK6 | Agglomerate | 26.27-26.53 | 2.51 | T2 SK6 | Tuff | 38.00-38.29 | 4.67 |
| T1 SK7 | Agglomerate | 60.19-60.49 | 3.66 | T2 SK8 | Basalt | 67.54-67.83 | 0.30 |
| T1 SK9 | Agglomerate | 75.71-76.00 | 3.11 | T2 SK10 | Claystone | 61.30-61.50 | 0.75 |
| T1 SK9 | Agglomerate | 86.00-86.37 | 6.21 | T2 SK11 | Sandstone | 30.33-30.54 | 3.49 |
| T1 SK10 | Limestone | 82.35-82.57 | 3.25 | | | | |
| T1 SK12 | Agglomerate | 136.00-136.23 | 2.53 | | | | |
| T1 SK15 | Basalt | 100.00-100.24 | 2.29 | | | | |
| T1 SK16 | Basalt | 63.85-64.14 | 5.02 | | | | |
| T1 SK17 | Agglomerate | 22.00-22.21 | 6.28 | | | | |

## 3.5 Seismicity

The project area is located between the eastern latitudes 37° and 38°, and between the longitudes 41° and 42°. According to the catalogue of Institute of Earthquake Research Department (2003), several earthquakes maximum magnitudes of which are 7.18MM (Moment magnitude), 6.65MM, 8.90MM and 9.120MM occurred in the project area situated between the latitudes and longitudes mentioned above.

According to the document "Earthquakes Zones of Turkey, Ministry of Public Works and Settlement" the project area lies in "3rd Degree Earthquake Zone". Accordingly the "Effective Ground Acceleration Coefficient ($a_h$ /g)" of 0.20 is recommended for the design works.

# CHAPTER IV

# ROCK MASS CLASSIFICATION SYSTEMS

## 4.1 Introduction

In rock engineering, the first major classification system was proposed over 40 years ago for tunneling with steel supports (Terzaghi, 1946). Considering the three main design approaches for excavation in rock – analytical, observational and empirical – as practiced in mining and civil engineering, rock mass classifications today form an integral part of the most predominant design approach, the empirical design methods. Indeed, on many underground construction and mining projects, rock mass classifications have provided the only systematic design aid in an otherwise haphazard "trial-and-error" procedure.

Empirical design methods assess the stability of mines and tunnels by the use of statistical analyses of underground observations. Engineering rock mass classifications most of which are tabulated in Table 4.1 constitute the best-known empirical approach for the assessment of the stability of underground openings in rock (Hoek and Brown, 1980).

Judgement and experience are major ingredients in rock engineering design. Empirical design methods solve the problem of our own limited experience by making available the accumulated experience of others. It requires three steps beyond simple judgement:

1. Description of GROUND QUALITY by a quantitative classification system, to provide a universal language whereby the experience gained globally working in ground of many different qualities can be related to future projects.
2. Description of GROUND PERFORMANCE by a formalized quantitative system, which defines such parameter as unsupported stand time and support requirements, bearing capacities and excavating methods.

3. CORRELATION OF GROUND QUALITY TO PERFORMANCE by a compilation and comparison of results from a variety of projects over a full spectrum of ground conditions (case histories).

Table 4.1. Best known empirical rock mass classification systems.

| Name of Classification | Originator and Date | Country of Origin | Applications |
|---|---|---|---|
| Rock Load | Terzaghi, 1946 | USA | Tunnels with steel support |
| Stand-up Time | Lauffer, 1958 | Austria | Tunneling |
| NATM | Pacher et al., 1964 | Austria | Tunneling |
| Rock Quality Designation | Deere et al., 1967 | USA | Core logging, Tunneling |
| RSR Concept | Wickham et al., 1972 | USA | Tunneling |
| RMR System (Geomechanics Classification) | Bieniawski, 1973 | South Africa | Tunnels, mines, slopes, foundations |
| Q – System | Barton et al., 1974 | Norway | Tunnels, chambers |
| Strength – Size | Franklin, 1975 | Canada | Tunneling |
| Basic Geotechnical Description | International Society for Rock Mechanics, 1981 | England | General, communication |
| Unified Classification | Williamson, 1984 | USA | General, communication |

Tunneling is an application in which empirical methods are widely used. Various rock mass and performance classifications have emerged specifically for tunneling. The two most widely used are the Rock Mass Quality (Q) System of Barton et al. (1974) from the Norwegian Geotechnical Institute, and the Geomechanics or Rock Mass Rating (RMR) System of Bieniawski (1973, 1989).

Empirical rules are safe to apply only in the context for which they were formulated, and extrapolation can be dangerous if a method has no theoretical basis. Semi-empirical methods are perhaps better, in which rock quality and performance are related through a "theoretically sound" formula where only the constants of the formula are determined from experience.

Unlike other engineering materials, rock presents the designer with unique problems. First of all, rock is a complex material varying widely in its properties and in most mining as well as civil engineering situations, not one but a number of rock types will be present. Moreover, a choice of rock materials is only possible, if there is a choice of alternative sites for a given project, although it may be available, to some extent, to reinforce the rock surrounding the excavation. Most of all, the design engineer and geologist are confronted with rock as an assemblage of blocks of rock material separated by various types of discontinuities, such as joints, faults, bedding planes and so on. This assemblage constitutes a rock mass. Consequently, the engineering properties of both the intact rock and the rock mass must be considered (Bieniawski, 1989).

In essence, rock mass classifications are not to be taken as a substitute for engineering design. They should be applied intelligently and used in conjunction with observational methods and analytical studies to formulate an overall design rationale compatible with the design objectives and site geology (Bieniawski, 1989).

The objectives of rock mass classifications are therefore to:

1. Identify the most significant parameters influencing the behavior of a rock mass.
2. Divide a particular rock mass formation into groups of similar behavior, that is, rock mass classes of varying quality.
3. Provide a basis for understanding the characteristics of each rock mass class.
4. Relate the experience of rock conditions at one site to the conditions and experience encountered at others.
5. Derive quantitative data and guidelines for engineering design.
6. Provide a common basis for communication between engineers and geologists.

Both the Q and RMR systems are classification methods that attempt to characterize the rock mass based on the important geological factors affecting the stability of an underground opening. Both systems have been widely used and have been adapted for many applications. However, they are continually extrapolated for use in situations for which they were not intended. The output for both, although quantitative in nature, was largely intended to provide the engineer with a “feel” for the rock mass. By comparing the current design situation with similar ones in the past, the engineer can gain valuable insight into the possible performance of the planned opening.

Before either classification system is used it is important that the underlying assumptions are known. Fundamental cases should be examined to determine the degree of confidence that can be placed on the results of a consultation.

In the following sections throughout this chapter, some of the most significant rock mass classification systems employed mainly in underground excavations are recapitulated. Of the many rock mass classification systems in existence, two requires special attention since they are most common, namely, the Geomechanics Classification (RMR) System and the Q-system. In addition, in this chapter, the Modified RMR (M-RMR) method is reviewed.

## 4.2 Geomechanics Classification (Rock Mass Rating System)

The Rock Mass Rating (RMR) system, otherwise known as the Geomechanics Classification, was developed by Bieniawski during 1972 – 1973. It was modified over the years as more case histories became available and to conform with international standards and procedures (Bieniawski, 1976). However, it's important to state that the system has remained essentially the same in principle despite the changes. Thus, any modifications and extensions were the outgrowth of the same basic method and should not be misconstrued as new systems.

In order to classify a rock mass using the RMR system (Geomechanics Classification), the following six parameters are utilized:

1. Uniaxial compressive strength of rock material
2. Rock quality designation (RQD)
3. Spacing of discontinuities
4. Condition of discontinuities
5. Groundwater conditions
6. Orientation of discontinuities

After some experience had been gained in the practical application of the original CSIR (South African Council for Scientific and Industrial Research) Geomechanics Classification, Bieniawski has modified his classification system by removing the orientation of discontinuities from the list of basic classification parameters and their effects allowed for by a rating adjustment made after the basic parameters had been considered.

To apply Geomechanics Classification, the rock mass is divided into a number of structural regions such that certain features are more or less uniform within each region. Although rock masses are discontinuous in nature, they may nevertheless be uniform in regions when, for example, the type of rock or the discontinuity spacings are the same throughout the region. The above classification parameters are determined for each structural region from measurements in the field and entered into the standard input data sheet as given in Table 4.2. Right at this point, the evaluation of some of these parameters such as, weathering condition, is directly related with the experience and the judgment of the geological engineer. Therefore, the distinction between the descriptions should be clear as much as possible so that anyone can get more or less the same outcome from the same field condition.

The explanations of these basic parameters are briefly given below.

1. Strength of Intact Rock Material

The first parameter needed for the rock mass classification is the intact rock strength. This value can be obtained from any of several testing methods in the laboratory or from rock descriptions in the field. Bieniawski uses the uniaxial compressive strength of intact rock for the classification. Alternatively, for rocks that exhibit very low strengths, the point load index may be used as a measure of the intact rock material strength. For anisotropic rocks, the strength most critical for failure should be used. The intact rock strength has a minimum value of 0 (Very Poor) for extremely weak rock, and a maximum of 15 (Very Good) for very strong rock (Section A-1 of Table 4.2).

2. Rock Quality Designation

The Rock Quality Designation (RQD) index was introduced about 40 years ago as an index of rock quality at a time when rock quality information was usually available from the geologists' descriptions and the percentage of core recovery (Deere and Deere, 1988). The RQD percentage includes only the pieces of sound core over 100mm long, which are summed and divided by the length of the core run. It was originally developed as a modified core recovery index for NX size core (54.7 mm in diameter). Larger sizes of drill core can be used without problems but with smaller cores, RQD values tend to be artificially low. An RQD value would usually be established for each core run of 1.5 or 2 meters. It has been correlated with fracture frequency, volumetric joint count, joint spacing, and seismic velocity.

Table 4.2. Rock Mass Rating System (After Bieniawski 1989)

| **A. CLASSIFICATION PARAMETERS AND THEIR RATINGS** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load Strength index | > 10 MPa | 4 - 10 MPa | 2 - 4 MPa | 1 - 2 MPa | For this low range uniaxial compressive test is preferred. | | |
| | | Uniaxial Compressive Strength | > 250 MPa | 100 - 250 MPa | 50 - 100 MPa | 25 - 50 MPa | 5 - 25 MPa | 1 - 5 MPa | < 1 MPa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core quality(RQD) | | 90% - 100% | 75% - 90% | 50% - 75% | 25% - 50% | < 25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | > 2 m | 0.6 - 2 m | 200 - 600 mm | 60 - 200 mm | < 60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation < 1 mm Slightly weathered walls | Slightly rough surfaces Separation < 1 mm Highly weathered walls | Slickensided surfaces or Gouge< 5 mm thick or Separation 1-5 mm Continuous | Soft gouge < 5 mm thick or Separation < 5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Groundwater | Inflow per 10 m Tunnel length (l/m) | None | < 10 | 10 - 25 | 25 - 125 | > 125 | | |
| | | (Joint water press) / (Major principal o) | 0 | < 0.1 | 0.1 - 0.2 | 0.2 - 0.5 | > 0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| **B.RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)** | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very unfavourable |
| Ratings | Tunnels & mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| **C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS** | | | | | |
|---|---|---|---|---|---|
| Rating | 100 - 81 | 80 - 61 | 60 - 41 | 40 - 21 | < 21 |
| Class number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| **D.MEANING OF ROCK CLASSES** | | | | | |
|---|---|---|---|---|---|
| Class number | I | II | III | V | V |
| Average stand-up time | 20 yrs. for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs. for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | > 400 | 300 - 400 | 200 - 300 | 100 - 200 | < 100 |
| Friction angle of rock mass (deg) | > 45 | 35 - 45 | 25 - 35 | 15 - 25 | < 15 |

| **E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS** | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) Rating | < 1m 6 | 1 - 3m 4 | 3 - 10m 2 | 10 - 20m 1 | > 20m 0 |
| Separation (aperture) Rating | None 6 | < 0.1mm 5 | 0.1 - 1.0mm 4 | 1 - 5mm 1 | > 5mm 0 |
| Roughness Rating | Very rough 6 | Rough 5 | Slightly rough 3 | Smooth 1 | Slickensided 0 |
| Infilling (gouge) Rating | None 6 | Hard filling <5mm 4 | Hard filling >5mm 2 | Soft filling < 5mm 2 | Soft filling >5mm 0 |
| Weathering Rating | Unweathered 6 | Slightly weathered 5 | Moderately weath. 3 | Highly weathered 1 | Decomposed 0 |

| **F. EFFECT OF DISCONTINUITY STRIKE AND ORIENTATION IN TUNNELING** | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis | |
| Drive with dip-Dip 45-90° | Drive with dip-Dip 20-45° | Dip 45-90° | Dip 20-45° |
| Very favourable | Favourable | Very favourable | Fair |
| Drive against dip-Dip 45-90° | Drive against dip-Dip 20-45° | Dip 0-20° - Irrespective of strike | |
| Fair | Unfavourable | Fair | |

$$RQD(\%) = \frac{\sum \text{Length of core pieces} \rangle 100\text{mm}}{\text{Total core run length}} \text{x} 100 \quad (1)$$

Today, the RQD is used as a standard parameter in drill core logging and forms a basic element of the two major rock mass classification systems: the RMR system and the Q-system.

Palmstrom (1982) has suggested that when core is unavailable the RQD may be estimated from the number of joints per unit volume, in which the number of joints per meter of each joint set is added. The conversion for clay-free rock masses is,

$$RQD = 115 - 3.3J_v \quad (2)$$

where $J_v$= total number of joints per $m^3$ (RQD=100 for $J_v$<4.5)

The RQD Rating has a minimum value of 3 (Very Poor) for an RQD of 0 % and a maximum of 20 (Very Good) for an RQD of 100%.

3. Spacing of Discontinuities

The term discontinuity is used to mean all that may be joints, faults, bedding planes and other surfaces of weaknesses. The mean spacing of each set must be found in order to determine the RMR Spacing Rating. The RMR Spacing Rating varies from a minimum of 5 (Very Poor) for mean spacings approaching 0 mm up to a maximum of 20 (Very Good) for mean spacings exceeding 2 m.

4. Condition of Discontinuities

The next parameters to be evaluated are the joint condition rating. This parameter accounts for the separation or aperture of discontinuities, their continuity, the surface roughness, the wall condition (hard or soft), joint wall weathering and the presence of infilling materials in the joints. These are important factors affecting the shear strength of a discontinuity. However, all factors may not be required. For example, if the joint aperture is large and filled with material, the joint wall roughness is irrelevant because it is the filling material that governs the shear strength. The Joint Condition Rating varies from 0 for joint

apertures above 5 mm filled with soft gouge (Very Poor) to 30 for tight, non-persistent, rough joints (Very Good).

5. Groundwater Conditions

The final parameter to be determined is the Ground Water Rating. An effort is made to determine the influence of ground water flow on the stability of underground excavations in terms of the observed rate of flow into the excavation, the ratio of the joint water pressure to the major principal stress or by some general qualitative observation of groundwater conditions.

Groundwater reduces the normal stress acting across a joint surface, thus reducing the effective shear strength of the joint. Also, inflows can wash out joint fillings, leading to higher inflows. The Ground Water Rating ranges from 0 (Very Poor) for high inflows, high water pressures, or flowing conditions to 15 (Very Good) for no inflow, no water pressures or very dry conditions. In the feasibility stage of tunnel design, groundwater conditions can be estimated from the depth below the water table.

6. Orientation of discontinuities

The orientation of the joint set with respect to the tunnel axis is important for stability during the excavation stage. The Orientation Adjustment Factor varies from -12 for steeply dipping joint sets parallel to the tunnel (Very Unfavorable) to 0 for steeply dipping joints perpendicular to the tunnel (Very Favorable). However, this parameter has no direct relation with the shear strength of the rock mass. Therefore, the final rating to determine the rock class according to RMR should exclude the scores due to this property whose influence can only be felt during excavation.

In the Geomechanics Classification presented in Table 4.2, five parameters are grouped into five ranges of values. Since the various parameters are not equally important for the overall classification of a rock mass, rating importance is allocated to the different value ranges of the parameters, a higher rating indicating better rock mass conditions. The importance ratings are assigned to each parameter according to Section A of Table 4.2. In this respect, the average typical conditions are evaluated and the ratings are interpolated. Moreover, it should be noted that the importance ratings given for discontinuity spacings were developed for rock masses having three sets of discontinuities. Thus, when only two sets of discontinuities are present a conservative assessment is obtained.

After the importance ratings of the classification parameters are established, the ratings for the five parameters listed in Section A of Table 4.2 are summed to yield the basic (unadjusted for discontinuity orientations) rock mass rating for the structural region under construction.

The next step is to include the sixth parameter, namely the influence of strike and dip orientation of discontinuities, by adjusting the basic rock mass rating according to Section B of Table 4.2. This step is treated separately since the influence of the discontinuity orientations depends upon the engineering applications. It will be noted that the "value" of the parameter "discontinuity orientation" is not given in quantitative terms but by qualitative descriptions such as "favorable". To facilitate a decision whether strike and dip orientations are favorable or not in tunneling, reference should be made to Section F of Table 4.2, which is based on studies by Wickham et al., 1972.

After the adjustment for discontinuity orientations, the rock mass is classified according to Section C of Table 4.2 which groups the final (adjusted) rock mass rating (RMR) into five rock mass classes. It must be emphasized that it is the actual numerical rating rather than the general rock mass class that is significant since the RMR values and not rock classes are used in engineering applications.

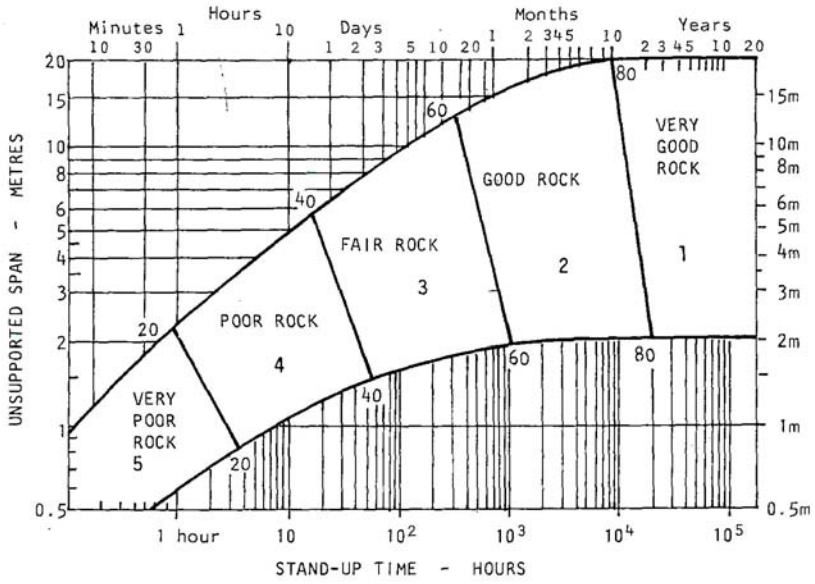
The Geomechanics Classification suggests shear strength parameters, namely cohesion (c), internal friction angle ($\phi$), Young's modulus (E) (Figure 4.1.a) and average stand-up time (Figure 4.1.b) for the rock masses assessed through RMR system as shown below.

$$E\,(\mathrm{GPa}) = 2\mathrm{xRMR} - 100; \qquad \mathrm{RMR} > 50 \tag{3a}$$

$$E\,(\mathrm{GPa}) = 10^{(\mathrm{RMR}-10)/40}; \qquad \mathrm{RMR} \le 50 \tag{3b}$$

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | |
|---|---|---|
| Rating | 80 – 61 | |
| Class number | II | |
| Description | Good rock | |
| **D.MEANING OF ROCK CLASSES** | | |
| Class number | II | |
| Average stand-up time | 1 year for 10 m span | |
| ***Cohesion*** of rock mass (kPa) | 300 – 400 | |
| ***Friction angle*** of rock mass (deg) | 35 – 45 | |

(a)




Relationship between the stand-up time of an unsupported underground excavation span and the CSIR Geomechanics Classification proposed by Bieniawski[26].

(b)

Figure 4.1 Outcomes via the Geomechanics Classification. (a) Rock mass shear strength parameters. (b) Average stand-up time vs. unsupported span graph.

In addition, the Geomechanics classification system provides guidelines for the selection of rock reinforcement for tunnels in accordance with Table 4.3. These guidelines depend on factors such as the depth below surface (in situ stresses), tunnel size and shape, and the method of excavation.

| Table 4.3. Geomechanics Classification guide for excavation and support in rock tunnels (horseshoe shape, 10m wide, vertical stress < 25 MPa, drilling-and –blasting construction) | | | | |
|---|---|---|---|---|
| **Rock Mass Class** | **Excavation** | **Support** | | |
| | | **Rock bolts (20 mm dia., fully bonded)** | **Shotcrete** | **Steel Sets** |
| **1. Very Good Rock RMR: 81-100** | Full face: 3 m advance | Generally no support required except for occasional spot bolting | | |
| **2. Good Rock RMR: 61-80** | Full face: 1.0-1.5 m advance: Complete support 20 m from face | Locally bolts in crown 3 m long, spaced 2.5 m with occasional wiremesh | 50 mm in crown where required | None |
| **3. Fair Rock RMR: 41-60** | Top heading and bench: 1.5-3.0 m advance in top heading: Commerce support after each blast: Complete support 10 m from face | Systematic bolts 4 m long, spaced 1.5-2 m in crown and walls with wiremesh in crown | 50-100 mm in crown and 30 mm in sides | None |
| **4. Poor Rock RMR: 21--40** | Top heading and bench: 1.0-1.5 m advance in top heading: Install support concurrently with excavation-10 m from face | Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wiremesh | 100-150 mm in crown and 100 mm in sides | Light ribs spaced 1.5 m where required |
| **5. Very Poor Rock RMR < 20** | Multiple drifts: 0.5-1.5 m advance in top heading: Install support concurrently with excavation: shotcrete as soon as possible after blasting | Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wiremesh. Bolt invert | 150-200 mm in crown and 150 mm in sides and 50 mm on face | Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert |

## 4.3 NGI Tunneling Quality Index (Q-system)

The vast majority of the thousands of kilometers of tunnels constructed worldwide every year do not have the benefit of performance monitoring. Design decisions are nevertheless required both before and during construction. No matter how many sophisticated rock mechanics test programs and finite element analyses are performed, design engineers will come back to the basic question: “Is this bolt spacing, shotcrete thickness or unsupported span width reasonable in the given rock mass?”

At present we have to rely on engineering judgment or on classification methods where the design is based on precedent and where a good classification method will allow us to extrapolate past designs to different rock masses and to different sizes and types of excavation. Underground excavations can be supported with some confidence primarily because many others have been supported before them and have performed satisfactorily.

The Q-system of rock mass classification was developed in Norway in 1974 by Barton, Lien and Lunde, all of the Norwegian Geotechnical Institute. Its development represented a major contribution to the subject of rock mass classification for a number of reasons: the system was proposed on the basis of analysis of 212 tunnel case histories from Scandinavia, it’s a quantitative classification system, and it’s an engineering system facilitating the design of tunnel supports.

The Q-system is based on a numerical assessment of the rock mass quality using six different parameters:

1. RQD
2. Number of Joints
3. Roughness of the most unfavorable joint or discontinuity
4. Degree of alteration or filling along the weakest joint
5. Water inflow
6. Stress Condition

These six parameters are grouped into three quotients to give the overall rock mass quality Q as follows:

$$Q = \frac{RQD}{J_n} \cdot \frac{J_r}{J_a} \cdot \frac{J_w}{SRF} \qquad (4)$$

where RQD = Rock quality designation,
$J_n$ = Joint set number,
$J_r$ = Joint roughness number,
$J_a$ = Joint alteration number,
$J_w$ = Joint water reduction number,
SRF = Stress reduction factor.

RQD

The rock quality designation ranged in a quite uniform manner from 0 up to 100%. Forty cases lay in the "very poor" category (0 to 25%) and fifty-three cases in the excellent category (90 to 100%).

Number of joint sets ($J_n$)

The number of joint sets was most commonly in the range of one set (plus random) to three sets (plus random). Fifty-two cases, the largest group, had exactly three joint sets. Extreme cases consisted of massive, unjointed rock and completely crushed, disintegrated rock.

Joint roughness ($J_r$)

The joint roughness numbers most commonly found in the 212 case records were 1.0-1.5-2.0, which represent smooth-planar, rough-planar and smooth-undulating surfaces, respectively.

Joint alteration ($J_a$)

The joint alteration parameter most commonly seen in the case records was represented by the number 1.0 (unaltered or unweathered). 103 cases were in this class. However, more than 80 of the case records involved clay mineral joint fillings of various kinds; these included 12 swelling clay occurrences.

Joint water ($J_w$)

The joint water reduction factor describing the degree of water inflow was strongly biased in the direction of "dry excavations or minor inflow" (5 l/min locally). 81% of the

cases fell in this category. 24 cases had medium inflow, occasional outwash of joint fillings ($J_w$= 0.66).

Stress reduction factor (SRF)

The stress reduction factor has 16 classes. These are divided into four broad groups: (a) weakness zones causing loosening or fall out, (b) rock stress problems in competent rock, (c) squeezing (flow of incompetent rock) and (d) swelling (chemical effect due to water uptake).

The quotient ($RQD/J_n$), representing the structure of the rock mass, is a crude measure of the block or particle size, with the two extreme values (100/0.5 and 10/20) differing by a factor of 400. If the quotient is interpreted in units of centimeters, the extreme "particle sizes" of 200 to 0.5 cm are seen to be crude but fairly realistic approximations. Probably the largest blocks should be several times this size and the smallest fragments lass than half the size (Hoek, 1998).

The other quotient ($J_r/J_a$) represents the roughness and frictional characteristics of the joint walls or filling materials. This quotient is weighted in favor of rough, unaltered joints in direct contact. It is to be expected that such surfaces will be close to peak strength, that they will dilate strongly when sheared, and they will therefore be specifically favorable to tunnel stability.

When rock joints have thin clay mineral coatings and fillings, the strength is reduced significantly. However, rock wall contact after small shear displacements have occurred may be a very important factor for preserving the excavation from ultimate failure.

The last quotient ($J_w$/SRF) consists of two stress parameters. SRF is a measure of (a) loosening load in case of an excavation through shear zones and clay bearing rock, (b) rock stress in competent rock, and (c) squeezing loads in plastic incompetent rocks. It can be regarded as a total stress parameter. The parameter $J_w$ is a measure of water pressure, which has an adverse affect on the shear strength of joints due to a reduction in effective normal stress. Water may, in addition, cause softening and possible out-wash in the case of clay-filled joints. This quotient is a complicated empirical factor describing the "active stress" (Hoek, 1998).

Barton and Grimstad (1994) have made some modifications to the SRF values. In situations where "competent rock, rock stress problems" exist, the values associated with the SRF term have been significantly increased (Table 4.4).

Table 4.4. The modified SRF values suggested by Barton and Grimstad (1994).

| | Competent rock, rock stress problems | $\sigma_c/\sigma_1$ | $\sigma_\theta/\sigma_c$ | **Updated SRF** |
|---|---|---|---|---|
| L | Moderate slabbing after > 1 hour in ***massive*** rock | 5-3 | 0.5-0.65 | **5-50** |
| M | Slabbing and rock burst after a few minutes in ***massive*** rock | 3-2 | 0.65-1 | **50-200** |
| N | Heavy rock burst (strain-burst) and immediate dynamic deformations in ***massive*** rock | < 2 | > 1 | **200-400** |

The new SRF values have been increased considerably from the original values, in some cases by a factor of 20 and an extra category has been added.

Table 4.5 gives the classification of individual parameters used to obtain the Tunneling Quality Index Q for a rock mass.

Table 4.5. Classification of Individual Parameters in the Tunneling Quality Index Q (After Barton et al 1974)

| DESCRIPTION | VALUE | NOTES |
|---|---|---|
| **1. ROCK QUALITY DESIGNATION** | ***RQD*** | |
| A. Very poor | 0 - 25 | 1. Where *RQD* is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate Q. |
| B. Poor | 25 - 50 | |
| C. Fair | 50 - 75 | |
| D. Good | 75 - 90 | 2. *RQD* intervals of 5, i.e. 100, 95, 90 etc. are sufficiently accurate. |
| E. Excellent | 90 - 100 | |
| **2. JOINT SET NUMBER** | $J_n$ | |
| A. Massive, no or few joints | 0.5 - 1.0 | |
| B. One joint set | 2 | |
| C. One joint set plus random | 3 | |
| D. Two joint sets | 4 | |
| E. Two joint sets plus random | 6 | |
| F. Three joint sets | 9 | 1. For intersections use $(3.0 \times J_n)$ |
| G. Three joint sets plus random | 12 | |
| H. Four or more joint sets, random, heavily jointed, 'sugar cube', etc. | 15 | 2. For portals use $(2.0 \times J_n)$ |
| J. Crushed rock, earthlike | 20 | |
| **3. JOINT ROUGHNESS NUMBER** | $J_r$ | |
| ***a. Rock wall contact*** | | |
| ***b. Rock wall contact before 10 cm shear*** | | |
| A. Discontinuous joints | 4 | |
| B. Rough and irregular, undulating | 3 | |
| C. Smooth undulating | 2 | |
| D. Slickensided undulating | 1.5 | 1. Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m. |
| E. Rough or irregular, planar | 1.5 | |
| F. Smooth, planar | 1.0 | |
| G. Slickensided, planar | 0.5 | 2. $J_r$ = 0.5 can be used for planar, slickensided joints having lineations, provided that the lineations are oriented for minimum strength. |
| ***c. No rock wall contact when sheared*** | | |
| H. Zones containing clay minerals thick enough to prevent rock wall contact | 1.0 (nominal) | |
| J. Sandy, gravely or crushed zone thick enough to prevent rock wall contact | 1.0 (nominal) | |
| **4. JOINT ALTERATION NUMBER** | $J_a$ | $\phi r$ degrees (approx.) |
| ***a. Rock wall contact*** | | |
| A. Tightly healed, hard, non-softening, impermeable filling | 0.75 | 1. Values of $\phi r$, the residual friction angle, are intended as an approximate guide to the mineralogical properties of the alteration products, if present. |
| B. Unaltered joint walls, surface staining only | 1.0 | 25 - 35 |
| C. Slightly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc. | 2.0 | 25 - 30 |
| D. Silty-, or sandy-clay coatings, small clay-fraction (non-softening) | 3.0 | 20 - 25 |
| E. Softening or low-friction clay mineral coatings, i.e. kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1 - 2 mm or less) | 4.0 | 8 - 16 |

Table 4.5 (cont.). Classification of Individual Parameters in the Tunneling Quality Index Q

(After Barton et al 1974)

| DESCRIPTION | VALUE | NOTES |
|---|---|---|
| **4, JOINT ALTERATION NUMBER** | $J_a$ | $\phi r$ degrees (approx.) |
| ***b. Rock wall contact before 10 cm shear*** | | |
| F. Sandy particles, clay-free, disintegrating rock etc. | 4.0 | 25 - 30 |
| G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick) | 6.0 | 16 - 24 |
| H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick) | 8.0 | 12 - 16 |
| J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of $J_a$ depend on percent of swelling clay-size particles, and access to water. | 8.0 - 12.0 | 6 - 12 |
| ***c. No rock wall contact when sheared*** | | |
| K. Zones or bands of disintegrated or crushed | 6.0 | |
| L. rock and clay (see G, H and J for clay | 8.0 | |
| M. conditions) | 8.0 - 12.0 | 6 - 24 |
| N. Zones or bands of silty- or sandy-clay, small clay fraction, non-softening | 5.0 | |
| O. Thick continuous zones or bands of clay | 10.0 - 13.0 | |
| P. & R. (see G.H and J for clay conditions) | 6.0 - 24.0 | |
| **5. JOINT WATER REDUCTION** | $J_w$ | approx. water pressure (kgf/cm$^2$) |
| A. Dry excavation or minor inflow i.e. < 5 l/m locally | 1.0 | < 1.0 |
| B. Medium inflow or pressure, occasional outwash of joint fillings | 0.66 | 1.0 - 2.5 |
| C. Large inflow or high pressure in competent rock with unfilled joints | 0.5 | 2.5 - 10.0 |
| D. Large inflow or high pressure | 0.33 | 2.5 - 10.0 |
| E. Exceptionally high inflow or pressure at blasting, decaying with time | 0.2 - 0.1 | > 10 |
| F. Exceptionally high inflow or pressure | 0.1 - 0.05 | > 10 |
| **6. STRESS REDUCTION FACTOR** | ***SRF*** | |
| ***a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated*** | | |
| A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth) | 10.0 | |
| B. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth < 50 m) | 5.0 | |
| C. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth > 50 m) | 2.5 | |
| D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth) | 7.5 | |
| E. Single shear zone in competent rock (clay free). (depth of excavation < 50 m) | 5.0 | |
| F. Single shear zone in competent rock (clay free). (depth of excavation > 50 m) | 2.5 | |
| G. Loose open joints, heavily jointed or 'sugar cube', (any depth) | 5.0 | |

1. Factors C to F are crude estimates; increase $J_w$ if drainage installed.
2. Special problems caused by ice formation are not considered.
1. Reduce these values of *SRF* by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation

Table 4.5 (cont.). Classification of Individual Parameters in the Tunneling Quality Index Q
(After Barton et al 1974)

| DESCRIPTION | VALUE | | | NOTES |
|---|---|---|---|---|
| **6. STRESS REDUCTION FACTOR** | | | ***SRF*** | |
| ***b. Competent rock, rock stress problems*** | | | | |
| | $\sigma_c/\sigma_1$ | $\sigma_t\sigma_1$ | | 2. For strongly anisotropic virgin stress field |
| H. Low stress, near surface | > 200 | > 13 | 2.5 | (if measured): when $5 \leq \sigma_1/\sigma_3 \leq 10$, reduce $\sigma_c$ |
| J. Medium stress | 200 - 10 | 13 - 0.66 | 1.0 | to $0.8\sigma_c$ and $\sigma_t$ to $0.8\sigma_t$. When $\sigma_1/\sigma_3$ > 10, |
| K. High stress, very tight structure | 10 - 5 | 0.66 - 0.33 | 0.5 - 2 | reduce $\sigma_c$ and $\sigma_t$ to $0.6\sigma_c$ and $0.6\sigma_t$, where |
| (usually favourable to stability, may | | | | $\sigma_c$ = unconfined compressive strength, and |
| be unfavourable to wall stability) | | | | $\sigma_t$ = tensile strength (point load) and $\sigma_1$ and |
| L. Mild rockburst (massive rock) | 5 - 2.5 | 0.33 - 0.16 | 5 - 10 | $\sigma_3$ are the major and minor principal stresses. |
| M. Heavy rockburst (massive rock) | < 2.5 | < 0.16 | 10 - 20 | 3. Few case records available where depth of |
| ***c. Squeezing rock, plastic flow of incompetent rock*** | | | | crown below surface is less than span width. |
| ***under influence of high rock pressure*** | | | | Suggest *SRF* increase from 2.5 to 5 for such |
| N. Mild squeezing rock pressure | | | 5 - 10 | cases (see H). |
| O. Heavy squeezing rock pressure | | | 10 - 20 | |
| ***d. Swelling rock, chemical swelling activity depending on presence of water*** | | | | |
| P. Mild swelling rock pressure | | | 5 - 10 | |
| R. Heavy swelling rock pressure | | | 10 - 15 | |

**ADDITIONAL NOTES ON THE USE OF THESE TABLES**

When making estimates of the rock mass Quality (Q), the following guidelines should be followed in addition to the notes listed in the tables:

1. When borehole core is unavailable, *RQD* can be estimated from the number of joints per unit volume, in which the number of joints per metre for each joint set are added. A simple relationship can be used to convert this number to *RQD* for the case of clay free rock masses: $RQD = 115 - 3.3\ J_v$ (approx.), where $J_v$ = total number of joints per $m^3$ ($0 < RQD < 100$ for $35 > J_v > 4.5$).
2. The parameter $J_n$ representing the number of joint sets will often be affected by foliation, schistosity, slaty cleavage or bedding etc. If strongly developed, these parallel 'joints' should obviously be counted as a complete joint set. However, if there are few 'joints' visible, or if only occasional breaks in the core are due to these features, then it will be more appropriate to count them as 'random' joints when evaluating $J_n$.
3. The parameters $J_r$ and $J_a$ (representing shear strength) should be relevant to the weakest significant joint set or clay filled discontinuity in the given zone. However, if the joint set or discontinuity with the minimum value of $J_r/J_a$ is favourably oriented for stability, then a second, less favourably oriented joint set or discontinuity may sometimes be more significant, and its higher value of $J_r/J_a$ should be used when evaluating Q. The value of $J_r/J_a$ should in fact relate to the surface most likely to allow failure to initiate.
4. When a rock mass contains clay, the factor *SRF* appropriate to loosening loads should be evaluated. In such cases the strength of the intact rock is of little interest. However, when jointing is minimal and clay is completely absent, the strength of the intact rock may become the weakest link, and the stability will then depend on the ratio rock-stress/rock-strength. A strongly anisotropic stress field is unfavourable for stability and is roughly accounted for as in note 2 in the table for stress reduction factor evaluation.
5. The compressive and tensile strengths ($\sigma_c$ and $\sigma_t$) of the intact rock should be evaluated in the saturated condition if this is appropriate to the present and future in situ conditions. A very conservative estimate of the strength should be made for those rocks that deteriorate when exposed to moist or saturated conditions.

Undoubtedly, there are several other parameters, which could be added to improve the accuracy of the classification system. One of these would be the joint orientation. Even though many case records include the necessary information on structural information in relation to excavation axis, it was not found to be the important general parameter that might be expected. Part of the reason for this may be that the orientations of many types of excavations can be, and normally are, adjusted to avoid the maximum effect of unfavorably oriented major joints. However, this choice is not available in the case of tunnels, and more than half the case records were in this category.

In connection the value of the index Q to the stability and support requirements of underground excavations, Barton et al. (1974) defined an additional parameter which they called the "Equivalent Dimension, $D_e$" of the excavation. This dimension is obtained by dividing the span, diameter or wall height of the excavation by a quantity called the "Excavation Support Ratio, ESR". Thus,

$$D_e = \frac{\text{Excavation span, diameter or height (m)}}{\text{Excavation Support Ratio, ESR}} \qquad (5)$$

The value of ESR is related to the intended use of the excavation and to the degree of security that is demanded of the support system installed to maintain the stability of the excavation. Barton et al. (1974) suggest the following values (Table 4.6):

Table 4.6. The updated ESR values suggested by Barton and Grimstad (1994).

| Excavation Category | Original ESR (1974) | **Updated ESR (1994)** |
|---|---|---|
| A. Temporary Mine Openings | 3– 5 | **2-5** |
| B. Vertical shafts: | | |
| Circular section | 2.5 | |
| Rectangular / square section | 2.0 | |
| C. Permanent Mine Openings, water tunnels for hydropower (excluding high-pressure pen stocks), pilot tunnels, drifts, and headings for large excavations. Rectangular Square Section | 1.6 | **1.6-2.0** |
| D. Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers, access tunnels | 1.3 | **1.2-1.3** |
| E. Power stations, major highway or railroad tunnels, civil defense chambers, portals, intersections | 1.0 | **0.9-1.1** |
| F. Underground nuclear power stations, railway stations, sports and public facilities, factories. | 0.8 | **0.5-0.8** |

The paper by Barton and Grimstad (1994) suggests the updated ESR values as given in table above.

The relationship between the index Q and the equivalent dimension of an excavation determines the appropriate support measures, as depicted in Figure 4.2.

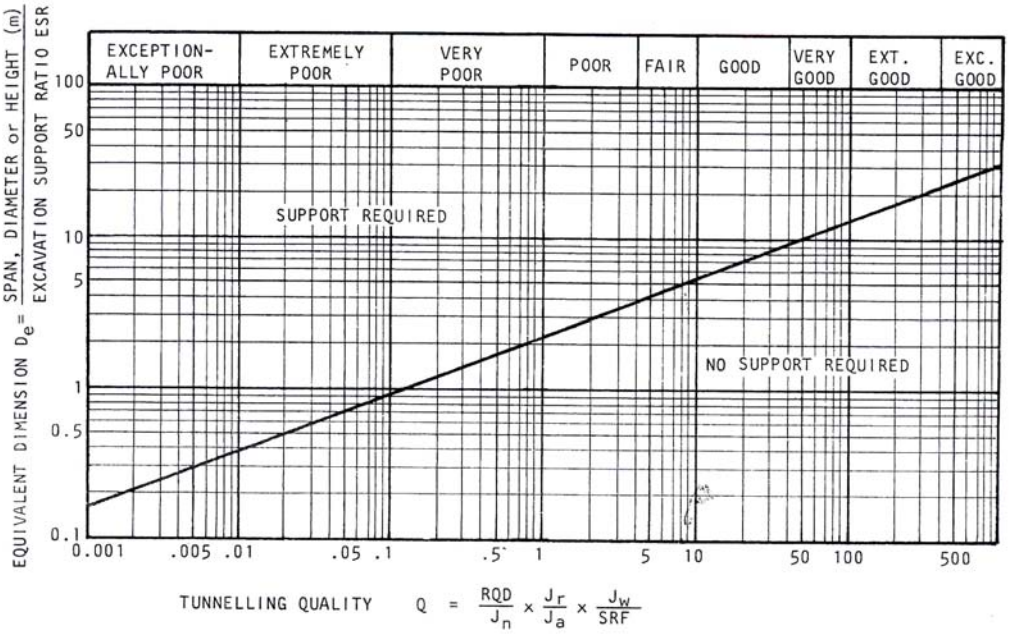



Figure 4.2. Q System: equivalent dimension versus rock mass quality (After Barton et. al 1974).

Barton et al. (1974) provided the corresponding 38 support categories specifying the estimates of permanent support as given in Figure 4.3. and in Appendix – C. For temporary support determination, either Q is increased to 5Q or ESR is increased to 1.5 ESR.

It should be noted that the length of bolts is not specified in the support tables, but the bolt length L is determined from the equation

$$L = \frac{2 + 0.15B}{ESR} \qquad (6)$$

where B is the excavation width.

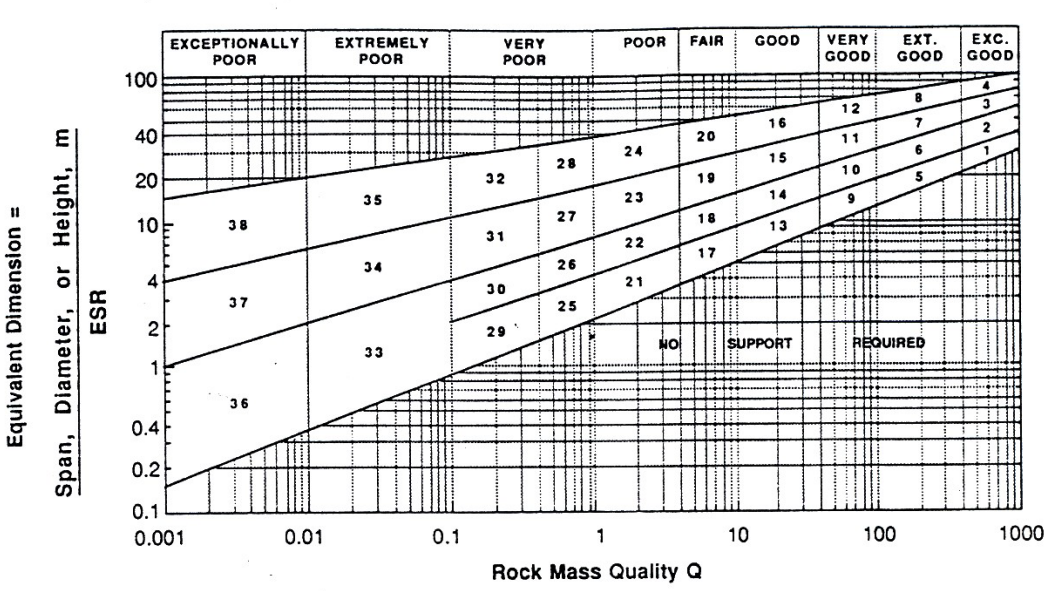



Figure 4.3. Q System: equivalent dimension versus rock mass quality (After Barton et al. 1974).

These support categories developed by Barton et al. (1974) have been updated by Grimstad and Barton (1993) to reflect the increasing use of steel fibre reinforced shotcrete in underground excavation support (Figure 4.4).

The maximum unsupported span can also be obtained as follows:

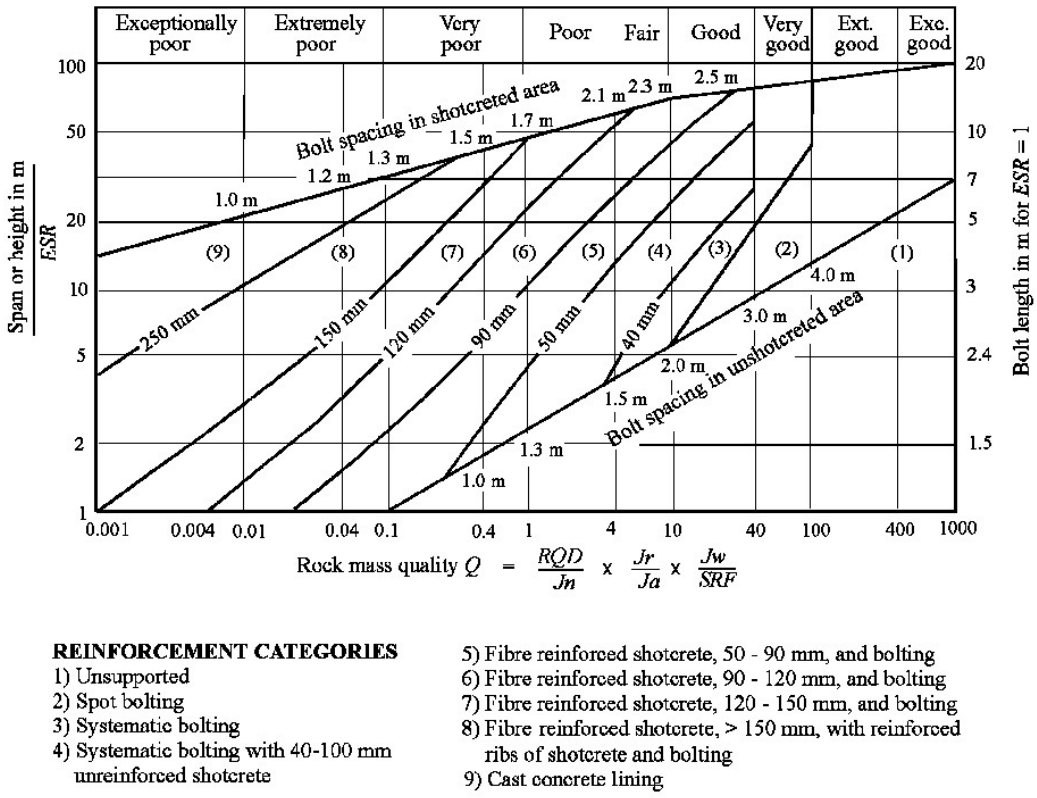
$$\text{Maximum span (unsupported)} = 2(\text{ESR})Q^{0.4} \qquad (7)$$

The relation between the Q value and the permanent support pressure $P_{roof}$ is calculated from the following equation:

$$P_{roof} = \frac{2.0}{J_r} Q^{-1/3} \qquad (8)$$

If the number of joint sets is less than three, the equation is expressed as

$$P_{roof} = \frac{2}{3} J_n^{1/2} J_r^{-1} Q^{-1/3} \qquad (9)$$




**REINFORCEMENT CATEGORIES**

1) Unsupported
2) Spot bolting
3) Systematic bolting
4) Systematic bolting with 40-100 mm unreinforced shotcrete
5) Fibre reinforced shotcrete, 50 - 90 mm, and bolting
6) Fibre reinforced shotcrete, 90 - 120 mm, and bolting
7) Fibre reinforced shotcrete, 120 - 150 mm, and bolting
8) Fibre reinforced shotcrete, > 150 mm, with reinforced ribs of shotcrete and bolting
9) Cast concrete lining

Figure 4.4. Estimated support categories based on the tunneling quality index Q (After Grimstad and Barton 1993).

Barton et al. (1980 and 1992) and Grimstad and Barton (1993) have found good agreement between measured displacements and predictions from numerical analyses using in-situ deformation modulus values estimated from:

$$E_m(\text{GPa}) = 25\text{Log}_{10}Q \qquad (10)$$

Naturally, this 1980 relation was only applicable to Q>1 and to generally hard rocks. There have been several stages in the development of empirical models that relate $E_m$, the static modulus of deformation modulus, and the rock mass quality terms, namely RMR and Q. The latest $Q_c$-based improvement, using the normalization of the Q-value has been derived by Barton (2002) as follows:

$$E_m = 10Q_c^{1/3} \qquad (11)$$

where $Q_c = Q \text{ x } \frac{\sigma_c}{100}$

The two curves shown in Figure 6 are seen to coalesce for Q values < 1 and RMR < 50, if one applies the conversion between Q and RMR shown in Figure 4.5, which gives by the elimination of the RMR term:

$$E_m = 10^{(15 \log Q + 40)/40} \qquad (12)$$

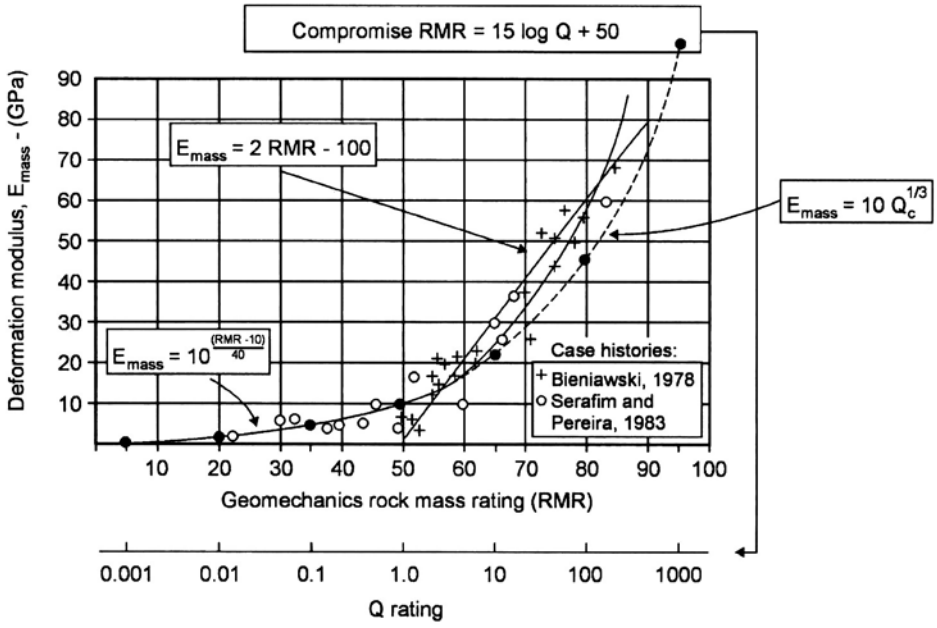



Figure 4.5. Static deformation modulus $E_m$ , Q and RMR and some empirical inter-relationships (Barton, 2002).

### 4.3.1 Comparison of the RMR and Q systems

The two classification systems that appear to be in widest use in tunneling that do not rely on performance monitoring (though they can be used in conjunction with monitoring) are the RMR and Q systems. These two systems are therefore compared here.

The common parameter used in both systems is Deere's RQD. Bieniawski also includes joint spacing and orientation, while the Q-system considers the number of joint sets. Orientation is included implicitly in the Q-system by classifying the joint roughness and alteration of only the most unfavorably oriented joint sets or discontinuities.

In the RMR system, rock stress is not used specifically as a parameter though it is apparently when selecting support measures. In the Q-system, however, the ratio ($\sigma_c/\sigma_1$)

(unconfined compression strength / major principal stress) is evaluated when treating rock stress problems.

Both classification systems have their own advantages and disadvantages. While the Geomechanics Classification provides span time and rock mass strength parameters in terms of cohesion and internal friction angle, which are vital for the assessments of stability, the Q-system suggests support patterns. Therefore, to obtain a complete solution for the specific underground projects, integration and correlation of these classification systems is inevitable.

A correlation was developed between the Q index and the RMR (Bieniawski, 1976). A total of 111 case histories were analyzed for this purpose: 62 Scandinavian cases, 28 South African cases, and 21 other case histories from the United States, Canada, Australia and Europe. The results are plotted in Figure 4.6, from which it can be observed that the following relationship is applicable:

$$RMR = 9 \ln Q + 44 \qquad (13)$$

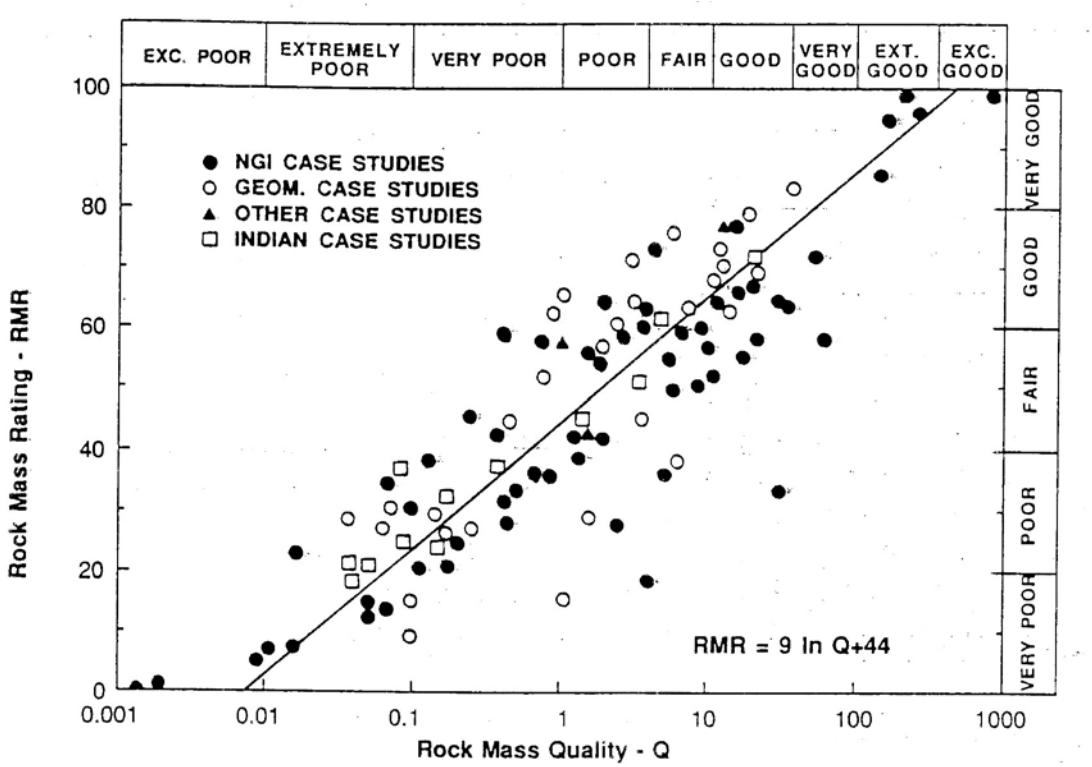



Figure 4.6. Correlation between the RMR and the Q index. (After Bieniawski, 1976 and Jethwa et al., 1982).

## 4.4 Modified Rock Mass Classification: M-RMR System

The Modified Rock Mass Rating (M-RMR) system has been developed based on four years of geotechnical investigations carried out in a borax mine and two coal mine regions in Turkey. An additional two years were devoted to the evaluation of classification results obtained from structural regions having extreme rock mass conditions, to the enhancement of classification steps by debugging and testing the system. It is believed that a wide range of rock mass conditions, especially the weak, stratified, anisotropic and clay-bearing rock masses, can be better characterized by using M-RMR system (Ünal, 1996).

The M-RMR system enables determination of a quality-rating index (M-RMR) for characterization of rock masses. In general, the M-RMR system is based on the RMR system developed by Bieniawski (1989), however, new features are added to the system for better characterization of wide ranges of rock mass conditions.

The M-RMR system includes the following new features:

1. Flexibility of determining the input parameters from field survey and/or from core boxes.

2. Inclusions of new parameters to the system, namely: the point load strength index ($I_{PL}$), weathering coefficient ($F_C$) and intact core recovery index (ICR).

3. Further description of the adjustment factors, reflecting the effects of blasting damage ($A_b$) and major plane of weakness ($A_w$).

4. Allocation of new joint filling conditions that can describe what is physically seen in core boxes.

5. Adjustment of the interval limits of the strength and joint parameters by subdividing them mostly based on descriptions and standards suggested by International Society of Rock Mass (ISRM).

6. Allocation of importance ratings to new conditions and intervals.

The total rating, suggested by the original RMR system for each individual input parameter has not been changed, however, after corrections due to the weathering effect, the M-RMR quality rating index may go up to 110.

The six input parameters considered in M-RMR system are; uniaxial compressive strength, RQD, condition of discontinuities, groundwater conditions and orientation of discontinuities. The steps that should be followed for determining the M-RMR value are illustrated in Figure 4.7. If there are more than one joint set in the rock mass, the M-RMR index should be determined by considering each joint set separately, and the lowest M-RMR value should be selected as an index representing the structural region (or domain) in question.

In order to determine the M-RMR value initially, the geotechnical data must be converted to numerical values, which reflect the ratings assigned to the input parameters. This can be accomplished by utilizing Figure 4.8, Tables 4.7 and 4.8, and following the five steps given below:

Step - 1. Determine the ratings assigned to strength, RQD and joint condition parameters and calculate the unit mass rating (UMR) value by summing up these three ratings (see Figures 4.7 and 4.8). In case of determining the strength index rating ($I_{PLT}$) from point load tests, firstly, determine the mean values of test results obtained both from diametral and axial tests and determine the $I_S(50)$values representing each test type. Secondly, calculate the $I_{PLT}$ index by taking the average of the two $I_S(50)$ values. Finally, determine the corresponding rating for strength from Figure 4.8(b). Details on these procedures and the effect of isotropy are given elsewhere (Ünal and Özkan, 1990; Özkan, 1995).

Step - 2. Find the Corrected Unit Mass Rating (CUMR) value by making a correction for weathering. To do this, multiply the (UMR) value with the weathering coefficient ($F_C$), which can be obtained from Figure 4.7 or 4.9.

Step - 3. Determine the ratings assigned to joint spacing ($I_{JS}$) and groundwater ($I_{GW}$) and add these ratings to CUMR value to calculate the corrected and Modified Rock Mass Rating Index (CM-RMR).

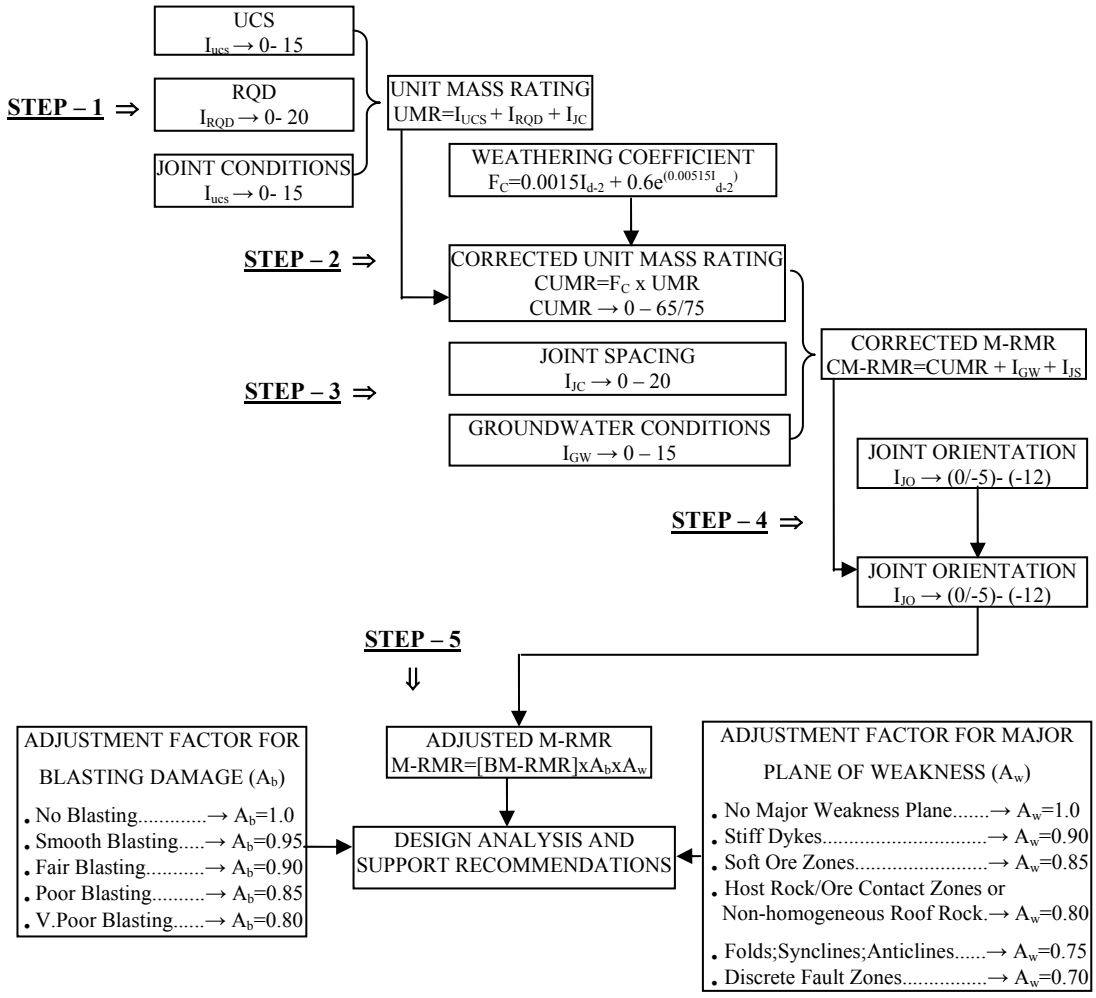



Figure 4.7. The overall structure of the Modified Rock Mass Rating, M-RMR, System and the classification steps (Ünal, 1996).

Step - 4. Calculate the Basic M-RMR by adding the rating of joint orientation index ($I_{50}$) to corrected M-RMR. If rock mass classification process is carried out by utilizing core boxes then, the $I_{JO}$ index should be determined from Figure 4.8 (f). In case of a field survey; however, the suggestions, for joint orientation ratings, given by Bieniawski (1989) is recommended. The following simplified equation may be used to calculate the Basic - Modified Rock Mass Rating directly:

$$BM - RMR = F_c \times [I_{UCS} + I_{RQD}\} + I_{JC}] + I_{JS} + I_{GW} + I_{JO} \qquad (14)$$

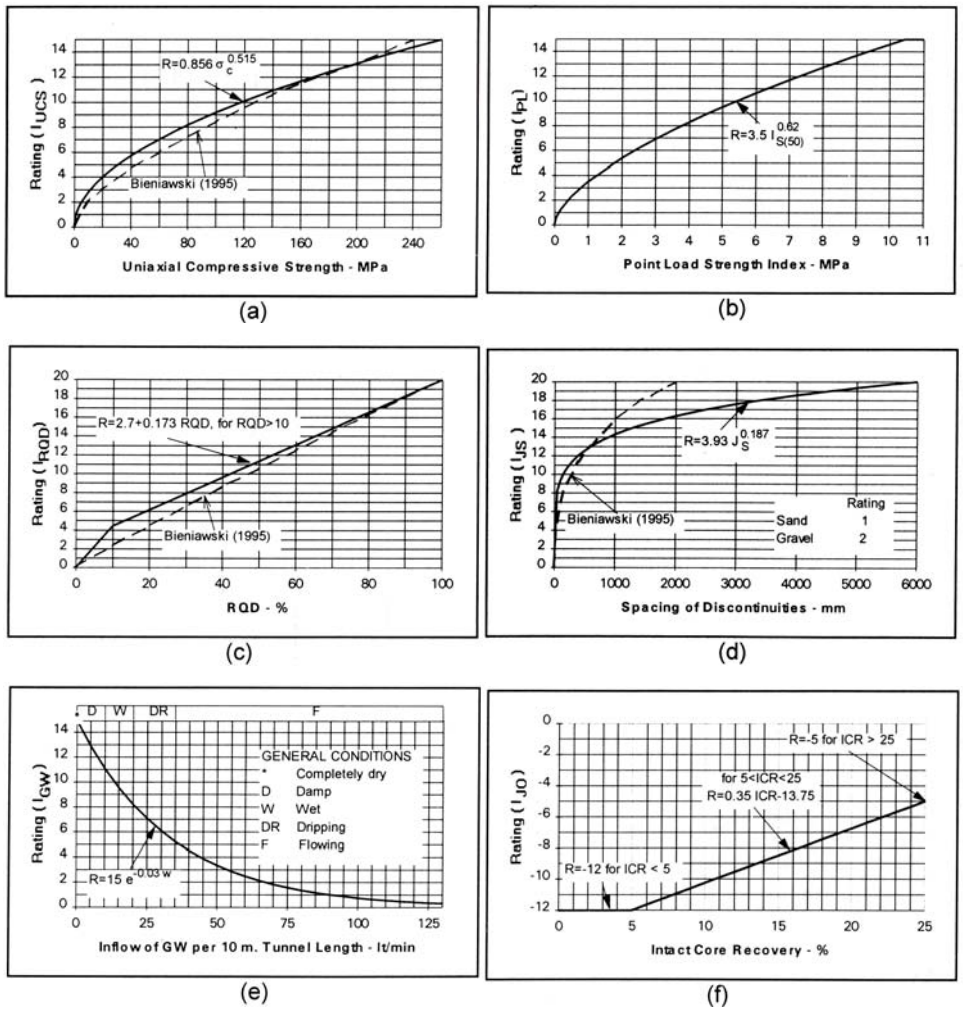



Figure 4.8. Suggested intervals and ratings for various input parameters (Ünal, 1996)

Table 4.7 Determination of joint condition index ($I_{JC}$) (Ünal, 1996)

| | | | $I_{JC}$ |
|---|---|---|---|
| ICR < 5 | F = 0 (without filling) | | 10 |
| | F = 1 (with filling) | | 0 |
| 5 ≤ ICR ≤ 25 | F = 0 | RQD = 0 | 13 |
| | | 0<RQD < 10 | 17 |
| | | RQD ≥ 10 | 22 |
| | F = 1 | $t_f \geq 5$ mm; $t_f$: filling thickness — soft | 0 |
| | | $t_f \geq 5$ mm; $t_f$: filling thickness — hard | 4 |
| | | 1 mm < $t_f$ < 5 mm — soft | 8 |
| | | 1 mm < $t_f$ < 5 mm — hard | 11 |
| | | $t_f$ < 1mm | 14 |
| ICR > 25 | F = 0 | Use $I_{JC}$ Rating Chart and Calculate $I_{JC}$ from the following equations: $I_{JC}$ = W + R + (CxAxD); D=1 | |
| | F = 1 | $t_f \geq 5$ mm — soft | $I_{JC}$ = 0 |
| | | $t_f \geq 5$ mm — hard | $I_{JC}$ = 2 + (CxD) |
| | | 1 mm < $t_f$ < 5 mm — soft | $I_{JC}$ = 4 + (CxD) |
| | | 1 mm < $t_f$ < 5 mm — hard | $I_{JC}$ = 6 + (CxD) |
| | | $t_f$ < 1 mm | $I_{JC}$ = 8 + (CxD) |

Note : Ratings for the following parameters should be determined from $I_{JC}$ Rating Chart (Table 2)
W : Alteration, R: Roughness, C: Persistence, A: Aperture, D: Filling

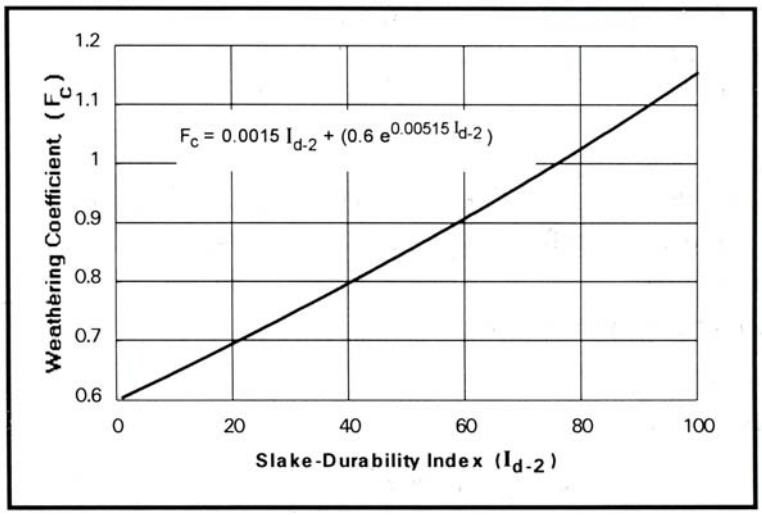


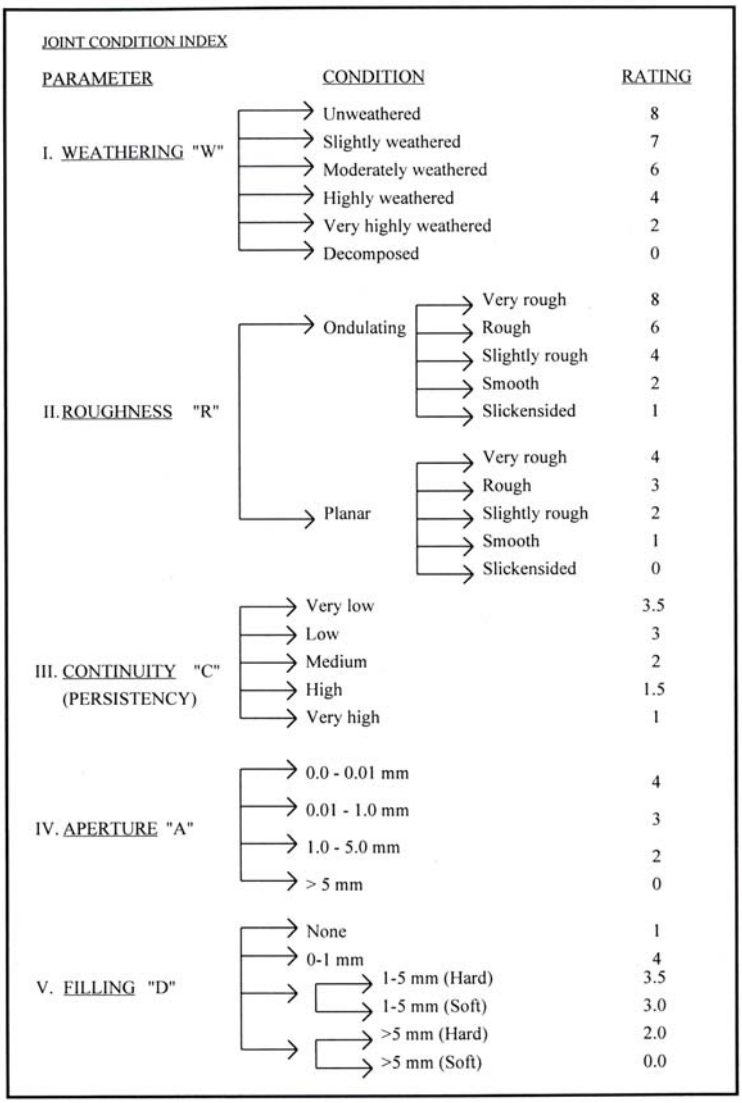

Figure 4.9. Suggested adjustment for the slaking affect of water. The weathering coefficient determined based on slake-durability index, is used in Step 2 of M-RMR calculations (Ünal, 1996).

Step - 5. Determine the Adjusted and Modified Rock Mass Rating (AM-RMR, or simply M-RMR) by multiplying the BM-RMR value by the two adjustment factors $A_b$, and $A_w$, which reflect the effects of blasting and major weakness planes respectively. The value of $A_b$ and $A_w$ constants can be selected from the associated adjustment charts given in Figure 4.7. Since the effect of stress is incorporated in rock load height equation, as suggested by Ünal and Ergür (1990), there is no need for stress adjustment at this stage.

### 4.4.1 Comparison of the RMR and M-RMR systems

One of the basic differences between the RMR and M-RMR rating system appears in characterization of the extreme ends in rock mass quality spectrum, namely, the very poor/poor and good/very good rock mass conditions. The results indicate that the rock mass is characterized within a wider quality rating range with M-RMR system. In conclusion, the M-RMR system estimates better rock mass quality ratings at the upper bounds of the rock mass condition spectrum, but worst ratings at the lower bounds.

Table 4.8. Intervals and ratings for "joint condition" index. (Ünal, 1996).




## 4.5 New Austrian Tunneling Method (NATM)

This section draws attention to the basic philosophy of NATM and identifies the conditions relating to its application and the principal features associated with its use in different geological conditions.

NATM is *a form of tunnel construction* consisting of all the relevant elements, including tunnel advancing method, debris removal, support, etc. (Whittaker and Frith, 1990). It is generally accepted that NATM has evolved as a result of experience and innovation achieved in Austrian Alpine tunneling conditions. It would appear, however, that the application of concrete blown onto a surface for the purpose of supporting walls may

have been employed in other countries and that certain aspects pertaining to how new the NATM concept was at the time it was named in Austria may not be too clear.

Historical details relating to the development of the concept of NATM have been discussed by Sauer and Gold, 1989 (Table 4.9). NATM has undoubtedly been fully developed by a number of prominent engineers in Europe during the early 1950s and 1960s who recognized its potential to the construction of tunnels in various rock conditions. Rabcewicz, Mueller, Brunner and Pacher in Austria contributed significantly to the development of NATM.

Table 4.9. Principal historical developments of NATM.
Source: based on Sauer, 1988; Sauer and Gold, 1989.

| *Year* | *Principal development* |
|---|---|
| 1848 to1920s | Development of the use of fast setting mortars as a tunnel support; invention of the cement gun and the registration of patents; early uses of gunite in civil and mining engineering tunnel operations. |
| 1948 | Development of concepts relating to controlled rock deformation and dual lining system involving systematic anchoring for tunneling which were postulated by Rabcewicz. |
| 1954 | The first application of shotcrete as a supporting element in squeezing ground in tunneling was carried out at the Runserau HEP Project, Austria by Srunner. |
| 1958 | Brunner filed a patent of this concept of tunnel construction in squeezing ground and called it the Shotcrete Method. |
| 1960 | Mueller recognized the roles played by load and deformation measurements as part of the design process aimed at preventing excessive rock loading of tunnels and consequently developed a systematic measuring system which formed part of the process. |
| 1962 | Rabcewicz first used the term the New Austrian Tunneling Method vvhilst speaking at a meeting in Salzburg. |
| 1964 | NATM achieved worldwide recognition and appears to have originated from the publication of Rabcewicz (1965) in connection with the application of the shotcrete method in the Schwaikheim Tunnel, which was designed under the guidance of Mueller, 1978 and Rabcewicz, 1965. |

### 4.5.1 General Concepts of NATM

The main philosophy in tunneling with NATM is allowing the rock mass to support itself as much as possible. During the excavation, allowing the rock mass to deform in tolerable limits mitigates the loads on support systems. Accordingly, this controlled deformation helps the rock mass to support itself at maximum level.

Instead of carrying the entire rock load, the support systems are used to provide the integrity of carrying arch by controlling the plastic deformations and preventing the loosening that may cause the rock to lose its strength. Therefore, the flexibility of the support systems is one of the major criteria in this system. If the rock is so weak to carry its load, the excavation can be stabilized by the application of support pressure close to the bearing capacity of the rock.

Mueller (1978) has drawn attention to some 22 principles which can be identified as being closely associated with NATM, although most authorities connected with tunnel design and support appear to reduce this number to between 5 and 7 as playing a major role.

Mobilization of rock mass strength:

This involves the recognition that the main component of tunnel support is the strength of the rock mass and that it can be mobilized by minimizing the rock deformations and preventing rock mass loosening.

Shotcrete Protection:

In order to preserve the rock mass strength, by minimizing the rock mass deformations, it is necessary to apply early temporary support. With NATM, several temporary support measures are identified, including steel sets, rock bolts and shotcrete. The application of shotcrete has become almost universally allied with NATM. This is due to its inherent suitability as a temporary support by virtue of its high early strength and rigidity quite apart from the less suitable nature of other methods which often need supplementing with the use of shotcrete, e.g. steel sets.

In practice, a relatively thin layer of shotcrete with or without supplementary support is applied immediately after excavation to limit the rock mass deformations. The fact that shotcrete produces full strata-support contact irrespective of the nature of irregularities along the tunnel profile, is a major factor in the success of such a support method. It is also noted

that since a tunnel is supported either totally or partially with shotcrete, this does not necessarily mean that it uses the NATM technique.

Rock Mass Deformation and Load Measurement:

A major aim of NATM is to learn from experience and continuously update the support system by monitoring the rock mass from within the tunnel.

A tunneling operation at New Studley, UK employed a temporary support system which was altered on almost 100 occasions as a result of the information provided by the support instrumentation; the support variation was considered necessary in view of changes in geological conditions encountered along the tunnel (Whittaker and Frith, 1990).

Flexible Support:

The concept of NATM stands behind the use of a flexible support system, which can be conveniently adapted to varying ground conditions. The emphasis is placed on limiting rock mass deformations from the earliest possible opportunity by the use of shotcrete normally in association with rock bolts, wire mesh or steel sets. These temporary support measures are seen as the major load-bearing component of NATM with the primary cast in situ concrete lining being constructed after the tunnel has become stable. The primary role of this lining is that of sealing the tunnel and producing the required opening shape and final dimensions.

Invert Closing:

In NATM, the support system is seen as a thick walled cylinder consisting of the rock and the lining. The cylinder will behave very differently depending on whether or not it is slit, i.e., whether the invert has been laid and closed or not. The timing of the invert closing is recognized in NATM as a vital support parameter, which has a significant bearing on the overall behavior of the lining and the surrounding ground. In soft ground, the invert is closed as quickly as possible in order to limit ground movements, whereas in rock tunnels, the invert will be closed at a certain distance behind the face so as to allow the ground destressing to occur by controlled deformation.

Tunneling Contract Agreement:

Due to the nature of NATM in terms of its flexible approach to tunnel support and recognition of the need to adapt to changing ground conditions, it will clearly require a contract, which contains the same degree of flexibility in terms of changes during construction. NATM could not have been developed under a system, which requires design

to be completed at the tender stage with full construction responsibility being transferred at this time.

Rock Mass Classification:

During tunnel construction, the ground is grouped into several classes (Table 4.10). This is carried out in accordance with the ground properties and other geological and hydrogeological considerations, with each class being given a specific type and amount of temporary support, in addition to specific excavation steps.

NATM is essentially a tunnel support concept based on using the strength of the surrounding ground as the major supporting component coupled with employing a two stage lining technique, namely temporary and primary support. The temporary support is the main load-bearing component.

In NATM, one of the important points regarding pace and economy is to install the support system at the appropriate time just before the rock mass loses its stability. In this way, allowing both elastic and plastic deformations to occur, carrying unnecessary load, which can be supported by the rock itself, by the support system is avoided. Therefore, the success of the method is accompanied with the instrumentation made and interpreted at the time of excavation. In Figure 4.10, how the time for the installation of support system should be is well defined. In this approach, the principle is to find the most appropriate time for the installation of support system by placing E and F points as much as close to the minimum value of the Load-Deformation curve. For this purpose, very sensitive monitoring is needed during excavation.

Table 4.10. Rock Classification System

| Rock Class Description | Austrian Standard ONORM 2203 previous | Classification after Rabcewicz-Pacher |
|---|---|---|
| **A1** STABLE | **1** STABLE | **I** STABLE ROCK, SLIGHTLY AFTERBREAKING |
| **A2** SLIGHTLY OVERBRAKING | **2** AFTER BEAKING | |
| **B1** FRIABLE | **3** SLIGHTLY FRIABLE | **II** FRIABLE |
| **B2** HEAVILY FRIABLE | **4** FRIABLE OR SLIGHTLY PRESSURE EXERTING | **III** HEAVILY FRIABLE |
| **C1** PRESSURE EXERTING | **5** HEAVILY FRIABLE OR PRESSURE EXERTING | **IV** PRESSURE EXERTING |
| **C2** HEAVILY PRESSURE EXERTING | **6** HEAVILY PRESSURE EXERTING | **V** HEAVILY PRESSURE EXERTING OR FLOWING |
| **L1** LOOSE GROUND HIGHLY COHESIVE | **7** FLOWING | **VI** SPECIAL CONDITIONS |
| **L2** LOOSE GROUND LOW COHESIVE | | |

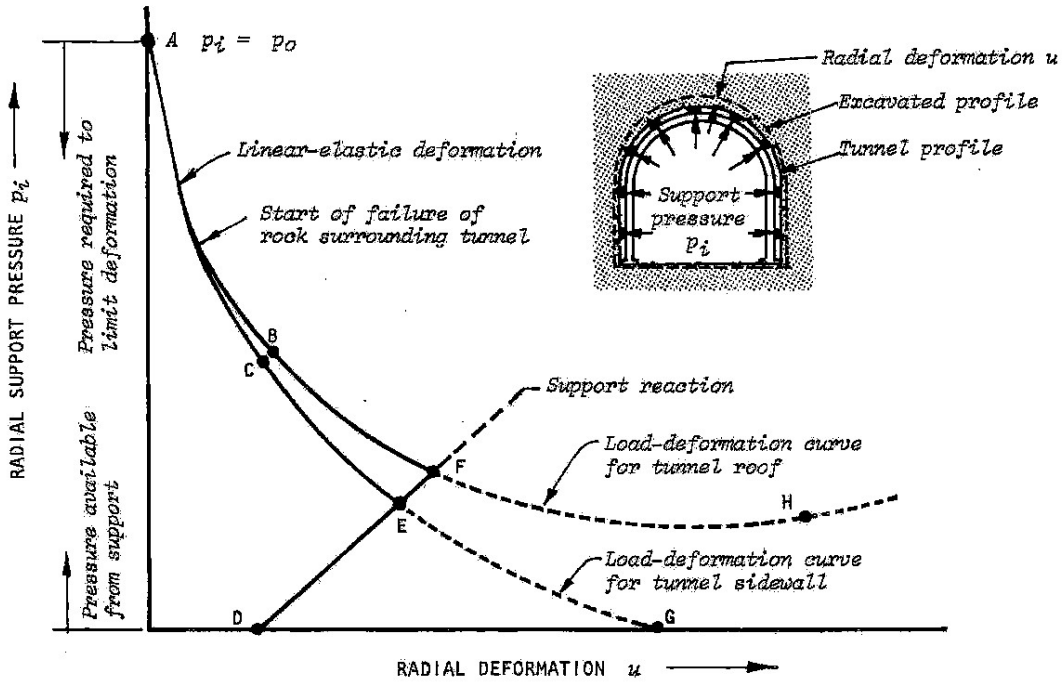



Figure 4.10. The relationship between support pressure and radial deformation in tunnels (Hoek and Brown, 1980).

The rock mass classification of NATM groups the ground into several classes – each class being given a specific type and amount of temporary support – in addition to specific excavation steps.

A1: No support required (may be local supports-random); full face or top heading and bench in large excavation profiles; drill and blast.

A2: Shotcrete and random rockbolts; top heading (2.5-3.5 m) and bench (4.00 m); drill and blast.

B1, B2: Shotcrete and systematic bolting; top heading (2.00-3.00 m) and bench (4.00 m); drill and blast.

B3: Shotcrete, systematic bolting, forepoling; top heading (1.5-2.5 m), bench (3.5 m); smooth blasting, road headers if rock masses are sensitive to vibrations.

C1: Shotcrete, systematic bolting, forepoling, steel ribs; top heading (1.0-1.5 m), bench (2.0 m), invert arch (100-150 m); smooth blasting or rock header or tunnel excavator.

C2, C3: Shotcrete, systematic bolting, forepoling, steel ribs; top heading (1.2 m), side gallery may be required, bench (2.0 m) invert arch (25-50 m); smooth blasting or rock header, or tunnel excavator.

C4: Shotcrete, forepolling or lagging, ribs; top heading (1.5 m), bench (3.0 m), invert arch (100-150 m); tunnel excavator.

C5: Shotcrete, forepolling or lagging, ribs; top heading (1.5 m), bench (2.0 m), invert arch (24-50 m); tunnel excavator.

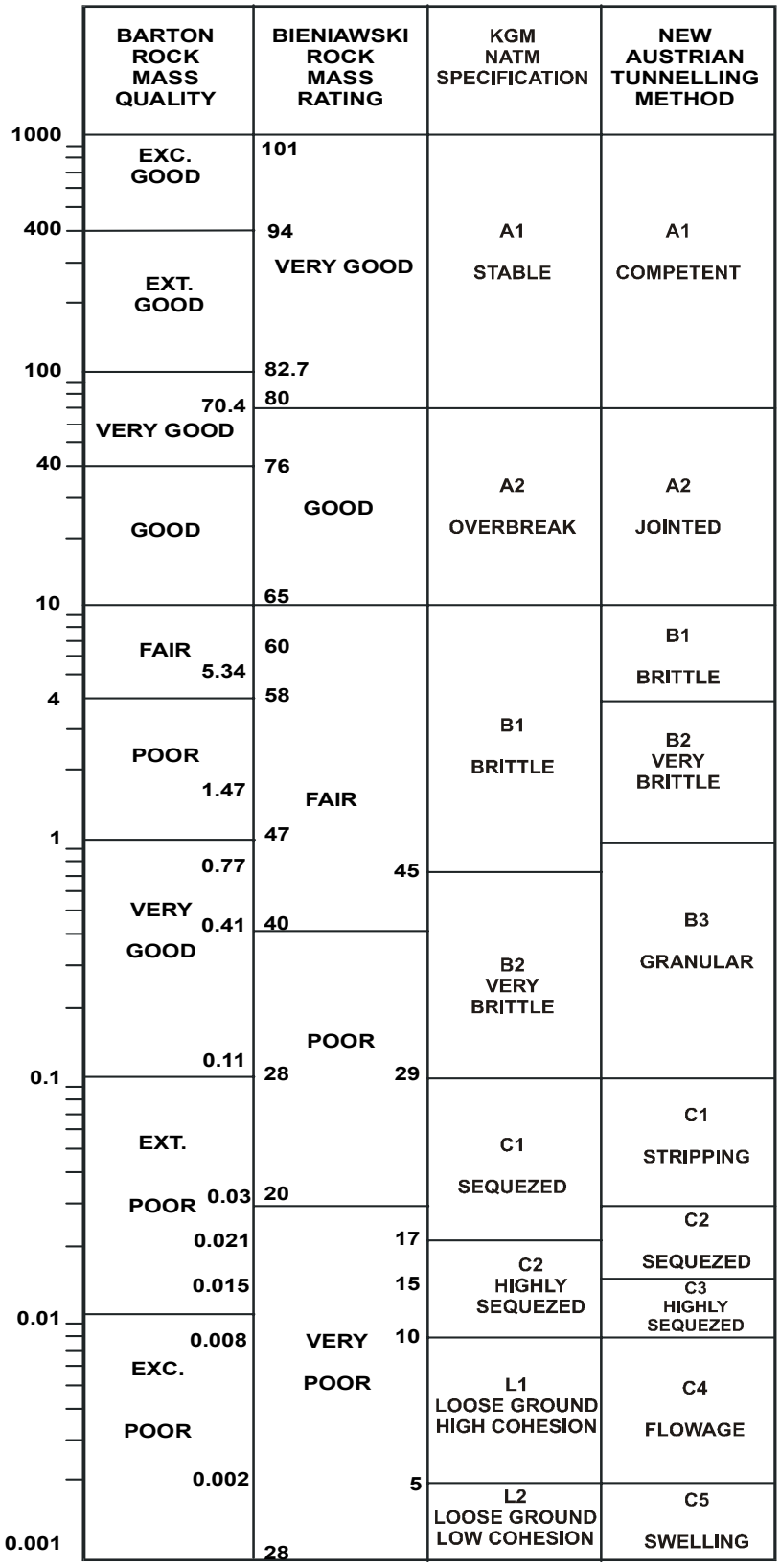
The *rock mass classification suggested by NATM* is descriptive and far away from being quantitative. The correlation, derived by Bieniawski (1996) among the classifications of NATM, RMR and Q system is presented below (Table 4.11. and 4.11 - a).

Table 4.11. Correlations of RMR, Q and NATM.

| Q | RMR BIENIAWSKI | RMR BARTON | RMR AVERAGE | NATM |
|---|---|---|---|---|
| 1000 | 106.2 | 95.0 | 100.6 | **A 1** |
| 400 | 97.9 | 89.0 | 93.5 | |
| 70 | 82.3 | 77.7 | 80.0 | |
| 40 | 77.2 | 74.0 | 75.6 | **A 2** |
| 10 | 64.7 | 65.0 | 64.9 | |
| 4 | 56.5 | 59.0 | 57.8 | **B 1** |
| 1 | 44.0 | 50.0 | 47.0 | **B 2** |
| 0.406 | 35.9 | 44.1 | 40.0 | **B 3** |
| 0.100 | 23.3 | 35.0 | 29.1 | |
| 0.031 | 12.7 | 27.3 | 20.0 | **C 1** |
| 0.016 | 6.9 | 23.1 | 15.0 | **C 2** |
| 0.008 | 1.1 | 18.9 | 10.0 | **C 3** |
| 0.002 | | 10.0 | 5.0 | **C 4** |
| 0.001 | | 5.0 | 2.5 | **C 5** |

**RMR (BIENIAWSKI)** = 9 Ln (Q) + 44, **RMR (BARTON)** = 15 Log (Q) + 50

Table 4.11 – a. Correlations of RMR, Q and NATM.



## 4.6 Geological Strength Index (GSI)

The Geological Strength Index (GSI) classification system greatly respects the geological constraints that occur in nature and are reflected in the geological information. GSI, details of which are provided in the next chapter, has been developed over many years of discussions with engineering geologists with whom E. Hoek has worked around the world (Marinos and Hoek, 2000).

Hoek and Brown (1980) proposed a method, which is described thoroughly in the following chapter, for obtaining estimates of the strength of jointed rock masses, based upon an assessment of the interlocking of rock blocks and the condition of the surfaces between these blocks. The most important component of the Hoek-Brown system for rock masses is the process of reducing the material constants $\sigma_{ci}$ and $m_i$ from their laboratory values to appropriate in situ values. This is accomplished through the GSI (Marinos and Hoek, 2000).

For better quality rock masses (GSI>25), the value of GSI can be estimated directly from the 1976 version of Bieniawski's Rock Mass Rating, with the groundwater rating set to 10 (dry) and the adjustment for joint orientation set to 0 (very favorable). For very poor quality rock masses the value of RMR is very difficult to estimate and the balance between the ratings no longer gives a reliable basis for estimating rock mass strength.

If the 1989 version of Bieniawski's RMR classification is used, then GSI=$RMR_{89}$-5 where $RMR_{89}$ has the groundwater rating set to 15 (dry) and the adjustment for joint orientation set to zero (very favorable).

## 4.7 Rock Mass Classifications of the Boztepe (T-1) and Öceli (T-2) Tunnel Rock Masses

### 4.7.1 NGI Q System

During the processing of the information about the tunneling locations where the classification parameters were compiled and integrated with drillings and laboratory test results, the software CLASSEX was employed. In order to use CLASSEX efficiently, the formerly prepared Q flow charts have been used. These flow charts consist of the information about rock masses in the form of an input for CLASSEX whose outputs and the related Q flow charts are presented in Appendix – D.

CLASSEX, developed at the University of Waterloo as a M.Sc. degree project (Butler, 1990), is a combined forward and backward chaining knowledge-based system designed with the VP-Expert development tool. The knowledge-based expert system CLASSEX incorporates three of the more commonly used empirical methods of rock tunnel design based on the Q, RMR and RQD ground classification systems. This software, especially, is sensitive in the determination of SRF parameter of NGI Q-system, which depends on some variables such as the tunnel depth, the ratios between the compressive and tensile strength with principal stresses.

In this section, the Q system classification parameters of each structural domain introduced in Chapter III are interpreted combining the intact rock material and rock mass properties together.

#### 4.7.1.1 Boztepe (T-1) Tunnel

The Boztepe (T-1) Tunnel along which sixteen boreholes were drilled is 3273 m long. Starting from KM: 23+050 and ending at KM: 26+323, Boztepe Tunnel has two tubes running parallel to each other. The tunnel has a horseshoe shape with 12.0 m span diameter and 9.0 m height. The tunnel would start to be driven at an elevation of 70.0 m and reach up to the surface at an elevation 150.0 m. The drillings at portals were executed on the axis of each tube, whereas the others were drilled on the project axis, which is the line in between the tube axes (Figure 2 in Appendix –A). Each tube starts at the same kilometer KM: 23+050, but the right tube[a] daylights 5.0 m after the left one does.

For the underground support determination via Q system, the tunnel alignment is separated into structural domains depending mainly on the formation discrepancies along tunnel axis. For this purpose, the tunneling elevation intervals at each drilling are thoroughly examined as summarized in Table 3.2. The impressions gathered from surface investigations and field observations are attempted to be interpreted at the excavation depth. At the end, seven structural domains including the entrance (T1-Pn) and exit (T1-Px) portals were established for the Boztepe (T-1) tunnel (Table 4.12).

The flow charts and details of Q value calculation for each domain are provided under the heading of “The Boztepe (T-1) tunnel” in Appendix – D. The ESR value for “major road

[a] The terms “right” and “left” are assigned in the order of km increase.

tunnels" is given between 0.9 and 1.1 in the updated version (Table 4.6). Thereupon, an average value of 1.0 is taken as the ESR value.

After the determination of the Q values for each domain, the equivalent dimensions ($D_e$) of the excavation have been determined (Figure 4.11 and Table 4.13). This equivalent dimension is related to the tunnel support requirements by defined Q values.

In order to assign a support category for each domain, the Q and $D_e$ values have been entered into the Q-system support chart supplied in Figure 4.12 and in Figure 4.13. Accordingly, the obtained support categories and their support members have been presented in Table 4.14. In the same table, the maximum unsupported span values related to each determined Q value is presented through the application of equation (7).

At the end, the rock masses represented by domains have been classified according to the Q values. The calculated Q values have been grouped into four rock mass classes of the Q system as given in Table 4.15, where the summary of the Q system findings of the Boztepe (T-1) tunnel rock masses are presented. Here, the support systems have been directly taken from the CLASSEX outputs, which can provide more precise support elements for roof and wall, separately (See Appendix D).

Table 4.12. NGI (Q) System Classification of the Boztepe (T-1) Tunnel as calculated by Classex software.

| Structural Domain | KM Chainage | Lithology at tunnel depth | Borehole No. | RQD | Jn | Jr | Ja | Jw | SRF * | Q | ROCK CLASS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 – Pn (Entrance) | 23+015 – 23+050 | Claystone, Agglomerate, Tuff | T1-SK5 T1-SK6 | 54.5 | 2 x (9) | 3 | 4 | 0.66 | 2.311 | 0.64 | Very Poor Rock |
| T1 –1 | 23+050 – 23+375 | Claystone, Marl, Sandstone (Flysch) | T1-SK3 T1-SK4 | 43.5 | 9 | 3 | 2 | 1 | 3.617 | 2.00 | Poor Rock |
| T1 – 2 | 23+375 – 24+000 | Agglomerate | T1-SK7 T1-SK8 T1-SK9 | 96.1 | 4 | 4 | 1 | 1 | 5.099 | 18.80 | Good Rock |
| T1 – 3 | 24+000 – 25+000 | Claystone, Agglomerate, Basalt, Tuff, Limestone | T1-SK10 T1-SK11 T1-SK12 | 65.5 | 4 | 3 | 2 | 1 | 6.772 | 3.60 | Poor Rock |
| T1 – 4 | 25+000 – 25+775 | Claystone Tuff | T1-SK13 T1-SK14 | 60 | 4 | 3 | 2 | 1 | 21.126 | 1.00 | Very Poor Rock |
| T1 – 5 | 25+775 – 26+290 | Agglomerate, Claystone, Basalt, Siltstone | T1-SK15 T1-SK16 | 67.6 | 6 | 4 | 2 | 1 | 4.575 | 4.90 | Fair Rock |
| T1 – Px (Exit) | 26+290 – 26+323 | Agglomerate | T1-SK17 T1-SK18 | 49 | 2 x (9) | 4 | 4 | 0.66 | 2.311 | 0.77 | Very Poor Rock |

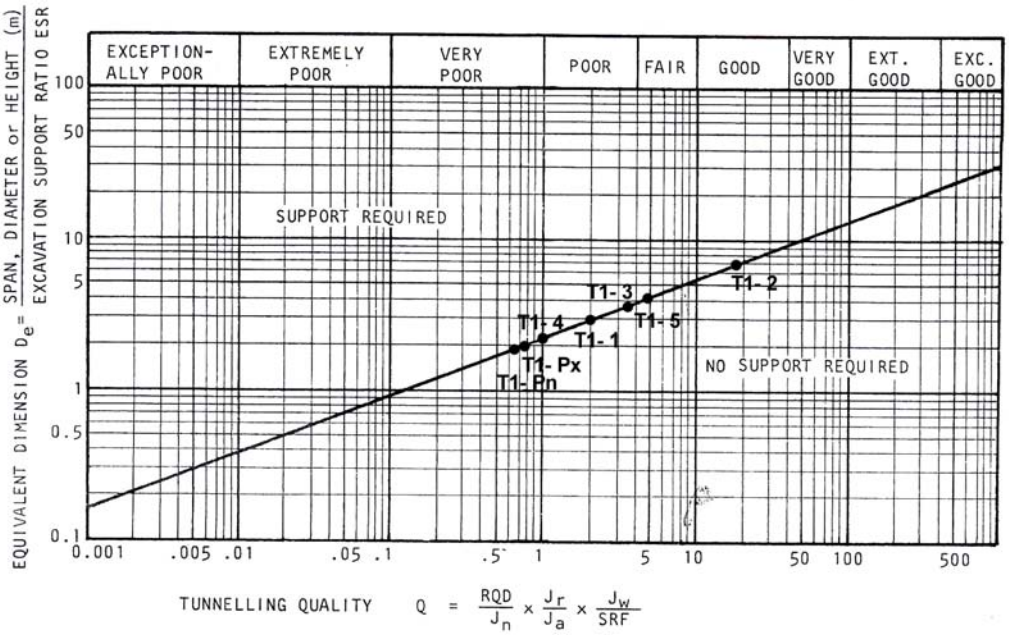



Figure 4.11. Correlation between NGI Q-System results and maximum unsupported wall height for Boztepe (T-1) Tunnel.
**Note:** T1-1, T1-2, etc. are the domain names mentioned in Table 3.2.

Table 4.13. Maximum unsupported wall height for domains of Boztepe (T-1) Tunnel.

| Domain Name | Q | De (m) | ESR | Wall height (De x ESR) (m) |
|---|---|---|---|---|
| **T1 – Pn** | 0.64 | 1.90 | 1.00 | 1.90 |
| **T1 – 1** | 2.00 | 3.00 | 1.00 | 3.00 |
| **T1 – 2** | 18.80 | 6.80 | 1.00 | 6.80 |
| **T1 – 3** | 3.60 | 3.80 | 1.00 | 3.80 |
| **T1 – 4** | 1.00 | 2.20 | 1.00 | 2.20 |
| **T1 – 5** | 4.90 | 4.20 | 1.00 | 4.20 |
| **T1 – Px** | 0.77 | 2.00 | 1.00 | 2.00 |

Table 4.14. Suggested support requirements for Boztepe (T-1) Tunnel by NGI Q system.

| Domain Name | NGI Q | Support category | Span / ESR (m) | Type of Support | Maximum unsupported span (m) |
|---|---|---|---|---|---|
| **T1 – Pn** | 0.64 | 27 | ≥12 | B (tg) 1m + S (mr) 7.5-10cm | 1.67 |
| | | | <12 | B (utg) 1m + S (mr) 5-7.5cm | |
| | | | >12 | CCA 20-40 cm + B (tg) 1m | |
| | | | <12 | S (mr) 10-20 cm + B (tg) 1m | |
| **T1 – 1** | 2.00 | 23 | ≥15 | B (tg) 1-1.5m + S (mr) 10-15cm | 2.64 |
| | | | <15 | B (tg) 1-1.5m + S (mr) 5-10cm | |
| **T1 – 2** | 18.80 | 14 | ≥15 | B (tg) 1.5-2m + clm | 6.47 |
| | | | ≥15 | B (tg) 1.5-2m + S (mr) 5-10cm | |
| | | | <15 | B (utg) 1.5-2m + clm | |
| **T1 – 3** | 3.60 | 23 | ≥15 | B (tg) 1-1.5m + S (mr) 10-15cm | 3.34 |
| | | | <15 | B (tg) 1-1.5m + S (mr) 5-10cm | |
| **T1 – 4** | 1.00 | 27 | ≥12 | B (tg) 1m + S (mr) 7.5-10cm | 2.00 |
| | | | <12 | B (utg) 1m + S (mr) 5-7.5cm | |
| | | | >12 | CCA 20-40 cm + B (tg) 1m | |
| | | | <12 | S (mr) 10-20 cm + B (tg) 1m | |
| **T1 – 5** | 4.90 | 18 | ≥10 | B (tg) 1-1.5m + clm | 3.78 |
| | | | <10 | B (utg) 1-1.5m + clm | |
| | | | ≥10 | B (tg) 1-1.5m + S (mr) 2-3cm | |
| | | | <10 | B (utg) 1-1.5m + S (mr) 2-3cm | |
| **T1 – Px** | 0.77 | 27 | ≥12 | B (tg) 1m + S (mr) 7.5-10cm | 1.80 |
| | | | <12 | B (utg) 1m + S (mr) 5-7.5cm | |
| | | | >12 | CCA 20-40 cm + B (tg) 1m | |
| | | | <12 | S (mr) 10-20 cm + B (tg) 1m | |

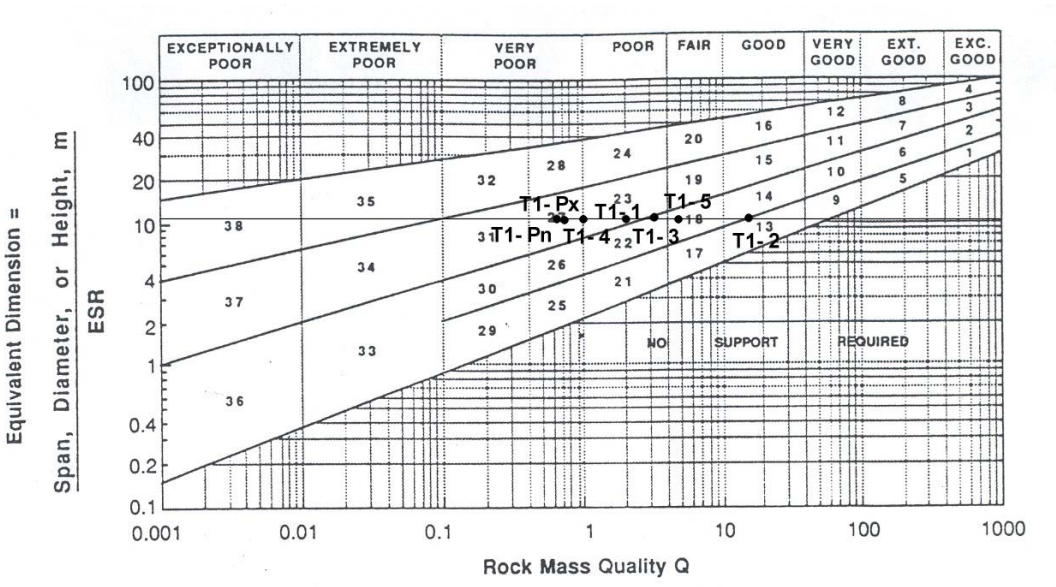



Figure 4.12. Support categories determined through NGI Q-System results for Boztepe (T-1) Tunnel. The details of the support categories are provided in Appendix D.

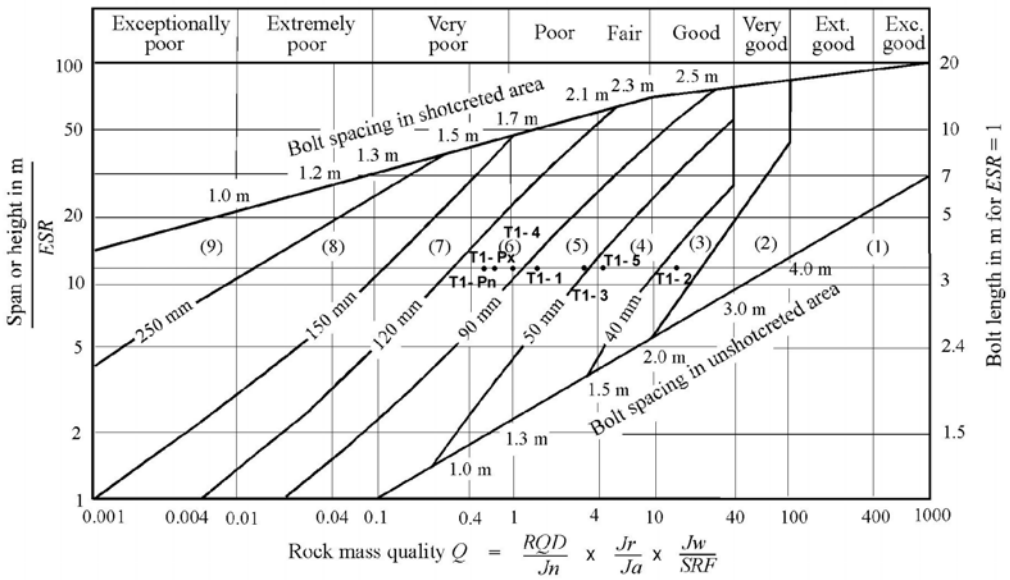



Figure 4.13. Estimated support based on tunneling quality index Q for Boztepe (T-1) Tunnel.

Table 4.15. Summary of NGI Q index and related support requirements for Boztepe (T-1) Tunnel.

| **Q range** | | **10 ≤ Q < 40** | **4 ≤ Q < 10** | **1 ≤ Q < 4** | **0.4 ≤ Q < 1** |
|---|---|---|---|---|---|
| **Q (calculated)** | | 18.80 | 4.90 | 1.00-2.00-3.60 | 0.64-0.77 |
| **Uniaxial Compressive Strength (MPa)** | | 30 | 40 | 20-25-35 | 25 |
| **Max. Unsupported Roof Span (m)** | | 6.47 | 3.78 | 2.00-2.64-3.34 | 1.67-1.80 |
| **Max. Unsupported Wall Height (m)** | | 6.80 | 4.20 | 2.20-3.00-3.80 | 1.90-2.00 |
| **Suggested Support Categories by Q-system** | **Roof** | Untensioned grouted dowels (Ø26mm, spacing 1.5-2m, L=3.80m) + Chainlink mesh anchored to bolts and intermediate points. + when needed tenisoned rockbolts (Ø26mm, spacing 1m, L=3.80m) | Tensioned rockbolts (Ø26mm, spacing 1-1.5m, L=3.80m) + Chainlink mesh anchored to bolts and intermediate points + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 - 10 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1-1.5m, L=3.80m) + Chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 – 12.5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.80m) + Chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) |
| | **Wall** | No support required. | 2 - 3 cm shotcrete + Spot reinforcement with untensioned grouted dowels (Ø26mm, spacing 1.5-2m, L=3.35m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 2.5 – 5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.80m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 – 7.5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.35m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) |

As it can be noticed from the tables given above, the Q-based rock quality varies from “Very Poor Rock” to “Good Rock” along the Boztepe (T-1) tunnel. The Q values of the Boztepe (T-1) tunnel can be grouped into four Q-interval whose suggested support categories have been mentioned in Table 4.15.

#### 4.7.1.2 Öceli (T-2) Tunnel

Öceli (T-2) Tunnel along which twenty boreholes were drilled is 2039 m long. Starting from KM: 26+453 and ending at KM: 28+492, Öceli Tunnel has two tubes like T-1, running parallel to each other. The tunnel section dimensions are the same as that of T-1. The tunnel would start to be driven at an elevation of 105.0 m, rise to a maximum elevation of 155.0 m and reach up to the surface at elevations 105.0 m again. The drillings at portals were executed on the axis of each tube, whereas the others were drilled on the project axis, which is the line in between the tube axes (Figure 2 in Appendix – A). Left tube starts at KM: 26+453 while right one at 26+458, and the left tube daylights at KM: 28+467 while right one at KM: 28+492.

For the underground support determination via Q system, the tunnel alignment is separated into structural domains depending mainly on the formation discrepancies along tunnel axis as in the case of Boztepe (T-1) Tunnel. At the end, seven structural domains including entrance (T2-Pna and T2-Pnb) and exit (T2-Px) portals were established for Öceli (T-2) tunnel (Table 4.16). The rock masses surrounding the entrance portals of T-2 display different behavior regarding especially uniaxial compressive strength. Accordingly, they have been examined separately as T2-$Pn_a$ and T2-$Pn_b$.

The flow charts and details of Q value calculation of each domain are provided under the heading of "The Öceli (T-2) tunnel" in Appendix – D. The ESR value for "major road tunnels" is given between 0.9 and 1.1 in the updated version (Table 4.6). Thereupon, an average value of 1.0 is taken for the ESR value.

After the determination of the Q values for each domain, the equivalent dimensions (De) of the excavation have been determined (Figure 4.14 and Table 4.17). This equivalent dimension is related to the tunnel support requirements by defined Q values.

In order to assign a support category for each domain, the Q and $D_e$ values have been entered into the Q-system support chart supplied in Figure 4.15 and in Figure 4.16. Accordingly, the obtained support categories and their support members have been presented in Table 4.18. In the same table, the maximum unsupported span values related to each determined Q value is presented through the application of equation (7).

At the end, the rock masses represented by domains have been classified according to the Q values. The calculated Q values have been grouped into four rock mass classes of the

Q system as given in Table 4.19, where the summary of the Q system findings of the Öceli (T-2) tunnel rock masses are presented. Here, the support systems have been directly taken from the CLASSEX outputs, which can provide more precise support elements for roof and wall, separately (Appendix – D).

Table 4.16. NGI (Q) System Classification of the Öceli (T-2) Tunnel as calculated by CLASSEX software.

| Structural Domain | KM Chainage | Lithology at tunnel depth | Borehole No. | RQD | Jn | Jr | Ja | Jw | SRF * | Q | ROCK CLASS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T2 – $Pn_a$ (Entrance) | 26+453 – 26+550 | Agglomerate, Tuff | T2-SK5 T2-SK6 | 60 | 2 x (6) | 4 | 4 | 0.66 | 7.686 | 0.42 | Very Poor Rock |
| T2 – $Pn_b$ (Entrance) | 26+458 – 26+550 | Agglomerate, Tuff | T2-SK5 T2-SK6 | 60 | 2 x (6) | 4 | 4 | 0.66 | 1.347 | 2.40 | Poor Rock |
| T2 – 1 | 26+550 – 26+800 | Agglomerate | T2-SK7 | 63 | 6 | 4 | 2 | 1 | 6.734 | 3.10 | Poor Rock |
| T2 – 2 | 26+800 – 27+050 | Agglomerate | T2-SK8 | 88.5 | 6 | 4 | 1 | 1 | 4.711 | 12.50 | Good Rock |
| T2 – 3 | 27+050 – 27+375 | Agglomerate, Claystone | T2-SK9 | 76.5 | 6 | 4 | 1 | 1 | 6.095 | 8.30 | Fair Rock |
| T2 – 4 | 27+375 – 27+750 | Tuff, Agglomerate, Claystone, Sandstone | T2-SK10 | 82 | 6 | 4 | 2 | 1 | 8.909 | 3.00 | Poor Rock |
| T2 – Px (Exit) | 27+750 – 28+492 | Agglomerate, Tuff, Sandstone | T2-SK1 T2-SK2 T2-SK3 T2-SK4 T2-SK11 T2-SK12 | 60 | 2 x (6) | 4 | 4 | 0.66 | 7.686 | 0.42 | Very Poor Rock |

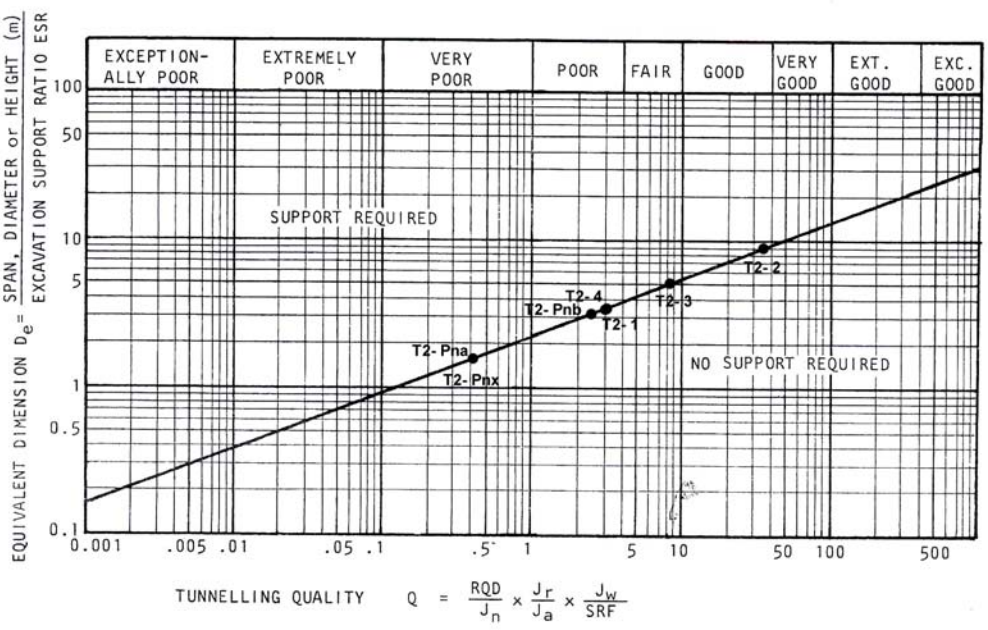



Figure 4.14. Correlation between NGI Q-System results and maximum unsupported wall height for Öceli (T-2) Tunnel.

**Note:** T2-1, T2-2, etc. are the domain names mentioned in Table 3.2.

Table 4.17. Maximum unsupported wall height for domains of Öceli (T-2) Tunnel.

| Domain Name | Q | De (m) | ESR | Wall height (De x ESR) (m) |
|---|---|---|---|---|
| **T2 – $Pn_a$** | 0.42 | 1.30 | 1.00 | 1.30 |
| **T2 – $Pn_b$** | 2.40 | 3.05 | 1.00 | 3.05 |
| **T2 – 1** | 3.10 | 3.30 | 1.00 | 3.30 |
| **T2 – 2** | 12.50 | 9.00 | 1.00 | 9.00 |
| **T2 – 3** | 8.30 | 5.00 | 1.00 | 5.00 |
| **T2 – 4** | 3.00 | 3.20 | 1.00 | 3.20 |
| **T2 – Px** | 0.42 | 1.30 | 1.00 | 1.30 |

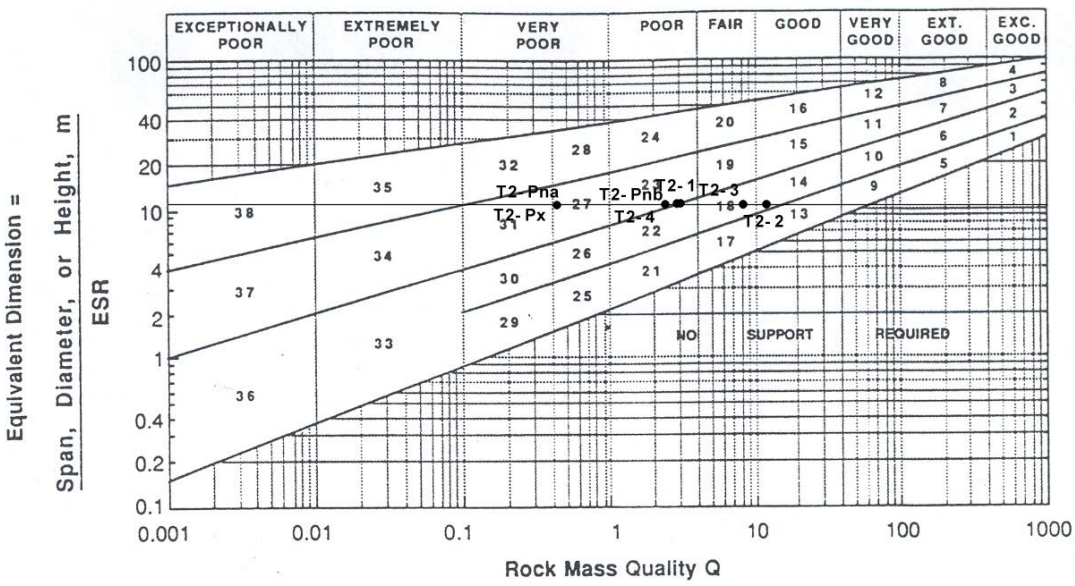



Figure 4.15. Support categories determined through NGI Q-System results for Öceli (T-2) Tunnel. The details of the support categories are provided in Appendix – D.

Table 4.18. Suggested support requirements for the Öceli (T-2) Tunnel by NGI Q system (from Barton et al., 1977).

| Domain Name | NGI Q | Support category | Span / ESR (m) | Type of Support | Maximum unsupported span (m) |
|---|---|---|---|---|---|
| **T2 – $Pn_a$** | 0.42 | 27 | ≥12 | B (tg) 1m + S (mr) 7.5-10cm | 1.41 |
| | | | <12 | B (utg) 1m + S (mr) 5-7.5cm | |
| | | | >12 | CCA 20-40 cm + B (tg) 1m | |
| | | | <12 | S (mr) 10-20 cm + B (tg) 1m | |
| **T2 – $Pn_b$** | 2.40 | 23 | ≥15 | B (tg) 1-1.5m + S (mr) 10-15cm | 2.84 |
| | | | <15 | B (tg) 1-1.5m + S (mr) 5-10cm | |
| **T2 – 1** | 3.10 | 23 | ≥15 | B (tg) 1-1.5m + S (mr) 10-15cm | 3.14 |
| | | | <15 | B (tg) 1-1.5m + S (mr) 5-10cm | |
| **T2 – 2** | 12.50 | 14 | ≥15 | B (tg) 1.5-2m + clm | 5.49 |
| | | | ≥15 | B (tg) 1.5-2m + S (mr) 5-10cm | |
| | | | <15 | B (utg) 1.5-2m + clm | |
| **T2 – 3** | 8.30 | 18 | ≥10 | B (tg) 1-1.5m + clm | 4.66 |
| | | | <10 | B (utg) 1-1.5m + clm | |
| | | | ≥10 | B (tg) 1-1.5m + S (mr) 2-3cm | |
| | | | <10 | B (utg) 1-1.5m + S (mr) 2-3cm | |
| **T2 – 4** | 3.00 | 23 | ≥15 | B (tg) 1-1.5m + S (mr) 10-15cm | 3.10 |
| | | | <15 | B (tg) 1-1.5m + S (mr) 5-10cm | |
| **T2 – Px** | 0.42 | 27 | ≥12 | B (tg) 1m + S (mr) 7.5-10cm | 1.41 |
| | | | <12 | B (utg) 1m + S (mr) 5-7.5cm | |
| | | | >12 | CCA 20-40 cm + B (tg) 1m | |
| | | | <12 | S (mr) 10-20 cm + B (tg) 1m | |

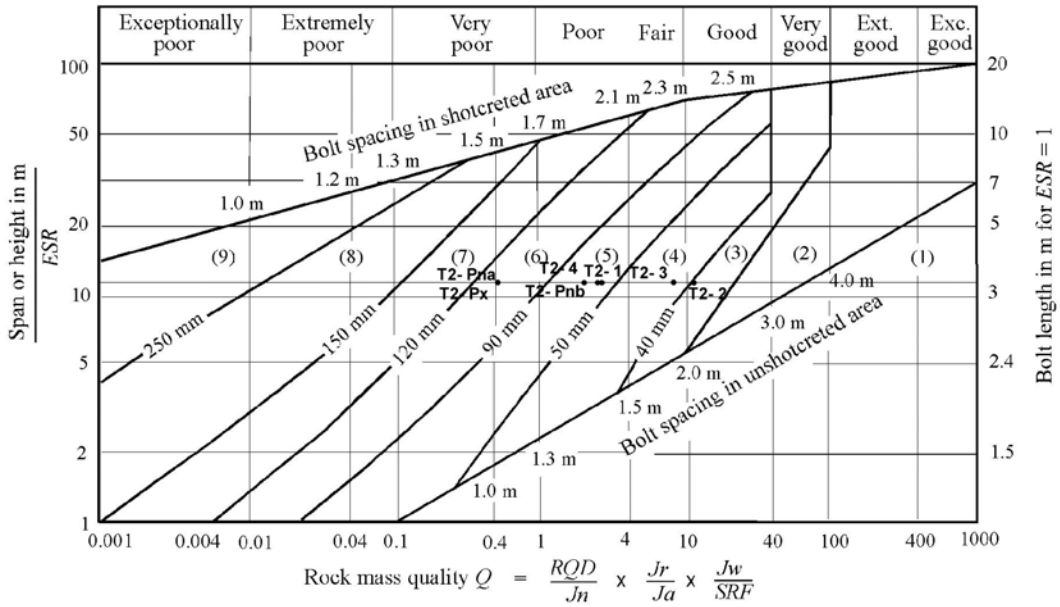



Figure 4.16. Estimated support based on tunneling quality index Q for the Öceli (T-2) Tunnel.

As it can be noticed from the tables given above, the Q-based rock quality varies from "Very Poor Rock" to "Good Rock" along the Öceli (T-2) tunnel. The Q values of the Öceli (T-2) tunnel can be grouped into four Q-interval whose suggested support categories have been mentioned in Table 4.19.

Table 4.19. Summary of NGI Q index and related support requirements for Öceli (T-2) Tunnel.

| **Q range** | | **10 ≤ Q < 40** | **4 ≤ Q < 10** | **1 ≤ Q < 4** | **0.4 ≤ Q < 1** |
|---|---|---|---|---|---|
| **Q (calculated)** | | 12.50 | 8.30 | 2.40-3.00-3.10 | 0.42 |
| **Uniaxial Compressive Strength (MPa)** | | 25-40 | 20-50 | 15-60 | 10-25 |
| **Max. Unsupported Roof Span (m)** | | 5.49 | 4.66 | 2.84-3.10-3.14 | 1.41 |
| **Max. Unsupported Wall Height (m)** | | 9.00 | 5.00 | 3.05-3.20-3.30 | 1.30 |
| **Suggested Support Categories by Q-system** | **Roof** | Untensioned grouted dowels (Ø26mm, spacing 1.5-2m, L=3.80m) + chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 1m, L=3.80m) | Tensioned rockbolts (Ø26mm, spacing 1-1.5m, L=3.80m) + chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 - 10 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1-1.5m, L=3.80m) + chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 – 12.5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.80m) + chainlink mesh + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) |
| | **Wall** | No Support Required. | 2 - 3 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1.5-2m, L=3.35m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 2.5 – 5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.35m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) | 5 – 7.5 cm shotcrete + Tensioned rockbolts (Ø26mm, spacing 1m, L=3.35m) + when needed tenisoned rockbolts (Ø26mm, spacing 0.8-1m, L=3.80m) |

### 4.7.2 Geomechanics Classification (RMR) System

The rudimentary form of the Geomechanics Classification developed by Bieniawski (1973) assigns a rating; a number for a range of one of the six parameters considered, e.g., a rating (12) is assigned for the rock mass having uniaxial compressive strength between 100-250 MPa. However, it should be noted that it is unfair to give the same rating to rock masses having a uniaxial compressive strength of 100 MPa and 250 MPa, respectively.

Especially the three parameters, namely the strength of rock material, RQD and discontinuity spacing, among the five basic parameters of RMR are relatively more quantitative. Hence, to give only one number for a wide range of parameter quality should be avoided. At this stage, it is believed that the Modified RMR (M-RMR) developed by Ünal, 1996 presents more precise values for those parameters concerned. On that account, the ratings of these parameters were calculated from the M-RMR. Accordingly, a kind of combination of RMR and M-RMR rock mass classifications was employed in this project.

The other two basic parameters, namely groundwater and discontinuity conditions are relatively more descriptive and are clearly defined by the given sufficient details in the basic form of RMR. The weathering condition among those deserves special attention. Correspondingly, the ratings of them were provided from Geomechanics Classification (RMR) by Bieniawski, 1973.

Finally, the new RMR, called A-RMR from this point forward in this project, was determined by summing the ratings up from RMR and M-RMR for those particular parameters. In determining the rock mass shear strength parameters, A-RMR value will be processed and the rock mass class will be determined as in the case of the basic form of the RMR. In other words, A-RMR rating will be treated as basic RMR value in order to determine the rock mass engineering properties such as rock mass stand-up time, rock mass class and the related shear strength parameters like RMR does. Consequently, what is done is the tuning or adjusting the RMR value, which will be employed in the same charts of RMR.

Moreover, regarding the structural geology, specifically the joint orientation, it is again unfair to punish the rock mass with some correction factors from (0) up to (–12). The ratings coming from this classification parameter should not be included in the overall RMR value of the rock mass since it is not fair to classify the rock mass as “FAIR ROCK” as the tunnel is entered from one side, and as “POOR ROCK” as the tunnel is entered from the other side. It has no relation with the rock mass strength parameters governed by the Geomechanics

(RMR) Classification. The rock itself is there as it stands except from the different joint orientations. Besides, in some regions exposed to high tectonic movements similar to the project area, it is not easy to determine the joint orientations that change so often even within the very small intervals. Therefore, it is believed that the influence of the discontinuity orientation should be held during excavation concerning the excavation easiness and uncorrected RMR values were employed in these tunnels. Similarly, in the calculation of the A-RMR values of the rock masses, the correction factors resulted from discontinuity orientations will be disregarded.

The other attempt is the assessment of RMR values at the tunnel portal faces. In the Q system of Barton et al. (1974), when a portal is of concern, joint number (Jn) is assigned a value two times the value that would be assigned to a structural region if there were no intersection and portal. At the locations of portal, therefore, the tunneling quality index Q of a region is reduced to by half of its original value. Accordingly, someone may consider the use of reduced values of RMR for portals. Actually, if one considers $Q_{portal}=Q/2$ in the empirical expression RMR=9LnQ+44, the rock mass rating for the portals becomes =RMR-6.24 (Table 4.20). Therefore, $RMR_P$ values will be considered at the portal faces while determining the rock mass shear strength parameters for the portal slope stability analyses.

Table 4.20. Comparison and Correlation of RMR and Q systems at tunnel portals.

| Q | RMR (Q) [9LnQ+44] | RMR (Q/2) [9Ln(Q/2)+44] | RMR (Q)-RMR (Q/2) |
|---|---|---|---|
| 100.00 | 85.45 | 79.21 | 6.24 |
| 70.00 | 82.24 | 76.00 | 6.24 |
| 40.00 | 77.20 | 70.69 | 6.24 |
| 10.00 | 64.72 | 58.48 | 6.24 |
| 4.00 | 56.48 | 50.24 | 6.24 |
| 1.00 | 44.00 | 37.76 | 6.24 |
| 0.40 | 35.75 | 29.52 | 6.24 |
| 0.10 | 23.28 | 17.04 | 6.24 |
| 0.04 | 15.03 | 8.79 | 6.24 |
| 0.01 | 2.55 | -3.68 | 6.24 |

#### 4.7.2.1 A-RMR calculation of the Boztepe (T-1) Tunnel

In order to find out the A-RMR value, the previously determined structural domains (Table 3.2) of the rock mass for the Q-system were re-considered. The detailed calculation of

A-RMR parameters and the related ratings of each domain are provided in Appendix – E under the heading of each domain name such as T1-Pn, T1-1, etc.

The results of A-RMR calculations given in Appendix – E are presented in Figure 4.17 and Tables 4.21 and 4.22, as a summary.

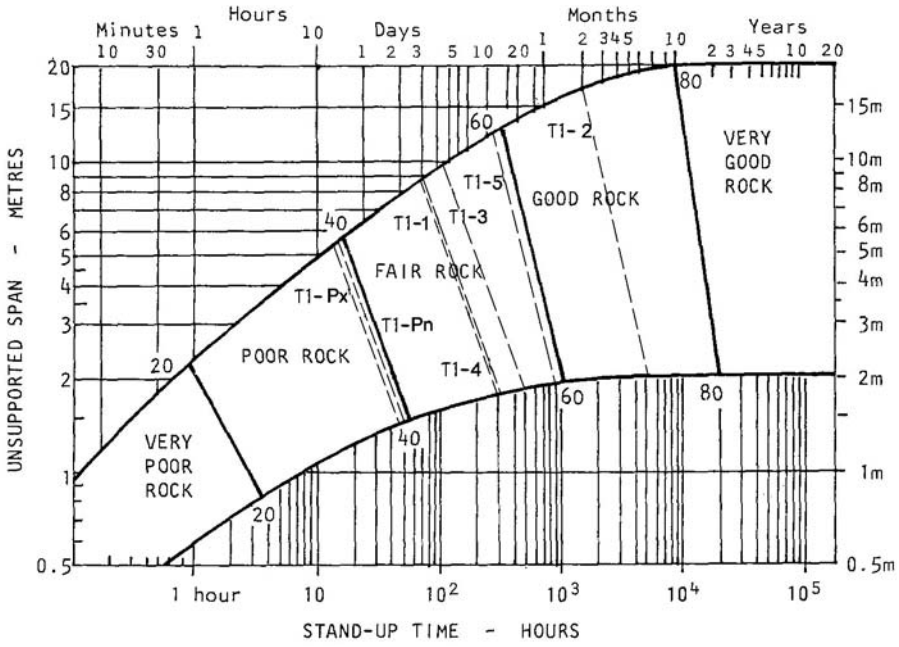



Figure 4.17. Relationship between the stand-up time of an unsupported underground excavation span and the A-RMR values for the Boztepe (T-1) Tunnel. **Note:** T1-1, T1-2, etc. are the domain names mentioned in Table 3.2.

Table 4.21. Maximum and possible spans with stand-up times for the Boztepe (T-1) Tunnel.

| Domain Name | A-RMR | Max. unsupported span (m) | Stand-up time for unsupported span | Max. possible span (m) |
|---|---|---|---|---|
| **T1 – Pn** | 38.65 | 1.47 | 2.2 days | 5.5 m with stand-up time of 17 hours |
| **T1 – 1** | 50.75 | 1.80 | 14 days | 8.80 m with stand-up time of 2.9 days |
| **T1 – 2** | 69.51 | 2.0 | 6.5 months | 17.5 m with stand-up time of 2 months |
| **T1 – 3** | 53.20 | 1.85 | 23 days | 9.75 m with stand-up time of 4 days |
| **T1 – 4** | 50.77 | 1.82 | 15 days | 9.0 m with stand-up time of 2.9 days |
| **T1 – 5** | 59.01 | 1.90 | 1.3 months | 12.5 m with stand-up time of 12 days |
| **T1 - Px** | 39.46 | 1.45 | 1.9 days | 5.3 m with stand-up time of 14 hours |

Table 4.22. Support categories determined through A-RMR classification of the Boztepe (T-1) tunnel. **Note:** Support categories are determined considering horseshoe tunnel with 10m span and excavated by drilling and blasting.

| **BOZTEPE (T-1) TUNNEL** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Domain** | **T1 - Pn** | **T1 – Px** | **T1 – 1** | **T1 – 2** | **T1 – 3** | **T1 – 4** | **T1 – 5** |
| **A-RMR** | 38.65 | 39.46 | 50.75 | 69.51 | 53.20 | 50.77 | 59.01 |
| **Rock Class** | IV | IV | III | II | III | III | III |
| **Description** | Poor Rock | Poor Rock | Fair Rock | Good Rock | Fair Rock | Fair Rock | Fair Rock |
| **Friction angle (ϕ)** | 15-25 | 15-25 | 25-35 | 35-45 | 25-35 | 25-35 | 25-35 |
| **Cohesion, c (kPa)** | 100-200 | 100-200 | 200-300 | 300-400 | 200-300 | 200-300 | 200-300 |
| **Modulus of Elasticity, E (MPa)** | 5451 | 5161 | 10441 | 30743 | 12023 | 10453 | 16798 |
| **Support Suggestions by RMR (Roof and Wall)** | | | | | | | |
| **Excavation** | Top heading and bench 1-1.5m advance in top heading. Install support concurrently with excavation 10m from face. | | Top heading and bench 1.5-3m advance in top heading. Commence support after each blast. Complete support 10m from face. | | | | Full face 1-1.5m advance. Complete support 20m from face. |
| **Rockbolts (ϕ= 26mm, fully bonded)** | Systematic bolts 4-5m long, spaced 1-1.5m in roof and walls with wire mesh. | | Systematic bolts 4m long, spaced 1.5-2m in roof and walls with wire mesh in roof. | | | | Locally, bolts in crown, 3m long spaced 2.5m with occasional wire mesh |
| **Shotcrete** | 100-150mm in roof and 100mm in sides. | | 50-100mm in roof and 30mm in sides. | | | | 50mm in crown where required. |
| **Steel sets** | Light to medium ribs spaced 1.5m where required. | | None | | | | None |

As it can be noticed from the tables given above, the A-RMR-based rock quality varies from “Poor Rock” to “Good Rock” along the Boztepe (T-1) tunnel. The A-RMR values of the Boztepe (T-1) provide engineering parameters of the rock masses, namely, c and ϕ, as an interval. Considering the conditions of the rock mass, the upper and lower limits or the average values of these intervals can be utilized in the engineering calculations, such as slope stability assessments.

#### 4.7.2.2 A-RMR calculation of the Öceli (T-2) Tunnel

In order to find out the A-RMR value, the previously determined structural domains (Table 3.2) of the rock masses for the Q-system were re-considered. The detailed calculation of A-RMR parameters and the related ratings of each domain are provided in Appendix – E under the heading of each domain name such as T2-Pna, T2-1, etc.

The results of A-RMR calculations given in Appendix – E are presented in Figure 4.18 and Tables 4.23 and 4.24, as a summary.

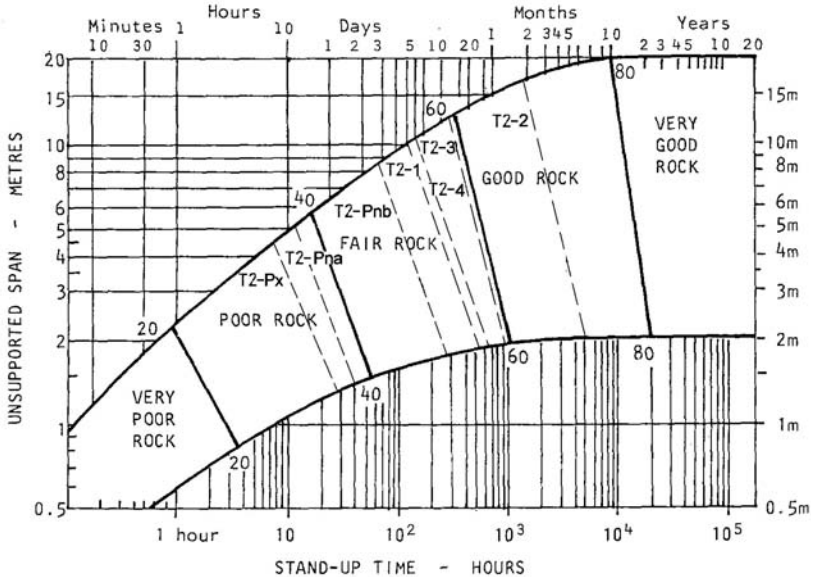



Figure 4.18. Relationship between the stand-up time of an unsupported underground excavation span and the A-RMR values for the Öceli (T-2) Tunnel.
**Note:** T2-1, T2-2, etc. are the domain names mentioned in Table 3.2.

Table 4.23. Maximum and possible spans with stand-up times for the Öceli (T-2) Tunnel.

| Domain Name | A-RMR | Max. unsupported span (m) | Stand-up time for unsupported span | Max. possible span (m) |
|---|---|---|---|---|
| **T2 – $Pn_a$** | 38.33 | 1.40 | 1.7 days | 5.1 m with stand-up time of 13 hours |
| **T2 – $Pn_b$** | 50.08 | 1.80 | 12 days | 8.50 m with stand-up time of 2.8 days |
| **T2 – 1** | 54.36 | 1.87 | 24 days | 10.0 m with stand-up time of 5 days |
| **T2– 2** | 64.48 | 2.00 | 7 months | 17.0 m with stand-up time of 1.9 months |
| **T2 – 3** | 59.75 | 1.92 | 1.3 months | 13.0 m with stand-up time of 13 days |
| **T2 – 4** | 55.92 | 1.90 | 28 days | 11.0 m with stand-up time of 6 days |
| **T2 - Px** | 35.33 | 1.3 | 1.4 days | 4.5 m with stand-up time of 9 hours |

Table 4.24. Support categories determined through A-RMR classification of the Öceli (T-2) tunnel. **Note:** Support categories are determined considering horseshoe tunnel with 10m span and excavated by drilling and blasting.

| **ÖCELİ (T-2) TUNNEL** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Domain** | **T2 - $Pn_a$** | **T2 – Px** | **T2 – $Pn_b$** | **T2 – 1** | **T2 – 2** | **T2 – 3** | **T2 – 4** |
| **A-RMR** | 38.33 | 35.33 | 50.08 | 54.36 | 64.48 | 59.75 | 55.92 |
| **Rock Class** | IV | IV | III | III | II | III | III |
| **Description** | Poor Rock | Poor Rock | Fair Rock | Fair Rock | Good Rock | Fair Rock | Fair Rock |
| **Friction angle (ϕ)** | 15-25 | 15-25 | 25-35 | 25-35 | 35-45 | 25-35 | 25-35 |
| **Cohesion, c (kPa)** | 100-200 | 100-200 | 200-300 | 200-300 | 300-400 | 200-300 | 200-300 |
| **Modulus of Elasticity, E (MPa)** | 5108 | 4298 | 10046 | 12853 | 23014 | 17529 | 14060 |
| **Support Suggestions by RMR (Roof and Wall)** | | | | | | | |
| **Excavation** | Top heading and bench 1-1.5m advance in top heading. Install support concurrently with excavation 10m from face. | | Top heading and bench 1.5-3m advance in top heading. Commence support after each blast. Complete support 10m from face. | | | | Full face 1-1.5m advance. Complete support 20m from face. |
| **Rockbolts (ϕ= 26mm, fully bonded)** | Systematic bolts 4-5m long, spaced 1-1.5m in roof and walls with wire mesh. | | Systematic bolts 4m long, spaced 1.5-2m in roof and walls with wire mesh in roof. | | | | Locally, bolts in crown, 3m long spaced 2.5m with occasional wire mesh |
| **Shotcrete** | 100-150mm in roof and 100mm in sides. | | 50-100mm in roof and 30mm in sides. | | | | 50mm in crown where required. |
| **Steel sets** | Light to medium ribs spaced 1.5m where required. | | None | | | | None |

As it can be noticed from the tables given above, the A-RMR-based rock quality varies from “Poor Rock” to “Good Rock” along the Öceli (T-2) tunnel. The A-RMR values of the Öceli (T-2) provide engineering parameters of the rock masses, namely, c and ϕ, as an interval. Considering the conditions of the rock mass, the upper and lower limits or the average values of these intervals can be utilized in the engineering calculations, such as slope stability assessments.

As having been given by the intervals, the rock mass shear strength parameters c and ϕ which will be used in the portal slope stability analyses will be specified and mentioned for each case in Chapter VI.

#### 4.7.2.3 Correlation of A-RMR values with NGI Q index

Various empirical correlations between RMR and Q classifications have been made in previous studies. The empirical equation, RMR=9LnQ+44, proposed by Bieniawski (1976) is the most popular and applicable, linking Q and RMR. Similarly, the project A-RMR values can be correlated with the project Q values (Figure 4.19).

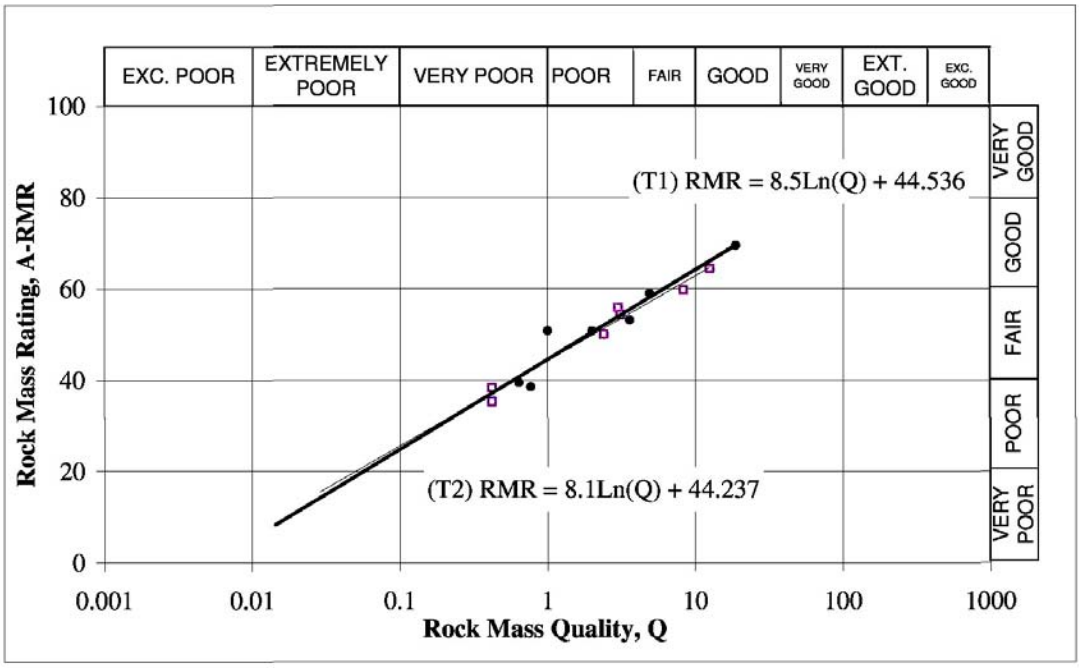



Figure 4.19. Correlation of RMR and Q-system assessments of the Boztepe (T-1) and Öceli (T-2) Tunnels.

The results of the rock mass correlations for the T-1 and T-2 tunnels show that the equation of the correlation line is similar to that of correlation between the basic RMR and Q rock mass classification systems.

### 4.7.3 New Austrian Tunneling Method (NATM) descriptions

The NATM descriptions of both tunnels, in this section, were again provided on the basis of structural domains to be consisted with the other two classifications made before. Moreover, this way of presentation gives the opportunity to correlate NATM descriptions with the other two rock mass classifications, namely RMR and Q-systems for both tunnels.

In addition, the support recommendations by NATM were presented with respect to the domains considered (Tables 4.25, 4.26, 4.27 and 4.28).

Consequently, NATM being rather far away from the purpose of rock mass classification provides the determination of excavation stages and methods as it can be revealed from the Tables 4.26 and 4.28.

Table 4.25. NATM descriptions correlated with Q and RMR for the Boztepe (T-1) Tunnel.

| DOMAINS | LITHOLOGY TO BE EXCAVATED | Q | A-RMR | TUNNELING DEPTH (m) | *NATM DESCRIPTION |
|---|---|---|---|---|---|
| **(T1-Pn)** | Flysch: Claystone+Sandstone+ Conglomerate+Limestone Volcanics: Tuff+Agglomerate | 0.64 | 39.46 | 35 | **B3** |
| **(T1-Px)** | Flysch: Claystone+Sandstone+ Conglomerate+Limestone Volcanics: Tuff+Agglomerate | 0.77 | 38.51 | 35 | **B3** |
| **(T1-1)** | Flysch: Claystone+Sandstone+ Limestone Volcanics: Tuff+Agglomerate | 2.00 | 50.75 | 50 | **B2** |
| **(T1-2)** | Flysch: Claystone+Sandstone+ Conglomerate+Limestone Volcanics: Agglomerate | 18.8 | 69.51 | 80 | **A2** |
| **(T1-3)** | Flysch: Claystone+Sandstone+ Conglomerate+Limestone Volcanics: Agglomerate | 3.60 | 53.20 | 120 | **B2** |
| **(T1-4)** | Flysch: Claystone+Sandstone+ Conglomerate+Limestone Volcanics: Agglomerate+Tuff | 1.00 | 50.77 | 170 | **B3** |
| **(T1-5)** | Flysch: Claystone+Sandstone+ Limestone+Siltstone Volcanics: Agglomerate+Basalt | 4.90 | 59.01 | 100 | **B1** |

* Descriptions are directly taken from the correlations made in Table 4.11 – a.

Table 4.26. Support and excavation recommendations by NATM for the Boztepe (T-1) Tunnel.

| NATM DESCRIPTION | | A2 | B1 | B2 | B3 |
|---|---|---|---|---|---|
| **Excavation Stage** | | Full face or two stage-excavation | Two stages. top heading and bench | Two stages. top heading and bench | Two stages. top heading and bench |
| **Excavation Method** | | Drill and smooth blasting | Drill and smooth blasting | Drill and smooth blasting, mechanical excavation if needed | Drill and smooth blasting, mechanical excavation if needed |
| **Round Length** | | 2.5-3.5 m top heading, 4.0 m bench | 2.0-3.0 m top heading, 4.0 m bench | 2.0-2.5 m top heading, 3.5 m bench | 1.5-2 m top heading, 3 m bench |
| **Stand-up Time** | | A few days-week | Minimum 10 hours – 2 days | Appx. 5 – 10 hours | Less than 5 hours |
| **Support Timing** | | Except places requiring immediate support, apply support at most one round back from the face. | Except places requiring immediate support, apply support at most one round back from the face. | Commence support just after face. Pillars at top heading if needed. | Commence support just after face. Take measures to improve rock mass quality and stand-up time. Pillars at top heading if needed. |
| **Support Requirements by NATM** | **Roof** | 5 cm shotcrete + when needed spot bolting (Ø26, L=4 m) | 10 cm shotcrete + wiremesh + Systematic grouted 8-9 bolts (Ø26, L=4 m, spacing 2 m) | 15 cm shotcrete + wiremesh + Systematic grouted 10-11 bolts (Ø26, L=4 m, spacing 1.5 m) + when needed I100/150-200 steel support + when needed pillar at face | 20-25 cm shotcrete + wiremesh (2 layers) + Systematic grouted 16-17 bolts (Ø26, L=4 m, spacing 1 m) + I140/100 steel support + when needed forepiling (Ø26 L=4 m, spacing 0.4 m), pillar at face |
| | **Wall** | 5 cm shotcrete + when needed spot bolting (Ø26, L=4 m) | 10 cm shotcrete + when needed spot bolting (Ø26, L=4 m) | 15 cm shotcrete + wiremesh + Systematic grouted 4 bolts (Ø26 L=4 m, spacing 1.5 m) | 20 cm shotcrete + wiremesh (2 layers) + Systematic grouted 6 bolts (Ø26 L=4 m, spacing 1 m) + I140/100 steel support |

Table 4.27. NATM descriptions correlated with Q and RMR for the Öceli (T-2) Tunnel

| DOMAINS | LITHOLOGY TO BE EXCAVATED | Q | A-RMR | TUNNELING DEPTH (m) | *NATM DESCRIPTION |
|---|---|---|---|---|---|
| **(T2-Pn$_a$)** | Volcanics: Tuff + Agglomerate | 0.42 | 38.33 | 35 | **B3** |
| **(T2-Pn$_b$)** | Volcanics: Tuff + Agglomerate | 2.40 | 50.08 | 35 | **B2** |
| **(T2-1)** | Flysch: Rare Claystone Volcanics: Tuff + Agglomerate | 3.10 | 54.36 | 65 | **B2** |
| **(T2-2)** | Volcanics: Tuff + Agglomerate | 12.50 | 64.48 | 75 | **A2** |
| **(T2-3)** | Flysch: Sandstone+Conglomerate+ Claystone Volcanics: Tuff + Agglomerate | 8.30 | 59.75 | 60 | **B1** |
| **(T2-4)** | Flysch: Sandstone+Claystone Volcanics: Tuff + Agglomerate | 3.00 | 55.92 | 60 | **B2** |
| **(T2-Px)** | Flysch: Sandstone+Claystone Volcanics: Tuff + Agglomerate | 0.42 | 35.33 | 35 | **B3** |

***** Descriptions are directly taken from the Table 4.11 – a.

Table 4.28. Support and excavation recommendations by NATM for the Öceli (T-2) Tunnel

| NATM DESCRIPTION | | A2 | B1 | B2 | B3 |
|---|---|---|---|---|---|
| **Excavation Stage** | | Full face or two stage-excavation | Two stages. top heading and bench | Two stages. top heading and bench | Two stages. top heading and bench |
| **Excavation Method** | | Drill and smooth blasting | Drill and smooth blasting | Drill and smooth blasting, mechanical excavation if needed | Drill and smooth blasting, mechanical excavation if needed |
| **Round Length** | | 2.5-3.5 m top heading, 4.0 m bench | 2.0-3.0 m top heading, 4.0 m bench | 2.0-2.5 m top heading, 3.5 m bench | 1.5-2 m top heading, 3 m bench |
| **Stand-up Time** | | A few days-week | Minimum 10 hours – 2 days | Appx. 5 – 10 hours | Less than 5 hours |
| **Support Timing** | | Except places requiring immediate support, apply support at most one round back from the face. | Except places requiring immediate support, apply support at most one round back from the face. | Commence support just after face. Pillars at top heading if needed. | Commence support just after face. Take measures to improve rock mass quality and stand-up time. Pillars at top heading if needed. |
| **Support Requirements by NATM** | **Roof** | 5 cm shotcrete + when needed spot bolting (Ø26 L=4 m) | 10 cm shotcrete + wiremesh + Systematic grouted 8-9 bolts (Ø26, L=4 m, spacing 2 m) | 15 cm shotcrete + wiremesh + Systematic grouted 10-11 bolts (Ø26, L=4 m, spacing 1.5 m) + when needed I100/150-200 steel support + when needed pillar at face | 20-25 cm shotcrete + wiremesh (2 layers) + Systematic grouted 16-17 bolts (Ø26, L=4 m, spacing 1 m) + I140/100 steel support + when needed forepiling (Ø26 L=4 m, spacing 0.4 m), pillar at face |
| | **Wall** | 5 cm shotcrete + when needed spot bolting (Ø26 L=4 m) | 10 cm shotcrete + when needed spot bolting (Ø26 L=4 m) | 15 cm shotcrete + wiremesh + Systematic grouted 4 bolts (Ø26, L=4 m, spacing 1.5 m) | 20-25 cm shotcrete + wiremesh (2 layers) + Systematic grouted 6 bolts (Ø26, L=4 m, spacing 1 m) + I140/100 steel support |

### 4.7.4 Tunnel Support Determination

According to the results of the Q classification combined with NATM, four main support categories have been determined. Each tunnel domain having specific Q value would be supported by one of these support classes in which the domain's Q value is included. Accordingly, the descriptions of these support categories are presented below:

*Support Category I:*

$10 \leq Q$, where the rock is defined as A-2 by NATM:

Two-stage-excavation is proposed. Firstly, top heading would be executed. The maximum unsupported span is 12.0 m, wall height is 5.0 m and the calculated stand-up time is more than one week. The estimated advance speed is 2.5~3.5 m / round. The support system should be completed at most 7.0 m far away from the tunnel face.

The bench stage would advance from 50.0 m behind the top heading stage. The estimated advance speed is at most 4.0m / round. The support system should be completed at most 7.0 m far away from the excavation face.

*Support Category II:*

$4 \leq Q < 10$, where the rock is defined as B-1 by NATM:

Two-stage-excavation. Firstly, top heading would be executed. The maximum unsupported span is 12.0 m, wall height is 5.0 m and the calculated stand-up time is a few days. The estimated advance speed is 2.0~3.0 m / round. The support system should be completed at most 6.0 m far away from the tunnel face.

The bench stage would advance from 50.0 m behind the top heading stage. The estimated advance speed is at most 4.0m / round. The support system should be completed at most 7.0 m far away from the excavation face.

*Support Category III:*

$1 \leq Q < 4$, where the rock is defined as B-2 by NATM:

Two-stage-excavation. Firstly, top heading would be executed. The maximum unsupported span is 12.0 m, wall height is 5.0 m and the calculated stand-up time is 5-10 hours. The estimated advance speed is 2.0~2.5 m / round. The support system should be completed at most 6.0 m far away from the tunnel face.

The bench stage would advance from 18.0 m behind the top heading stage. The estimated advance speed is at most 3.5m / round. The support system should be completed at most 7.0 m far away from the excavation face.

*Support Category IV:*

$0.4 \leq Q < 1$, where the rock is defined as B-3 by NATM :

Two-stage-excavation. Firstly, top heading would be executed. The maximum unsupported span is 10 ~ 12.0 m, wall height is 4.0 - 5.0 m and the calculated stand-up time is 3-5 hours, The estimated advance speed is 2.0~2.5 m / round. The support system should be implemented just behind the tunnel face (at most 0.5 m). Owing to short stand-up time, forepiling and steel support might be needed. In case of the weakness at the face, tunnel would be advanced with pillars and they would be removed after installation of supports of top heading. Top heading support system should be completed at most 4.5m far away from the tunnel face.

The bench stage would advance from 18.0 m behind the top heading stage. In order to install support system without delay bench stage might be needed to execute in two stages. (first lower inner half, then outer half). The estimated advance speed is at most 3.0m / round. The support system should be completed at most 3.0 m far away from the excavation face.

# CHAPTER V

# ROCK MASS STRENGTH

## 5.1 Introduction

The stability of underground excavations is strictly controlled by the rock mass consisting of intact rock blocks and discontinuities in the form of cracks, joints, bedding planes, etc. Therefore, the assessment of the strength and deformability of the surrounding rock mass around excavations is of great concern for rock engineers.

One of the major hurdles to be overcome by a geological engineer is the determination of reliable rock mass properties, which is not an easy task since the size of representative specimens is mostly too large for laboratory testing. One way to defeat this difficulty is the utilization of field visit findings; if one is unable to bring the samples into laboratory then there is a need to examine the samples in-situ.

When one assesses the stability of rock engineering structures, the actual structure of rock masses must be taken into account. Due to enormous efforts involved in characterization as well as numerical modeling, many designers attempt to assess rock masses as equivalent continua for which one can find numerous approaches in literature (Koçkar and Akgün, 2003). Most of the equivalent models are restricted to elastic deformability constants and it is very rare to find any model for assessing the strength of rock masses. There are presently three main approaches to assess the strength of rock masses (Kawamoto, et al., 1996):

1. Empirical relations based on jointing index and intact rock strength;
2. Rock mass classifications;
3. Reduction factor using the elastic wave velocity of intact rock, and of rock mass and uniaxial strength of rock.

## 5.2 The Mohr-Coulomb Failure Criterion

The strength expressed by the Mohr-Coulomb failure criterion is:

$$\tau_f = c + \sigma_f \tan \phi \tag{15}$$

where c is called the cohesion or cohesion intercept, and $\phi$ is called the friction angle or angle of shearing resistance. In accordance with Terzaghi's fundamental concept that shear stress in a soil can be resisted only by the skeleton of solid particles, shear strength is expressed as a function of effective normal stress:

$$\tau_f = c' + \sigma'_f \tan \phi' \tag{16}$$

where $c'$ and $\phi'$ are the shear strength parameters in terms of effective stress (Figure 5.1).

The shear strength of a soil can also be expressed in terms of the effective major and minor principal stresses $\sigma'_1$ and $\sigma'_3$ at failure:

$$\tau_f = \frac{1}{2}(\sigma'_1 - \sigma'_3)\sin 2\theta \tag{17}$$

$$\sigma'_f = \frac{1}{2}(\sigma'_1 + \sigma'_3) + \frac{1}{2}(\sigma'_1 - \sigma'_3)\cos 2\theta \text{ and } \theta = 45^o + \frac{\phi'}{2} \tag{18}$$

Therefore ,

$$(\sigma'_1 - \sigma'_3) = (\sigma'_1 + \sigma'_3)\sin \phi' + 2c' \cos \phi' \tag{19}$$

or

$$\sigma'_1 = \sigma'_3 \tan^2\left(45^o + \frac{\phi'}{2}\right) + 2c' \tan\left(45^o + \frac{\phi'}{2}\right) \tag{20}$$

The criterion does not involve consideration of strains at, or prior to, failure and implies that the effective intermediate principal stress $\sigma'_2$ has no influence on the shear strength of the soil. The Mohr-Coulomb failure criterion, because of its simplicity, is widely used in practice although it is by no means the only possible failure criterion for soils. The failure envelope may exhibit slight curvature in certain cases but a straight-line

approximation can be taken over the stress range of interest and the shear strength parameters determined for that range.

By plotting ½ ($\sigma'_1$-$\sigma'_3$) against ½ ($\sigma'_1$+$\sigma'_3$) any state of stress can be represented by a stress point rather than by a Mohr circle (Figure 5.2):

$$\frac{1}{2}(\sigma'_1 - \sigma'_3) = a' + \frac{1}{2}(\sigma'_1 + \sigma'_3)\tan\alpha' \tag{21}$$

where a′ and α′ are the modified shear strength parameters. The parameters c′ and ϕ′ are then given by:

$$\phi' = \sin^{-1}(\tan\alpha') \tag{22}$$

$$c' = \frac{a'}{\cos\phi'} \tag{23}$$

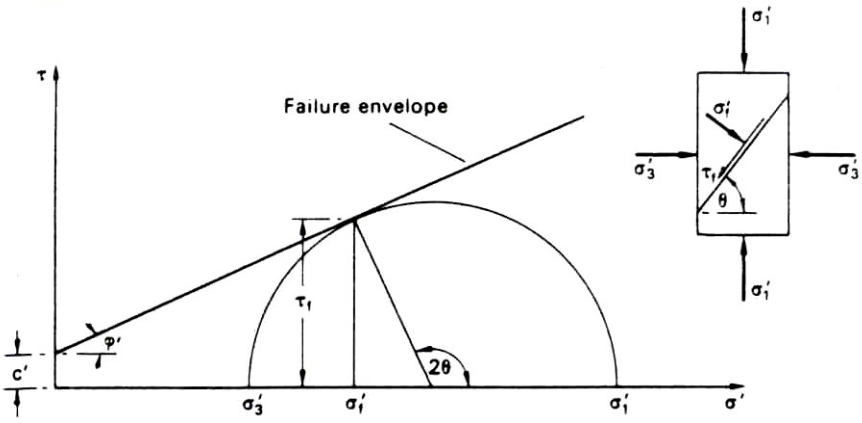



Figure 5.1. Expression of Mohr-Coulomb failure criterion by Mohr circles.

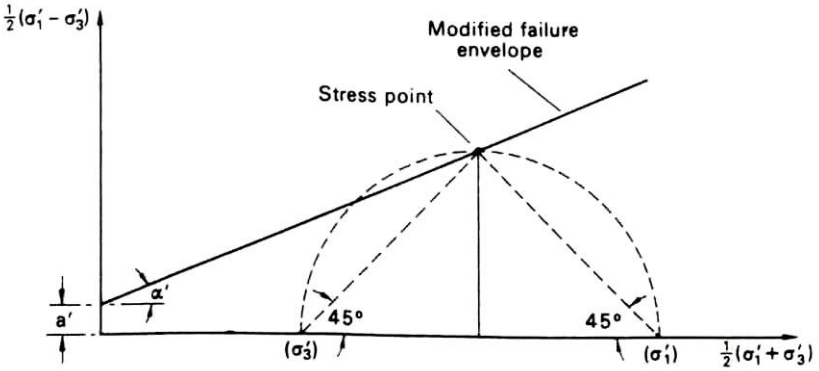



Figure 5.2. Expression of Modified Mohr-Coulomb failure criterion by stress points.

## 5.3 Hoek-Brown Failure Criterion

### 5.3.1 Introduction

Hoek and Brown introduced their failure criterion in an attempt to provide input data for the analyses required for the design of underground excavations in hard rock. The criterion was derived from the results of research into the brittle failure of intact rock by Hoek and on model studies of jointed rock mass behavior by Brown. The criterion started from the properties of intact rock and then introduced factors to reduce these properties on the basis of the characteristics of joints in a rock mass. The Hoek-Brown failure criterion for rock masses is widely accepted and has been applied in a large number of projects around the world. While, in general, it has been found to be satisfactory, there are some uncertainties and inaccuracies that have made the criterion inconvenient to apply and to incorporate into numerical models and limit equilibrium programs (Hoek et al., 2002).

### 5.3.2 Historical Development

The original failure criterion was developed during the preparation of the book by Hoek and Brown (1980). The criterion was required in order to provide input information for the design of underground excavations. Since no suitable methods for estimating rock mass strength appeared to be available at that time, the efforts were focused on developing a dimensionless equation that could be scaled in relation to geological information. The original Hoek-Brown equation was neither new nor unique – an identical equation had been used for describing the failure of concrete as early as 1936. The significant contribution, however, that Hoek and Brown made was to link the equation to geological observations in the form of Bieniawski's Rock Mass Rating (Hoek, 2002).

The original criterion, with its bias towards hard rock, was based upon the assumption that rock mass failure is controlled by translation and rotation of individual rock pieces, separated by numerous joint surfaces. Failure of the intact rock was assumed to play no significant role in the overall failure process and it was assumed that the joint pattern was "chaotic" so that there are no preferred failure directions and the rock mass can be treated as isotropic.

Since its introduction in 1980, the Hoek-Brown failure criterion has evolved to meet the needs of users who have applied it to conditions which were not visualized when it was

originally developed. In particular, the increasing number of applications to very poor quality rock masses has necessitated some significant changes. The brief summary of the evolution of Hoek-Brown criterion is presented by Table 5.1.

Until 1983, one of the issues that had been troublesome throughout the development of the criterion has been the relationship between the Hoek-Brown criterion, with the non-linear parameters m and s, and the Mohr-Coulomb criterion, with the parameters c and $\phi$. Dr. John W. Bray developed an exact theoretical solution to this problem at the Imperial College of Science and Technology and this solution was first published in the 1983 Rankine Lecture.

By 1988, the criterion was being widely used for a variety of rock engineering problems, including slope stability analyses. In 1988, the idea of undisturbed and disturbed rock masses was introduced by an update to provide a method for downgrading the properties of near surface rock masses. This paper also defined a method of using Bieniawski's 1974 RMR classification for estimating the input parameters.

In 1992, the use of Hoek-Brown criterion had become widespread and, due to the lack of suitable alternatives, it was being used on very poor quality rock masses. These rock masses differed significantly from the tightly interlocked hard rock mass model used in the development of the original criterion. Based upon the work carried out by Dr. Sandip Shah for his Ph.D thesis, a modified criterion was proposed. This criterion contained a new parameter "a" that provided the means for changing the curvature of the failure envelope, particularly in the very low normal stress range.

In 1994 and 1995, it became evident that the modified criterion was too conservative when used for better quality rock masses and a "generalized" failure criterion was proposed in these two publications. This generalized criterion incorporated both the original and the modified criteria with a 'switch' at an RMR value of approximately 25. Hence, for excellent to fair quality rock masses, the original Hoek Brown criterion is used while, for poor and extremely poor rock masses, the modified criterion with zero tensile strength is used. These papers also introduced the concept of the Geological Strength Index (GSI) described later in this chapter as a replacement for Bieniawski's RMR. It had become increasingly obvious that Bieniawski's RMR is difficult to apply to very poor quality rock masses and also that the relationship between RMR and m and s is no longer linear in these very low ranges. It was also felt that a system based more heavily on fundamental geological observations and less on 'numbers' was needed.

Table 5.1. Development of the Hoek-Brown Criterion – Summary of Equations.

(Hoek, 2002)

| *Publication* | *Coverage* | *Equations* |
|---|---|---|
| Hoek & Brown 1980 | Original criterion for heavily jointed rock masses with no fines. Mohr envelope was obtained by statistical curve fitting to a number of $(\sigma_n', \tau)$ pairs calculated by the method published by Balmer [1].<br>$\sigma_1', \sigma_3'$ are major and minor effective principal stresses at failure, respectively<br>$\sigma_t$ is the tensile strength of the rock mass<br>$m$ and $s$ are material constants<br>$\sigma_n', \tau$ are effective normal and shear stresses, respectively. | $\sigma_1' = \sigma_3' + \sigma_{ci}\sqrt{m\sigma_3'/\sigma_{ci} + s}$<br>$\sigma_t = \frac{\sigma_{ci}}{2}\left(m - \sqrt{m^2 + 4s}\right)$<br>$\tau = A\sigma_{ci}\left((\sigma_n' - \sigma_t)/\sigma_{ci}\right)^B$<br>$\sigma_n' = \sigma_3' + \left((\sigma_1' - \sigma_3')/(1 + \partial\sigma_1'/\partial\sigma_3')\right)$<br>$\tau = (\sigma_1' - \sigma_3')\sqrt{\partial\sigma_1'/\partial\sigma_3'}$<br>$\partial\sigma_1'/\partial\sigma_3' = m\sigma_{ci}/2(\sigma_1' - \sigma_3')$ |
| Hoek 1983 | Original criterion for heavily jointed rock masses with no fines with a discussion on anisotropic failure and an exact solution for the Mohr envelope by Dr J.W. Bray. | $\sigma_1' = \sigma_3' + \sigma_{ci}\sqrt{m\sigma_3'/\sigma_{ci} + s}$<br>$\tau = \left(Cot\phi_i' - Cos\phi_i'\right)m\sigma_{ci}/8$<br>$\phi_i' = \arctan\left(1/\sqrt{4h\cos^2\theta - 1}\right)$<br>$\theta = \left(90 + \arctan(1/\sqrt{h^3 - 1})\right)/3$<br>$h = 1 + \left(16(m\sigma_n' + s\sigma_{ci})/(3m^2\sigma_{ci})\right)$ |
| Hoek & Brown 1988 | As for Hoek (1983) but with the addition of relationships between constants $m$ and $s$ and a modified form of *RMR* (Bieniawski [2]) in which the Groundwater rating was assigned a fixed value of 10 and the Adjustment for Joint Orientation was set at 0. Also a distinction between *disturbed* and *undisturbed* rock masses was introduced together with means of estimating deformation modulus $E$ (after Serafim and Pereira [3]). | *Disturbed rock masses:*<br>$m_b/m_i = \exp\left((RMR - 100)/14\right)$<br>$s = \exp\left((RMR - 100)/6\right)$<br>*Undisturbed or interlocking rock masses*<br>$m_b/m_i = \exp\left((RMR - 100)/28\right)$<br>$s = \exp\left((RMR - 100)/9\right)$<br>$E = 10^{\left((RMR-10)/40\right)}$<br>$m_b, m_i$ are for broken and intact rock, respectively. |
| Hoek, Wood & Shah 1992 | Modified criterion to account for the fact the heavily jointed rock masses have zero tensile strength. Balmer's technique for calculating shear and normal stress pairs was utilised | $\sigma_1' = \sigma_3' + \sigma_{ci}\left(m_b\sigma_3'/\sigma_{ci}\right)^\alpha$<br>$\sigma_n' = \sigma_3' + \left((\sigma_1' - \sigma_3')/(1 + \partial\sigma_1'/\partial\sigma_3')\right)$<br>$\tau = (\sigma_1' - \sigma_3')\sqrt{\partial\sigma_1'/\partial\sigma_3'}$<br>$\partial\sigma_1'/\partial\sigma_3' = 1 + \alpha m_b^\alpha\left(\sigma_3'/\sigma_{ci}\right)^{(\alpha-1)}$ |
| Hoek 1994<br>Hoek, Kaiser & Bawden 1995 | Introduction of the Generalised Hoek-Brown criterion, incorporating both the original criterion for fair to very poor quality rock masses and the modified criterion for very poor quality rock masses with increasing fines content. The Geological Strength Index *GSI* was introduced to overcome the deficiencies in Bieniawski's *RMR* for very poor quality rock masses. The distinction between disturbed and undisturbed rock masses was dropped on the basis that disturbance is generally induced by engineering activities and should be allowed for by downgrading the value of *GSI*. | $\sigma_1' = \sigma_3' + \sigma_c\left(m\sigma_3'/\sigma_{ci} + s\right)^a$<br>for $GSI > 25$<br>$m_b/m_i = \exp\left((GSI - 100)/28\right)$<br>$s = \exp\left((GSI - 100)/9\right)$<br>$a = 0.5$<br>for $GSI < 25$<br>$s = 0$<br>$a = 0.65 - GSI/200$ |

Table 5.1. (cont.) Development of the Hoek-Brown Criterion – Summary of Equations. (Hoek, 2002)

| *Publication* | *Coverage* | *Equations* |
|---|---|---|
| Hoek, Carranza-Torres, & Corkum 2002 | An "exact" method for calculating the cohesive strength and angle of friction is presented and appropriate stress ranges for tunnels and slopes are given. A rock mass damage criterion is introduced to account for strength reduction due to stress relaxation and blast damage in slope stability and foundation problems. The "switch" at GSI = 25 for the coefficients s and a, is eliminated, which gives smooth continuous transitions for the entire range of GSI values. Corrections made to original Balmer equations. | $\sigma_1' = \sigma_3' + \sigma_{ci}\left(m_b \frac{\sigma_3'}{\sigma_{ci}} + s\right)^a$<br>$m_b = m_i \exp\left(\frac{GSI-100}{28-14D}\right)$<br>$s = \exp\left(\frac{GSI-100}{9-3D}\right)$<br>$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$<br>$\sigma_c = \sigma_{ci}.s^a$<br>$\sigma_t = -\frac{s\sigma_{ci}}{m_b}$<br>$\sigma_n' = \frac{\sigma_1' + \sigma_3'}{2} - \frac{\sigma_1' - \sigma_3'}{2} \cdot \frac{d\sigma_1'/d\sigma_3' - 1}{d\sigma_1'/d\sigma_3' + 1}$ (see note 1)<br>$\tau = (\sigma_1' - \sigma_3')\frac{\sqrt{d\sigma_1'/d\sigma_3'}}{d\sigma_1'/d\sigma_3' + 1}$ (see note 1)<br>$d\sigma_1'/d\sigma_3' = 1 + am_b\left(m_b\sigma_3'/\sigma_{ci} + s\right)^{a-1}$ (see note 1)<br>$E_m(GPa) = \left(1 - \frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}} \cdot 10^{((GSI-10)/40)}$ (sigci <= 100)<br>$E_m(GPa) = \left(1 - \frac{D}{2}\right) \cdot 10^{((GSI-10)/40)}$ (sigci > 100)<br>$\phi' = \sin^{-1}\left[\frac{6am_b(s + m_b\sigma_{3n}')^{a-1}}{2(1+a)(2+a) + 6am_b(s + m_b\sigma_{3n}')^{a-1}}\right]$<br>$c' = \frac{\sigma_{ci}\left[(1+2a)s + (1-a)m_b\sigma_{3n}'\right](s + m_b\sigma_{3n}')^{a-1}}{(1+a)(2+a)\sqrt{1 + \left(6am_b(s + m_b\sigma_{3n}')^{a-1}\right)/\left((1+a)(2+a)\right)}}$<br>$\sigma_{3n} = \sigma_{3\max}'/\sigma_{ci}$ |

Table 5.1 (cont.) Development of the Hoek-Brown Criterion – Summary of Equations (Hoek, 2002).

$$\sigma'_{cm} = \frac{2c' \cos\phi'}{1-\sin\phi'}$$

$$\sigma'_{cm} = \sigma_{ci} \cdot \frac{(m_b + 4s - a(m_b - 8s))(m_b/4 + s)^{a-1}}{2(1+a)(2+a)}$$

$$\frac{\sigma'_{3\max}}{\sigma'_{cm}} = 0.47\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.94} \quad \text{(tunnels)}$$

$$\frac{\sigma'_{3\max}}{\sigma'_{cm}} = 0.72\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.91} \quad \text{(slopes)}$$

NOTE 1: These are the corrected Balmer equations. The original equations were incorrect.

In 1997, the most comprehensive paper was published to date and it incorporates all of the refinements described above. In addition, a method for estimating the equivalent Mohr-Coulomb cohesion and friction angle was introduced. In this method the Hoek Brown criterion is used to generate a series of values relating axial strength to confining pressure (or shear strength to normal stress) and these are treated as the results of a hypothetical large scale in situ triaxial or shear test. A linear regression method is used to find the average slope and intercept and these are then transformed into a cohesive strength c and a friction angle $\phi$.

In the years 1998-2001, a group of papers put more geology into the Hoek-Brown failure criterion than that which has been available previously. In particular, the properties of very weak rocks were addressed in detail for the first time. A new GSI chart for heterogeneous weak rock masses was introduced in these papers.

The paper by Hoek, et al., (2002) addresses the long running issue of the relationship between the Hoek-Brown and Mohr-Coulomb criteria. An "exact" method for calculating the cohesive strength and angle of friction is presented and appropriate stress ranges for tunnels and slopes are given. A rock mass damage criterion is introduced to account for the strength reduction due to stress relaxation and blast damage in slope stability and foundation problems.

### 5.3.3 Generalized Hoek-Brown Criterion

Hoek, et al., (2002) defined the generalized Hoek-Brown criterion as:

$$\sigma_1' = \sigma_3' + \sigma_{ci}\left( m_b \frac{\sigma_3'}{\sigma_{ci}} + s \right)^a \tag{24}$$

where $m_b$ is a reduced value of the material constant $m_i$ and is given by

$$m_b = m_i \exp\left( \frac{GSI - 100}{28 - 14D} \right) \tag{25}$$

s and a are constants for the rock mass given by the following relationships:

$$s = \exp\left( \frac{GSI - 100}{9 - 3D} \right) \tag{26}$$

$$a = \frac{1}{2} + \frac{1}{6}\left( e^{-GSI/15} - e^{-20/3} \right) \tag{27}$$

D is a factor which depends upon the degree of disturbance to which the rock mass has been subjected to blast damage and stress relaxation. It varies from 0 for undisturbed in situ rock masses to 1 for very disturbed rock masses.

Determination of the intact rock uniaxial compressive strength $\sigma_c$ ($\sigma_3' = 0$) and the Hoek-Brown constant $m_i$ should be carried out by triaxial testing wherever possible. The tests should be carried out over a confining stress range from zero to one-half of the uniaxial compressive strength. At least five data points should be included in the analysis. When laboratory tests are not possible, Table 5.2. and 5.3. can be used to obtain estimates of $\sigma_c$ and $m_i$. These estimates can be used for preliminary design purposes but for detailed design studies laboratory tests should be carried out to obtain values that are more reliable (Hoek and Brown, 1997).

Table 5.2. Field estimates of uniaxial compressive strength of intact rock (Brown, 1981).

Field estimates of uniaxial compressive strength of intact rock.[3]

| Grade* | Term | Uniaxial Comp. Strength (MPa) | Point Load Index (MPa) | Field estimate of strength | Examples |
|---|---|---|---|---|---|
| R6 | Extremely Strong | > 250 | >10 | Specimen can only be chipped with a geological hammer | Fresh basalt, chert, diabase, gneiss, granite, quartzite |
| R5 | Very strong | 100 - 250 | 4 - 10 | Specimen requires many blows of a geological hammer to fracture it | Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, peridotite , rhyolite, tuff |
| R4 | Strong | 50 - 100 | 2 - 4 | Specimen requires more than one blow of a geological hammer to fracture it | Limestone, marble, sandstone, schist |
| R3 | Medium strong | 25 - 50 | 1 - 2 | Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer | Concrete, phyllite, schist, siltstone |
| R2 | Weak | 5 - 25 | ** | Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer | Chalk, claystone, potash, marl, siltstone, shale, rocksalt, |
| R1 | Very weak | 1 - 5 | ** | Crumbles under firm blows with point of a geological hammer, can be peeled by a pocket knife | Highly weathered or altered rock, shale |
| R0 | Extremely Weak | 0.25 - 1 | ** | Indented by thumbnail | Stiff fault gouge |

* Grade according to Brown (1981).

** Point load tests on rocks with a uniaxial compressive strength below 25 MPa are likely to yield highly ambiguous results.

[3] Note that this table contains a few changes in the column of examples from previously published version.

Table 5.3. Values of constant $m_i$ (Hoek and Brown, 1997).

Values of the constant $m_i$ for intact rock, by rock group[4]. Note that values in parenthesis are estimates. The range of values quoted for each material depends upon the granularity and interlocking of the crystal structure – the higher values being associated with tightly interlocked and more frictional characteristics.

| | Rock type | Class | Group | Texture | | | |
|---|---|---|---|---|---|---|---|
| | | | | Coarse | Medium | Fine | Very fine |
| SEDIMENTARY | | Clastic | | Conglomerates * Breccias * | Sandstones 17 ± 4 | Siltstones 7 ± 2 Greywackes (18 ± 3) | Claystones 4 ± 2 Shales (6 ± 2) Marls (7 ± 2) |
| | | Non-Clastic | Carbonates | Crystalline Limestone (12 ± 3) | Sparitic Limestones ( 10 ± 2) | Micritic Limestones (9 ± 2 ) | Dolomites (9 ± 3) |
| | | | Evaporites | | Gypsum 8 ± 2 | Anhydrite 12 ± 2 | |
| | | | Organic | | | | Chalk 7 ± 2 |
| METAMORPHIC | | Non Foliated | | Marble 9 ± 3 | Hornfels (19 ± 4 ) Metasandstone (19 ± 3) | Quartzites 20 ± 3 | |
| | | Slightly foliated | | Migmatite (29 ± 3) | Amphibolites 26 ± 6 | Gneiss 28 ± 5 | |
| | | Foliated** | | | Schists 12 ± 3 | Phyllites (7 ± 3) | Slates 7 ± 4 |
| IGNEOUS | | Plutonic | Light | Granite 32 ± 3 Diorite 25 ± 5 Granodiorite (29 ± 3) | | | |
| | | | Dark | Gabbro 27 ± 3 Norite 20 ± 5 | Dolerite (16 ± 5) | | |
| | | Hypabyssal | | Porphyries (20 ± 5) | | Diabase (15 ± 5) | Peridotite (25 ± 5) |
| | | Volcanic | Lava | | Rhyolite (25 ± 5) Andesite 25 ± 5 | Dacite (25 ± 3) Basalt (25 ± 5) | |
| | | | Pyroclastic | Agglomerate (19 ± 3) | Breccia (19 ± 5) | Tuff (13 ± 5) | |

* Conglomerates and breccias may present a wide range of $m_i$ values depending on the nature of the cementing material and the degree of cementation, so they may range from values similar to sandstone, to values used for fine grained sediments (even under 10).

** These values are for intact rock specimens tested normal to bedding or foliation. The value of mi will be significantly different if failure occurs along a weakness plane.

[4] Note that this table contains several changes from previously published versions, These changes have been made to reflect data that has been accumulated from laboratory tests and the experience gained from discussions with geologists and engineering geologists.

The uniaxial compressive strength is obtained by setting in Equation (24) $\sigma_3'=0$ giving:

$$\sigma_c = \sigma_{ci}.s^a \tag{28}$$

and, the tensile strength is:

$$\sigma_t = -\frac{s\sigma_{ci}}{m_b} \tag{29}$$

Note that the "switch" at GSI=25 for the coefficients s and a has been eliminated in Equations (28) and (29) which give smooth continuous transitions for the entire range of GSI values. The numerical values of s and a (Hoek and Brown, 1997), given by these equations, are very close to those given by the previous equations.

Normal and shear stresses are related to principal stresses by the following equations:

$$\sigma_n' = \frac{\sigma_1' + \sigma_3'}{2} - \frac{\sigma_1' - \sigma_3'}{2}.\frac{d\sigma_1'/d\sigma_3' - 1}{d\sigma_1'/d\sigma_3' + 1} \tag{30}$$

$$\tau = (\sigma_1' - \sigma_3')\frac{\sqrt{d\sigma_1'/d\sigma_3'}}{d\sigma_1'/d\sigma_3' + 1} \tag{31}$$

where

$$d\sigma_1'/d\sigma_3' = 1 + am_b(m_b\sigma_3'/\sigma_{ci} + s)^{a-1} \tag{32}$$

The rock mass modulus of deformation is given by:

$$E_m(\text{GPa}) = \left(1 - \frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}}.10^{((\text{GSI}-10)/40)} \tag{33}$$

Note that the original equation proposed by Hoek and Brown (1997) has been modified, by the inclusion of the factor D, to allow for the effects of blast damage and stress relaxation.

Since most geotechnical software is still written in terms of the Mohr-Coulomb failure criterion, it is necessary to determine equivalent angles of friction and cohesive strengths for each rock mass and stress range. This is done by fitting an average linear relationship to the

curve generated by solving Equation (24) for a range of minor principal stress values defined by $\sigma_t < \sigma_3 < \sigma'_{3max}$ , as illustrated in Figure 5.3. The fitting process involves balancing the areas above and below the Mohr-Coulomb plot. This results in the following equations for the angle of friction, $\phi'$ and cohesive strength $c'$ :

$$\phi' = \sin^{-1}\left[\frac{6am_b\left(s + m_b\sigma'_{3n}\right)^{a-1}}{2(a+1)(a+2) + 6am_b\left(s + m_b\sigma'_{3n}\right)^{a-1}}\right] \tag{34}$$

$$c' = \frac{\sigma_{ci}\left[(1+2a)s + (1-a)m_b\sigma'_{3n}\right]\left(s + m_b\sigma'_{3n}\right)^{a-1}}{(1+a)(2+a)\sqrt{1 + \left(6am_b\left(s + m_b\sigma'_{3n}\right)^{a-1}\right)/(1+a)(2+a)}} \tag{35}$$

where

$$\sigma'_{3n} = \sigma'_{3\,max} / \sigma'_{ci} \tag{36}$$

Note that the value $\sigma'_{3max}$ , the upper limit of confining stress over which the relationship between the Hoek-Brown and the Mohr-Coulomb criteria is considered, has to be determined for each individual case.

The Mohr-Coulomb shear strength, $\tau$, for a given normal stress, $\sigma$, is found by substitution of these values c' and $\phi$' into the equation:

$$\tau = c' + \sigma \tan\phi' \tag{37}$$

The equivalent plot, in terms of the major and minor principal stresses, is defined by:

$$\sigma'_1 = \frac{2c'\cos\phi'}{1-\sin\phi'} + \frac{1+\sin\phi'}{1-\sin\phi'}\sigma'_3 \tag{38}$$

The uniaxial compressive strength of the rock mass $\sigma_c$ is given by Equation (28). Failure initiates at the boundary of an excavation when $\sigma_c$ is exceeded by the stress induced on that boundary. The failure propagates from this initiation point into a biaxial stress field and it eventually stabilizes when the local strength, defined by Equation (24), is higher than the induced stresses $\sigma'_1$ and $\sigma'_3$. Most numerical models can follow this process of fracture propagation and this level of detailed analysis is very important when considering the stability of excavations in rock and when designing support systems (Hoek, et al., 2002).

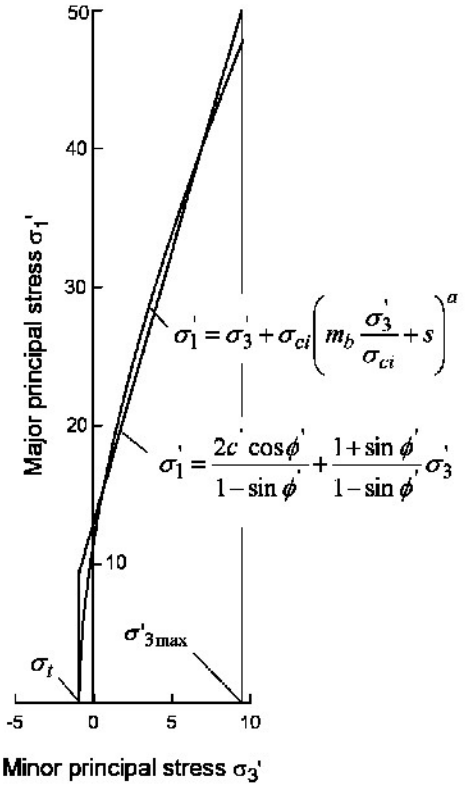



Figure 5.3. Relationships between major and minor principal stresses for Hoek-Brown and equivalent Mohr-Coulomb criteria (Hoek and Brown, 1997).

However, there are times when it is useful to consider the overall behavior of a rock mass rather than the detailed failure propagation process described above. This leads to the concept of a global "rock mass strength" and Hoek and Brown (1997) proposed that this could be estimated from the Mohr-Coulomb relationship:

$$\sigma'_{cm} = \frac{2c'\cos\phi'}{1-\sin\phi'} \tag{39}$$

with $c'$ and $\phi'$ determined for the stress range $\sigma_t < \sigma'_3 < \sigma'_{ci}/4$ giving,

$$\sigma'_{cm} = \sigma_{ci}.\frac{(m_b + 4s - a(m_b - 8s))(m_b/4 + s)^{a-1}}{2(1+a)(2+a)} \tag{40}$$

The issue of determining the appropriate value of $\sigma'_{3max}$ for use in Equations (34) and (35) depends upon the specific application. The results of the studies for deep tunnels are plotted in Figure 5.4 and the fitted equation for both cases is:

$$\frac{\sigma'_{3\max}}{\sigma'_{cm}} = 0.47\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.94} \tag{41}$$

where $\sigma'_{cm}$ is the rock mass strength, defined by Equation (40), $\gamma$ is the unit weight of the rock mass and H is the depth of the tunnel below surface. In cases where the horizontal stress is higher than the vertical stress, the horizontal stress value should be used in place of $\gamma H$.

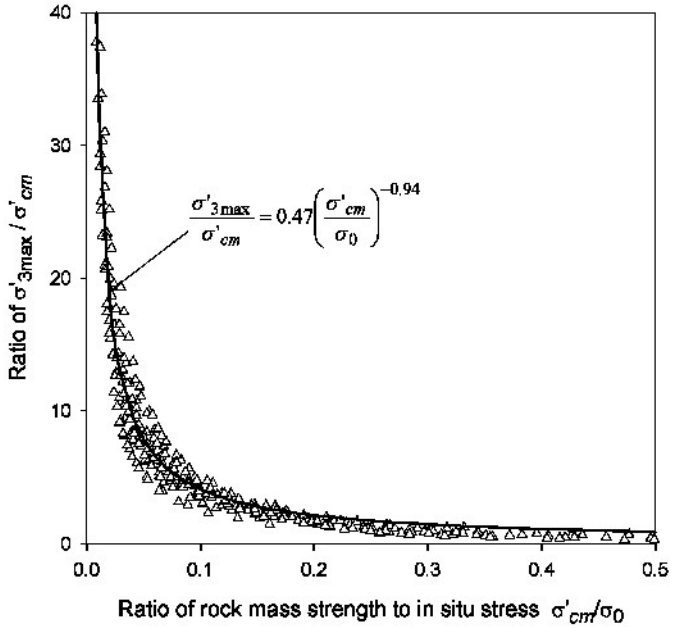



Figure 5.4. Relationship for the calculation of $\sigma_{3max}$ for equivalent Mohr-Coulomb and Hoek-Brown parameters for tunnels (Hoek and Brown, 1997).

Similar studies for slopes, using Bishop's circular failure analysis for a wide range of slope geometries and rock mass properties, gave (Hoek et al., 2002):

$$\frac{\sigma'_{3\max}}{\sigma'_{cm}} = 0.72\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.91} \tag{42}$$

where H is the height of the slope.

The determination of the disturbance factor for rock mass surrounding an excavation depends on a large number of factors and it may never be possible to quantify these factors

precisely. Experience in the design of slopes in very large open pit mines has shown that the Hoek-Brown criterion for undisturbed in situ rock masses (D=0) results in rock mass properties that are too optimistic. The effects of heavy blast damage as well as stress relief due to removal of the overburden result in disturbance of the rock mass. It is considered that the "disturbed" rock properties, D=1 in Equations (25) and (26), are more appropriate for these rock masses (Hoek, et al., 2002).

Mostyn and Douglas (2000) states that there are inadequacies in the Hoek-Brown empirical failure criterion as currently proposed for intact rock and, by inference, as extended to rock mass strength. The parameters $m_i$ and $\sigma_c$ are not material properties if the exponent is fixed at 0.5. Published values of $m_i$ can be misleading, as $m_i$ does not appear to be related to rock type.

### 5.3.4 Geological Strength Index (GSI)

The Geological Strength Index (GSI), introduced by Hoek (1994), Hoek et al. (1995) and Hoek and Brown (1997) provides a system for estimating the reduction in rock mass strength for different geological conditions. GSI is mostly based upon the visual impression on the rock mass structure. This system is presented at Tables 5.4 and 5.5. In Table 5.4, which is sufficient for the field observations, the rock masses are classified by the letter codes identifying each rock mass categories. Careful consideration has been given to the precise wording in each box and to the relative weights assigned to each combination of structural and surface conditions, in order to respect the relative geological conditions existing in nature. These codes determined can then be used to estimate the GSI value from Table 5.5.

Having described the parameters $\sigma_{ci}$, $m_i$ and GSI as explained above, the next step is to estimate the engineering rock mass properties. The procedure of making these estimates has been described in Chapter 5.2.3.

The uniaxial compressive strength of the rock mass $\sigma_{cm}$ is a particularly useful parameter for evaluating potential tunnel squeezing problems. The following equation, obtained by a curve fitting process on the plots presented in Figure 5.5, gives a very close approximation of $\sigma_{cm}$ for selected values of the intact rock strength $\sigma_{ci}$ , constant $m_i$ and the GSI (Hoek and Marinos, 2000):

$$\sigma_{cm} = \left(0.0034 m_i^{0.8}\right) \sigma_{ci} \left\{1.029 + 0.025 e^{(-0.1 m_i)}\right\}^{GSI} \qquad (43)$$

Note that the Hoek and Brown criterion and indeed any of the other published criteria that can be used for this purpose, assume that the rock mass behaves isotropically. In other words, while the behaviour of the rock mass is controlled by movement and rotation of rock elements separated by intersecting structural features such as bedding planes and joints, there are no preferred failure directions. GSI, by the combination of the two fundamental parameters of geological process, the blockiness of the mass and the conditions of discontinuities, respects the main geological constraints that govern a formation and is thus both a geologically friendly index and is practical to assess (Hoek and Marinos, 2000).

#### 5.3.4.1 GSI Assessment for Heterogenous Rock Masses

The design of tunnels and slopes in heterogeneous rock masses such as flysch presents a major challenge to geological engineers. The complex structure of these materials, resulting from their depositional and tectonic history, means that they cannot easily be classified in terms of widely used rock mass classification systems (Hoek and Marinos, 2000).

The determination of the Geological Strength Index for these rock masses composed of frequently tectonically disturbed alternations of strong and weak rocks, presents some special challenges. Hence, in order to accommodate this group of materials in the GSI system, a chart for estimating this parameter has been developed recently (Hoek and Marinos, 2000) and is presented in Table 5.6.

Table 5.4. Characterization of rock masses on the basis of interlocking and joint alteration (Hoek and Brown, 1998)

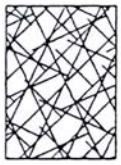
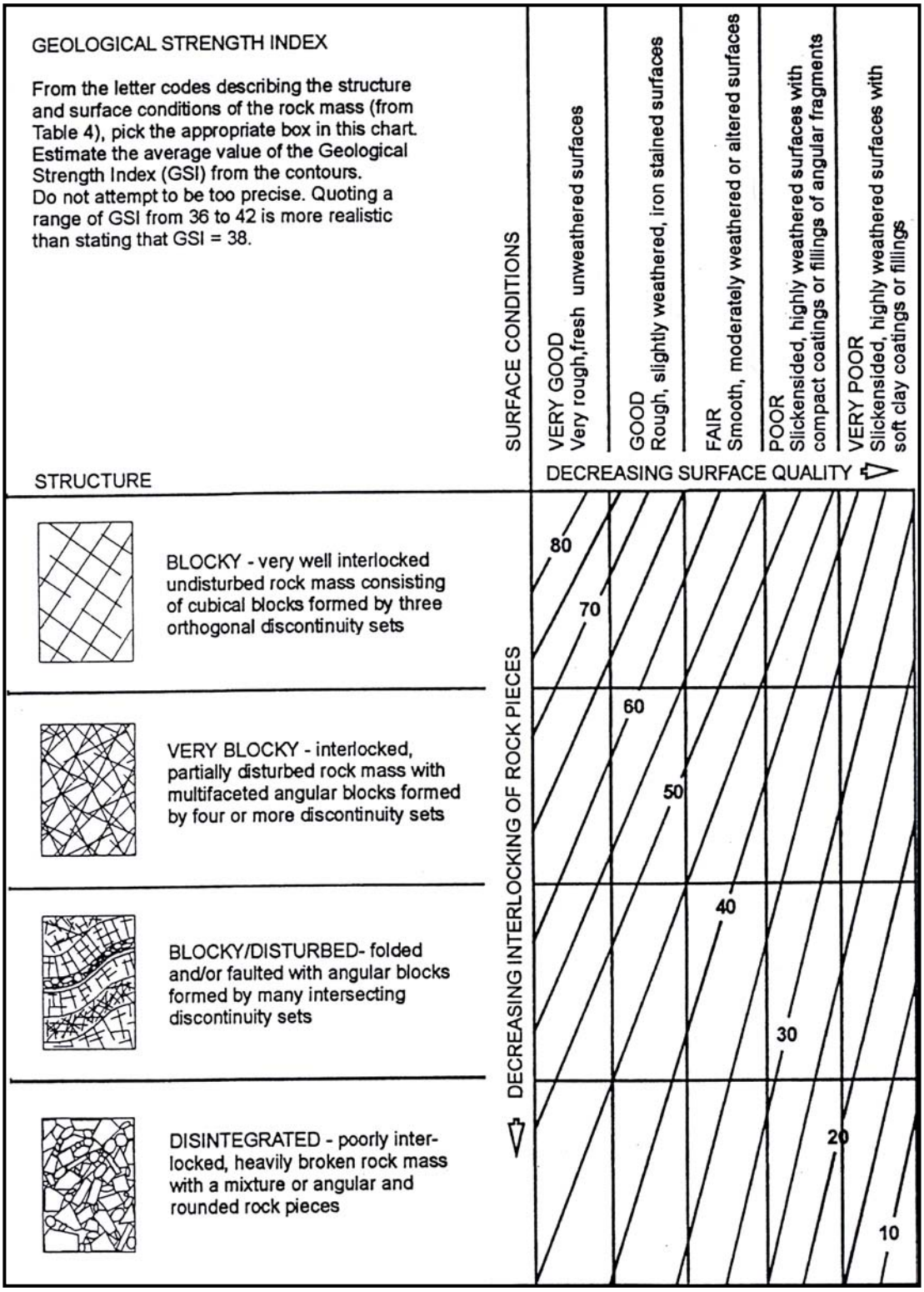
| ROCK MASS CHARACTERISTICS FOR STRENGTH ESTIMATES<br><br>Based upon the appearance of the rock, choose the category that you think gives the best description of the 'average' undisturbed in situ conditions. Note that exposed rock faces that have been created by blasting may give a misleading impression of the quality of the underlying rock. Some adjustment for blast damage may be necessary and examination of diamond drill core or of faces created by pre-split or smooth blasting may be helpful in making these adjustments. It is also important to recognize that the Hoek-Brown criterion should only be applied to rock masses where the size of individual blocks is small compared with the size of the excavation under consideration. | | SURFACE CONDITIONS | | | | | |
|---|---|---|---|---|---|---|
| | | VERY GOOD<br>Very rough, fresh unweathered surfaces | GOOD<br>Rough, slightly weathered, iron stained surfaces | FAIR<br>Smooth, moderately weathered or altered surfaces | POOR<br>Slickensided, highly weathered surfaces with compact coatings or fillings of angular fragments | VERY POOR<br>Slickensided, highly weathered surfaces with soft clay coatings or fillings |
| STRUCTURE | | DECREASING SURFACE QUALITY ⇨ | | | | |
| BLOCKY - very well interlocked undisturbed rock mass consisting of cubical blocks formed by three orthogonal discontinuity sets | DECREASING INTERLOCKING OF ROCK PIECES | B/VG | B/G | B/F | B/P | B/VP |
|  VERY BLOCKY - interlocked, partially disturbed rock mass with multifaceted angular blocks formed by four or more discontinuity sets | | VB/VG | VB/G | VB/F | VB/P | VB/VP |
| BLOCKY/DISTURBED- folded and/or faulted with angular blocks formed by many intersecting discontinuity sets | | BD/VG | BD/G | BD/F | BD/P | BD/VP |
| DISINTEGRATED - poorly interlocked, heavily broken rock mass with a mixture or angular and rounded rock pieces | ⇩ | D/VG | D/G | D/F | D/P | D/VP |

Table 5.5. Estimate of Geological Strength Index GSI based on geological descriptions (Hoek and Brown, 1998).



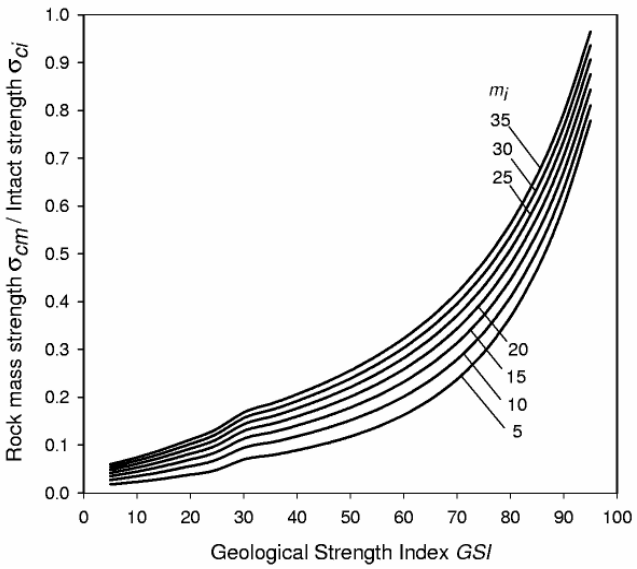



Figure 5.5. Relationship between rock mass strength $\sigma_{cm}$, intact rock strength $\sigma_{ci}$, constant $m_i$ and the Geological Strength Index GSI, for depths of more than 30 m. (Hoek and Brown, 1998).

In addition to the GSI values presented in Table 5.6, it is necessary to consider the selection of the other "intact" rock properties $\sigma_{ci}$ and $m_i$ for heterogeneous rock masses such as flysch. Different types of alternations occur in the flysch series: e.g predominance of sandstone, or typical sandstone/claystone/siltstone alternations, or predominance of either siltstone or claystone. The overall thickness of the formation might often be reduced considerably by erosion or by thrusting. This, together with tectonic movement, results in a significant degradation of the geotechnical quality of the flysch rock mass.

Consequently, it is not appropriate to use the properties of the relatively strong rocks such as sandstone to determine the overall strength of the rock mass. On the other hand, using the "intact" properties of weaker rocks such as claystone or marl only is too conservative since the relatively strong rock skeleton certainly contributes to the rock mass strength. Therefore, it is proposed by Hoek and Marinos (2000) that a "weighted average" of the intact strength properties of the strong and weak layers should be employed. Suggested values for the components of this weighted average are given in Tables 5.6 and 5.7.

Table 5.6. GSI estimates for heterogeneous rock masses such as flysch (Marinos and Hoek, 2000).

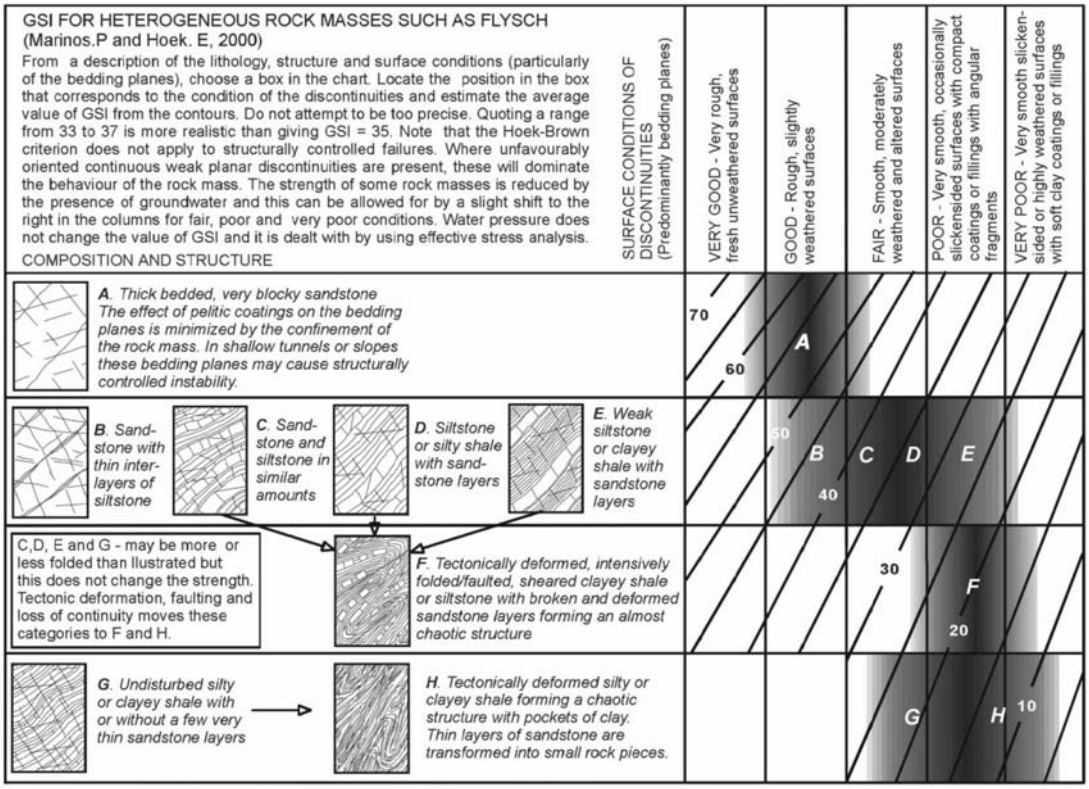



Table 5.7. Suggested proportions of parameters $\sigma_{ci}$ and $m_i$ for estimating rock mass properties for flysch (Marinos and Hoek, 2000).

| Flysch type see Table 12 | Proportions of values for each rock type to be included in rock mass property determination |
|---|---|
| A and B | Use values for sandstone beds |
| C | Reduce sandstone values by 20% and use full values for siltstone |
| D | Reduce sandstone values by 40% and use full values for siltstone |
| E | Reduce sandstone values by 40% and use full values for siltstone |
| F | Reduce sandstone values by 60% and use full values for siltstone |
| G | Use values for siltstone or shale |
| H | Use values for siltstone or shale |

## 5.4 Rock Mass Strength Determination along the Boztepe (T-1) and Öceli (T-2) tunnels

The lithological units or formations existing on the route of the Boztepe (T-1) and the Öceli (T-2) tunnels can generally be grouped into two categories as volcanics and flysch type deposits in sense of their engineering behaviors. The geotectonical conditions juxtapose these two groups of rock so often in the project area. Therefore, the in place strength of the whole rock mass, which is hard to estimate, may show some differences than estimated rates. Most of the time, this in-situ condition serves better ground conditions than estimated ones for engineering applications.

So, to be closer to the fact mentioned in the preceding paragraph, the rock mass strength of the flysch type deposit consisting mainly of claystone, sandstone and marl has been determined through the charts by Marinos and Hoek (2000) rather than the calculation of its individual member's rock mass strength. In order to utilize weighted average in flysch, the drilling data belonging to each tunnel has been employed (Table 5.8 and 5.9). The length of the rock units comprising of the flysch in each drilling has been used for an approximation during the calculation of the lithological rock unit percentage in the mass. The field observations of the flysch can be best represented by E and C categories in Table 5.7 for T-1 and T-2 tunnels, respectively. In this chart, the siltstone constituent has been replaced by the claystone included as the major constituent of flysch in the project area. Accordingly, the $m_i$ values of the flysch have been calculated and inserted into each structural domain for the rock mass strength calculation.

The other parameter, $\sigma_{ci}$, for the rock masses has been assessed from both the field investigation and the rock mechanics laboratory test results.

The evaluation of the rock mass strength has been executed by the software RocLab Version 1.004 (Rocscience Inc., 2002). RocLab is a software program for determining rock mass strength parameters, based on the generalized Hoek-Brown failure criterion. It is the product of Rocscience Inc. The program provides a simple and intuitive implementation of the Hoek-Brown failure criterion, allowing users to easily obtain reliable estimates of rock mass properties, and to visualize the effects of changing rock mass parameters, on the failure envelopes. The RocLab outputs of each structural domain are presented in the pages entitled with their names such as T1-Pn, T1-1, etc. in Appendix – F. The brief information of the rock mass strength parameters is also given in Tables 5.10 and 5.11.

Table 5.8. The determination of the lithology percentages that constitute flysch in the area of the Boztepe (T-1) tunnel.

| ROCK UNIT | THE LENGTH OF FLYSCH MEMBERS IN BOREHOLES FOR THE BOZTEPE (T-1) TUNNEL (m) | | | | | | | | | | | | | | | | | Σ (m) | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SK3 | SK4 | SK5 | SK6 | SK7 | SK8 | SK9 | SK10 | SK11 | SK12 | SK13 | SK14 | SK15 | SK16 | SK17 | SK18 | | | |
| Sandstone | 2 | 7 | 2 | - | 15.5 | - | - | 4 | 3 | - | 10 | - | - | 4 | - | - | | 47.5 | 6.8 |
| Claystone | 31 | 22 | 5 | 9.5 | 30 | 10 | - | 65.5 | 79 | 48 | 64.5 | 87.5 | 5 | 16 | - | 10.5 | | 483.5 | 69.1 |
| Marl | 10 | 26 | - | 3 | - | 5 | - | - | - | 12 | - | - | - | - | - | - | | 56 | 8.0 |
| Limestone | 7 | - | - | 4 | - | 5 | - | 23.5 | - | 5 | - | - | - | - | - | - | | 44.5 | 6.4 |
| Siltstone | - | - | - | 3 | - | - | - | - | 30 | - | 11 | - | 5 | 8 | - | - | | 57 | 8.1 |
| Conglomerate | - | - | 2.5 | - | - | - | - | - | - | 5 | - | 3.5 | - | - | - | - | | 11 | 1.6 |
| TOTAL | | | | | | | | | | | | | | | | | | 699.5 | 100 |

Table 5.9. The determination of the lithology percentages that constitute flysch in the area of the Öceli (T-2) tunnel.

| ROCK UNIT | THE LENGTH OF FLYSCH MEMBERS IN BOREHOLES FOR THE ÖCELİ (T-2) TUNNEL (m) | | | | | | | | | | | | Σ (m) | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SK1 | SK2 | SK3 | SK4 | SK5 | SK6 | SK7 | SK8 | SK9 | SK10 | SK11 | SK12 | | |
| Sandstone | - | - | - | - | - | - | - | - | 4 | 3 | 16.5 | 8.5 | 32 | 35.4 |
| Claystone | 3 | 3 | 4 | 7 | - | 5 | 13 | 3 | 9 | - | 1 | - | 48 | 53.0 |
| Marl | - | - | - | - | - | 1.5 | - | - | - | - | - | 5 | 6.5 | 7.2 |
| Limestone | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0.0 |
| Siltstone | - | - | - | - | - | - | - | - | - | - | - | - | **0** | 0.0 |
| Conglomerate | - | - | - | - | - | - | - | - | 4 | - | - | - | 4 | 4.4 |
| TOTAL | | | | | | | | | | | | | **90.5** | **100** |

Table 5.10. The shear strength parameters determined via GSI of the rock masses constituting the formerly set domains of the Boztepe (T-1) tunnel.

| Domain Name | Rock Unit | GSI (A-RMR – 5) | $\sigma_{ci}$ (MPa) | $m_i$ | $s_i$ | m | s | $\gamma$ (kN/m$^3$) | c (MPa) | $\phi$ (°) | Poisson's ratio, v | Young's modulus, E (MPa) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1-Pn | Tuff, Agglomerate, Claystone | ~ 35 | 25 | 13 | 1 | 1.276 | 0.0007 | 23 | 0.177 | 50.11 | 0.20-0.30 | 2108 |
| T1-Px | Agglomerate | ~ 35 | 25 | 19 | 1 | 1.865 | 0.0007 | 23 | 0.192 | 53.16 | 0.20-0.30 | 2108 |
| T1-1 | Flysch (Marl, Claystone, Sandstone) | ~ 45 | 25 | 7.1 | 1 | 0.996 | 0.0022 | 23 | 0.262 | 45.29 | 0.20-0.30 | 3750 |
| T1-2 | Agglomerate | ~ 65 | 30 | 19 | 1 | 5.444 | 0.0205 | 23 | 0.698 | 56.26 | 0.20-0.30 | 12989 |
| T1-3 | Flysch (Limestone, Claystone), Tuff, Basalt | ~ 50 | 35 | 16 | 1 | 2.683 | 0.0039 | 23 | 0.609 | 49.72 | 0.20-0.30 | 5916 |
| T1-4 | Claystone, Tuff | ~ 45 | 20 | 9 | 1 | 1.308 | 0.0025 | 23 | 0.475 | 36.70 | 0.20-0.30 | 3552 |
| T1-5 | Flysch (Claystone, Siltstone), Basalt, Agglomerate | ~ 55 | 40 | 17 | 1 | 3.408 | 0.0067 | 23 | 0.669 | 53.65 | 0.20-0.30 | 8434 |

Table 5.11. The shear strength parameters determined via GSI of the rock masses constituting the formerly set domains of the Öceli (T-2) tunnel.

| Domain Name | Rock Unit | GSI (A-RMR – 5) | $\sigma_{ci}$ (MPa) | $m_i$ | $s_i$ | m | s | $\gamma$ (kN/m$^3$) | c (MPa) | $\phi$ (°) | Poisson's ratio, v | Young's modulus, E (MPa) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T2-Pn$_a$ | Agglomerate, Tuff | ~ 35 | 10 | 16 | 1 | 1.570 | 0.0007 | 25 | 0.137 | 44.53 | 0.20-0.30 | 1334 |
| T2-Pn$_b$ | Agglomerate, Tuff | ~ 45 | 60 | 16 | 1 | 2.244 | 0.0022 | 25 | 0.394 | 59.37 | 0.20-0.30 | 5809 |
| T2-Px | Agglomerate, Tuff, Sandstone | ~ 30 | 10 | 16 | 1 | 1.313 | 0.0004 | 25 | 0.123 | 42.84 | 0.20-0.30 | 1000 |
| T2-1 | Agglomerate | ~ 50 | 20 | 19 | 1 | 3.186 | 0.0039 | 25 | 0.366 | 50.90 | 0.20-0.30 | 4472 |
| T2-2 | Agglomerate | ~ 60 | 30 | 19 | 1 | 4.553 | 0.0117 | 25 | 0.604 | 55.11 | 0.20-0.30 | 9740 |
| T2-3 | Agglomerate, Claystone | ~ 55 | 20 | 19 | 1 | 3.809 | 0.0067 | 25 | 0.389 | 52.74 | 0.20-0.30 | 5964 |
| T2-4 | Agglomerate, Tuff, Flysch (Claystone, Sandstone) | ~ 50 | 15 | 14 | 1 | 2.347 | 0.0039 | 25 | 0.291 | 46.88 | 0.20-0.30 | 3873 |

As it can be noticed from Tables 5.10 and 5.11, the rock mass shear strength parameters, namely, c and $\phi$ estimated via GSI have been high. This is mostly because GSI had been produced and designed for weak to very weak rock masses whose RMR rock class can be stated as "VERY POOR ROCK" where RMR rating is less than 21 (Table 4.2). In this frame, rock mass c and $\phi$ values estimated from the rock mass parameters "m" and "s", which are also estimations, through GSI will not be used in the slope stability calculations. Instead, the direct estimations of c and $\phi$ values from A-RMR assessments whose details are provided in the next chapter will be utilized.

On the other hand, the rock mass properties of E, m and s determined by RocLab (Rocscience Inc., 2002) in Appendix – F would be used as input for the numerical analysis program Phase$^2$ (finite element stress analysis and support design for excavations, Rocscience Inc., 2002) where the Hoek-Brown failure criterion will be employed, in Chapter VII.

The comparison of the shear strength parameters determined via field estimations by means of A-RMR and GSI, and the laboratory test results has been compiled in the following Table 5.12 where c, $\phi$, $m_i$ and $\sigma_{ci}$ parameters have been correlated. As it can be seen from this table, some c and $\phi$ values calculated via Hoek-Brown failure criterion are missing. This is because the $m_i$ values calculated from lab samples are greater than 50 which is not acceptable. Therefore, RocLab (Rocscience Inc., 2002) could not calculate the related c and $\phi$ values.

As the "$\phi$" values are considered at Table 5.12, the field estimations via A-RMR, which have represented the worst rock mass conditions to be on the safe side, can be said to be successful when they are compared with the results from lab tests.

In case of "c" values, however, the results display wide range of numbers. The Mohr-Coulomb criterion can only calculate the cohesion of intact rock samples without integrated with GSI or A-RMR ratings. However, Hoek-Brown criterion calculates the rock mass c and $\phi$ values via GSI which is taken as 50 (average rock quality) by RocLab. This is the reason why c values of Hoek-Brown criterion are much smaller than that of Mohr-Coulomb. On the other hand, the values approximated via A-RMR, which are more conservative values rather than that of Hoek-Brown criterion, have been utilized in the slope stability analyses.

The "$m_i$" values from the estimation charts and the lab results show similarity most of the time as it can be noticed from Table 5.12. Hence, there would be no any drawback to utilize the field estimation values in the finite element analyses.

Table 5.12 The comparison of lab results and the field estimations on rock mass shear strength parameters

| Sample No. | Included Domain | Lithology | LAB RESULTS | | | | | | FIELD ESTIMATES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HOEK-BROWN * | | | | MOHR-COLOUMB | | | | | |
| | | | $m_i$ | $\sigma_{ci}$ (MPa) | c (MPa) | $\phi$ ( ° ) | c (MPa) | $\phi$ ( ° ) | $m_i$ | $\sigma_{ci}$ (MPa) | c (MPa) | $\phi$ ( ° ) |
| T1 SK7 | T1-2 | Volcanics (Agglomerate) | 36 | 11 | 0.80 | 41.7 | 11.6 | 32 | 19 | 30 | 0.3-04 | 35-45 |
| T1 SK9 | | Volcanics (Agglomerate) | 48 | 3.6 | 0.28 | 44.1 | 6.8 | 27 | | | | |
| T1 SK9 | | Volcanics (Agglomerate) | 7 | 42 | 1.87 | 27.4 | 15.7 | 27 | | | | |
| T1 SK10 | T1-3 | Flysch (Limestone) | 150 | 1.4 | | | 6.7 | 29 | 16 | 35 | 0.2-0.3 | 25-35 |
| T1 SK16 | T1-5 | Volcanics (Agglomerate) | 16 | 26 | 1.46 | 34.4 | 13.5 | 31 | 17 | 40 | 0.2-0.3 | 25-35 |
| T1 SK18 | T1-Px | Volcanics (Agglomerate) | 87 | 2.3 | | | 13.5 | 33 | 19 | 25 | 0.2-0.3 | 25-35 |
| T2 SK2<br>T2 SK4<br>T2 SK1 | T2-Px | Volcanics (Agglomerate) | 16 | 16 | 0.93 | 34.6 | 8.9 | 33 | 16 | 10 | 0.1-0.2 | 15-25 |
| T2 SK12 | | Volcanics (Agglomerate and basaltic tuff) | 8.5 | 45 | 2.13 | 29.1 | 35.8 | 35 | | | | |
| T2 SK3<br>T2 SK5<br>T2 SK6 | T2-Pn | Volcanics (Agglomerate and basaltic tuff) | 8 | 127 | 5.91 | 28.6 | 1.8 | 28 | 16 | 10<br>60 | 0.2-0.3<br>0.1-0.2 | 25-35<br>15-25 |
| T2 SK8 | T2-2 | Volcanics (Agglomerate) | 59 | 1.8 | | | 16.4 | 30 | 19 | 30 | 0.3-04 | 35-45 |

* Parameters determined via the software RocLab (Rocscience, 2003).

# CHAPTER VI

# TUNNEL PORTAL SLOPE DESIGN

## 6.1 Introduction

The main purposes of rock slope engineering are to determine rock slope stability conditions, to stabilize unstable natural slopes and to design, while maintaining safety conditions, the rock excavation slopes by obtaining optimal conditions from the reliability and the economical points of view. Different types of slope failure are associated with different geological structures and it is important that the slope designer should be able to recognize the potential stability problems during the early stages of a project.

All the features, starting from ultra microscopic to macroscopic, which influence the strength and the deformation characteristics of rocks, can be called defects. Rock slope stability, accordingly, depends on the strength features of the rocks, the geometrical and strength features of the discontinuities and the presence of weathering action on the rock and rock defects (Giani, 1992).

The first stage in slope design involves an examination of existing regional geology maps, air photographs, easily accessible outcrops and the core recovered during exploration drilling. In rock slopes, especially, the geological discontinuities play the dominant role. While many slopes are stable at steep angles and at heights of several meters, many flat slopes fail at heights of only tens of meters. This difference is due to the fact that the stability of rock slopes varies with inclination of discontinuity surfaces, such as faults, joints and bedding planes, within the rock mass (Hoek and Bray, 1981).

Rock slope excavations have been classified on the basis of the relative importance of the defects and alterations to the slope stability (Duncan and Goodman, 1968) (Figure 6.1).

A rock slope can be homogeneous or can be made up of a complex of rocks of different geological origins with a different sequence of sediments or to be intruded by bodies of igneous rocks or partially metamorphosed. Different lithological units can have different strength, deformation and competence features.

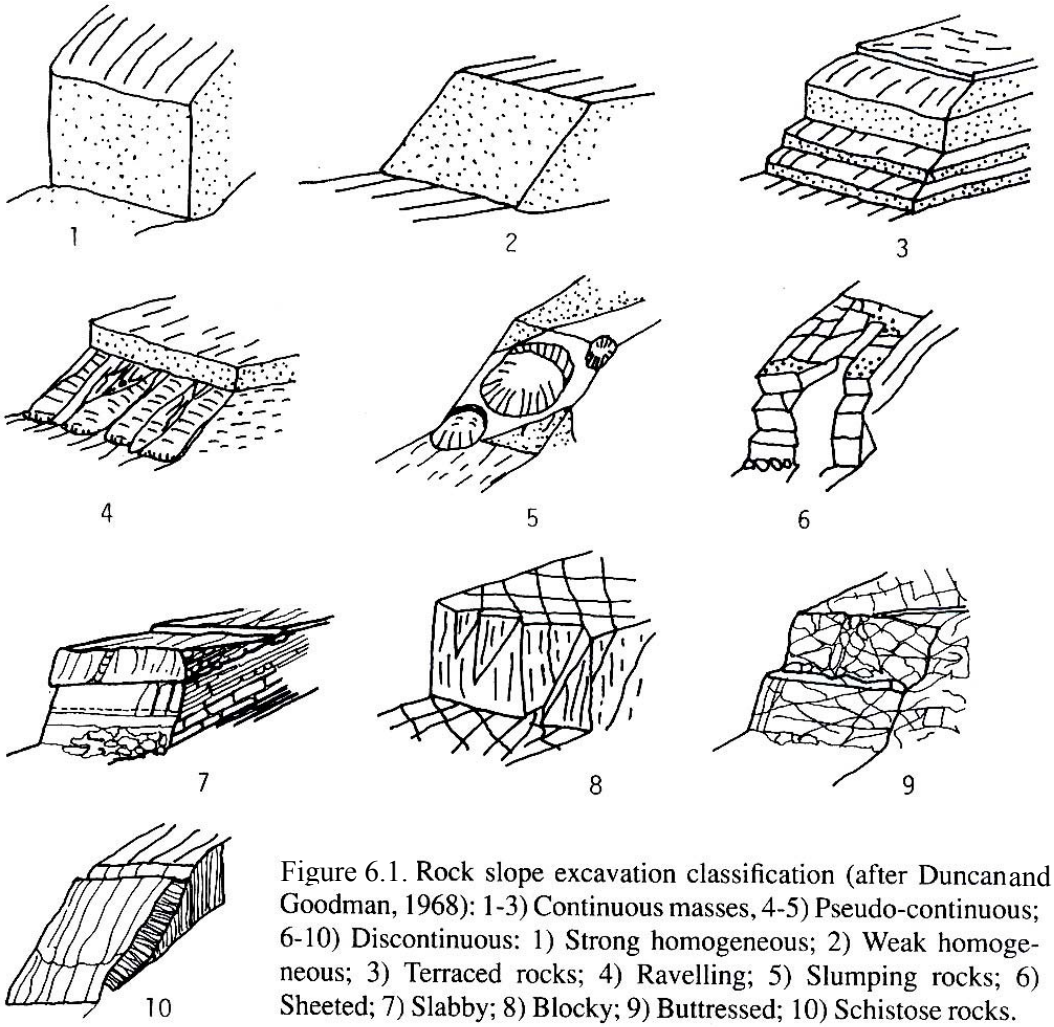



Figure 6.1. Rock slope excavation classification (after Duncan and Goodman, 1968): 1-3) Continuous masses, 4-5) Pseudo-continuous; 6-10) Discontinuous: 1) Strong homogeneous; 2) Weak homogeneous; 3) Terraced rocks; 4) Ravelling; 5) Slumping rocks; 6) Sheeted; 7) Slabby; 8) Blocky; 9) Buttressed; 10) Schistose rocks.

There are mainly four methods for stability analysis of slopes; method of kinematical analysis, limit equilibrium method (deterministic approach), deformation analysis (finite element method) and probabilistic approach.

## 6.2 Kinematical Analyses

The method of kinematical analysis is based on stereographic projection technique. In this method, orientation of the slope and discontinuities together with internal friction angle is included. However, the weight of sliding block, pore pressure, seismic acceleration and external forces are not considered.

Kinematical analysis method is mostly applied for structurally controlled failures commonly observed in jointed rock masses. This method helps the designer to eliminate kinematically stable slopes for further detailed analyses. The main types of kinematical failure modes in slopes of rock masses are plane failure, wedge failure and toppling. In case of highly jointed and fractured rock masses, moreover, mode of circular failures is possible.

### 6.2.1 Plane Failure

Plane failure occurs in natural slopes or in slope excavations and in stratified or jointed rock masses where beddings or joint sets have an average dip direction similar to the slope face dip direction. Plane failure on a single plane may occur if the following geometrical conditions are satisfied:

- The plane on which sliding occurs must strike parallel or nearly parallel (within approximately ± 20° ) to the slope.

- The failure plane must daylight in the slope face. This means that its dip must be smaller than the dip of the slope face, i.e. $\psi_f > \psi_p$ (Figure 6.2).

- The dip of the failure plane must be greater than the angle of friction of this plane, i.e. $\psi_p > \phi$.

- Release surfaces, which provide negligible resistance to sliding, must be present in the rock mass to define the lateral boundaries of the slide. Alternatively, failure can occur on a failure plane passing through the convex nose of a slope.

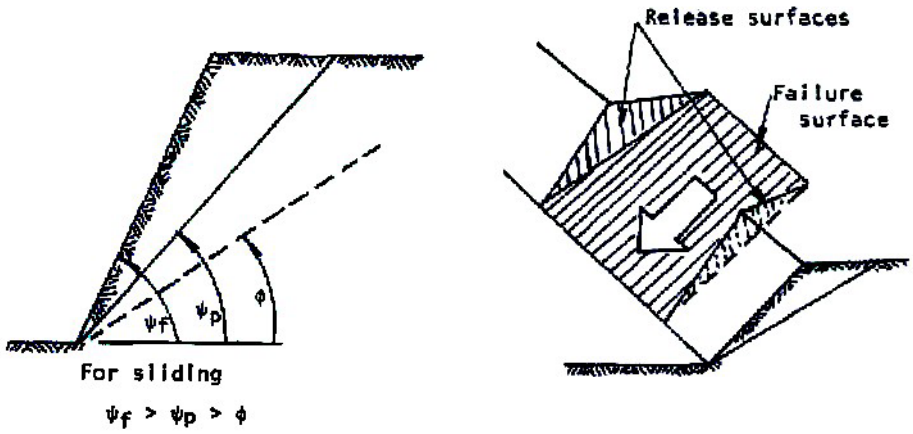



Figure 6.2. Plane sliding (Hoek and Bray, 1981).

If the conditions mentioned above are fulfilled, in other words plane sliding would most probably occur, then, the factor of safety of this slope is calculated as follows; but note that two cases must be considered.

a) A slope with a tension crack (Figure 6.3).

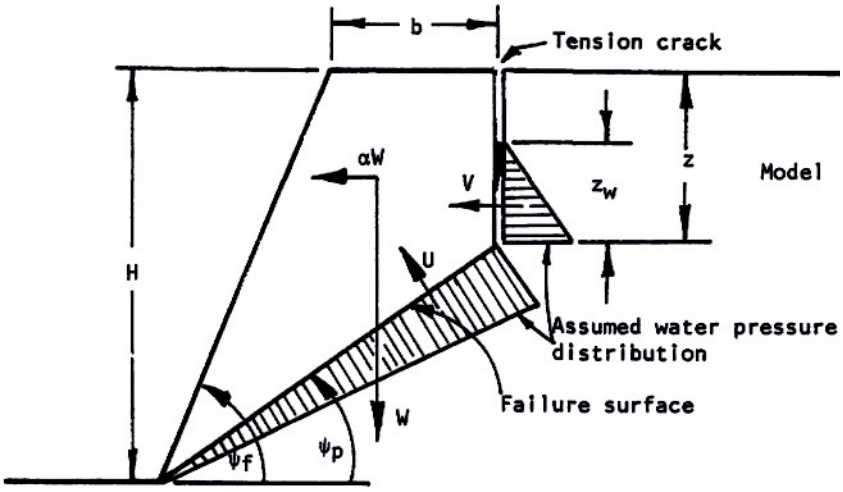



Figure 6.3. A slope with a tension crack (Hoek and Bray, 1981).

$$F = \frac{cA + \left(W\left(Cos\psi_p - \alpha Sin\psi_p\right) - U - V.Sin\psi_p\right)Tan\phi}{W\left(Sin\psi_p + \alpha Cos\psi_p\right) + V.Cos\psi_p} \tag{44}$$

where

$$z = H\left(1 - \sqrt{Cot\psi_f.Tan\psi_p}\right) \tag{44 a}$$

$$A = \left(H - z\right)Cosec\psi_p \tag{44 b}$$

$$W = \frac{1}{2}\gamma H^2\left(\left(1 - \left(z/H\right)^2\right)Cot\psi_p - Cot\psi_f\right) \tag{44 c}$$

$$U = \frac{1}{2}\gamma_w z_w A \tag{44 d}$$

$$V = \frac{1}{2}\gamma_w z_w^2 \tag{44 e}$$

$\alpha$ = Earthquake acceleration

b) A slope with a full length of discontinuity surface (Figure 6.4).

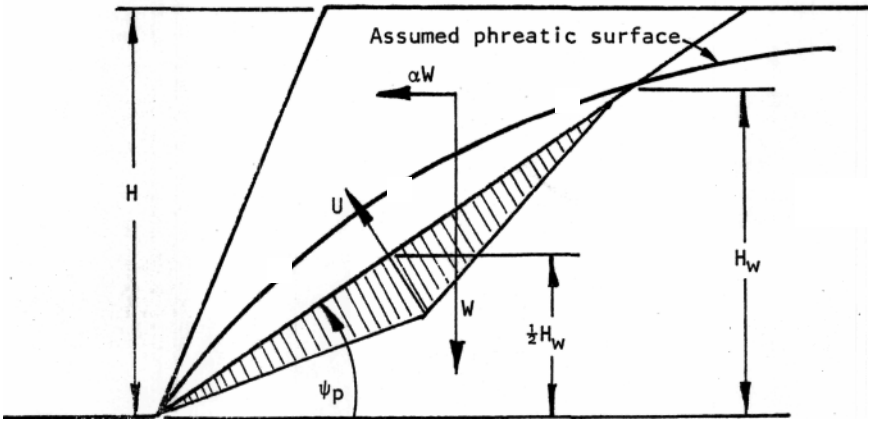



Figure 6.4. A slope with a full length of discontinuity surface (Hoek and Bray, 1981).

$$F = \frac{cA + \left(W\left(Cos\psi_p - \alpha Sin\psi_p\right) - U\right)Tan\phi}{W\left(Sin\psi_p + \alpha Cos\psi_p\right)} \tag{45}$$

where

$$U = \frac{1}{4}\gamma_w H_w^2 Cosec\psi_p \tag{45 a}$$

### 6.2.2 Wedge Failure

The wedge of rock resting on the discontinuities striking obliquely across the slope face and whose intersection daylights in the slope face will slide down the line of intersection, provided that the inclination of this line is significantly greater than the angle of friction (Hoek and Bray, 1981) (Figure 6.5). The calculation of the factor of safety is more complicated than that for plane failure since base areas of both failure planes as well as the normal forces on these planes must be calculated.

As in the case of plane failure, a condition of sliding is defined by $\psi_{fi} > \psi_i > \phi$, where $\psi_{fi}$ is the inclination of the slope face, measured in the view at right angles to the line of intersection, and $\psi_i$ is the dip of the line of intersection. Note the $\psi_i$ would only be the same as $\psi_f$, if the true dip of the line of intersection was the same as the dip direction of the slope face (Figure 6.5).

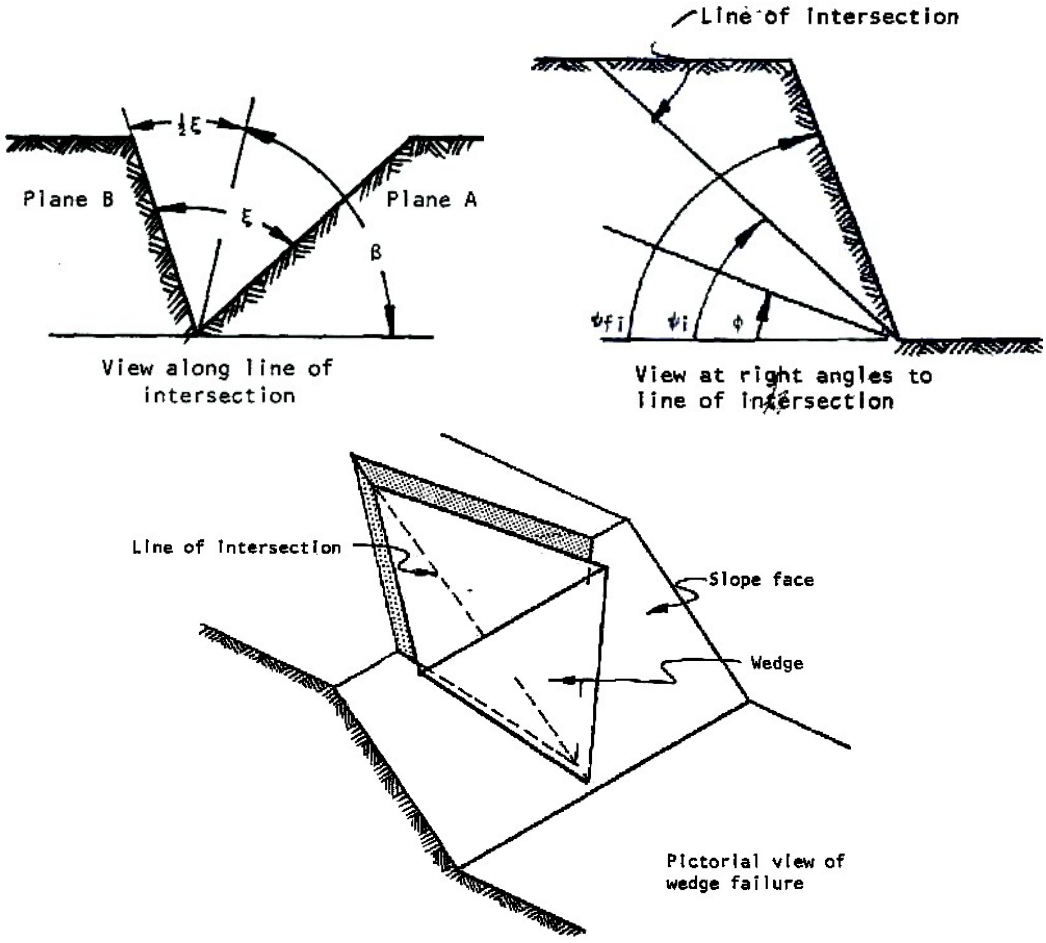



Figure 6.5. Wedge sliding (Hoek and Bray, 1981).

Figure 6.6 displays the geometry of the wedge, which will be considered in the following analysis. The water pressure distribution assumed for this analysis is based upon the hypothesis that the wedge itself is impermeable and that water enters the top of the wedge along lines of intersection 3 and 4 and leaks from the slope face along lines of intersection 1 and 2. The maximum pressure occurs along the line of intersection 5 and the pressure being zero along the lines 1, 2, 3 and 4. This water pressure is believed to be representative of the extreme conditions, which could occur during very heavy rain.

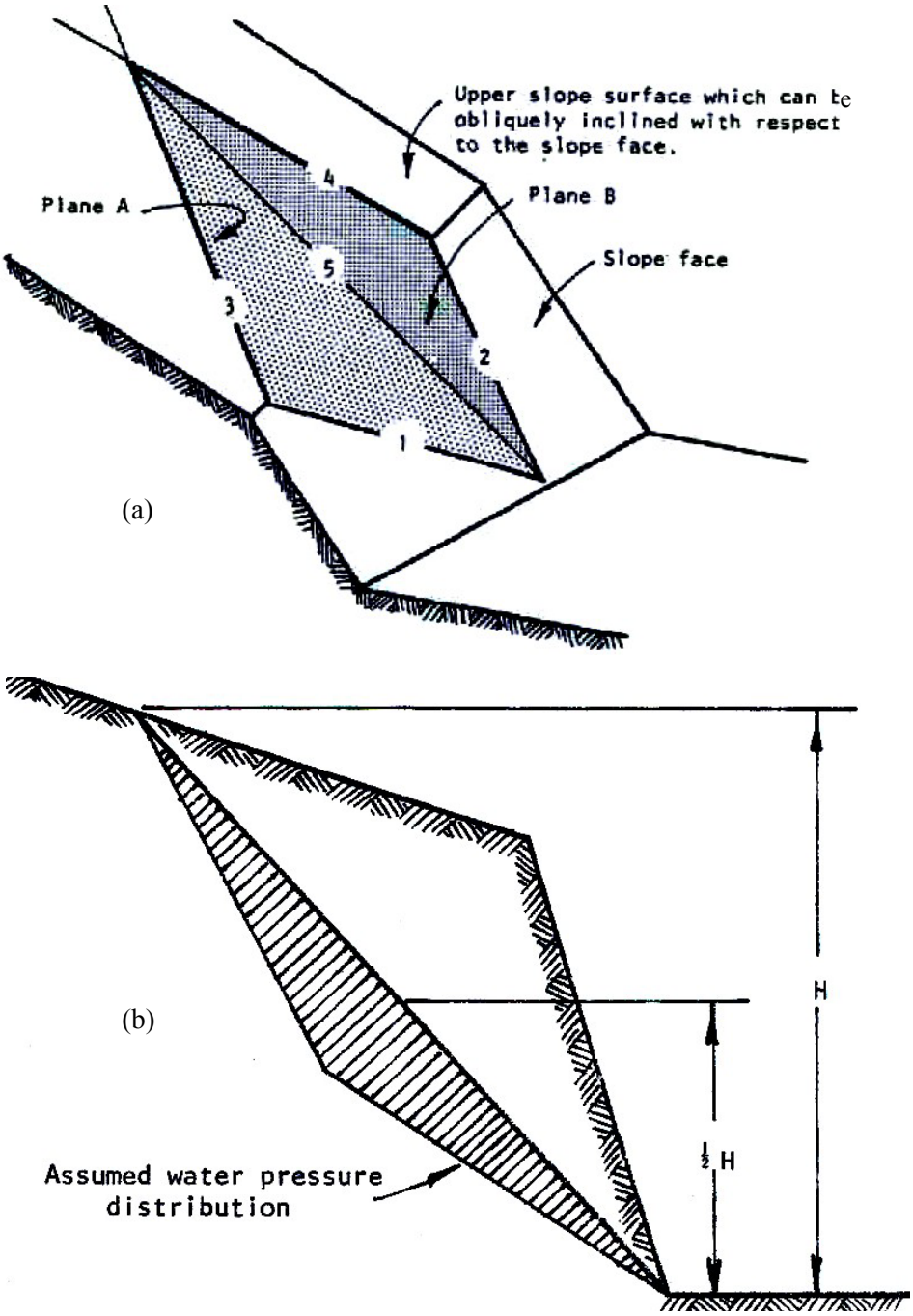



Figure 6.6. Geometry of wedge used for stability analysis (Hoek and Bray, 1981).

The numbering of the lines of intersection of the various planes involved is of extreme importance since total confusion can arise in the analysis if these numbers are mixed up. The numbering used, therefore, is as follows:

1 – intersection of plane A with the slope face.
2 – intersection of plane B with the slope face.
3 – intersection of plane A with the upper slope surface.
4 – intersection of plane B with the upper slope surface.
5 – intersection of plane A and B.

It is assumed that sliding of the wedge always takes place along the line of intersection numbered 5. The factor of safety of this slope is:

$$F = \frac{3}{\gamma H}\left(c_A X + c_B Y\right) + \left(A - \frac{\gamma_w}{2\gamma} X\right)\mathrm{Tan}\phi_A + \left(B - \frac{\gamma_w}{2\gamma}\gamma\right)\mathrm{Tan}\phi_B \qquad (46)$$

where $c_A$ and $c_B$ are the cohesive strengths of planes A and B
$\phi_A$ and $\phi_B$ are the angles of friction on planes A and B
$\gamma$ is the unit weight of the rock
$\gamma_w$ is the unit weight of water
H is the total height of the wedge
X, Y, A and B are dimensionless factors which depend upon the geometry of the wedge.

$$X = \frac{\mathrm{Sin}\theta_{24}}{\mathrm{Sin}\theta_{45}.\mathrm{Cos}\theta_{2na}} \qquad (46\ a)$$

$$Y = \frac{\mathrm{Sin}\theta_{13}}{\mathrm{Sin}\theta_{35}.\mathrm{Cos}\theta_{1nb}} \qquad (46\ b)$$

$$A = \frac{\mathrm{Cos}\psi_a - \mathrm{Cos}\psi_b.\mathrm{Cos}\theta_{na.nb}}{\mathrm{Sin}\psi_5.\mathrm{Sin}^2\theta_{na.nb}} \qquad (46\ c)$$

$$B = \frac{\mathrm{Cos}\psi_b - \mathrm{Cos}\psi_a.\mathrm{Cos}\theta_{na.nb}}{\mathrm{Sin}\psi_5.\mathrm{Sin}^2\theta_{na.nb}} \qquad (46\ d)$$

where $\psi_a$ and $\psi_b$ are the dips of planes A and B respectively and $\psi_5$ is the dip of the line of intersection 5.

The angles needed for the solution of these equations can mostly conveniently be measured on a stereoplot of the data, which defines the geometry of the wedge and the slope (Figure 6.7).

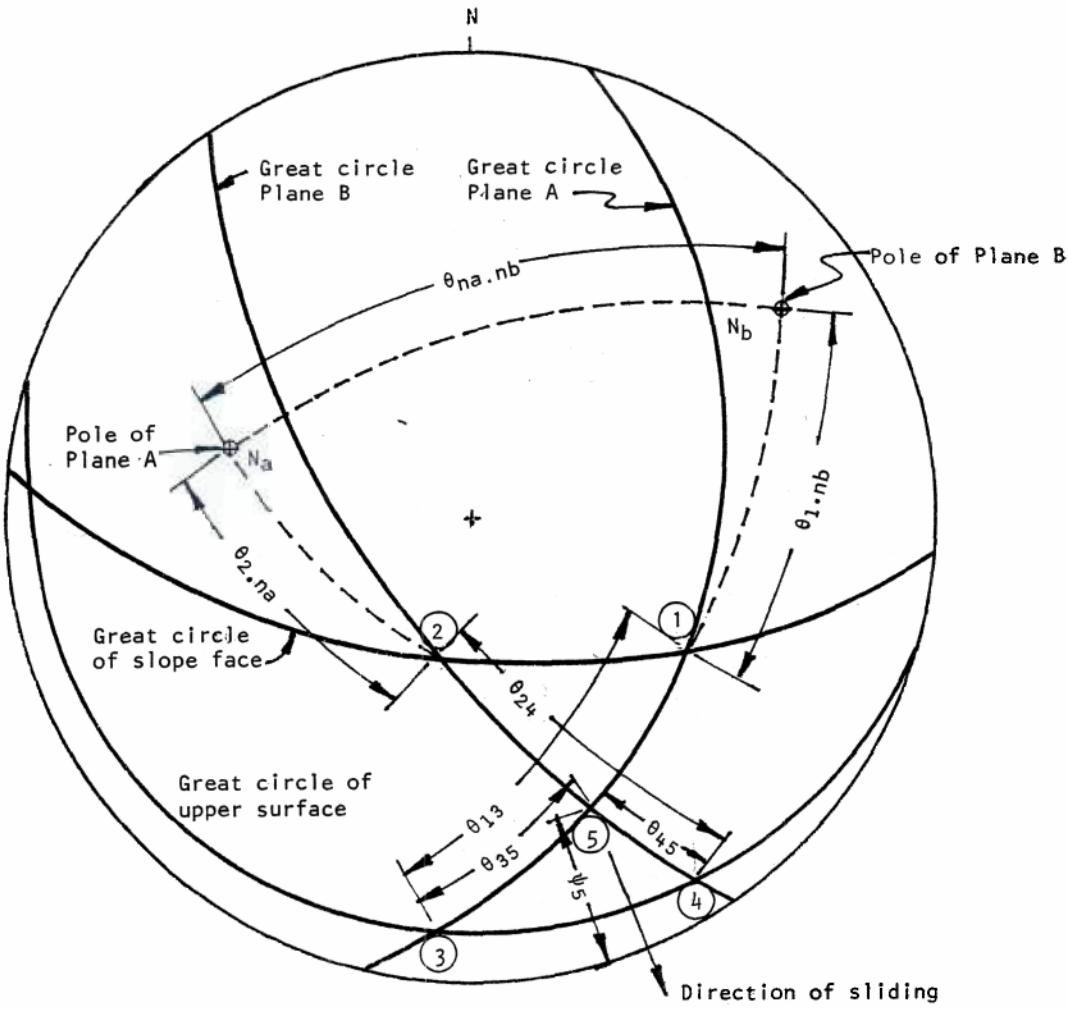



Figure 6.7. Stereoplot of data required for wedge stability analysis (Hoek and Bray, 1981).

### 6.2.3 Toppling

Toppling movements are due to forces that cause an overturning moment about a pivot point below the toppling block unit center of gravity. In a blocky rock mass, the resultant force that determines the block toppling is due to block weight, water pressure in the joint and the adjacent block thrust (Giani, 1992).

Goodman and Bray (1976) have described a number of different types of toppling failures, namely, flexural toppling, block toppling, block-flexural toppling and secondary toppling modes.

### *Flexural toppling*

Flexural toppling occurs when continuous columns of rock, which are separated by well developed steeply dipping discontinuities, break in flexure as they bend forward. Sliding, undermining or erosion of the toe of the slope allows the toppling process to start and it retrogresses backwards into the rock mass with the formation of deep, wide tension cracks. The lower portion of the slope is covered with disoriented and disordered blocks and it is sometimes very difficult to recognize a toppling failure from the bottom of a slope (Figure 6.8 a).

### *Block toppling*

Block toppling occurs when individual columns of hard rock are divided by widely spaced orthogonal joints. The short columns forming the toe of the slope are pushed forward by the loads from the longer overturning columns behind and this sliding of the toe allows further toppling to develop higher up the slope. The base of the failure is better defined than that in a flexural topple and it generally consists of a stairway rising from one cross-joint to the next (Figure 6.8 b).

### *Block-flexure toppling*

This type of toppling failure is characterized by pseudo-continuous flexure along long columns which are divided by numerous cross joints. Instead of the flexural failure of continuous columns, resulting in flexural toppling, the toppling of the columns in this case results from accumulated displacements on the cross joints. Because of the large number of small movements in this type of topple, there are fewer tension cracks than in flexural toppling and fewer edge-to-face contacts and voids than in block toppling (Figure 6.8 c).

### *Secondary toppling modes*

In general, these failures are initiated by some undercutting of the toe of the slope, either by natural agencies such as erosion or weathering or by the activities of man. In all cases, the primary failure mode involves sliding or physical breakdown of the rock and toppling is induced in some part of the slope as a result of this primary failure (Figure 6.1).

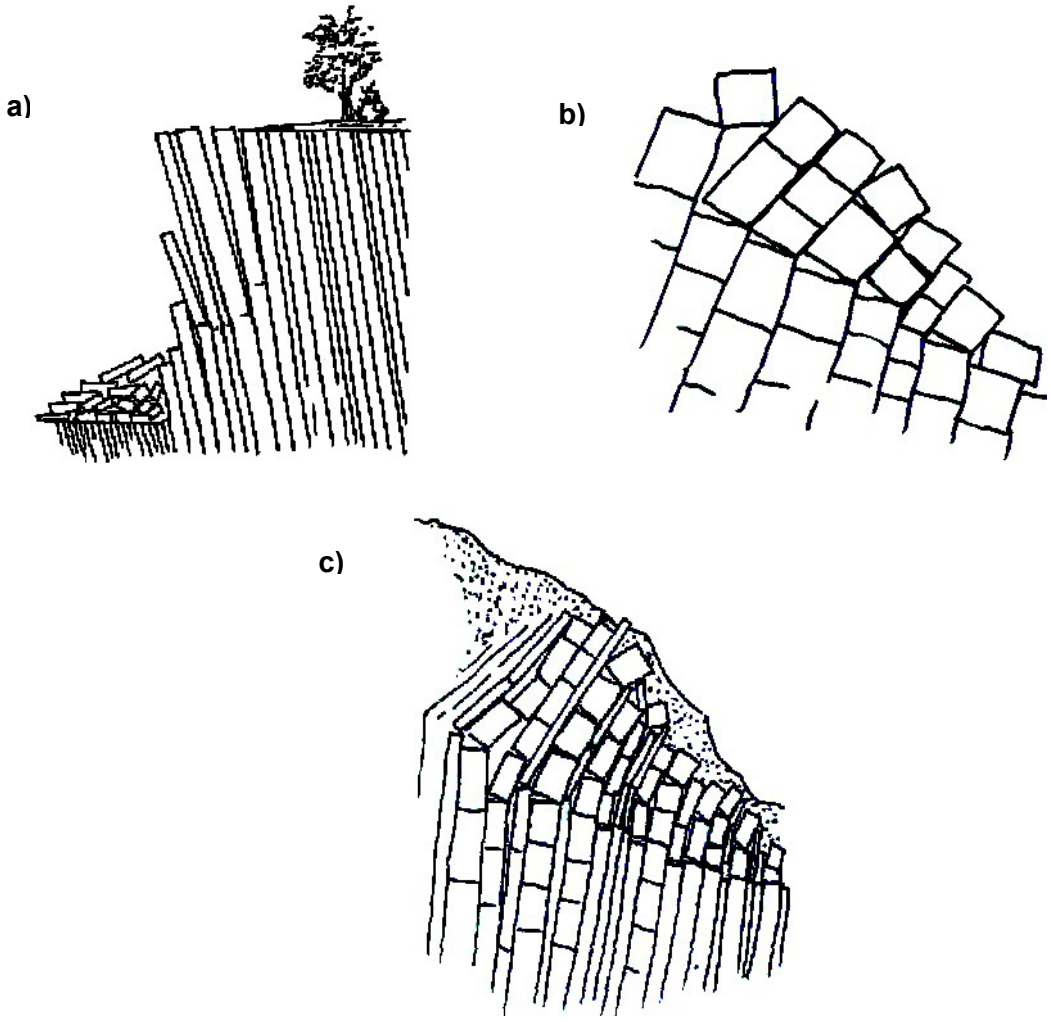



Figure 6.8. Toppling failure modes. a) Flexural toppling. b) Block toppling. c) Block-flexure toppling.

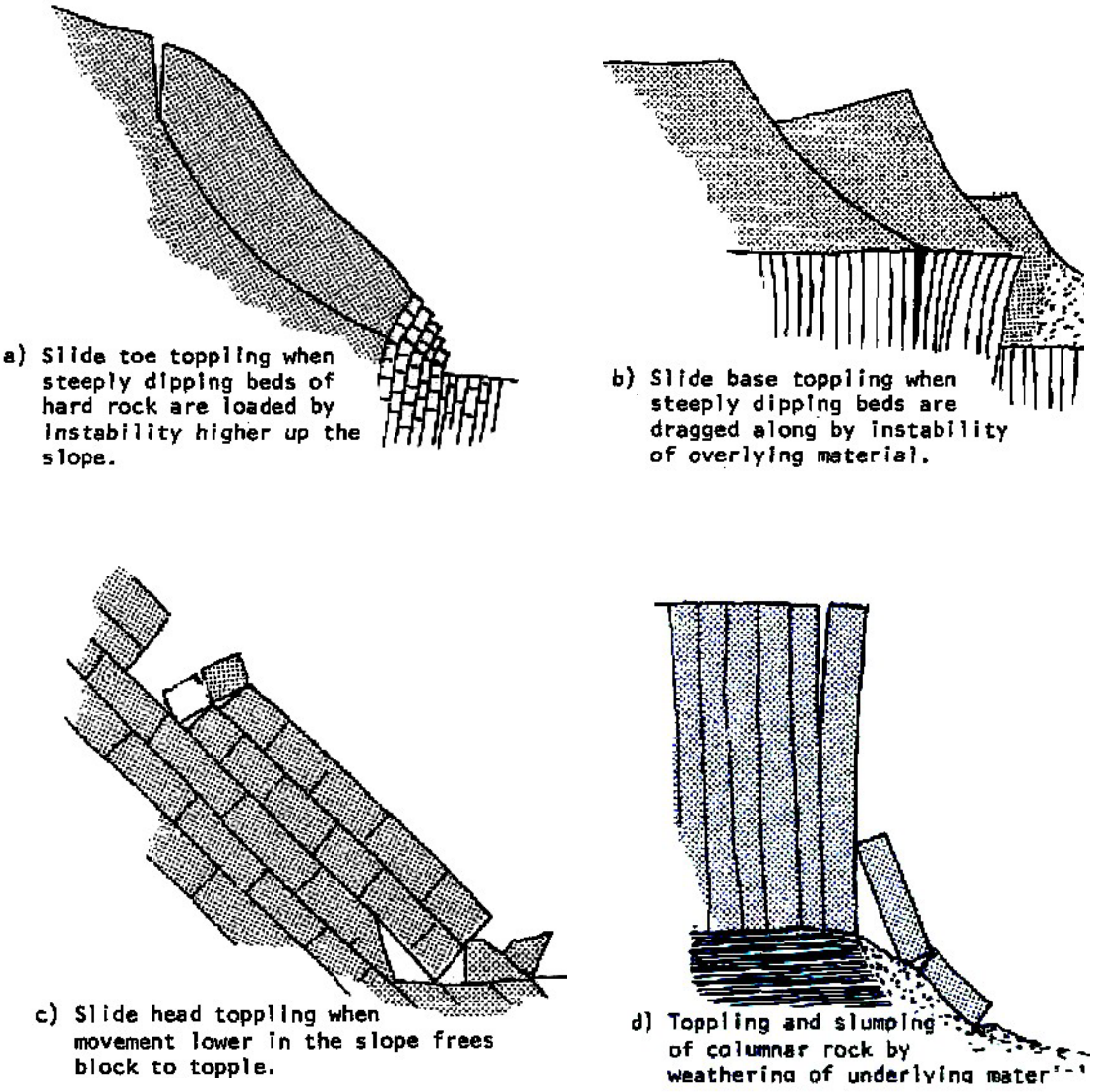



Figure 6.9.

Secondary toppling mechanisms suggested by Goodman and Bray (1968).

### 6.3 Limit Equilibrium Method (Deterministic Approach)

The conventional methods of slope analysis are based on the concept of limit equilibrium and enable the calculation of the minimum factor of safety, which is a unitless indicator of the stability. The aim of the method is to analyze the stability of any mass of soil or rock assuming incipient failure along a potential sliding surface. Limit equilibrium methods are based on analytical solutions and consider, being different from kinematical analyses, the followings (Hoek and Bray, 1981):

- weight of the sliding block
- cohesion (c), internal friction angle ($\phi$)
- pore water pressure, u
- geometry of the slope
- seismic acceleration
- tension crack position
- external loads

The simplified Bishop and Janbu methods for slope stability analysis have been used extensively since their presentation in the 1950s. The limit equilibrium formulation leads to a statically indeterminate solution, and one cannot directly compare these results with a closed-form correct solution. Although a direct comparison between the different methods is not always possible, the factor of safety determined using Bishop's simplified method for circular surfaces can be expected to differ by less than 5 percent with respect to the more rigorous Spencer or Morgenstern-Price solutions.

### 6.4 Deformation Analysis (Finite Element Method)

The limit equilibrium method allows engineers to evaluate the stability of slopes quickly. However, these procedures are the same whether the analysis considers (1) slope of newly constructed embankment, (2) slope of a recent excavation, or (3) an existing natural slope. The stresses within these slopes are strongly influenced by the ratio of lateral to vertical normal effective stresses, but conventional limit equilibrium procedures ignore this important feature (Chowdhury, 1978). In reality, the stress distributions within these three slopes would be different and hence significantly influence their stability.

The finite element method (FEM) bypasses many of the deficiencies that are inherent with the limit equilibrium methods. For typical cases, the FEM can incorporate incremental construction for embankments and excavations in an attempt to simulate the stress history of the soil within the slope.

SLIDE is a 2D slope stability program for evaluating the safety factor of circular or non-circular failure surfaces in soil or rock slopes. SLIDE can be employed for complex models to be created and analyzed quickly and easily. External loading, groundwater and support can all be modeled in a variety of models. SLIDE analyzes the stability of slip surfaces using vertical slice limit equilibrium methods. Individual slip surfaces can be analyzed, or search methods can be applied to locate the critical slip surface for a given slope.

### 6.5 Geotechnical Field Evaluation of Tunnel Portals

In this report, the word "portal" implies two different meanings. One is the tunnel portal, which can be defined as the interval from the tunnel entrance kilometer to the place where the height of overburden rock mass is three times of tunnel span. The other meaning, however, indicates the slopes of the tunnel entrance or exit. These slopes are side cut slopes at the right and left sides, and the face slopes through which the tunnel is drilled. No matter whichever meaning is employed, the entrance and exit portals of tunnels are a special concern for tunneling engineers. In this section, however, only the slopes of the portals will be examined.

In general, the portal with either meaning is the place where the engineer meets with the rock mass for the first time. The conditions at the portals, therefore, are a clue for the engineer to examine and recognize the behavior of the rock mass. It is the most critical part of the tunneling since the worst conditions are relatively present at the portals which concerns the whole tunnel alignment. The reason for this is that the weathering rate is relatively high and the commencement of the excavation may create some slope stability problems at portals.

In the portal design, the first step for the design engineers is the determination of the safe slope angles at which no failure occurs. One can take samples from field and measure the shear strength parameters in the laboratory. Then, putting these parameters into the limit equilibrium analyses, safe slope angels may be obtained. However, most of the time, these samples removed from field and brought to laboratory do not represent the real conditions,

in-situ properties. For example, the portals and the cut slopes may be composed of heterogeneous, different types of lithological units. Moreover, the shear strength parameters of the samples may not be reliable since they are already being disturbed as they were removed from their in-situ places.

The need for the determination of some slope angles at preliminary stages of the project brings the necessity of usage of some empirical relations. The angles gathered from these empirical relations are not hundred percent safe angles. These angles, later, have to be checked by limit equilibrium analyses for the final design. One of the practical estimation tables for the preliminary slope angles is provided in the "Slope Design Guide Book, Technical Research Department, 1989" prepared and issued by General Directorate of Turkish State Highways (KGM) (Table 6.1). This table is easy to use and very practical in the field since the information on lithology, rock mass quality and the groundwater would be sufficient. The safe slope angle determination in the field by the first impression is not an easy task. Therefore, the angles tabulated in this table are the initial step, not the final, for slope stability analyses.

Together with the first step, the necessity of the determination of shear strength parameters of rock masses making up the slopes comes into consideration spontaneously. As it has already been mentioned in Chapter IV, the A-RMR values at the portal faces have been assessed through the relation, $A\text{-}RMR_p = A\text{-}RMR - 6.24$. The portal faces deserve much more attention than side open-cut slopes since they are more susceptible to deformations as the tunneling proceeds. The portal faces feel the effect of blasting inside the tunnel intensely.

These two decisions are strictly tied up with each other and so critical for not only portal design but also, in general, slope stability problems.

In the calculations, the inclination of the lower slopes of the portal face has been chosen as 1h:5v instead of the value suggested by Table 6.1. The contractor's specifications have been played an important role in the selection of the slope angle. Moreover, since the rock quality in the portal areas is "fair rock" as the A-RMR values would be given in the following sections, it is capable to stand stable with such a slope gradient. It has been observed in the field that this rock mass can stand at steeper inclinations. Also, since the portal face slopes are supported routinely, the strength conditions of the rock mass comprising of the face slopes will be improved. Furthermore, the steeper the slope inclination at which rock mass is stable the lesser the cost and excavation amount with lesser slope height in total.

Table 6.1. The slope gradients for highway cuts, KGM "Slope Design Guide Book, Technical Research Department", 1989.

| ROCK QUALITY | GROUNDWATER EFFECT | CARBONATE ROCKS WITH WELL DEVELOPED CRYSTAL CLEAVAGE dolomite, limestone and marble | | | LITHIFIED ARGILLACEOUS ROCKS mudstone, siltstone, shale and slate (normal to cleavage) | | | ARENACEOUS ROCKS WITH STRONG CRYSTALS AND POORLY DEVELOPED CRYSTAL CLEAVAGE sandstone and quartzite | | | FINE GRAINED POLYMINERALIC IGNEOUS CRYSTALLINE ROCKS andesite, dolerite, diabase and rhyolite | | | COARSE GRAINED POLYMINERALLIC IGNEOUS AND METAMORPHIC CRYSTALLINE ROCKS amphibolite, gabbro, gneiss, granite, norite and quartz-diorite | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SLOPE HEIGHT | | | | | | | | | | | | | | |
| | | 5 m | 10 m | 15 m | 5 m | 10 m | 15 m | 5 m | 10 m | 15 m | 5 m | 10 m | 15 m | 5 m | 10 m | 15 m |
| INTACT ROCK SAMPLES Laboratory size rock specimens free from structural defects. CSIR rating 100+, NGI rating 500 | NO | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 |
| | YES | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 | 1:5 |
| VERY GOOD QUALITY ROCK MASS Tightly interlocking undisturbed rock with unweathered joints spaced at +- 3 metres. CSIR rating 85, NGI rating 100 | NO | 1:5 | 1:5 | 1:5 | 1:5 | 1:4 | 1:4 | 1:5 | 1:4 | 1:4 | 1:5 | 1:5 | 1:4 | 1:5 | 1:5 | 1:4 |
| | YES | 1:5 | 1:4 | 1:4 | 1:5 | 1:4 | 1:3 | 1:4 | 1:4 | 1:3 | 1:5 | 1:5 | 1:4 | 1:5 | 1:5 | 1:4 |
| GOOD QUALITY ROCK MASS Fresh to slightly weathered rock, slightly disturbed with joints spaced at 1 to 3 metres. CSIR rating 65, NGI rating 10 | NO | 1:5 | 1:4 | 1:4 | 1:4 | 1:3 | 1:3 | 1:4 | 1:3 | 1:3 | 1:5 | 1:4 | 1:4 | 1:5 | 1:5 | 1:4 |
| | YES | 1:4 | 1:4 | 1:3 | 1:4 | 1:3 | 1:2 | 1:4 | 1:3 | 1:3 | 1:4 | 1:4 | 1:3 | 1:4 | 1:4 | 1:4 |
| FAIR QUALITY ROCK MASS Several sets of moderately weathered joints spaced at 0.3 to 1 metre. CSIR rating 44, NGI rating 1.0 | NO | 1:4 | 1:3 | 1:3 | 1:3 | 1:2 | 1:2 | 1:4 | 1:3 | 1:2 | 1:4 | 1:3 | 1:3 | 1:4 | 1:3 | 1:3 |
| | YES | 1:4 | 1:3 | 1:2 | 1:2 | 1:2 | 2:3 | 1:3 | 1:2 | 1:2 | 1:3 | 1:3 | 1:3 | 1:3 | 1:3 | 1:3 |
| POOR QUALITY ROCK MASS Numerous weathered joints spaced at 30 to 500 mm with some gouge filling / clean waste rock. CSIR rating 23, NGI rating 0.1 | NO | 1:3 | 1:3 | 1:2 | 1:2 | 2:3 | 3:4 | 1:3 | 1:2 | 1:2 | 1:3 | 1:3 | 1:2 | 1:3 | 1:3 | 1:2 |
| | YES | 1:3 | 1:2 | 1:2 | 2:3 | 3:4 | 1:1 | 1:2 | 2:3 | 2:3 | 1:2 | 1:2 | 2:3 | 1:2 | 1:2 | 2:3 |
| VERY POOR QUALITY ROCK MASS Numerous heavily weathered joints spaced less than 50 mm with gouge filling / waste rock with fines. CSIR rating 3, NGI rating 0.01 | NO | 1:2 | 2:3 | 2:3 | 2:3 | 3:4 | 1:1 | 2:3 | 2:3 | 3:4 | 2:3 | 2:3 | 3:4 | 1:2 | 2:3 | 2:3 |
| | YES | 2:3 | 3:4 | 1:1 | 3:4 | 1:1 | 1:1 | 2:3 | 3:4 | 1:1 | 2:3 | 3:4 | 3:4 | 2:3 | 3:4 | 3:4 |

### 6.5.1 Kinematical Analyses

In this section, the portal slopes of the tunnels will be examined for the contingency of the above-described kinematical failure modes. Among these, the plane failure and the toppling possibilities will be investigated due to the existence of only one persistent discontinuity set in the rock masses.

Before the execution of the kinematical analyses, rock masses surrounding each tunnel portal will be described in detail and the shear strength parameters will be determined as per A-RMR rock mass evaluation. Once the rock mass class has been determined by A-RMR, the related shear strength parameter intervals will be utilize to assign specific values of parameters of the rock masses. These specific values can be either the average or upper and lower limits of the related interval.

The kinematical analyses, then, have been executed by the software DIPS, which is employed in the plotting analysis and presentation of structural data using spherical projection techniques, 1989-96 M. Diederichs and E. Hoek Rock Engineering Group, University of Toronto. The results of the kinematical analyses have been presented in Appendix – G.

#### 6.5.1.1 Boztepe Tunnel

##### 6.5.1.1.1 Cut Slopes of Boztepe Tunnel Entrance

The stability of the cut slopes of the Boztepe Tunnel entrance portal is controlled by the Upper Cretaceous volcanics and the concurrent flysch (See Figure 3, 6 and 8 in Appendix – A).

The sandstone and limestone member of Akveren formation (flysch) intertonguing with the volcanics has continuous and distinct bedding planes with 120/20 dip direction and dip amount, respectively. In the kinematical analyses, orientations of these bedding planes determining the stability of slopes were employed as if they were discontinuity surfaces. Bedding plane surfaces are undulating and irregularly rough with the aperture size between 1.00-5.00 mm. Having a spacing between 60-600 mm, these surfaces are slightly altered.

These same members do not accommodate well-developed and continuous joints. However, two sets of joint surfaces were observed, which were not effective on the stability of these slopes. The orientations of them are measured in the field as 200/80 and 265/75.

According to the contractor's specifications, the maximum excavation height of the cut slopes was designed to be about 15.0 m above which 5.0 m wide benches were planned. While the cut slopes on the left and right have 1h:3v inclination, the portal face was designed to be 1h:5v for lower slope and 1h:2v for upper slope. The orientations of the cut slopes are as following:

| Slope Location | Section | Dip/Dip Direction | Gradient | Max. Height (m) |
|---|---|---|---|---|
| LEFT CUT-SLOPE | Lower slope | 72/020 | 1:3 | 15.00 |
| | Upper slope | 72/020 | 1:3 | 8.40 |
| RIGHT CUT-SLOPE | Lower slope | 72/200 | 1:3 | 15.00 |
| | Upper slope | 72/200 | 1:3 | 5.40 |
| PORTAL FACE | Lower slope | 79/290 | 1:5 | 14.56 |
| | Upper slope | 63/290 | 1:2 | 9.30 |

In general, the rock mass dominating the entrance portal area was classified as FAIR ROCK according to A-RMR classification. This rock mass, in fact, is formed by volcanics and concurrent flysch deposits. The shear strength parameters used in the analyses of this two different lithology groups were determined by A-RMR classification whose details are given in the Appendix – E under the heading of "The Boztepe (T-1) tunnel". Consequently, the shear strength parameters of the volcanics have been determined to be the average of "FAIR ROCK" limits whereas the lower limits of "FAIR ROCK" interval have been chosen for the concurrent flysch. In addition to this, the first 5-6m from the ground surface displays highly weathered character as a "VERY POOR ROCK", which can be treated as residual soil (Figure 6.10).

The parameters for kinematical analyses, therefore, can be summarized as:

| Rock Mass Parameters (from RMR) | Volcanics | Flysch | Weathered Zone (residual soil) |
|---|---|---|---|
| $\phi$ ( ° ) | 30 | 25 | 15 |
| c (kPa) | 250 | 200 | 50 |
| $\gamma$ (kN/m$^3$) | 23 | 21 | 21 |

As it can be seen obviously from the analyses results in Appendix – G, there is no risk for either plane or toppling failure. Therefore, the limit equilibrium analyses for this portal will not be performed.

(a)

(b)

Figure 6.10. A view of core boxes where the first 5-6 m have been treated as residual soil.

#### 6.5.1.1.2 Cut Slopes of Boztepe Tunnel Exit

The stability of the cut slopes of the Boztepe Tunnel exit is controlled by the Upper Cretaceous volcanics and the concurrent flysch (See Figure 4, 6 and 8 in Appendix – A and Figure 6.11).

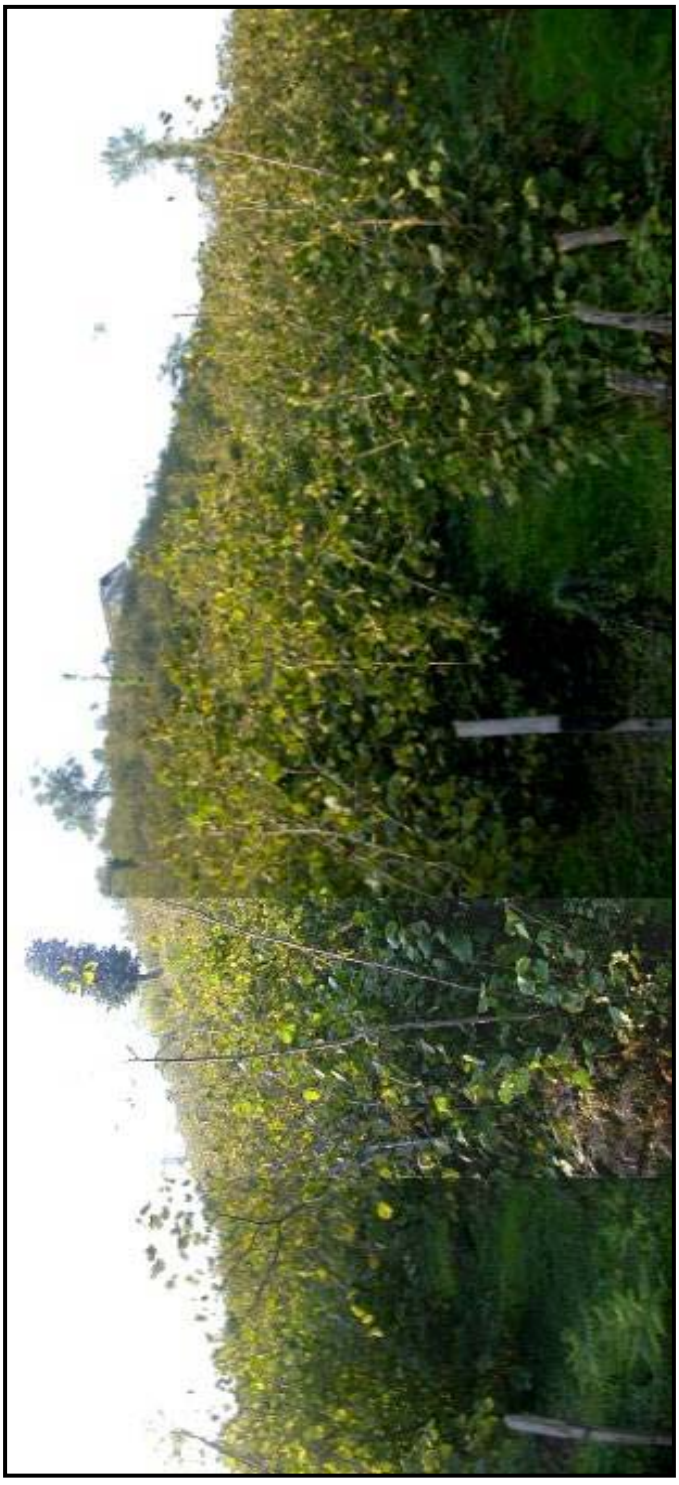


Figure 6.11. A view of Boztepe (T-1) exit portal covered with dense vegetation.

The greenish marl and brown claystone component of the flysch intertonguing with the volcanics are the weakest (UCS is between 1.25-5.0 MPa) components having slightly altered, undulating and irregularly rough, discontinuous bedding plane surfaces whose aperture size is between 1.00-5.00 mm.

The sandstone and limestone member has continuous and distinct bedding planes with 115/15 dip direction and dip amount, respectively. Bedding plane surfaces are undulating and irregularly rough with the aperture size between 1.00-5.00 mm. Having a spacing between 60-600 mm, these surfaces are slightly altered.

According to the contractor's specifications, the maximum excavation height of the cut slopes was designed to be 15.0 m above which 5.0 m wide benches were planned. While the cut slopes on the left and right have 1h:3v inclination, the portal face was designed to be 1h:5v for lower slope and 1h:2v for upper slope. In this exit portal, since the ending kilometers of the tubes are not the same, the slope angle of the interface formed between the tubes is designed as 1h:5v.

In summary, the orientations of the cut slopes are as following:

| Slope Location | Section | Dip/Dip Direction | Gradient | Max. Height (m) |
|---|---|---|---|---|
| LEFT CUT-SLOPE (LEFT TUBE) | Lower slope | 72/235 | 1:3 | 15.00 |
| | Upper slope | 72/235 | 1:3 | 6.30 |
| RIGHT CUT-SLOPE | Lower slope (Left Tube) | 79/055 | 1:5 | 14.00 |
| | Lower slope (Right Tube) | 72/055 | 1:3 | 15.00 |
| PORTAL FACE | Lower slope (Left Tube) | 79/145 | 1:5 | 14.56 |
| | Upper slope (Left Tube) | 63/145 | 1:2 | 10.00 |
| | U.most slope (Left Tube) | 63/145 | 1:2 | 8.35 |
| | Lower slope (Right Tube) | 79/145 | 1:5 | 14.56 |
| | Upper slope (Right Tube) | 63/145 | 1:2 | 8.70 |

In general, the rock mass dominating the entrance portal area was classified as FAIR ROCK according to A-RMR classification. Appendix – E. Accordingly, the shear strength parameters of the volcanics have been determined to be the average of "FAIR ROCK" limits

whereas, for the flysch, the lower limits of the “FAIR ROCK” at the side slopes and the upper limits of the “POOR ROCK” interval at the portal faces have been assigned. The first 5-6 m of the mass from the ground surface displays highly weathered character as a “VERY POOR ROCK”, which can be treated as residual soil (Figure 6.12).

(a)

(b)

Figure 6.12. A view of core boxes where the first 5-6 m have been treated as residual soil.

The parameters for kinematical analyses, therefore, can be summarized as:

| Rock Mass Parameters (from RMR) | Volcanics | Flysch | Weathered Zone (residual soil) |
|---|---|---|---|
| $\phi$ ( ° ) | 30 | 25 | 15 |
| c (kPa) | 250 | 200 | 50 |
| $\gamma$ (kN/m$^3$) | 24 | 21 | 21 |

As it can be seen obviously from the analyses results in Appendix – G, there is no risk for either plane or toppling failure. Therefore, the limit equilibrium analyses for this portal will not be performed.

#### 6.5.1.2 Öceli Tunnel

##### 6.5.1.2.1 Cut Slopes of Öceli Tunnel Entrance

The Upper Cretaceous volcanics, namely, agglomerate and tuff, intertonguing with flysch type sedimentary rocks control the slope stability at this portal (See Figure 4, 7, 9 and 10 in Appendix – A and Figure 6.13). There exists a distinct and persistent bedding plane with an orientation of 115/15 in this unit. The bedding planes and joints are discontinuous, undulating and irregularly rough. The spacing of the discontinuities is between 200-600 mm revealing RQD=50-75%. The 1.00-5.00 mm opened (aperture) bedding planes are slightly altered and filled with non-softening, non-cohesive rock mineral or crushed rock filling.

Some layers of andesitic and basaltic tuff compared to the agglomerates serve poorer conditions regarding grain size, weathering and strength parameters. In this frame, the moderately weathered sections of the tuff are moderately strong (UCS is between 12.5-50.0 MPa) to weak (UCS is between 1.25-5.0 MPa), and the slightly weathered and fresh sections are moderately strong (UCS is between 12.5-50.0 MPa). These sections are highly fractured where RQD value ranges between 25-50% together with the average joint spacing of 60-200 mm.

The maximum excavation height of the cut slopes was designed to be 15.0 m above which 5.0 m wide benches were planned. While the cut slopes on the left and right have 1h:3v inclination, the portal face was designed to be 1h:5v for lower slope and 1h:3v for upper slopes. In this entrance portal, since the starting kilometers of the tubes are not the same, the slope angle of the interface formed between the tubes is designed as 1h:5v.

Figure 6.13. A view of Öceli (T-2) tunnel entrance portal covered with dense vegetation.

| Slope Location | Section | Dip/Dip Direction | Gradient | Max. Height (m) |
|---|---|---|---|---|
| LEFT CUT-SLOPE | Lower slope (Left Tube) | 72/235 | 1:3 | 13.00 |
| | Lower slope (Right Tube) | 79/235 | 1:5 | 15.40 |
| RIGHT CUT-SLOPE (RIGHT TUBE) | Lower slope | 72/055 | 1:3 | 15.00 |
| | Lower slope | 72/055 | 1:3 | 6.70 |
| PORTAL FACE | Lower slope (Left Tube) | 79/325 | 1:5 | 14.56 |
| | Upper slope (Left Tube) | 72/325 | 1:3 | 8.00 |
| | Lower slope (Right Tube) | 79/325 | 1:5 | 14.56 |
| | Upper slope (Right Tube) | 72/325 | 1:3 | 10.00 |
| | U.most slope (Right Tube) | 72/325 | 1:3 | 11.40 |

In general, the rock mass dominating the entrance portal area was classified as FAIR ROCK according to A-RMR classification. Appendix – E under the heading of "The Öceli (T-2) tunnel". Consequently, the shear strength parameters of the volcanics have been determined to be the average of "FAIR ROCK" limits at the side slopes and the upper limits of the "POOR ROCK" interval at the portal faces of the left tube. In contrast to the left tube, the portal of the right tube accommodates better conditions where the upper limits of the "FAIR ROCK" interval have been selected. For the flysch, the lower limits of the "FAIR ROCK" at the side slopes and the upper limits of the "POOR ROCK" interval at the portal faces have been assigned. The drillings at this portal reveals that the first 5-6 m of the mass from the ground surface at the left tube and the first 10 m at the right tube display highly weathered character as a "VERY POOR ROCK", which can be treated as residual soil. The portal of the right tube has relatively better rock mass conditions mostly dominated by agglomerates. Therefore, the rock mass parameters have been evaluated separately at the Öceli (T-2) tunnel entrance portal (Figure 6.14).

The parameters for kinematical analyses, therefore, can be summarized as:

LEFT TUBE:

| Rock Mass Parameters (from RMR) | Volcanics | Flysch | Weathered Zone (residual soil) |
|---|---|---|---|
| $\phi$ ( ° ) | 30/25* | 25 | 15 |
| c (kPa) | 250/200* | 200 | 50 |
| $\gamma$ (kN/m$^3$) | 25 | 23 | 23 |

* The values to be used in the analyses of the portal faces.

RIGHT TUBE:

| Rock Mass Parameters (from RMR) | Volcanics | Flysch | Weathered Zone (residual soil) |
|---|---|---|---|
| **ϕ ( ° )** | 35 | 25 | 15 |
| **c (kPa)** | 300 | 200 | 50 |
| **γ (kN/m$^3$)** | 25 | 23 | 23 |

As it can be seen obviously from the analyses results in Appendix – G, there is no risk for either plane or toppling failure. Therefore, the limit equilibrium analyses for this portal will not be performed.

(a)

(b)

Figure 6.14. A view of core boxes where the first 10 m have been treated as residual soil.

#### 6.5.1.2.2 Cut Slopes of Öceli Tunnel Exit

Upper Cretaceous volcanics buried by Neogene terrestrial deposits as a thin cover control the stability of cut slopes of Öceli Tunnel exit (See Figure 5, 7, 9 and 10 in Appendix – A).

Figure 6.15. A view of Öceli (T-2) tunnel exit portal covered with dense vegetation.

Agglomerate component of the volcanics have poorly developed joints. In general, however, two main joint systems have been determined with the orientations of 270/80, 190/60 in the field. In the same unit, there exists a distinct and persistent bedding plane with

its orientation of 110/15. This discontinuous, undulating and irregularly rough bedding plane is the discontinuity controlling the slope stability at this portal.. The spacing of the bedding planes is between 200-600 mm revealing RQD=50-75%.

The maximum excavation height of the cut slopes was designed to be 15.0 m above which 5.0 m wide benches were planned. While the cut slopes on the left and right have 1h:3v inclination, the portal face was designed to be 1h:5v for lower slope and 1h:2v for upper slopes. In this exit portal, since the ending kilometers of the tubes are not the same, the slope angle of the interface formed between the tubes is designed as 1h:5v. The orientations of the cut slopes are as following:

| Slope Location | Section | Dip/Dip Direction | Gradient | Max. Height (m) |
|---|---|---|---|---|
| LEFT CUT-SLOPE (LEFT TUBE) | Lower slope | 72/185 | 1:3 | 15.00 |
| | Lower slope | 72/185 | 1:3 | 2.00 |
| RIGHT CUT-SLOPE | Lower slope (Left Tube) | 79/005 | 1:5 | 15.50 |
| | Lower slope (Left Tube) | 63/005 | 1:2 | 10.50 |
| | Lower slope (Right Tube) | 72/005 | 1:3 | 15.00 |
| | Upper slope (Right Tube) | 72/005 | 1:3 | 10.00 |
| | U.most slope (Right Tube) | 72/005 | 1:3 | 7.30 |
| PORTAL FACE | Lower slope (Left Tube) | 79/095 | 1:5 | 14.56 |
| | Upper slope (Left Tube) | 63/095 | 1:2 | 10.00 |
| | U.most slope (Left Tube) | 63/095 | 1:2 | 7.80 |
| | Lower slope (Right Tube) | 79/095 | 1:5 | 14.56 |
| | Upper slope (Right Tube) | 63/095 | 1:2 | 10.00 |
| | U.most slope (Right Tube) | 63/095 | 1:2 | 6.60 |

The rock mass dominating the entrance portal area was classified as FAIR ROCK according to A-RMR classification Appendix – E. Accordingly, the shear strength parameters of the volcanics have been determined to be the average of “FAIR ROCK” limits whereas, for the flysch, the lower limits of the “FAIR ROCK” at the side slopes and the upper limits of the “POOR ROCK” interval at the portal faces have been assigned. The first 12-13 m of the mass from the ground surface display highly weathered character as a “VERY POOR ROCK”, which can be treated as residual soil (Figure 6.16).

(a)

(b)

Figure 6.16. A view of core boxes where the first 12-13 m have been treated as residual soil.

The parameters for kinematical analyses, therefore, can be summarized as:

| Rock Mass Parameters (from RMR) | Volcanics | Flysch | Weathered Zone (residual soil) |
|---|---|---|---|
| **ϕ ( ° )** | 30 | 25 | 15 |
| **c (kPa)** | 250 | 200 | 50 |
| **γ (kN/m$^3$)** | 25 | 22 | 22 |

As it can be seen obviously from the analyses results in Appendix – G, there is only a risk for plane failure at the portal face. Therefore, the limit equilibrium analysis for this portal face has been performed. The details of this analysis have been presented in the following sections.

### 6.5.2 The limit equilibrium method analyses

*(a) Plane failure*

The results of the kinematical analyses presented in Appendix – G indicate the contingency of the plane failure, where the pole of the discontinuity surface has fallen into the critical region, for only the portal face of Öceli (T-2) tunnel exit. In spite of the failure possibility at this portal, all the portal slopes are kinematically stable as it is revealed by analyses results.

In order to investigate the factor of safety (F.S.) for this portal face, the limit equilibrium analysis has been executed. The bedding plane observed in the flysch deposits has been considered as a discontinuity surface kinematically controlling the slope stability. Therefore, the shear strength parameters of the flysch at this portal region have been used considering the explanations given previously.

As it can be seen from the following Figure 6.17, the portal face of the Öceli (T-2) tunnel exit portal is stable with the calculated F.S. =2.952 via the limit equilibrium method.

*(b) Toppling*

According to the kinematical analyses results presented in Appendix – G, there exists no contingency of toppling for tunnel portals. Therefore, there is no need for further investigation. All the portal slopes are stable regarding the toppling failure.

| ÖCELİ (T-2) TUNNEL EXIT PORTAL / PORTAL FACE | | | | |
|---|---|---|---|---|
| PLANE FAILURE ANALYSIS | | | | |
| INPUT | | | EQUATIONS | RESULTS |
| $\gamma$ | Density (kN/m$^3$) | 22 | $W = \gamma * L * \tan(\beta-\alpha) * L / 2$ | W= 4751.00 kN/m |
| c | Cohesion (kPa) | 200 | | |
| $\phi$ | Internal friction angle | 25 | $L = H / ( ( \text{Tan}(\beta-\alpha) * \text{Cos}\,\alpha) + \text{Sin}\,\alpha )$ | L= 14.514 m |
| $A_o$ | Earthquake coefficient | 0.1 | | |
| $\beta$ | Slope face angle | 79 | $F.S. = \dfrac{W * ( \text{Cos}\,\alpha - A_o * \text{Sin}\,\alpha ) * \text{Tan}\,\phi + c * L}{W * ( \text{Sin}\,\alpha + A_o * \text{Cos}\,\alpha )}$ | **F.S= 2.952** |
| $\alpha$ | Apparent dip angle | 15 | | |
| H | Slope height (m) | 32.5 | | |




Figure 6.17 Limit equilibrium plane failure analysis of the Öceli (T-2) tunnel exit portal face.

*(c) Circular failure*

The field observations and the drillings have revealed the existence of the weathered zone at the portal areas. This zone is the product of the weathering of the underlying volcanics or flysch deposits by the mechanical and chemical processes. The thickness of the weak zones shows variations between 5.0 to 15.0 m (Figures 6, 7, 8, 9, 10 in Appendix – A). This highly weathered parts of the underlying rock units behave like a residual soil in the field. In other words, it can be classified as "VERY POOR ROCK" according to RMR rock categories. Hence, the circular failure investigation in this soil-like rock quality has been considered. For the circular failure analyses the same rock mass shear strength parameters determined previously in Chapter V for each portal section have been employed.

The circular failure analyses of the portal slopes have been carried out by the software SLIDE V.5.00 (Rocscience, 2003), which is a 2D limit equilibrium slope stability analysis program for soil and rock slopes. In the analyses, Bishop's simplified method has been used. This method yields virtually the same value of F obtained from the other rigorous methods with a difference of ± 0.1% (Hoek and Bray, 1981).

The results of the circular failure analyses have been presented in Appendix – H. The F.S. values, as a summary, of the portal slopes together with the slope gradients and the shear strength parameters are given in the following tables (from Table 6.2 to 6.7). The analyses have been also executed under seismic loading ($a_h/g=0.1$) conditions other than the static conditions ($a_h/g=0$).

In order to check the efficiency of the support systems suggested at the end of this chapter for the portal slopes, the stability of the right tube portal face of the Öceli (T-2) tunnel entrance portal having the smallest F.S. value has been analyzed with supports, namely rock bolts. As it can be clearly seen from the analyses results with and without support combinations from Appendix – G, the unsupported F.S values 1.171 ($a_h/g=0.1$) and 1.284($a_h/g=0$) have been elevated to 1.201 ($a_h/g=0.1$) and 1.388 ($a_h/g=0$), respectively. This single case proves the efficiency of the suggested support systems for tunnel portal slopes. In addition, the contribution of the shotcrete and wire mesh to the slope stability has been neglected in the analyses as a means of extra safety.

Table 6.2. Boztepe (T-1) Tunnel / Plane Failure Analyses of the Portal Faces

| BOZTEPE (T-1) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRANCE | | | | | | EXIT | | | | | |
| LEFT TUBE | | | RIGHT TUBE | | | LEFT TUBE | | | RIGHT TUBE | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:2 | 50<br>200 | 15<br>25 | 1:2 | 50<br>200 | 15<br>25 | 1:2<br>1:2 | 50<br>200 | 15<br>25 | 1:2 | 50 | 15 |
| 1:5 | 250 | 30 | 1:5 | 250 | 30 | 1:5 | 250 | 30 | 1:5 | 250 | 30 |
| F.S.: 2.048 ($a_h$/g=0.1)<br>F.S. : 2.291 | | | F.S. : 1.758 ($a_h$/g=0.1)<br>F.S. : 1.969 | | | F.S. : 1.890 ($a_h$/g=0.1)<br>F.S. : 2.084 | | | F.S. : 1.974 ($a_h$/g=0.1)<br>F.S. : 2.155 | | |

Table 6.3. Boztepe (T-1) Tunnel / Plane Failure Analyses of the Entrance Portal Side Slopes

| BOZTEPE (T-1) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRANCE | | | | | | | | | | | |
| LEFT TUBE | | | | | | RIGHT TUBE | | | | | |
| LEFT CUT | | | RIGHT CUT | | | LEFT CUT | | | RIGHT CUT | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:3 | 50<br>200 | 15<br>25 | - | - | - | - | - | - | 1:3 | 50 | 15 |
| 1:3 | 250 | 30 | | - | - | | - | - | 1:3 | 200<br>250 | 25<br>30 |
| F.S. : 1.312 ($a_h$/g=0.1)<br>F.S. : 1.495 | | | X | | | X | | | F.S. : 2.302 ($a_h$/g=0.1)<br>F.S. : 2.590 | | |

Table 6.4. Boztepe (T-1) Tunnel / Plane Failure Analyses of the Exit Portal Side Slopes

| BOZTEPE (T-1) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EXIT | | | | | | | | | | | |
| LEFT TUBE | | | | | | RIGHT TUBE | | | | | |
| LEFT CUT | | | RIGHT CUT | | | LEFT CUT | | | RIGHT CUT | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:3 | 50 | 15 | 1:5 | 50 | 15 | - | - | - | 1:3 | 50 | 15 |
| 1:3 | 250 | 30 | | 250 | 30 | | - | - | 1:3 | 250 | 30 |
| F.S. : 2.012 ($a_h$/g=0.1)<br>F.S. : 2.238 | | | F.S. : 1.829 ($a_h$/g=0.1)<br>F.S. : 1.897 | | | X | | | F.S. : 2.402 ($a_h$/g=0.1)<br>F.S. : 2.554 | | |

Table 6.5. Öceli (T-2) Tunnel / Plane Failure Analyses of the Portal Faces

| ÖCELİ (T-2) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRANCE | | | | | | EXIT | | | | | |
| LEFT TUBE | | | RIGHT TUBE | | | LEFT TUBE | | | RIGHT TUBE | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:3 | 50<br>200 | 15<br>25 | 1:3<br>1:3 | 50<br>200 | 15<br>25 | 1:2<br>1:2 | 50 | 15 | 1:2<br>1:2 | 50 | 15 |
| 1:5 | 200 | 25 | 1:5 | 300 | 35 | 1:5 | 250 | 30 | 1:5 | 250 | 30 |
| F.S.: 1.774 ($a_h$/g=0.1)<br>F.S.: 2.048 | | | F.S.: 1.201 ($a_h$/g=0.1)<br>F.S.: 1.388 | | | F.S.: 1.371 ($a_h$/g=0.1)<br>F.S.: 1.569 | | | F.S.: 1.284 ($a_h$/g=0.1)<br>F.S.: 1.505 | | |

Table 6.6. Öceli (T-2) Tunnel / Plane Failure Analyses of the Entrance Portal Side Slopes

| ÖCELİ (T-2) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRANCE | | | | | | | | | | | |
| LEFT TUBE | | | | | | RIGHT TUBE | | | | | |
| LEFT CUT | | | RIGHT CUT | | | LEFT CUT | | | RIGHT CUT | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:3 | 50 | 15 | - | - | - | 1:5 | 50 | 15 | 1:3 | 50 | 15 |
| 1:3 | 250 | 30 | | - | - | | 300 | 35 | 1:3 | 300 | 35 |
| F.S. : 2.209 ($a_h$/g=0.1)<br>F.S. : 2.437 | | | X | | | F.S. : 1.471 ($a_h$/g=0.1)<br>F.S. : 1.335 | | | F.S. : 1.574 ($a_h$/g=0.1)<br>F.S. : 1.704 | | |

Table 6.7. Öceli (T-2) Tunnel / Plane Failure Analyses of the Exit Portal Side Slopes

| ÖCELİ (T-2) TUNNEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EXIT | | | | | | | | | | | |
| LEFT TUBE | | | | | | RIGHT TUBE | | | | | |
| LEFT CUT | | | RIGHT CUT | | | LEFT CUT | | | RIGHT CUT | | |
| Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) | Slope gradient | c (kPa) | ϕ (°) |
| 1:3 | 50 | 15 | 1:2 | 50 | 15 | - | - | - | 1:3 | 50 | 15 |
| | | | | | | | | | 1:3 | 50 | 15 |
| 1:3 | 250 | 30 | 1:5 | 250 | 30 | | - | - | 1:3 | 250 | 30 |
| F.S. : 1.200 ($a_h$/g=0.1)<br>F.S. : 1.316 | | | F.S. : 1.329 ($a_h$/g=0.1)<br>F.S. : 1.477 | | | X | | | F.S. : 1.327 ($a_h$/g=0.1)<br>F.S. : 1.529 | | |

According to the results summarized in the preceding tables, the portal slopes are stable with the designed slope gradients and the shear strength parameters of the rock masses. As it can be interpreted from the results, the Öceli (T-2) tunnel portal slopes seem to be relatively more critical on the basis of the F.S. values.

Although these F.S. values have been obtained via the consideration of the most unfavorable rock mass conditions, there might be undefined and unforeseen effects during the service life of these portal slopes. The open-cut excavations at the portals are the preparation excavations before the underground excavations. Therefore, the open-cut excavations are so vital to assess and comprehend the rock mass behavior under different conditions concerning the following concepts:

- The rock masses at tunnel portals are continuously under the affect of stress relief since they are close to the ground surface where lithostatic overburden load diminishes by physical and mechanical weathering during geological time period. The persistency and the aperture of the discontinuity surfaces determining the engineering behavior of the rock mass increase under this conditions. As a natural consequent of these mass characteristics, the weathering rate, infilling and roughness of the discontinuities have a negative effect on the engineering behavior of the rock mass.

- In addition, the closeness of the rock masses to the ground surface causes these masses to be worn out by the external agents during geological time periods. The result of this interaction is the weathering of the rock mass and a chemical change to the soil state.

- The sections excavated by blasting at the portal regions are the surfaces meeting with blasting dynamics for the first time. The first applications in these surfaces are generally resulted in wearing out of rock masses.

- The wearing out of the rock mass by blasting affect, which has a negative affect on the engineering behavior of the rock mass, is significant for all open-cut excavations. However, this negative affect is more influential especially for portal faces. The main underlying reason for that is the medium change created on rock masses by the later tunnel excavation.

- Another feature concerning especially the stability of the portal face is the impulsion affect of the blasting mechanics of dynamite utilized in underground excavations. The compressive stress created by gasses at the first stages of the blasting mechanics of dynamite turns into the tensile stress and wears out the rock mass in the subsequent stages. The worn out rock mass pushes itself towards front and create impulsion affect to the out of portal face during the final stages of the tensile stress.

- As a concluding remark, some local instabilities are always possible since the rock masses do not behave as well-designed "concrete".

As a conclusion, to get rid of the defined and unforeseen negative affects of the internal and external dynamics summarized above to the rock masses, the open-cut excavations are sensitively considered in international applications where the recommended support systems are determined by technical specifications and engineering judgment. In the framework of this comprehension, for the open-cut excavations at portals, the following support systems are suggested to utilize in applications:

*(i) Portal Face Excavation*

In all regions within first 15.0 m starting from the tunnel base elevation:

- Systematical, grouted rock bolts with 1.5m split-spacing, diameter $\phi$=26mm and length L=4.00m.
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh,

In all regions above 15.0 m:

- Grouted spot bolting with diameter $\phi$=26mm and length L=4.00m.
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

*(ii) Side Slope Excavation*

In case of local instabilities during excavation:

- Grouted spot bolting with diameter $\phi$=26mm and length L=4.00m.
- 5cm thick shot-crete.

# CHAPTER VII

# IN SITU AND INDUCED STRESS ANALYSIS

## 7.1 Introduction

Previous tunneling experience shows that the rock at depth is subjected to stresses resulting from the weight of the overlying strata and from locked in stresses of tectonic origin. These stresses, which exist in virgin rock before excavation, are called the residual or in situ stresses. When an opening is excavated in this rock, the stress field is locally disrupted and new sets of stresses are induced in the rock surrounding the opening. The magnitudes and the directions of these in situ and induced stresses are the essential components of underground excavation design because, in many cases, the strength of the rock is exceeded and the resulting instability can have serious consequences on the behavior of the opening.

In the following sections of this chapter, the question of in situ stresses and also the stress changes that are induced when tunnels or caverns are excavated in stressed rock will be handled.

## 7.2 In Situ Stresses

The Swiss geologist Heim, observing the behavior of rock masses in the big trans-alpine tunnel excavations, was one of the first to conclude that the tunnels were highly stressed in all directions. He assumed that there was a vertical stress component $\sigma_v$ related to the weight of the rock overburden and proportional to it, but added that there was also a horizontal component $\sigma_h$ to the stresses. Heim related these residual stresses to the gigantic forces which, many million years ago, caused the mountain ridges of the Secondary and Tertiary geological periods to be lifted. According to Heim, the in situ stresses have a geological origin, a view to some extent confirmed by the fact that very large masses of rock

show a horizontal stress component much greater than the vertical stress field. This can only be satisfactorily explained by geological forces (Jaeger, 1979).

The vertical stress due to the overlying weight of rock at a particular depth is estimated from the simple relationship.

$$\sigma_v = \gamma z \tag{47}$$

where, $\sigma_v$ is the vertical stress

$\gamma$ is the unit weight of the overlying rock

$z$ is the depth below surface

The horizontal stress ($\sigma_h$) acting on an element of rock at a depth z below the surface are much more difficult to estimate than the vertical stresses ($\sigma_v$). Normally, the ratio of the average horizontal stress to the vertical stress is denoted by k holding the relationship:

$$\sigma = k\,\sigma = k\gamma z \tag{48}$$

Measurements of horizontal stresses at civil and mining sites around the world show that the ratio $k$ tends to be high at shallow depth and that it decreases at depth (Brown and Hoek, 1981). In order to understand the reason for these horizontal stress variations it is necessary to consider the problem on a much larger scale than that of a single mine site.

Sheory (1994) developed an elasto-static thermal stress model of the earth. This model considers curvature of the crust and variation of elastic constants, density and thermal expansion coefficients through the crust and mantle. A simplified equation, which can be used for estimating the horizontal to vertical stress ratio k, is:

$$k = 0.25 + 7E_h[0.01 + 1/z] \tag{49}$$

where z (m) is the depth below surface and $E_h$ (GPa) is the average deformation modulus of the upper part of the earth's crust measured in a horizontal direction.

## 7.3 Induced Stresses

As soon as an underground opening is excavated into a stressed rock mass, the stress fields in the vicinity of the new opening are re-shaped. An analytical solution for the stress distribution in a stressed elastic plate containing a circular hole was published by Kirsch (1898) and this formed the basis for many early studies of rock behavior around tunnels. The convention used in rock mechanics is that compressive stresses are always positive and the three principal stresses are numbered such that $\sigma_1$ is the largest and $\sigma_3$ is the smallest (algebraically) of the three.

Following along the path pioneered by Kirsch, researchers such as Love (1927), Muskhelishvili (1953) and Savin (1961) published solutions for excavations of various shapes in elastic plates.

Closed form solutions still possess great value for conceptual understanding of behavior and for the testing and calibration of numerical models. For design purposes, however, these models are restricted to very simple geometries and material models; and are of limited practical value (Hoek, 1998).

## 7.4 Numerical Methods of Stress Analyses

Most underground mining excavations are irregular in shape. These groups of 203 excavations, which may be stopes or the various service openings associated with a ramp or shaft system, form a set of complex three-dimensional shapes. In addition, since ore bodies are frequently associated with geological features such as faults and intrusions, the rock properties are seldom uniform within the rock volume of interest.

Consequently, the closed form solutions described earlier are of limited value in calculating the stresses, displacements and failure of the rock mass surrounding these mining excavations. Fortunately a number of computer-based numerical methods have been developed over the past few decades and these methods provide the means for obtaining approximate solutions to these problems. Numerical methods for the analysis of stress driven problems in rock mechanics can be divided into two classes, namely boundary methods and domain methods (Hoek, Kaiser, Bawden, 1995).

Boundary methods are the methods in which only the boundary of the excavation is divided into elements and the interior of the rock mass is represented mathematically as an infinite continuum.

Domain methods are the methods in which the interior of the rock mass is divided into geometrically simple elements each with assumed properties. The collective behavior and interaction of these simplified elements model the more complex overall behavior of the rock mass. Finite element and finite difference methods are domain techniques which treat the rock as a continuum. The distinct element method is also a domain method which models each individual block of rock as a unique element.

Hybrid approaches involve the combination of these two methods in order to maximize the advantages and minimize the disadvantage of each method. The objective of a hybrid method is to combine the above methods in order to eliminate undesirable characteristics while retaining as many advantages as possible. For example in modeling an underground excavation, most non-linearity will occur close to the excavation boundary, while the rock mass at some distance will behave in an elastic fashion. Thus, the near field rock mass might be modeled, using a distinct element or finite element method, which is then linked at its outer limits to a boundary element model, so that the far field boundary conditions are modeled exactly. In such an approach, the direct boundary element technique is favored as it results in 204 increased programming and solution efficiency.

### 7.4.1 The Phase$^2$ Software

PHASE$^2$ is a software which is able to compute the tunnel stress and deformation analyses through either boundary method, finite element method or hybrid method that is the combination of the former two methods. This two dimensional hybrid model computer program was developed by Rock Engineering Group of the University of Toronto, Canada in order to model the tunnels via the methods suggested by Hoek and Brown (Hoek, Kaiser and Bawden, 1995). Phase$^2$ is able to meet the requirements of modeling the post failure behavior of rock masses, to analyze the in situ and induced stresses and deformations around underground excavations and the interaction of these rocks with support.

The excavations can be designed in stages where the stresses calculated from predefined field stresses can be expressed either totally or for that particular stage only whenever desired. Support systems can be modeled for each stage separately. The load carried by support systems can be defined as the percentage of the total load of the system. Thereby, the rock mass can be allowed to carry its load itself in tolerable deformations and the remaining load can be transmitted to the support systems.

## 7.5 In Situ and Induced Stress Analysis of the Boztepe (T-1) and Öceli (T-2) Tunnels

The determination of the in situ and induced stresses and deformations developed around the Boztepe (T-1) and Öceli (T-2) tunnels and the interaction of the proposed support categories with the tunnel ground have been investigated by above introduced software Phase$^2$. In the analyses, four support categories determined by empirical relations for four different ground conditions categorized by NGI Q system in Tables 4.15 and 4.19 have been examined to observe the efficiency and accuracy of the support systems.

Ground category (I) : $10 \leq Q < 40$, supported by support category (I)
Ground category (II) : $4 \leq Q < 10$, supported by support category (II)
Ground category (III) : $1 \leq Q < 4$, supported by support category (III)
Ground category (IV) : $0.1 \leq Q < 1$, supported by support category (IV)

For each ground conditions of both tunnels, the most unsuitable conditions have been considered. Thereby, the geotechnical parameters for each ground conditions have been chosen in a way that the geotechnical parameters of the most critical structural domains (Table 3.2) included in one of the four ground conditions have been utilized in the analyses. In determining the most critical structural domains for each ground condition, the average tunneling depth, uniaxial compressive strength of the rock mass and the related Q values have been taken into consideration. These most critical domains and their related parameters will be mentioned in the following sections.

Each tunnel has been modeled as double tube with 12.0 m of span and 9.0 m height horseshoe shaped tunnel. The field stresses at portals have been modeled by gravity loading where the most critical ratios of $\sigma_h / \sigma_v$ (in plane)= k =1 and $\sigma_h / \sigma_v$ (out of plane)= k =0.5 have been used. In tunnel sections, on the other hand, constant field stress conditions where both ratios were taken as 1.0 being the most critical ratio have been applied.

Both double tubed tunnels have been modeled in two stage excavation as top heading and bench. This situation has been simulated in four stages by Phase$^2$. Accordingly, in the first stage, top heading was executed and let the rock mass to carry its load itself, then, in the second stage, the related supports were installed for the upper half. In the third stage, the bench was excavated and the related supports were installed in the fourth stage, similarly.

The analyses results present the outputs of the final excavation stages of the ground types in Appendix – I. These outputs consists of the illustrations of the analysis model, $\sigma_1$, $\sigma_3$, strength factor and total displacement queries.

### 7.5.1 In Situ and Induced Stress Analysis of the Boztepe (T-1) tunnel

Along the Boztepe (T-1) tunnel, four different ground conditions each of which supported by separate support categories have been determined as stated before. During the in situ and induced stress analysis, these four sections have been examined. The structural domains T1-4 and T1-Pn have been studied as the most critical sections of ground categories (III) and (IV), respectively while the structural domains T1-2 and T1-5 have been examined for ground categories (I) and (II). Hence, the geotechnical parameters (see Table 7.1) of these domains have been utilized in the analyses whose mesh model is given in Figure 7.1.

Table 7.1 Geotechnical parameters utilized in the hybrid analysis of the Boztepe (T-1) tunnel

| | | PORTAL SECTIONS | | TUNNEL SECTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| **Domain** | | *T1-Pn | T1-Px | T1-1 | T1-2 | T1-3 | *T1-4 | T1-5 |
| **KM Chainage** | | 23+015<br>23+050 | 26+290<br>26+323 | 23+050<br>23+375 | 23+375<br>24+000 | 24+000<br>25+000 | 25+000<br>25+775 | 25+775<br>26+290 |
| **RMR** | | 40.0 | 41.6 | 50.2 | 70.4 | 55.5 | 44.0 | 58.3 |
| **A-RMR** | | 38.65 | 39.46 | 50.75 | 69.51 | 53.20 | 50.77 | 59.01 |
| **MAX. Unsup. Span (m)** | | 1.47 | 1.45 | 1.80 | 2.00 | 1.85 | 1.82 | 1.90 |
| **MAX. Unsup. Wall Height (m)** | | 1.90 | 2.00 | 3.00 | 6.80 | 3.80 | 2.20 | 4.20 |
| **Q** | | 0.64 | 0.77 | 2.00 | 18.80 | 3.60 | 1.00 | 4.90 |
| **Q Interval** | | 0.1<Q<1.0 | 0.1<Q<1.0 | 1<Q<4 | 10<Q<40 | 1<Q<4 | 1<Q<4 | 4<Q<10 |
| **GSI (A-RMR-5)** | | 33.7 | 34.5 | 45.8 | 64.5 | 48.2 | 45.8 | 54.0 |
| **NATM Rock Description** | | B3 | B3 | B2 | A2 | B2 | B2 | B1 |
| **Young's modulus, E (MPa)** | | 2108 | 2108 | 3749 | 12999 | 5916 | 3354 | 8434 |
| **Poisson's Ratio, ν** | | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 |
| **Uniaxial Compressive Strength, $\sigma_c$ (MPa)** | | 25 | 25 | 25 | 30 | 35 | 20 | 40 |
| **Unit Weight, γ (MN/m$^3$)** | | 0.023 | 0.023 | 0.022 | 0.024 | 0.022 | 0.022 | 0.024 |
| **Cohesion, c (MPa)** | **A-RMR** | 0.2 | 0.2 | 0.25 | 0.35 | 0.25 | 0.25 | 0.3 |
| | **GSI** | 0.177 | 0.192 | 0.262 | 0.698 | 0.609 | 0.475 | 0.669 |
| **Internal Friction Angle, ϕ** | **A-RMR** | 25 | 25 | 30 | 40 | 30 | 30 | 35 |
| | **GSI** | 50 | 53 | 45 | 56 | 50 | 37 | 54 |
| **$m_i$** | | 13 | 19 | 7.1 | 19 | 16 | 9 | 17 |
| **$m_b$** | | 1.276 | 1.865 | 0.996 | 5.444 | 2.683 | 1.308 | 3.408 |
| **$s_i$** | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **s** | | 0.0007 | 0.0007 | 0.0022 | 0.0205 | 0.0039 | 0.0025 | 0.0067 |
| **Average Tunnel Depth, h (m)** | | 35.00 | 35.00 | 50.00 | 80.00 | 120.00 | 170.00 | 100.00 |
| **Support Category** | | IV | IV | III | I | III | III | II |

* The most critical structural domains regarding the ground conditions they are included.

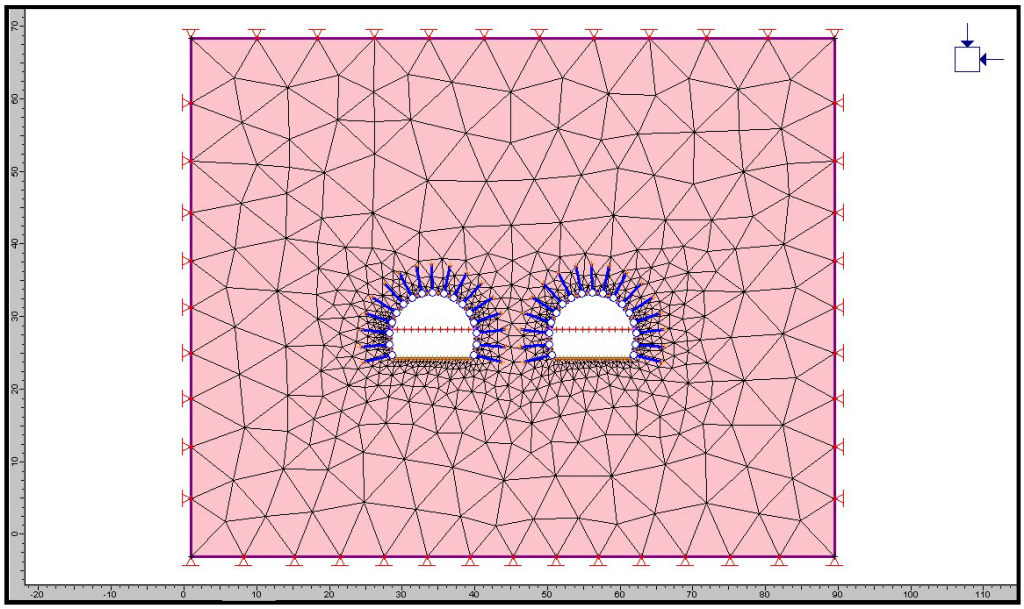


Figure 7.1 Finite element mesh for the analysis of the Boztepe (T-1) tunnel.

### 7.5.2 In Situ and Induced Stress Analysis of the Öceli (T-2) tunnel

Along the Öceli (T-2) tunnel, four different ground conditions each of which supported by separate support categories have been determined as stated before. During the in situ and induced stress analysis, these four sections have been examined. The structural domains T2-4 and T2-Px have been studied as the most critical sections of ground categories (III) and (IV), respectively while the structural domains T2-2 and T2-3 have been examined for ground categories (I) and (II). Hence, the geotechnical parameters (see Table 7.2) of these domains have been utilized in the analyses whose mesh model is given in Figure 7.2.

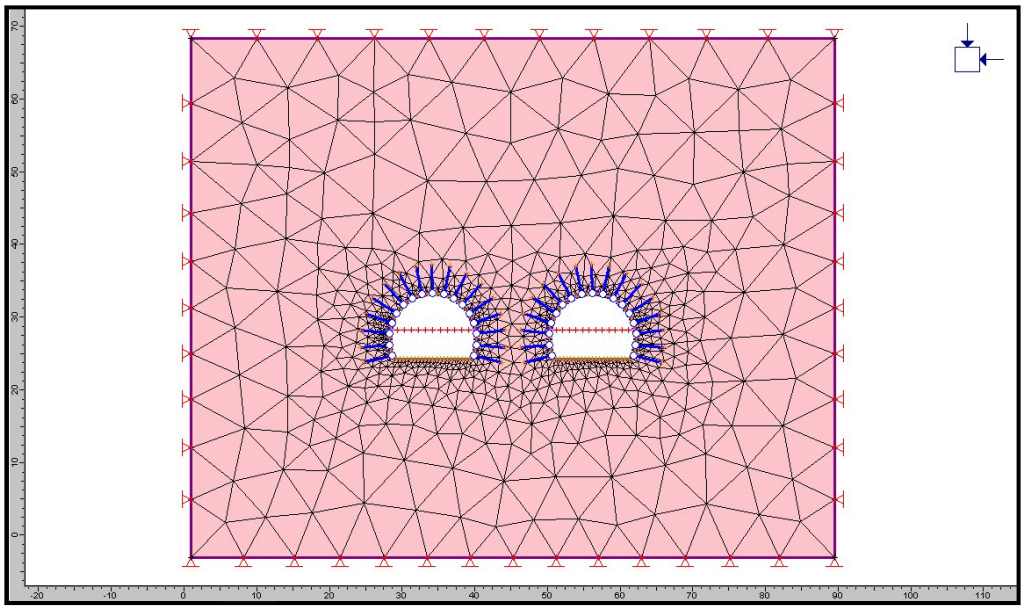


Figure 7.2 Finite element mesh for the analysis of the Öceli (T-2) tunnel.

Table 7.2 Geotechnical parameters utilized in the hybrid analysis of the Öceli (T-2) tunnel

| | | PORTAL SECTIONS | | | TUNNEL SECTIONS | | | |
|---|---|---|---|---|---|---|---|---|
| **Domain** | | T2-Pna | T2-Pnb | *T2-Px | T2-1 | T2-2 | T2-3 | *T2-4 |
| **KM Chainage** | | 26+453<br>26+550 | 26+458<br>26+550 | 27+750<br>28+492 | 26+550<br>26+800 | 26+800<br>27+050 | 27+050<br>27+375 | 27+375<br>27+750 |
| **RMR** | | 36.2 | 51.9 | 36.2 | 54.2 | 66.7 | 63.0 | 53.9 |
| **A-RMR** | | 38.33 | 50.08 | 35.33 | 54.36 | 64.48 | 59.75 | 55.92 |
| **MAX. Unsup. Span (m)** | | 1.40 | 1.80 | 1.30 | 1.87 | 2.00 | 1.92 | 1.90 |
| **MAX. Unsup. Wall Height (m)** | | 1.30 | 3.05 | 1.30 | 3.30 | 9.00 | 5.00 | 3.20 |
| **Q** | | 0.42 | 2.40 | 0.42 | 3.10 | 12.50 | 8.30 | 3.00 |
| **Q Interval** | | 0.1<Q<1.0 | 1<Q<4 | 0.1<Q<1.0 | 1<Q<4 | 10<Q<40 | 4<Q<10 | 1<Q<4 |
| **GSI** | | 31.2 | 46.9 | 31.2 | 49.2 | 61.7 | 58.0 | 48.9 |
| **NATM Rock Description** | | B3 | B2 | B3 | B2 | A2 | B1 | B2 |
| **Young's modulus, E (MPa)** | | 1334 | 5809 | 1000 | 4472 | 9740 | 5964 | 3873 |
| **Poisson's Ratio, $\nu$** | | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 | 0.25-0.30 |
| **Uniaxial Compressive Strength, $\sigma_c$ (MPa)** | | 10 | 60 | 10 | 20 | 30 | 20 | 15 |
| **Unit Weight, $\gamma$ (MN/m$^3$)** | | 0.024 | 0.024 | 0.024 | 0.025 | 0.025 | 0.025 | 0.024 |
| **Cohesion, c (MPa)** | **A-RMR** | 0.2 | 0.25 | 0.2 | 0.25 | 0.3 | 0.3 | 0.3 |
| | **GSI** | 0.137 | 0.394 | 0.123 | 0.366 | 0.604 | 0.389 | 0.291 |
| **Internal Friction Angle, $\phi$** | **A-RMR** | 25 | 30 | 25 | 30 | 35 | 35 | 35 |
| | **GSI** | 45 | 59 | 43 | 51 | 55 | 53 | 47 |
| **$m_i$** | | 16 | 16 | 16 | 19 | 19 | 19 | 14 |
| **$m_b$** | | 1.570 | 2.244 | 1.313 | 3.186 | 4.553 | 3.809 | 2.347 |
| **$s_i$** | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **s** | | 0.0007 | 0.0022 | 0.0004 | 0.0039 | 0.0117 | 0.0067 | 0.0039 |
| **Average Tunnel Depth, h (m)** | | 35.00 | 35.00 | 35.00 | 65.00 | 75.00 | 60.00 | 60.00 |
| **Support Category** | | IV | III | IV | III | I | II | III |

* The most critical structural domains regarding the ground conditions they are included.

### 7.5.3 Summary of the hybrid analysis results

In order to analyze the interaction of applied support systems with the rock mass and the in situ and induced stresses during the tunnel excavation, which has been modeled in four stages, the excavations have been studied for each structural domain conditions separately. The output illustrations of the analyses have been presented in Appendix – I.

The characteristics of the support elements used in the analyses have been presented in Table 7.3 where the tensile strength of the shotcrete has been taken as the 12 % of its compressive strength concordant with the engineering practices. The shear and tensile

strength of the steel wire mesh have been neglected. The plain strand cable type rock bolts with attached face plates have been modeled. The cable type has been chosen as S-420 whose properties have been supplied in Table 7.3. The support systems utilized can be said to be effective in mitigating the deformation affects as indicated by the considerable decrease in the volume of the yield zone after support installation.

The maximum stress concentration develops at the corner of the excavations whereas the maximum displacements occur at the base of the tunnel excavation. This situation can be explained by the heaving of the excavation base due to the removal of the rock mass.

Among the structural domains, the tunnel portals, especially the Öceli (T-2) tunnel exit portal, are the most critical according to the analyses results. The following tables, from Table 7.4 to Table 7.11, summarize the results of the analyses executed for each structural domain of the both tunnels.

Table 7.3 The characteristics of the support elements employed in the analyses.

| **Material type** | **Unit weight ($MN/m^3$)** | **E (MPa)** | **Poisson's ratio, ν** | **Cohesion c (MPa)** | **Int. friction angle ϕ** | **Comp. Strength (MPa)** | **Tensile strength (MPa)** |
|---|---|---|---|---|---|---|---|
| **Shotcrete** | 0.024 | 15000 | 0.20 | 2 | 37 | 10 | 1.20 |
| **Rock Bolt** | 0.079 | 210000 | - | - | - | 365 | 365 |

Table 7.4 Finite element analyses results of the Boztepe (T-1) tunnel: Ground Category (I).
a) Maximum Principal Stresses

| **Excavation Stage** | **Max. Principal Stress ($\sigma_1$) (MPa)** | | **Min. Principal Stress ($\sigma_3$) (MPa)** | | **Stresses on Rock Bolts** | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.95 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 5.87 | 3.72 | 0.0 | 1.04 | - | - | - |
| **3rd Stage** | 6.19 | 2.16 | 0.0 | 0.86 | - | - | - |
| **4th Stage** | 7.30 | 2.66 | 0.0 | 0.46 | - | - | - |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 15.38 | Compression | - | - |
| **2nd Stage** | 5.11 | Compression | 2.69 | Compression |
| **3rd Stage** | 4.85 | Compression | 4.63 | Compression |
| **4th Stage** | 4.11 | Compression | 3.76 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.33 | 0.21 | 0.45 | - | - | - |
| **2nd Stage** | 0.98 | 0.70 | 1.34 | - | - | - |
| **3rd Stage** | 1.23 | 1.13 | 1.61 | - | - | - |
| **4th Stage** | 1.46 | 1.30 | 1.90 | - | - | - |

Table 7.5 Finite element analyses results of the Boztepe (T-1) tunnel: Ground Category (II).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 2.52 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 6.99 | 1.98 | 0.0 | 6.29 | 0.010 | 18.27 | 0.017 |
| **3rd Stage** | 7.63 | 1.37 | 0.0 | 4.06 | 0.016 | 30.12 | 0.030 |
| **4th Stage** | 8.97 | 0.76 | 0.0 | 4.99 | 0.019 | 35.87 | 0.034 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 15.87 | Compression | - | - |
| **2nd Stage** | 5.72 | Compression | 5.05 | Compression |
| **3rd Stage** | 5.24 | Compression | 7.29 | Compression |
| **4th Stage** | 4.46 | Compression | 13.16 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.64 | 0.43 | 0.87 | - | - | - |
| **2nd Stage** | 1.87 | 1.33 | 2.59 | - | - | - |
| **3rd Stage** | 2.34 | 1.49 | 3.10 | - | 500 | - |
| **4th Stage** | 2.77 | 2.38 | 3.67 | - | 600 | - |

Table 7.6 Finite element analyses results of the Boztepe (T-1) tunnel: Ground Category (III).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.52 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 4.34 | 9.93 | 0.0 | 3.95 | 0.03 | 57.1 | 0.037 |
| **3rd Stage** | 3.43 | 8.45 | 0.0 | 5.63 | 0.05 | 89.1 | 0.061 |
| **4th Stage** | 3.81 | 9.95 | 0.0 | 0.75 | 0.05 | 92.7 | 0.067 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 13.16 | Compression | - | - |
| **2nd Stage** | 4.61 | Compression | 1.008 | Compression |
| **3rd Stage** | 5.83 | Compression | 1.180 | Compression |
| **4th Stage** | 5.25 | Compression | 1.005 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.92 | 0.60 | 1.26 | - | - | - |
| **2nd Stage** | 3.66 | 2.70 | 5.53 | 700 | 800 | 2800 |
| **3rd Stage** | 4.83 | 5.33 | 7.34 | 700 | 1650 | 3150 |
| **4th Stage** | 5.36 | 5.97 | 8.56 | 800 | 1500 | 4000 |

Table 7.7 Finite element analyses results of the Boztepe (T-1) tunnel: Ground Category (IV).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.03 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 2.26 | 4.32 | 0.0 | 0.46 | 0.009 | 16.77 | 0.014 |
| **3rd Stage** | 2.96 | 4.95 | 0.0 | 0.36 | 0.040 | 74.37 | 0.060 |
| **4th Stage** | 3.50 | 6.15 | 0.0 | 0.15 | 0.041 | 77.37 | 0.060 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 24.27 | Compression | - | - |
| **2nd Stage** | 11.06 | Compression | 2.32 | Compression |
| **3rd Stage** | 8.45 | Compression | 2.02 | Compression |
| **4th Stage** | 7.14 | Compression | 1.63 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 1.16 | 0.75 | 1.27 | - | - | - |
| **2nd Stage** | 2.93 | 2.02 | 3.84 | - | - | - |
| **3rd Stage** | 4.03 | 3.44 | 5.36 | - | 1150 | 750 |
| **4th Stage** | 4.49 | 3.85 | 6.26 | - | 1130 | 750 |

Table 7.8 Finite element analyses results of the Öceli (T-2) tunnel: Ground Category (I).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.94 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 5.75 | 2.88 | 0.0 | 1.36 | - | - | - |
| **3rd Stage** | 5.88 | 2.78 | 0.0 | 1.78 | - | - | - |
| **4th Stage** | 6.94 | 3.44 | 0.0 | 0.60 | - | - | - |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 15.46 | Compression | - | - |
| **2nd Stage** | 5.22 | Compression | 3.47 | Compression |
| **3rd Stage** | 5.10 | Compression | 3.59 | Compression |
| **4th Stage** | 4.32 | Compression | 2.91 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.43 | 0.28 | 0.59 | - | - | - |
| **2nd Stage** | 1.28 | 0.87 | 1.76 | - | - | - |
| **3rd Stage** | 1.60 | 1.35 | 2.10 | - | - | - |
| **4th Stage** | 1.89 | 1.60 | 2.48 | - | - | - |

Table 7.9 Finite element analyses results of the Öceli (T-2) tunnel: Ground Category (II).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.56 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 4.23 | 6.07 | 0.0 | 1.76 | 0.007 | 14.06 | 0.013 |
| **3rd Stage** | 4.64 | 3.76 | 0.0 | 1.59 | 0.015 | 27.65 | 0.025 |
| **4th Stage** | 5.44 | 4.75 | 0.0 | 0.71 | 0.017 | 31.08 | 0.028 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 12.82 | Compression | - | - |
| **2nd Stage** | 4.73 | Compression | 1.65 | Compression |
| **3rd Stage** | 4.31 | Compression | 2.66 | Compression |
| **4th Stage** | 3.68 | Compression | 2.11 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.56 | 0.32 | 0.77 | - | - | - |
| **2nd Stage** | 1.64 | 0.95 | 2.30 | - | - | - |
| **3rd Stage** | 2.07 | 1.73 | 2.76 | - | - | - |
| **4th Stage** | 2.44 | 2.05 | 3.27 | - | - | - |

Table 7.10 Finite element analyses results of the Öceli (T-2) tunnel: Ground Category (III).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 1.44 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 3.64 | 0.073 | 0.0 | -0.067 | 0.0096 | 17.92 | 0.016 |
| **3rd Stage** | 4.13 | 0.127 | 0.0 | -0.073 | 0.0203 | 38.29 | 0.037 |
| **4th Stage** | 4.64 | 0.160 | 0.0 | -0.090 | 0.0234 | 44.15 | 0.043 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 10.42 | Compression | - | - |
| **2nd Stage** | 4.12 | Compression | 137.00 | 17.90 |
| **3rd Stage** | 3.63 | Compression | 78.74 | 16.44 |
| **4th Stage** | 3.23 | Compression | 62.50 | 13.30 |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 0.85 | 0.51 | 1.11 | - | - | - |
| **2nd Stage** | 2.32 | 1.63 | 3.38 | - | - | 1000 |
| **3rd Stage** | 3.31 | 3.35 | 4.43 | - | 1100 | 2000 |
| **4th Stage** | 3.87 | 4.00 | 5.49 | - | 1500 | 2400 |

Table 7.11 Finite element analyses results of the Öceli (T-2) tunnel: Ground Category (IV).

a) Maximum Principal Stresses

| Excavation Stage | Max. Principal Stress ($\sigma_1$) (MPa) | | Min. Principal Stress ($\sigma_3$) (MPa) | | Stresses on Rock Bolts | | |
|---|---|---|---|---|---|---|---|
| | Rock Mass | Shotcrete | Rock Mass | Shotcrete | Max. Axial Force (MN) | Max. Axial Stress (MPa) | Average Shear Stress between rock mass and bolt (MPa) |
| **1st Stage** | 0.88 | - | 0.0 | - | - | - | - |
| **2nd Stage** | 2.38 | 0.72 | 0.0 | 0.360 | 0.068 | 127.43 | 0.786 |
| **3rd Stage** | 1.60 | 0.58 | 0.0 | -0.019 | 0.195 | 367.89 | 0.309 |
| **4th Stage** | 2.03 | 0.95 | 0.0 | 0.143 | 0.197 | 370.81 | 0.312 |

b) Ratios of Strength / Maximum Principal Stresses

| Excavation Stage | Rock Mass | | Shotcrete | |
|---|---|---|---|---|
| | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ | $\sigma_{ci} / \sigma_1$ | $\sigma_t / \sigma_3$ |
| **1st Stage** | 11.36 | Compression | - | - |
| **2nd Stage** | 4.20 | Compression | 13.89 | Compression |
| **3rd Stage** | 6.25 | Compression | 17.24 | 63.16 |
| **4th Stage** | 4.93 | Compression | 10.54 | Compression |

c) Displacements and plastic zone dimensions

| Excavation Stage | Displacement (mm) | | | Plastic zone thickness (mm) | | |
|---|---|---|---|---|---|---|
| | Roof | Wall | Base | Roof | Wall | Base |
| **1st Stage** | 2.87 | 1.51 | 2.68 | 800 | 950 | - |
| **2nd Stage** | 6.79 | 5.49 | 8.44 | 800 | 950 | 1500 |
| **3rd Stage** | 14.78 | 16.90 | 13.31 | 800 | 2800 | 2500 |
| **4th Stage** | 15.15 | 17.79 | 15.69 | 800 | 2800 | 3000 |

# CHAPTER VIII

# CONCLUSIONS AND RECOMMENDATIONS

In this thesis, the stability of the tunnels and the tunnel portals of the Ordu peripheral highway have been investigated. The rock mass conditions together with the geotectonical characteristics in both regional and local scale have been assessed to suggest appropriate support design and stabilization techniques along the two long double-tube highway tunnels, namely, 3310 meter-long Boztepe (T-1) and 2035 meter-long Öceli (T-2) tunnels. Temelsu International Engineering Services Inc. has taken the responsibility of the design works for the entire project.

The regional geological and tectonical studies have revealed that the area is situated in a place where the geomorphology has been shaped by the characteristics of convergent plate boundary and the related lithological formations. In the light of these information, a geotectonical model has been constructed. In regards to that model, the sedimentary and volcanic rocks shall show lateral and vertical transitions so often since the mode of occurrences of these formations are controlled by convergence of the plates where sub-marine conditions are dominant. The common rock types observed in the area, accordingly, are the agglomerates, tuff, flysch type sedimentary rocks and basaltic lavas. Both tunnel alignments pass through these rock types, which are highly intertounguing laterally and vertically.

According to the constructed geotectonical model, surface and subsurface investigations, the rock masses surrounding both tunnels have been classified by rock mass classifications of RMR, Q, GSI, NATM, and new attempt A-RMR into four main rock classes each of which is supported by different support systems. These rock mass groups are:

1) $10 \leq Q$, where the rock is defined as A2 by NATM (Ground/Support category I).
2) $4 \leq Q < 10$, where the rock is defined as B1 by NATM (Ground/Support category II).
3) $1 \leq Q < 4$, where the rock is defined as B2 by NATM (Ground/Support category III).
4) $0.4 \leq Q < 1$, where the rock is defined as B3 by NATM (Ground/Support category IV).

After the implementation of rock mass classifications (NGI-Q, A-RMR, GSI, and NATM), four tunnel support categories and the related geotechnical rock mass parameters forming tunnels have been determined. These parameters gathered from empirical classifications and from lab tests have been correlated.

The most conservative rock mass parameters, which are the values from A-RMR, have been employed in portal slope stability analyses. The rock mass parameters obtained through A-RMR classification has been employed in the portal slope design. The primarily determined slope angles from the charts have been checked by the slope stability analyses. As a first step, kinematical analyses, have been made by the aid of computer program DIPS (Rocsicence, 2002) using stereographic projection method. There has been only one case where the kinematical analyses indicated failure possibility, a plane failure possibility for the Öceli (T-2) tunnel exit portal face. Thereupon, the limit equilibrium analysis has been performed for that particular slope location where bedding planes of limestone and sandstone members of flysch structurally control the stability with their orientations of 110/15º. The factor of safety (F.S) of 2.952 obtained at the end of this analysis has been proved the stability even in earthquake case ($a_h/g=0.1$).

The analytical analyses, then, have been executed for the weathered zones observed in the field by another computer program SLIDE (Rocsicence, 2002) performing Bishop's simplified method. These zones are highly weathered parts of the underlying either volcanic or sedimentary rocks, therefore, they behave like a residual soil in engineering regard. This condition has brought the necessity of checking circular failure contingency within these zones whose depth shows variation between 5.0 to 15.0 m. At the end of the calculations, it's observed that all the slopes are stable with the pre-determined slope angles and providing the required limits of factor of safety, which are F.S.≅1.5 for statical conditions and F.S.≅1.3 for dynamical conditions in which earthquake acceleration has been considered.

These support categories have also been modeled in the computer program Phase$^2$ (finite element stress analysis and support design for excavations, Rocscience Inc., 2002) where excavation has been designed in four stages as:

1st stage: Excavation of the upper half of the tunnel.

2nd stage: Supporting of the upper half of the tunnel.

3rd stage: Excavation of the lower half of the tunnel.

4th stage: Supporting of the lower half of the tunnel.

To obtain the entries to this modeling, which are the rock mass geotechnical parameters as c (cohesion), ϕ (internal friction angle), m, s and E (Young's modulus), a computer program RocLab has been used. Being capable of determination of the rock mass parameters via both Mohr-Coulomb and Hoek-Brown failure criterions, this program supplies the values after inputting GSI, uniaxial intact rock strength ($\sigma_{ci}$), $m_b$, s, unit weight and the depth of the tunnel section examined. The comparison of the field estimations and the laboratory results for determining these parameters have been made. According to this comparison, "ϕ" values can be said to be successful when they are compared with the results from lab tests. In case of "c" values, on the other hand, the results display wide range of numbers. The Mohr-Coulomb criterion can only calculate the cohesion of intact rock samples without integrated with GSI or A-RMR ratings. However, Hoek-Brown criterion calculates the rock mass c and ϕ values via GSI which is taken as 50 (average rock quality) by RocLab. This is the reason why c values of Hoek-Brown criterion are much smaller than that of Mohr-Coulomb. On the other hand, the values approximated via A-RMR, which are more conservative values rather than that of Hoek-Brown criterion, have been utilized in the slope stability analyses. The geotechnical parameter "$m_i$" value from the estimation charts and the lab results show similarity most of the time. Hence, the field estimation values in the finite element analyses have been utilized.

The results of the finite element analyses executed for each pre-determined ground conditions of the tunnels have revealed that the support systems determined by means of empirical rock mass classification systems, namely, Q-system and NATM, work well and stop the further deformation as they have been applied. Support systems have been successful in controlling the dimensions of the plastic zone occurring inevitably around the tunnel openings. The deformation values of the rock mass reflecting the most unsuitable conditions have been calculated within the limits of the acceptable range.

However, just incase, it is suggested that continuous deformation measurements should be made during construction at each step of excavation. The sharp corners where the maximum stress concentration has been observed during the finite element analyses should be avoided or smoothened, especially in underground excavations. In case of any local

geological adversities in tunnel construction, support category relevant to the in situ calculated Q value, should be applied. In order not to weaken the rock mass and control the deformations, the smooth blasting and pre-splitting are recommended in tunnel and at portal, respectively.

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# APPENDIX – A
# GEOLOGICAL MAPS AND PROFILES

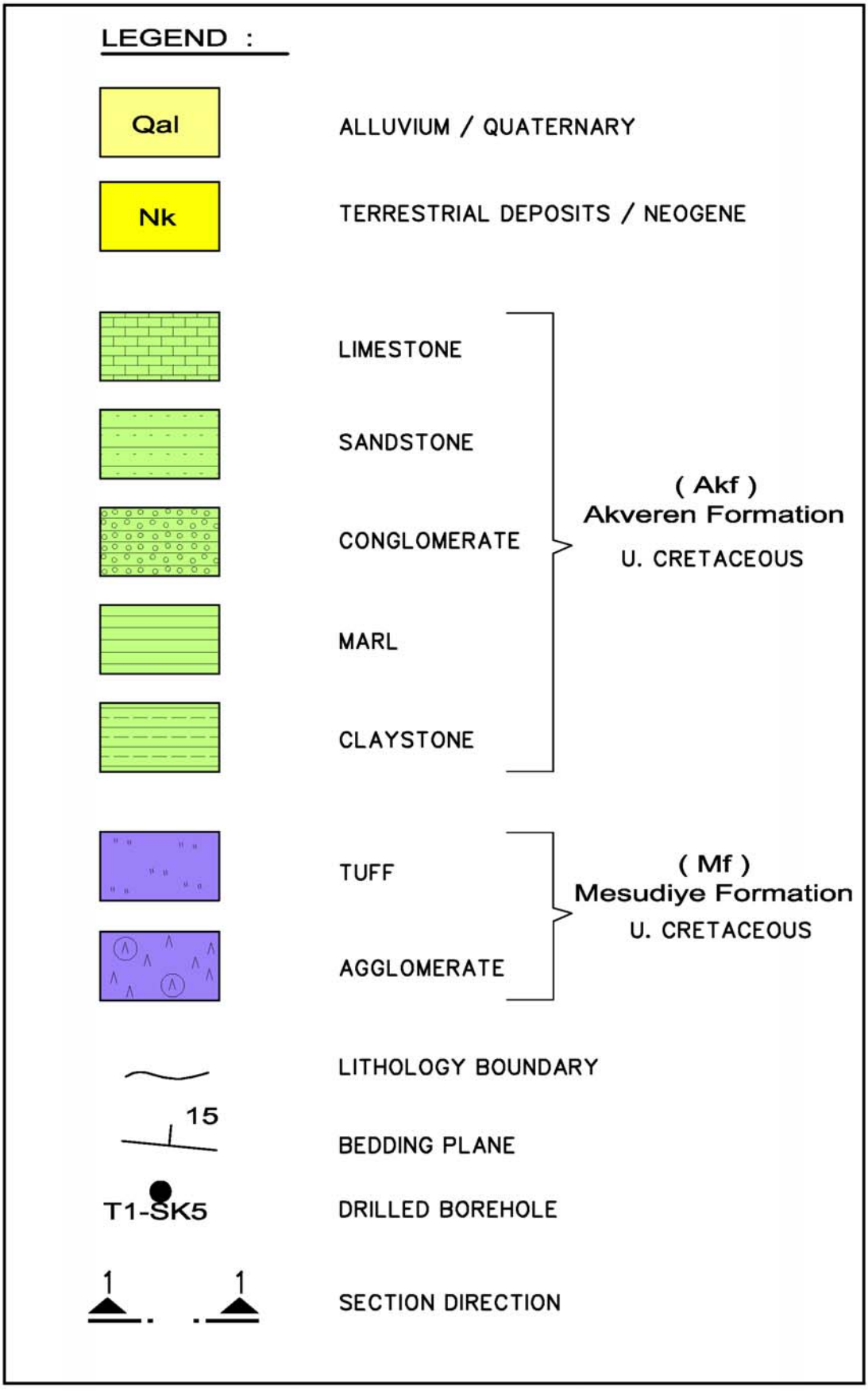
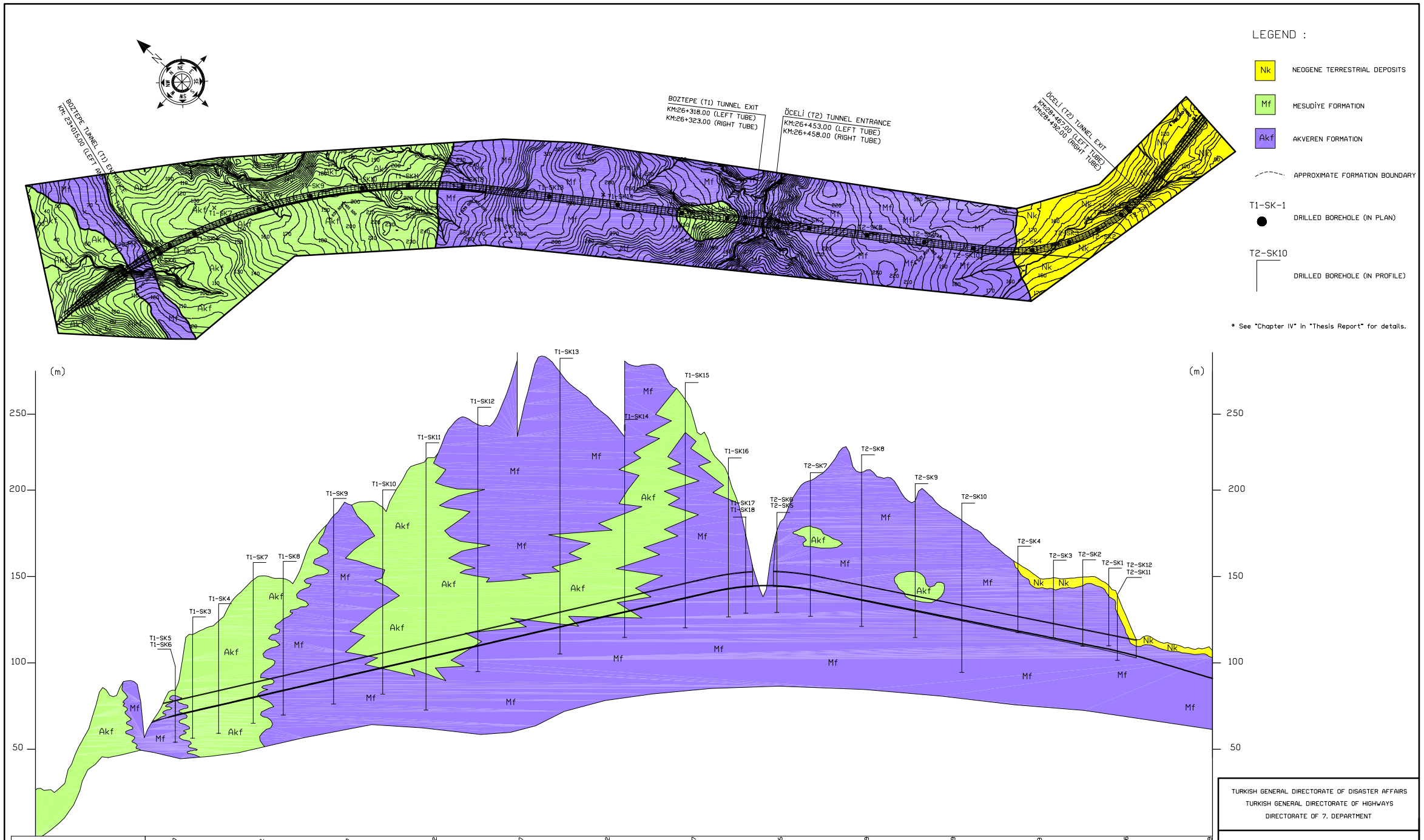



Figure 1. Legend of the geological maps and profiles.




| PLANNED ROAD / TUNNEL ELAVATION | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KILOMETER | 23+069.7 | 23+081.2 | 24+092.7 | 24+104.2 | 25+115.7 | 25+127.2 | 26+038.7 | 26+044.5 | 27+035.9 | 27+045.9 | 28+055.9 | 28+065.6 | 28+075.9 | | | | | |
| STRUCTURAL DOMAIN | T1-Pn | T1-1 | T1-2 | T1-3 | T1-4 | T1-5 | T1-Px | T2-Pn | T2-1 | T2-2 | T2-3 | T2-4 | T2-Px | | | | | |
| NGI Q | 0.64 | 2.00 | 18.80 | 3.60 | 1.00 | 4.90 | 0.77 | 0.42<br>2.40 | 3.10 | 12.50 | 8.30 | 3.00 | 0.42 | | | | | |
| A-RMR | 38.65 | 50.75 | 69.51 | 53.20 | 50.77 | 59.01 | 39.46 | 38.32<br>50.08 | 54.36 | 64.48 | 59.75 | 55.92 | 35.33 | | | | | |
| RMR | 40.0 | 50.2 | 70.4 | 55.5 | 44.0 | 58.3 | 41.6 | 36.2<br>51.9 | 54.2 | 66.7 | 63.0 | 53.9 | 36.2 | | | | | |
| GSI | 33.7 | 45.8 | 64.5 | 48.2 | 45.8 | 54.0 | 34.5 | 31.2<br>46.9 | 49.2 | 61.7 | 58.0 | 48.9 | 31.2 | | | | | |
| NATM | B3 | B2 | A2 | B2 | B3 | B1 | B3 | B3<br>B2 | B2 | A2 | B1 | B2 | B3 | | | | | |
| GROUND CONDITION (Q INTERVAL) | 0.1<Q<1.0 | 1.0 < Q < 4.0 | 10 < Q < 40 | 1.0 < Q < 4.0 | 1.0 < Q < 4.0 | 4.0 < Q < 10.0 | 0.1<Q<1 | 0.1<Q<1<br>1<Q<4 | 1.0<Q<4.0 | 10.0< Q <40.0 | 4.0 < Q < 10.0 | 1.0 < Q < 4.0 | 0.1 < Q < 1.0 | | | | | |
| SUGGESTED SUPPORT CATEGORY* | IV | III | I | III | III | II | IV | IV<br>III | III | I | II | III | IV | | | | | |

TURKISH GENERAL DIRECTORATE OF DISASTER AFFAIRS
TURKISH GENERAL DIRECTORATE OF HIGHWAYS
DIRECTORATE OF 7. DEPARTMENT

ORDU PERIPHERAL HIGHWAY
KM: 21+000.000 - 40+114.000

Figure 2.
GEOLOGICAL PLAN AND PROFILE
OF
BOZTEPE (T-1) AND ÖCELİ (T-2) TUNNELS
(LEFT TUBE: KM: 23+015-26+318) (LEFT TUBE: KM: 26+453-28+467)
(RIGHT TUBE: KM: 23+015-26+323) (RIGHT TUBE: KM: 26+458-28+492)

Figure 2. Geological Plan and Profile of Boztepe (T-1) and Öceli (T-2) Tunnels.

Figure 3. Geological map of the Boztepe (T-1) tunnel entrance portal.

Figure 4. Geological map of the area between the Boztepe (T-1) tunnel exit portal and the Öceli (T-2) tunnel entrance portal.

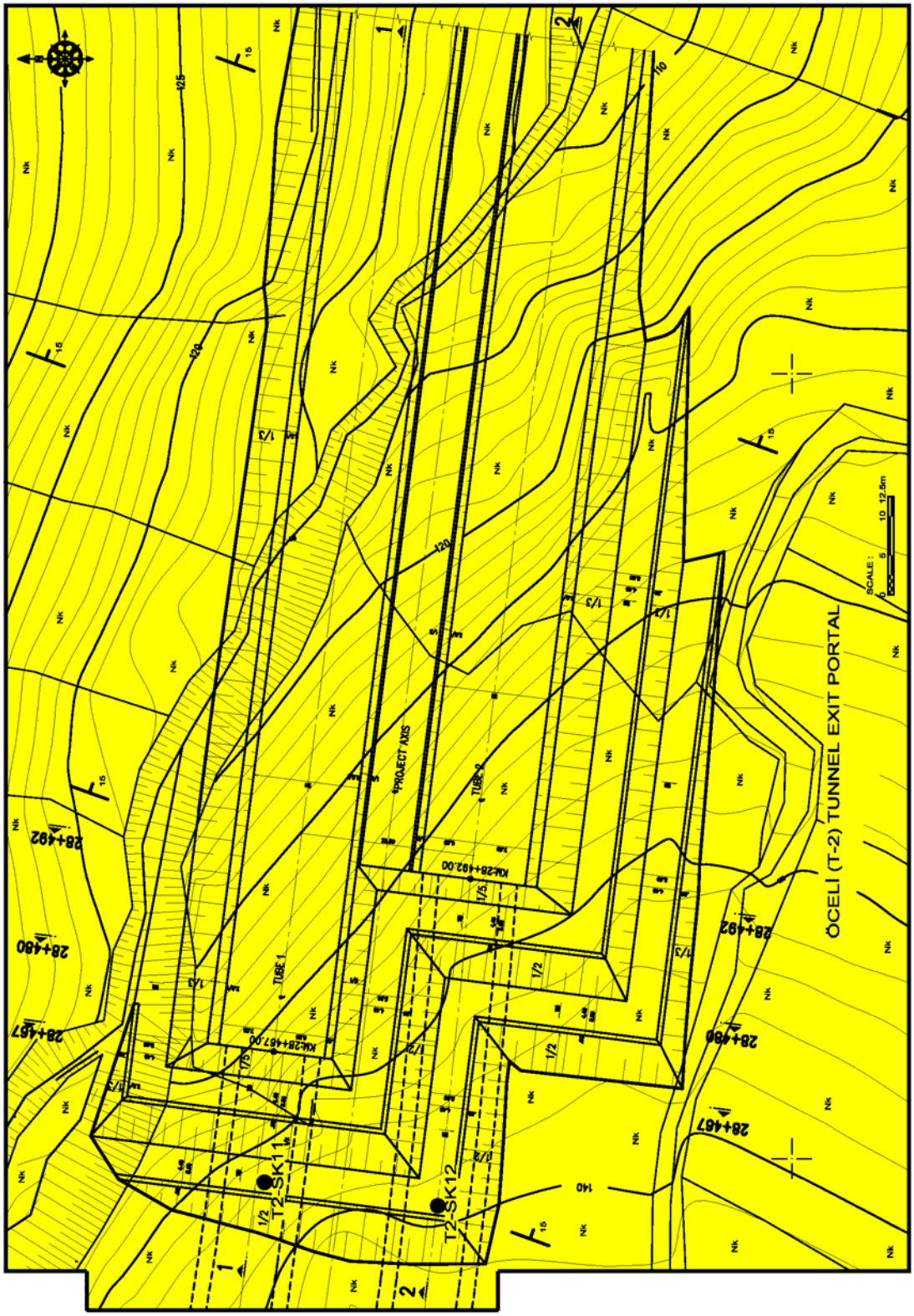



Figure 5. Geological map of the Öceli (T-2) tunnel exit portal.

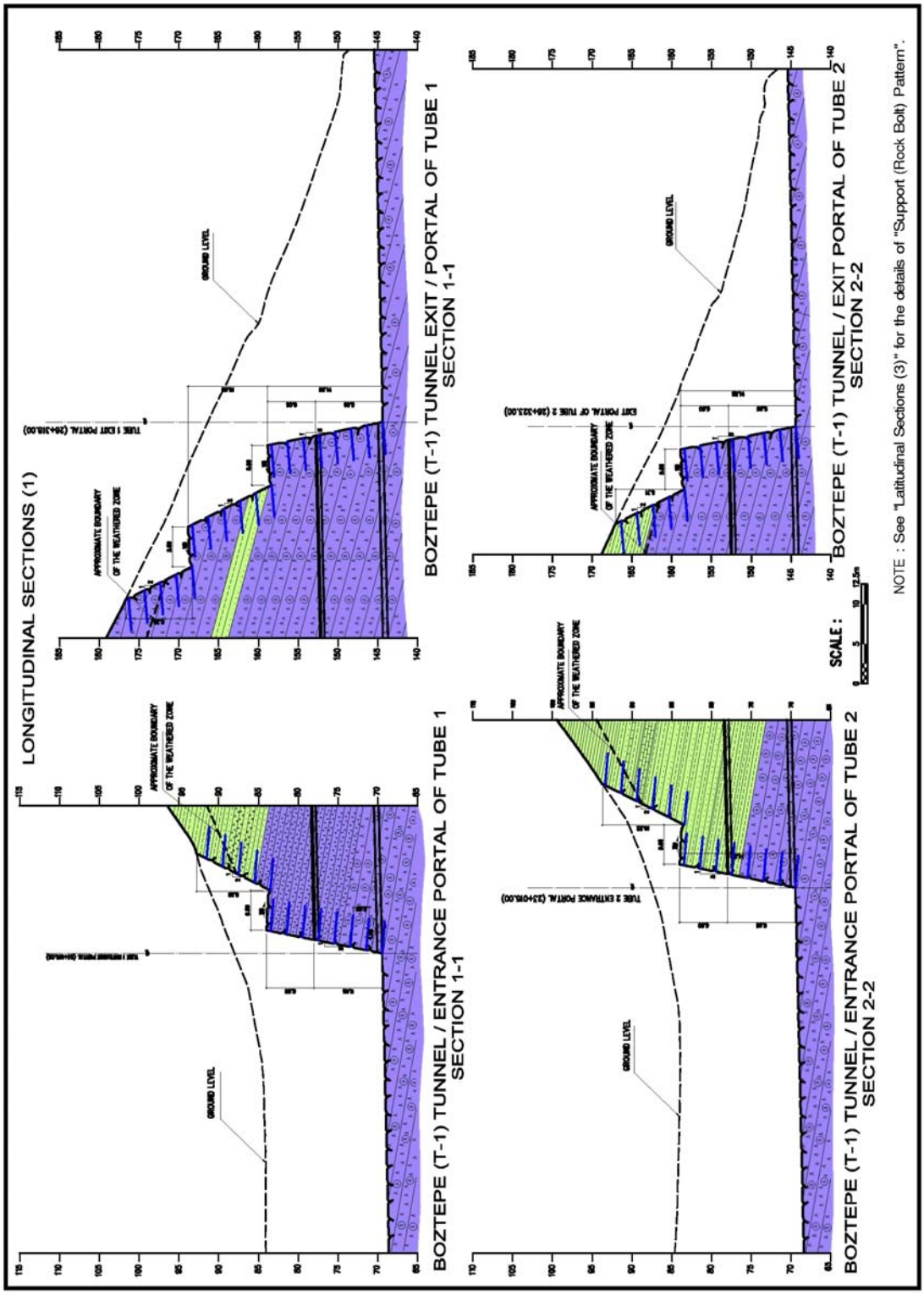



Figure 6. Geological longitudinal sections of the Boztepe (T-1) tunnel portals.

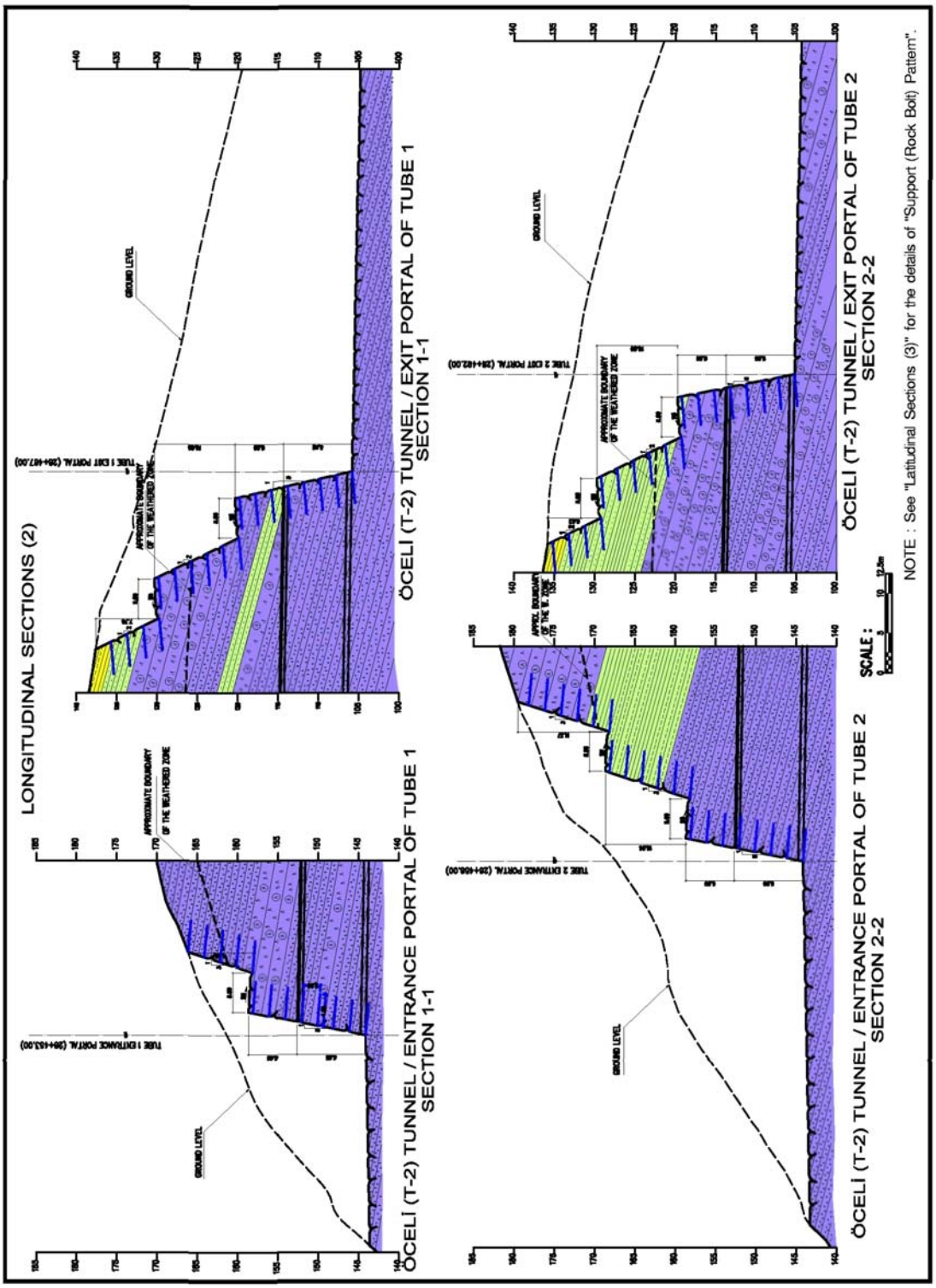



Figure 7. Geological longitudinal sections of the Öceli (T-2) tunnel portals.

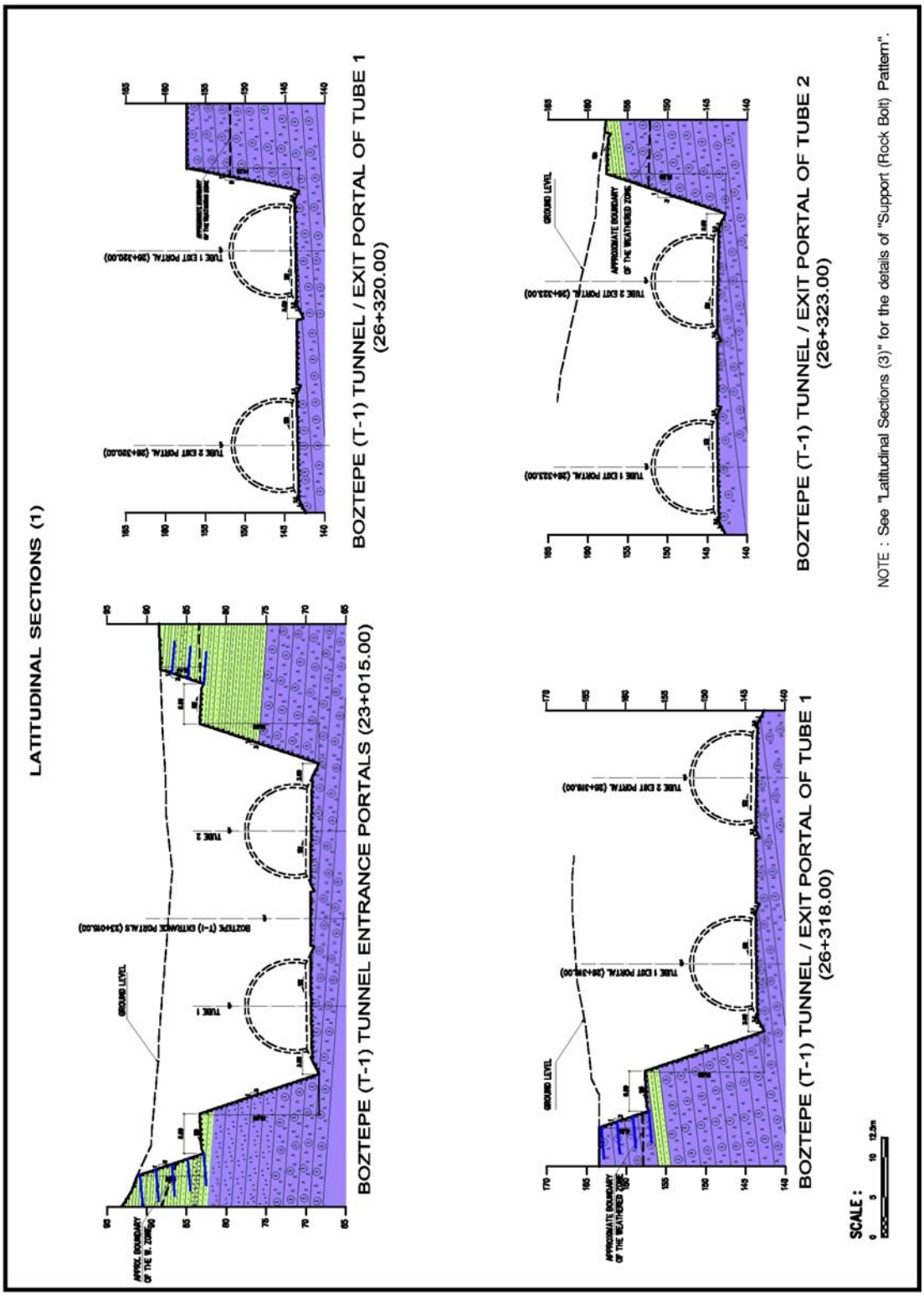



Figure 8. Geological latitudinal sections of the Boztepe (T-1) tunnel portals.

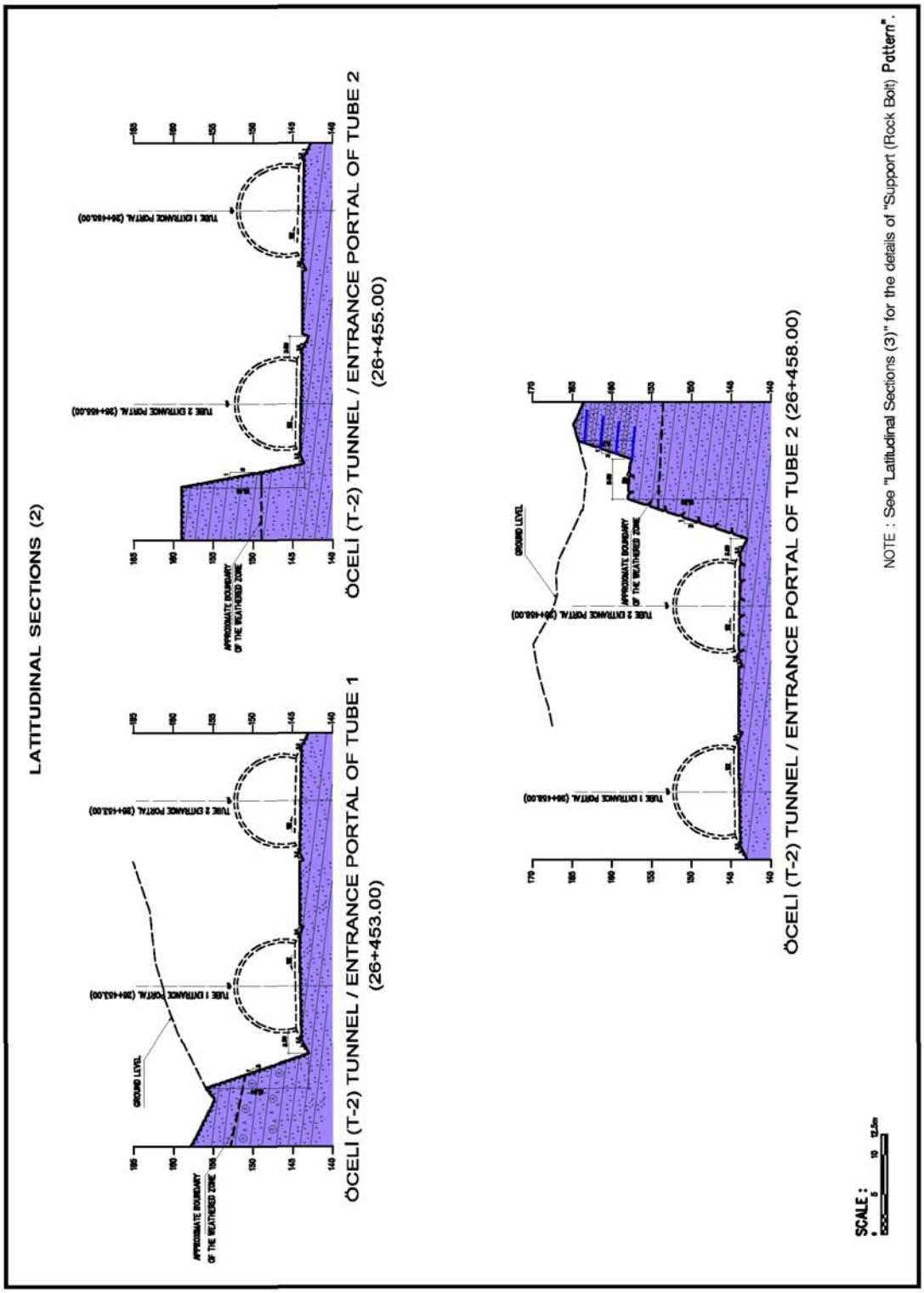



Figure 9. Geological latitudinal sections of the Öceli (T-2) tunnel entrance portals.

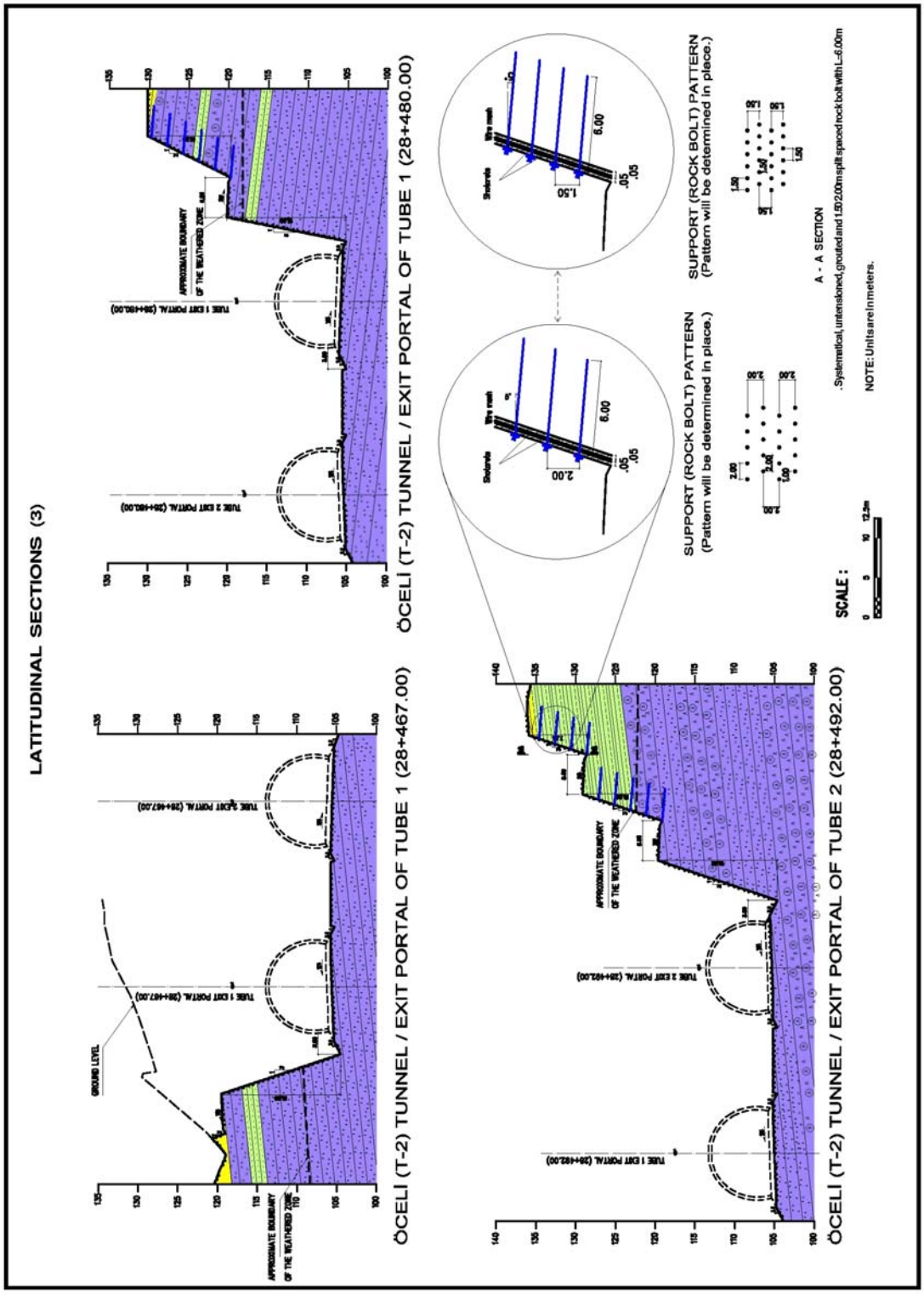



Figure 10. Geological latitudinal sections of the Öceli (T-2) tunnel exit portals.

# APPENDIX – B
# DRILLING LOGS

# THE BOZTEPE (T-1) TUNNEL

| TEMELSON | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK3

SAYFA / PAGE NO : 2/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 9 | 10.50 | | | | | | | 10 | 100 |
| | | | 10 | 11.00 | | | | | | | 40 | 50 |
| 11 | | | 11 | 12.00 | | | | | | | 90 | 100 |
| 12 | | | 12 | 13.00 | | NW | | | | | 50 | 87 |
| 13 | | | 13 | 13.70 | | | | | | | 43 | 89 |
| 14 | | **MARN + KİLTAŞI ($E_f$)** Gri - koyu gri, orta çok ayrışmalı ve zayıf. Çoğu düzeylerde orta kalınlıkta kireçtaşı ara katmanları ardalanmakta. | 14 | 15.00 | | | | | | Genellikle çok çatlaklı ve kırıklı düzlemler kil dolgulu ve kalsit sıvalı. | 20 | 93 |
| 15 | | | 15 | 16.00 | | | | | | | 50 | 53 |
| 16 | | | 16 | 17.00 | | | | | | | 90 | 100 |
| 17 | | | 17 | 18.50 | 54 | | | | | | 10 | 64 |
| 18 | | | 18 | 19.00 | | | | | | | 90 | 100 |
| 19 | | | 19 | 20.00 | | | | | | | 10 | 87 |
| 20 | | | 20 | 21.00 | | | | | | | 15 | 100 |
| 21 | | | 21 | 22.50 | | | | | | | 53 | 92 |
| 22 | | | 22 | 23.00 | | | | | | | 90 | 92 |
| 23 | | | 23 | | | | | | | | 50 | 70 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK3

SAYFA / PAGE NO : 3/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 24 | 25.00 | | | | | | | 90 | 100 |
| 25 | | Tanımlama sayfa 2/4'de. | 25 | 26.00 | | | | | | Tanımlama Sayfa 2/4'de. | 30 | 70 |
| 26 | | | 26 | 27.00 | | | | | | | 31 | 83 |
| 27 | | | 27 | 28.00 | | | | | | | 40 | 72 |
| 28 | | **MARN + KİREÇTAŞI ($E_f$)** | 28 | 29.00 | | | | | | | 10 | 78 |
| 29 | | Beyaz-kirli beyaz, orta ayrışmalı zayıf MARN ve taze dayanımlı KİREÇTAŞI ardalanması. | 29 | 29.50 | | | | | | Çok çatlaklı ve kırıklı. | 40 | 76 |
| | | | 30 | 30.00 | | | | | | | 35 | 96 |
| 30 | | | 31 | 31.00 | | | | | | | 40 | 90 |
| 31 | | | 32 | 31.50 | 54 | | | | | | 10 | 96 |
| | | | 33 | 32.00 | | | | | | | 13 | 90 |
| 32 | | **KİREÇTAŞI ($E_f$)** Açık gri beyazımsı, taze ve dayanımlı. | 34 | 33 | | | | | | | 90 | 100 |
| 33 | | | 35 | 34.00 | | | | | | | 0 | 80 |
| 34 | | | 36 | 35.00 | | | | | | KİLTAŞI düzeyleri çok çatlaklı ve kırıklı. | 0 | 81 |
| 35 | | **KİLTAŞI ($E_f$)** Gri orta ayrışmalı ve zayıf.Kimi düzeylerde orta kalınlıkta; az ayrışmalı, orta dayanımlı KUMTAŞI ara katmanları içermekte. | 37 | 36.00 | | | | | | | 10 | 77 |
| 36 | | | 38 | 37.00 | | | | | | | 0 | 78 |
| 37 | | | 39 | | | | | | | | 30 | 83 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK3

SAYFA / PAGE NO : 4/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Tanımlama sayfa 3/4'de. | 35 | 39.00 | 54 | | | | | Tanımlama Sayfa 3/4'de. | 30 | 91 |
| | | | 36 | 40.00 | | | | | | | 100 | 100 |
| 40 | | | | 41.00 | | | | | | | 68 | 100 |
| 41 | | | | | | | | | | | 50 | 72 |
| 42 | | | | 43.00 | | | | | | | | |
| 43 | | **KİLTAŞI ($E_f$)** Gri, az orta ayrışmalı ve orta zayıf. | | 44.00 | | | | | | | 60 | 90 |
| 44 | | | | 45.00 | | | | | | | 100 | 100 |
| 45 | | **KİREÇTAŞI + KUMTAŞI ($E_f$)** Açık gri beyazımsı taze - az ayrışmalı dayanımlı - orta dayanımlı KİREÇTAŞI ve az ayrışmalı, orta dayanımlı KUMTAŞI ardalanması. Kireçtaşı egemen. | | 46.00 | | | | | | Çok çatlaklı ve kırıklı. | 90 | 100 |
| 46 | | | | 47.00 | | | | | | | 80 | 91 |
| 47 | | | | 48.00 | | | | | | | 100 | 100 |
| 48 | | | | 49.00 | | | | | | | 50 | 90 |
| 49 | | | | 50.00 | | | | | | | 90 | 100 |
| 50 | | KUYU SONU 50.00 m | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T1-SK4

SAYFA / PAGE NO : 1/5

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 124.90 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 1 | KOORD. / COORD. N-S (x) : 4 539 984 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (y) : 400 825 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+250 | | | | |
| BASL. TAR. / START DATE : 22.05.2000 | SAPMA / OFFSET (m) : - | | | | |
| BİTİŞ TAR. / FINISH DATE : 30.05.2000 | DERİNLİK / DEPTH (m) : 55.00 | | | | |

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BİTKİSEL TOPRAK** | | | | | | | | | | |
| 1 | | | 1 | 1.50 | | | | | | Ayrışma nedeniy-le süreksizlik göz-lenmedi. | 80 | 93 |
| 2 | | **KİLTAŞI (Eosen flişi-$E_f$)** Açık kahverengi, gri, çok-bütü-nüyle ayrışmalı ve zayıf - çok zayıf. | 2 | 3.00 | | | | | | | 53 | 92 |
| 3 | | | 3 | 4.50 | | | | | | | 63 | 86 |
| 4 | | | | | | | | | | | | |
| 5 | | | 4 | 6.00 | 54 | NW | | | | | 40 | 86 |
| 6 | | | 5 | 7.50 | | | | | | | 62 | 79 |
| 7 | | **MARN ($E_f$)** Açık gri, açık mavimsi, orta çok ayrışmalı ve zayıf. | | | | | | | | | | |
| 8 | | | 6 | 9.00 | | | | | | Çok çatlaklı ve kırıklı, düzlemler paslı. | 73 | 92 |
| 9 | | | 7 | | | | | | | | 20 | 92 |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | | | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | ZİHNİ EFE | |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXCELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATHERED | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | H.A.TİRYAKİ | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEATHERED | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK4

SAYFA / PAGE NO : 2/5

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama Sayfa 1/5'de. | 8 | 11.50 | | NW | | | | | 27 | 76 |
| | | | 9 | 12.00 | | | | | | | 0 | 100 |
| 12 | | | 10 | 13.00 | | | | | | Tanımlama Sayfa 1/6'de. | 30 | 100 |
| 13 | | | 11 | 14.00 | | | | | | | 30 | 82 |
| 14 | | | 12 | 15.50 | | | | | | | 38 | 87 |
| 15 | | | 13 | 16.00 | | | | | | | 24 | 40 |
| 16 | | | 14 | 17.00 | | | | | | Çok kırıklı ve çatlaklı, düzlemler kil dolgulu ve kalsit sıvalı. | 27 | 78 |
| 17 | | | 15 | 18.00 | 54 | | | | | | 69 | 72 |
| 18 | | **MARN + KİLTAŞI ($E_f$)** Açık gri açık mavimsi, orta ayrışmalı ve zayıf çoğu düzeylerde, az orta ayrışmalı ve orta dayanımlı orta zayıf ince KUMTAŞI ara katmanları içermekte. | 16 | 19.00 | | | | | | | 34 | 77 |
| 19 | | | 17 | 20.00 | | | | | | | 15 | 70 |
| 20 | | | 18 | 21.00 | | | | | | | 24 | 80 |
| 21 | | | 19 | 22.00 | | | | | | | 20 | 80 |
| 22 | | | 20 | 23.00 | | | | | | | 20 | 68 |
| 23 | | | 21 | | | | | | | | 10 | 80 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK4

SAYFA / PAGE NO : 3/5

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | Tanımlama sayfa 2/5'de. | 22 | 25.00 | 54 | | | | | Tanımlama Sayfa 2/5'de. | 30 | 68 |
| | | | 23 | 26.00 | | | | | | | 0 | 75 |
| 26 | | | 24 | 27.00 | | | | | | | 0 | 74 |
| 27 | | | 25 | 28.00 | | | | | | | 0 | 81 |
| 28 | | | 26 | 29.00 | | | | | | | 0 | 68 |
| 29 | | | 27 | 30.00 | | | | | | | 0 | 64 |
| 30 | | | 28 | 31.00 | | | | | | | 0 | 61 |
| 31 | | | 29 | 32.00 | | | | | | | 0 | 64 |
| 32 | | | 30 | 33.00 | | | | | | | 0 | 48 |
| 33 | | | 31 | 34.00 | | | | | | | 30 | 60 |
| 34 | | | 32 | 35.00 | | | | | | | 20 | 84 |
| 35 | | | 33 | 36.00 | | | | | | | - | 64 |
| 36 | | | 34 | 37.00 | | | | | | | 15 | 67 |
| 37 | | | 35 | | | | | | | | 0 | 55 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK4

SAYFA / PAGE NO : 4/5

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 36 | 39.00 | | | | | | | 10 | 50 |
| 39 | | | 37 | 40.00 | | | | | | | 31 | 73 |
| 40 | | | 38 | 41.00 | | | | | | | 40 | 60 |
| 41 | | | 40 | 42.00 | | | | | | | 17 | 80 |
| 42 | | | 41 | 43.00 | | | | | | | 0 | 77 |
| 43 | | | 42 | 44.00 | | | | | | Tanımlama Sayfa 2/5'de. | 62 | 89 |
| 44 | | **MARN+ KİLTAŞI+KUMTAŞI($E_f$)** | 43 | 44.50 | | | | | | | 32 | 78 |
| 45 | | Açık gri MARN VE KİLTAŞI ardaşık yüzeyleri orta ayrışmalı ve orta zayıf. Kimi düzeylerde ince katmanlı taze ve dayanımlı KİREÇTAŞI kesildi. | 44 | 46.00 | 54 | | | | | | 73 | 85 |
| 46 | | | 45 | 47.50 | | | | | | | 51 | 98 |
| 47 | | | 46 | 48.00 | | | | | | | 22 | 34 |
| 48 | | | 47 | 49.50 | | | | | | | 15 | 98 |
| 49 | | | 48 | 50.00 | | | | | | | 52 | 96 |
| 50 | | | 49 | 51.00 | | | | | | | 50 | 97 |
| 51 | | | 50 | 51.50 | | | | | | | 50 | 97 |
| | | | 51 | | | | | | | | 22 | 90 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK4

SAYFA / PAGE NO : 5/5

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 4/5'de. | 52 | 53.00 | 54 | | | | | | 47 | 95 |
| 53 | | **KUMTAŞI ($E_f$)** Açık gri boz renkli, az ayrışmalı ve orta dayanımlı. | 53 | 54.00 | | | | | | Çok Kırıklı | 31 | 98 |
| 54 | | | 54 | | | | | | | | 34 | 100 |
| 55 | | KUYU SONU 55.00 m. | | | | | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 61 | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK5<br>SAYFA / PAGE NO : 1/3 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 91.17 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 1 | KOORD. / COORD. N-S (y) : 400619 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE : CRALEIUS | KOORD. / COORD. E-W (x) : 4540081 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+030 | 16.80m | 04.06.2001 | 17.00 | |
| BASL. TAR. / START DATE : 10.11.2000 | SAPMA / OFFSET (m) : EKSEN (SOL TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE : 18.11.2000 | DERİNLİK / DEPTH (m) : 32.00 m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH<br>I II III IV V | <br>AYRIŞMA WEATHERING<br>I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **YAMAÇ DÖKÜNTÜSÜ**<br>Kaverengi, az çakıllı, kumlu, orta plastisiteli kil | 1 | 1.00 | | | | | | | - | 45 |
| 1 | | | 2 | | | NW | | | | | 35 | 78 |
| | | | | .2.00 | | | | | | | | |
| 2 | | | 3 | | | | | | | | 38 | 72 |
| | | | | 3.00 | | | | | | | | |
| 3 | | **KİLTAŞI (Ef Eosen Flişi)**<br>Kahverengi, çok bütünüyle ayrışmalı ve zayıf-çok zayıf. | 4 | | | | | | | | 50 | 72 |
| | | | | 4.00 | | | | | | | | |
| 4 | | | 5 | | | | | | | | 50 | 67 |
| | | | | 5.00 | | | | | | | | |
| 5 | | | 6 | | 54 mm | | | | | | 55 | 78 |
| | | | | 6.00 | | | | | | | | |
| 6 | | | 7 | | | | | | | | - | 74 |
| | | **KUMTAŞI+ÇAKILTAŞI (Ef)**<br>Kirli beyaz, az-orta ayrışmalı ve orta dayanımlı - orta zayıf-çakıltaşı, iri ve köşeli daneler içermektedir. | | 7.00 | | | | | | | | |
| 7 | | | 8 | | | | | | | Çok kırıklı ve parçalı seyrekçe gözlenen katmanlar kil dolgulu | 15 | 75 |
| | | | | 8.00 | | | | | | | | |
| 8 | | | 9 | | | | | | | | 36 | 76 |
| | | | | 9.00 | | | | | | | | |
| 9 | | | 10 | | | | | | | | 38 | 73 |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | Hüseyin Güngör | Mustafa Akıncı |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXELLENT | | |

| AYRIŞMA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|
| I : BÜT. AYRIŞMIŞ COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMIŞ HIGHLY WEATH | | | |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMIŞ SLIGHTLY WEAT. | | | |
| V : TAZE FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK5

SAYFA / PAGE NO : 2/3

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 1/3'de. | | | | | | | | | | |
| | | | 11 | 11.00 | | | | | | | - | 7 |
| 11 | | | 12 | 12.00 | | | | | | | 11 | 78 |
| 12 | | | 13 | 13.00 | | | | | | | - | 68 |
| 13 | | | 14 | 14.00 | | | | | | | 50 | 78 |
| 14 | | **BAZALTİK TÜF** **(Evc =Eosen volkanitleri)** Gri, koyugri az ayrışmalı ve orta dayanımlı. Çoğu - düzeylerde koyu gri tüf hamur (matrix) içinde köşeli çakıl boyutunda daneler içeren AGLOMERA katmanları gözlenmekte. | 15 | 15.00 | 54 mm | | | | | Kimi düzeyler çok kırıklı sayıca az gözlenen eklem düzlemleri pürüzlü paslı ve kalsit sıvalı. | 55 | 71 |
| 15 | | | 16 | 16.00 | | | | | | | 76 | 78 |
| 16 | | | 17 | 17.00 | | | | | | | 50 | 72 |
| 17 | | | 18 | 18.00 | | | | | | | 42 | 75 |
| 18 | | | 19 | 19.00 | | | | | | | 25 | 76 |
| 19 | | | 20 | 20.00 | | | | | | | - | 72 |
| 20 | | | 21 | 21.00 | | | | | | | 17 | 73 |
| 21 | | | 22 | 22.00 | | | | | | | 23 | 77 |
| 22 | | | 23 | 23.00 | | | | | | | 58 | 100 |
| 23 | | AGLOMERA (Ev) Tanımlama Sayfa 3/3'de. | 24 | | | | | | | | 75 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK5

SAYFA / PAGE NO : 3/3

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | **AGLOMERA (Ev)** Açık gri , genelde az ayrışmalı ve orta dayanımlı, kimi düzeylerde orta ayrışmalı ve orta zayıf | 25 | 25.00 | ▲ | | | | | | 45 | 92 |
| | | | 26 | 26.00 | | | | | | | 70 | 95 |
| 26 | | | 27 | 27.00 | | | | | | | 77 | 100 |
| 27 | | **BAZALTİK TÜF VE AGLOMERA (Ev)** Koyu Gri renkli, taze, az ayrışmalı, dayanımlı orta dayanımlı orta dayanımlı. | 28 | 28.00 | 54 mm | | | | | Genelde masif yapılı, seyrekçe gözlenen eklem düzlemleri pürüzlü paslı ve kalsit sıvalı. | 90 | 100 |
| 28 | | | 29 | 29.00 | | | | | | | 13 | 97 |
| 29 | | | 30 | 30.00 | | | | | | | 95 | 100 |
| 30 | | | 31 | 31.00 | | | | | | | 76 | 96 |
| 31 | | | 32 | | ▼ | | | | | | 96 | 96 |
| 32 | | KUYU SONU (32.00 m) | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK6<br>SAYFA / PAGE NO : 1/4 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 95.70 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG :TÜNEL - 1 | KOORD. / COORD. N-S (y) : 400615 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE : CRALEIUS | KOORD. / COORD. E-W (x) : 4540044 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+030 | 22.50m | 04.06.2001 | 17.00 | |
| BASL. TAR. / START DATE : 20.11.2000 | SAPMA / OFFSET (m) :EKSEN (SAĞ TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE : 29.11.2000 | DERİNLİK / DEPTH (m) : 47.00 m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **YAMAÇ DÖKÜNTÜSÜ** | | | | | | | | | - | 35 |
| 1 | | **MARN (Ef)**<br>Yeşilimsi, gri kireçtaşı arakatmanlı, çok - orta ayrışmalı. ve çok zayıf-zayıf. | 1<br>2 | 1.00 | 54 mm | NW | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | 34 | 67 |
| 2 | | | 3 | .2.00 | | | | | | | 26 | 72 |
| 3 | | | 4 | 3.00 | | | | | | | 45 | 74 |
| 4 | | **EOSEN FLİŞİ (Ef)**<br>Kireçtaşı+Silttaşı+Kiltaşı ardalanması. | 5 | 4.00 | | | | | | | 61 | 76 |
| 5 | | **KİREÇTAŞI:**<br>Kirli beyaz kumlu, az ayrışmalı, taze. | 6 | 5.00 | | | | | | | - | 72 |
| 6 | | **SİLTTAŞI + KİLTAŞI**<br>Yeşilimsi, az - orta ayrışmalı. Orta dayanımlı orta zayıf kimi zamanlarda seyrekçe aglomera gözlendi. | 7 | 6.00 | | | | | | Kireçtaşı düzeylerinde iyi gelişmiş ince katmanlar kil dolgulu. Öteki düzeyler çok kırıklı. | - | 70 |
| 7 | | | 8 | 7.00 | | | | | | | 17 | 78 |
| 8 | | | 9 | 8.00 | | | | | | | 12 | 61 |
| 9 | | | 10 | 9.00 | | | | | | | 32 | 79 |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK<br>II : ZAYIF WEAK<br>III : ORTA ZAYIF MOD. WEAK<br>IV : O. DAYANIMLI MOD. STRONG<br>V : DAYANIMLI STRONG | 0-25 : ÇOK ZAYIF VERY POOR<br>25-50 : ZAYIF POOR<br>50-75 : ORTA FAIR<br>75-90 : İYİ GOOD<br>90-100 : ÇOK İYİ EXELLENT | ----------<br>Yusuf Yıldız | '----------<br>Mustafa Akıncı |

| AYRIŞMA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY K.G.M |
|---|---|---|---|
| I : BÜT. AYRIŞMIŞ COMP. WEATHERED<br>II : ÇOK AYRIŞMIŞ HIGHLY WEATH<br>III : ORTA DER. AYR. MOD. WEATHERED<br>IV : AZ AYRIŞMIŞ SLIGHTLY WEAT.<br>V : TAZE FRESH | 1 2 3 M | ----------<br>B.Caner Kandemir | ---------- |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK6

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 11 | 11.00 | 54 mm | | | | | | 24 | 69 |
| 11 | | | 12 | | | | | | | | 44 | 79 |
| | | Tanımlama Sayfa 1/4'de. | | 12.00 | | | | | | Tanımlama Sayfa 1/4'de. | | |
| 12 | | | 13 | | | | | | | | 18 | 89 |
| 13 | | | | 13.50 | | | | | | | | |
| | | | 14 | 14.00 | | | | | | | 32 | 74 |
| 14 | | | 15 | 14.50 | | | | | | | - | 88 |
| 15 | | | 16 | | | | | | | | 46 | 97 |
| | | **KİLTAŞI (Ef)** | | 16.00 | | | | | | Çok seyrekçe | | |
| 16 | | Koyu gri, yeşilimsi, orta ayrışmalı ve orta zayıf, çoğu düzeylerde ince ve iri çakıl içermekte. | 17 | | | | | | | gözlenen katman düzeyleri kili dolgulu. | 70 | 97 |
| 17 | | | | 17.50 | | | | | | | | |
| | | | 18 | 18.00 | | | | | | | 90 | 90 |
| 18 | | | 19 | 18.50 | | | | | | | 36 | 66 |
| 19 | | | 20 | | | | | | | | 51 | 100 |
| | | | | 20.00 | | | | | | | | |
| 20 | | **AGLOMERA+TÜF** | | | | | | | | | | |
| | | Beyazımsı, açık gri, az ayrışmalı ve orta dayanımlı. | 21 | | | | | | | | 49 | 96 |
| 21 | | | | 21.50 | | | | | | | | |
| | | | 22 | 22.00 | | | | | | Tanımlama Sayfa 2/4'de. | 80 | 92 |
| 22 | | | 23 | | | | | | | | 90 | 97 |
| | | **AGLOMERA** | | | | | | | | | | |
| 23 | | Tanımlama Sayfa 3/4'de | | 23.50 | | | | | | | | |
| | | | 24 | | | | | | | | 100 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK6

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 25 | 25.50 | | | | | | | 97 | 97 |
| | | | 26 | 26.00 | | | | | | | 48 | 96 |
| 26 | | | 27 | 27.50 | | | | | | | 93 | 99 |
| | | | 28 | 28.00 | | | | | | | 100 | 100 |
| 28 | | | 29 | 29.50 | | | | | | | 94 | 96 |
| 29 | | **AGLOMERA** Genelde açık gri, sıkı çimentolu az ayrışmalı - taze ve orta dayanımlı. Koyu gri bazaltik düzeylerde orta-çok ayrışmalı ve orta dayanımlı-orta zayıf. | 30 | 30.00 | 54 mm | | | | | Kimi düzeylerde çok kırıklı. Seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 80 | 100 |
| | | | 31 | 30.50 | | | | | | | 60 | 90 |
| 31 | | | 32 | 32.00 | | | | | | | 48 | 92 |
| 32 | | | 33 | 33.50 | | | | | | | 90 | 99 |
| | | | 34 | 34.00 | | | | | | | 90 | 96 |
| 34 | | | 35 | 35.00 | | | | | | | 75 | 97 |
| 35 | | | 36 | 36.00 | | | | | | | 50 | 92 |
| 36 | | | 37 | 36.50 | | | | | | | 68 | 90 |
| 37 | | | 38 | | | | | | | | 92 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK6

SAYFA / PAGE NO : 4/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Tanımlama Sayfa 3/4'de. | 39 | 40.00 | 54 mm | | | | | | 96 | 100 |
| 40 | | | 40 | 42.00 | | | | | | Tanımlama Sayfa 3/4'de. | 90 | 98 |
| 42 | | | 41 | 44.00 | | | | | | | 90 | 97 |
| 43 | | **AGLOMERA** Yeşilimsi siyah, bazaltik, az - orta ayrışmalı ve orta zayıf ofiyolitik dokulu ve kalsit damarlı. | 42 | 45.00 | | | | | | Kimi düzeylerde eklemler kaygan ve kalsit sıvalı. | 60 | 98 |
| 45 | | | 43 | 46.00 | | | | | | | 42 | 84 |
| 46 | | | 44 | | | | | | | | 60 | 90 |
| 47 | | KUYU SONU (47.00 m) | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK7<br>SAYFA / PAGE NO : 1/7 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 151.07 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG : TÜNEL | KOORD. / COORD. N-S (y) : 401028 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE : CRAELIUS | KOORD. / COORD. E-W (x) : 4539889 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+450 | 11.90m | 17.02.2001 | 9.50 | |
| BASL. TAR. / START DATE : 10.11.2000 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE : 30.11.2000 | DERİNLİK / DEPTH (m) : 83.00 m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH<br>I II III IV V | <br>AYRIŞMA WEATHERING<br>I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00- 38.00 m. Arasında Sondaj Karotsuz açıldı.<br><br>EOSEN FLİŞİ (Ef) | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Fahri Çınar | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMIŞ | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMIŞ | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMIŞ | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK7

SAYFA / PAGE NO : 2/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES | | | | | | | | | | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DAYANIM STRENGTH | | | | | AYRIŞMA WEATHERING | | | | | | | |
| | | | | | | | | I | II | III | IV | V | I | II | III | IV | V | | | |
| 11 | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | |
| 15 | | Karotsuz açıldı<br>EOSEN FLİŞİ (Ef) | | | | | | | | | | | | | | | | | | |
| 16 | | | | | 54 mm | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK7

SAYFA / PAGE NO : 3/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES | | | | | | | | | | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DAYANIM STRENGTH | | | | | AYRIŞMA WEATHERING | | | | | | | |
| | | | | | | | | I | II | III | IV | V | I | II | III | IV | V | | | |
| 25 | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | |
| 30 | | Karotsuz açıldı<br>EOSEN FLİŞİ (Ef) | | | 54 mm | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T1-SK7<br>SAYFA / PAGE NO : 4/7 |
|---|---|

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | <br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | 1 | 39.00 | 54 mm | | | | | | 15 | 70 |
| | | | 2 | 40.00 | | | | | | | 50 | 80 |
| 40 | | | 3 | | | | | | | | 88 | 90 |
| 41 | | | | 42.00 | | | | | | | | |
| 42 | | **FLİŞ (Ef)**<br>**KİLTAŞI+KUMTAŞI**<br>Yeşilimsi, volkanik kökenli, az - orta ayrışmalı ve orta dayanımlı- orta zayıf<br><br>42.70 m 44.00m. ler arasında ki kumtaşı alacalı ve iri daneli. | 4 | | | | | | | 15-20 derece eğimli katman düzlemleri pürüzlü ve kalsit dolgulu. | 94 | 99 |
| 43 | | | | | | | | | | | | |
| 44 | | | 5 | 44.00 | | | | | | | 100 | 100 |
| 45 | | | | | | | | | | | | |
| 46 | | | 6 | 46.00 | | | | | | | 100 | 100 |
| 47 | | | | | | | | | | | | |
| 48 | | | 7 | 48.00 | | | | | | | 100 | 100 |
| 49 | | **AGLOMERA (Ev)**<br>Gri, yeşilimsi kimi düzeyler pembemsi ve alacalı. Genelde taze ve dayanımlı, çok seyrekçe az ayrışmalı ve orta dayanımlı. | | | | | | | | Genelde masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | | |
| 50 | | | | 50.00 | | | | | | | | |
| 51 | | | 8 | | | | | | | | 100 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK7

SAYFA / PAGE NO : 5/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | 9 | | | | | | | | 100 | 100 |
| | | | | 54.00 | | | | | | | | |
| 54 | | | | | | | | | | | | |
| | | | 10 | | | | | | | | 100 | 100 |
| 55 | | | | | | | | | | | | |
| | | | | 56.00 | | | | | | | | |
| 56 | | | | | | | | | | | | |
| | | | 11 | | | | | | | | 100 | 100 |
| 57 | | | | | | | | | | | | |
| | | | | 58.00 | | | | | | | | |
| 58 | | | | | | | | | | | | |
| | | | 12 | | | | | | | | 95 | 100 |
| 59 | | AGLOMERA (Ev) | | | | | | | | | | |
| | | Tanımlama Sayfa 4/7'de | | 60.00 | 54 mm | | | | | Tanımlama Sayfa 4/7'de | | |
| 60 | | | | | | | | | | | | |
| | | | 13 | | | | | | | | 100 | 100 |
| 61 | | | | | | | | | | | | |
| | | | | 62.00 | | | | | | | | |
| 62 | | | | | | | | | | | | |
| | | | 14 | | | | | | | | 100 | 100 |
| 63 | | | | | | | | | | | | |
| | | | | 64.00 | | | | | | | | |
| 64 | | | | | | | | | | | | |
| | | | 15 | | | | | | | | 96 | 100 |
| 65 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK7

SAYFA / PAGE NO : 6/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 16 | 67.00 | | | | | | | 100 | 100 |
| 67 | | | | | | | | | | | | |
| 68 | | | 17 | 69.00 | | | | | | | 100 | 100 |
| 69 | | | 18 | 70.00 | | | | | | | 100 | 100 |
| 70 | | | | | | | | | | | | |
| 71 | | | 19 | 72.00 | | | | | | | 100 | 100 |
| 72 | | | | | | | | | | | | |
| 73 | | **AGLOMERA (Ev)** Gri, yeşilimsi, kimi düzeylerde pembemsi ve alacalı. Genelde taze ve dayanımlı seyrekçe az ayrışmalı ve orta dayanımlı. | 20 | 74.00 | 54 mm | | | | | Genelde masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 74 | | | | | | | | | | | | |
| 75 | | | 21 | 76.00 | | | | | | | 100 | 100 |
| 76 | | | | | | | | | | | | |
| 77 | | | 22 | 78.00 | | | | | | | 100 | 100 |
| 78 | | | | | | | | | | | | |
| 79 | | | 23 | | | | | | | | 100 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK7

SAYFA / PAGE NO : 7/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | | AGLOMERA (Ev) | 24 | 82.00 | 54 mm | | | | | Tanımlama Sayfa 6/7'de. | 100 | 100 |
| 82 | | Tanımlama Sayfa 6/7'de. | 25 | | | | | | | | 100 | 100 |
| 83 | | KUYU SONU (83.00m) | | | | | | | | | | |
| 84 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK8<br>SAYFA / PAGE NO : 1/6 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 152.15 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG : TÜNEL - 1 | KOORD. / COORD. N-S (y) : 401143 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE : CRAELIUS | KOORD. / COORD. E-W (x) : 4539799 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+625 | 12.00 | 06.01.2001 | 10.00 | |
| BASL. TAR. / START DATE : 01.12.2000 | SAPMA / OFFSET (m) : EKSEN | | 17.02.2001 | | |
| BİTİŞ TAR. / FINISH DATE : 23.12.2000 | DERİNLİK / DEPTH (m) : 79.00 m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | **FLİŞ (Ef)**<br>0.00 m-10.00m arasında<br>Sondaj Karotsuz açıldı. | | | 54 mm | NW | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Dursun Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | ---------- | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK8

SAYFA / PAGE NO : 2/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **FİLİŞ (Ef)** Kirli beyaz renkli kireçtaşı - bloklu yeşilimsi kahverenkli-kiltaşı ( Marn) orta-az ayrış-malı | 1 | 11.00 | 54 mm | | | | | | 18 | 71 |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | **FİLİŞ (Ef)** 11.00-20.00m arası karotsuz sondaj | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | **AGLOMERA (Ev)** Gri renkli az- orta derecede ayrışmalı. Yer yer silt hamur dolgulu, ince kalsit damarlı çatlak - yüzeyleri pürüzlü ve kalsit dolgulu. | 2 | 20.00 21.00 | | | | | | | 42 | 77 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | **AGLOMERA (Ev)** 21.00-30.00m arası karotsuz sondaj | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK8

SAYFA / PAGE NO : 3/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | |
| 27 | | **AGLOMERA (Ev)**<br>21.00-30.00m arası karotsuz sondaj | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| | | | | 30.00 | | | | | | | | |
| 30 | | **AGLOMERA (Ev)**<br>Açık gri renkli az-orta ayrışmalı. | 3 | | 54 mm | | | | | | 100 | 100 |
| 31 | | Yer yer silt Hamur dolgulu, ince kalsit damarlı çatlak yüzeyleri pürüzlü ve kalsit dolgulu. | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | **AGLOMERA (Ev)**<br>31.00-34.00 arası karotsuz sondaj | | | | | | | | | | |
| | | | | 34.00 | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | **AGLOMERA**<br>Gri-koyu gri renkli, taze,gri-yeşilimsi, kimi düzeylerde pembemsi ve alacalı. Genelde taze ve dayanımlı çok seyrekçe az ayrışmalı ve orta dayanımlı. | 4 | | | | | | | Genel olarak masif, çok seyrek-çe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 36 | | | | 36.00 | | | | | | | | |
| 37 | | | 5 | | | | | | | | 100 | 100 |
| | | | | 38.00 | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T1-SK8<br>SAYFA / PAGE NO : 4/6 |
|---|---|

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | <br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | 6 | 40.00 | 54 mm | | | | | | 100 | 100 |
| 40 | | **AGLOMERA**<br>Gri-koyu gri renkli, taze,gri-yeşilimsi, kimi düzeylerde pembemsi ve alacalı. Genelde taze ve dayanımlı çok seyrekçe az ayrışmalı ve orta dayanımlı. | 7 | | | | | | | | 100 | 100 |
| 41 | | | | 42.00 | | | | | | | | |
| 42 | | | 8 | | | | | | | | 100 | 100 |
| 43 | | | | 44.00 | | | | | | | | |
| 44 | | | 9 | | | | | | | Genel olarak masif, çok seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 45 | | | | 46.00 | | | | | | | | |
| 46 | | | 10 | | | | | | | | 100 | 100 |
| 47 | | | | 48.00 | | | | | | | | |
| 48 | | | 11 | | | | | | | | 100 | 100 |
| 49 | | | | 50.00 | | | | | | | | |
| 50 | | | 12 | | | | | | | | 100 | 100 |
| 51 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK8

SAYFA / PAGE NO : 5/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | 13 | 54.00 | | | | | | | 100 | 100 |
| 54 | | | 14 | 56.00 | | | | | | | 100 | 100 |
| 55 | | | | | | | | | | | | |
| 56 | | | 15 | 58.00 | | | | | | | 100 | 100 |
| 57 | | | | | | | | | | | | |
| 58 | | | 16 | 60.00 | | | | | | | 100 | 100 |
| 59 | | **AGLOMERA** Gri-koyu gri renkli, taze,gri-yeşilimsi, kimi düzeylerde pembemsi ve alacalı. Genelde taze ve dayanımlı çok seyrekçe az ayrışmalı ve orta dayanımlı. | | | 54 mm | | | | | | | |
| 60 | | | 17 | 62.00 | | | | | | Genel olarak masif, çok seyrek-çe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 61 | | | | | | | | | | | | |
| 62 | | | 18 | 64.00 | | | | | | | 100 | 100 |
| 63 | | | | | | | | | | | | |
| 64 | | | 19 | 66.00 | | | | | | | 100 | 100 |
| 65 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK8

SAYFA / PAGE NO : 6/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | ▲ | | | | | | 100 | 100 |
| | | | | 68.00 | | | | | | | | |
| 68 | | | | | | | | | | | 100 | 100 |
| 69 | | | 20 | | | | | | | | | |
| | | | | 70.00 | | | | | | | | |
| 70 | | | | | | | | | | | 100 | 100 |
| 71 | | **AGLOMERA** Gri-koyu gri renkli, taze,gri-yeşilimsi, kimi düzeylerde pembemsi ve alacalı. Genelde taze ve dayanımlı çok seyrekçe az ayrışmalı ve orta dayanımlı. | 21 | | | | | | | | | |
| | | | | 72.00 | | | | | | Genel olarak masif, çok seyrek-çe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | | |
| 72 | | | | | | | | | | | 100 | 100 |
| 73 | | | 22 | | | | | | | | | |
| | | | | 74.00 | | | | | | | | |
| 74 | | | | | 54 mm | | | | | | 100 | 100 |
| 75 | | | 23 | | | | | | | | | |
| | | | | 76.00 | | | | | | | | |
| 76 | | | | | | | | | | | 100 | 100 |
| 77 | | | 24 | | | | | | | | | |
| | | | | 78.00 | | | | | | | | |
| 78 | | | | | | | | | | | 100 | 100 |
| | | | 25 | | | | | | | | | |
| | | | | 79.00 | | | | | | | | |
| 79 | | KUYU SONU 79.00 m. | | | | | | | | | | |

TEMELSON

ORDU ÇEVREYOLU
KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T1-SK9

SAYFA / PAGE NO : 1/9

| | | | | |
|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 184.76 | YERALTI SUYU DURUMU-GROUND WATER DATA | | |
| SOND. YERİ / BORING LOG :TÜNEL - 1 | KOORD. / COORD. N-S (y) : 401404 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (x) : 4539660 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 23+915 | 23.00 | 14.02/01 | | |
| BASL. TAR. / START DATE : 07.01.2001 | SAPMA / OFFSET (m) : EKSEN | 23.05 | 17.02.2001 | 11.15 | |
| BİTİŞ TAR. / FINISH DATE : 31.01.2001 | DERİNLİK / DEPTH (m) : 109.00M | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.00m-10.00m arasında Sondaj Karotsuz Açıldı. | | | 54 mm | NW | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Yusuf Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 2/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **AGLOMERA** | 1 | 11.00 | 54 mm | NW | | | | | 100 | 100 |
| | | Karotsuz açıldı. | | 20.00 | | | | | | | | |
| | | **AGLOMERA** | 2 | 21.00 | | | | | | | 100 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 3/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | 30.00 | | | | | | | | |
| | | **AGLOMERA** | 3 | | 54 mm | | | | | | 100 | 100 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | Karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 4/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | 54 mm | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | **AGLOMERA** | 4 | | | | | | | | 100 | 100 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | Karotsuz açıldı. | | | | | | | | | | |
| 44 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | **AGLOMERA** | 5 | | | | | | | | 100 | 100 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 5/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | 54 mm | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | Karotsuz açıldı. | | | | | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | | | 60.00 | | | | | | | | |
| | | **AGLOMERA** | 6 | 61.00 | | | | | | | 100 | 100 |
| 61 | | | | | | | | | | | | |
| 62 | | Karotsuz açıldı. | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | | | 64.00 | | | | | | | | |
| | | **AGLOMERA** | | | | | | | | | | |
| 65 | | Tanımlama Sayfa 6/7'de. | 7 | | | | | | | | 100 | 100 |
| | | | | 66.00 | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | SONDAJ / BORING NO : T1-SK9<br>SAYFA / PAGE NO : 6/9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER.<br>BOR DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BOR. DER.<br>CAS. DEP (m) | DOL. SUYU KAY.<br>CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | | | | | AYRIŞMA WEATHERING I II III IV V | | | | | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
| 67 | | | 8 | 68.00 | 54 mm | | | | | | | | | | | | | | 100 | 100 |
| 68 | | | 9 | 70.00 | | | | | | | | | | | | | | | 100 | 100 |
| 69 | | | | | | | | | | | | | | | | | | | | |
| 70 | | | 10 | 72.00 | | | | | | | | | | | | | | | 100 | 100 |
| 71 | | | | | | | | | | | | | | | | | | | | |
| 72 | | | 11 | 74.00 | | | | | | | | | | | | | | | 100 | 100 |
| 73 | | | | | | | | | | | | | | | | | | | | |
| 74 | | **AGLOMERA**<br>Gri,yeşilimsi kimi düzeyler pembemsi ve alacalı.<br>Genel olarak taze ve dayanım-lı.İnce kalsit damarları göz-lenmekte. | 12 | 76.00 | | | | | | | | | | | | | Genel olarak ma-sif, seyrekçe göz-lenen eklem düz-lemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 75 | | | | | | | | | | | | | | | | | | | | |
| 76 | | | 13 | 78.00 | | | | | | | | | | | | | | | 100 | 100 |
| 77 | | | | | | | | | | | | | | | | | | | | |
| 78 | | | 14 | | | | | | | | | | | | | | | | 100 | 100 |
| 79 | | | | | | | | | | | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | | SONDAJ / BORING NO : T1-SK9<br>SAYFA / PAGE NO : 7/9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER. | GÖS-TERİM | KAYAÇ TANIMLAMASI | MAN. NO. | MAN. DER. | KAR ÇAPI | MUH. BOR. DER. CAS. DEP | DOL. SUYU KAY. CIR. LOSS | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES | | | | | | | | | | SÜREKSİZLİK TANIMLAMASI | RQD | KAROT YÜZ. |
| | | | | | | | | DAYANIM STRENGTH | | | | | AYRIŞMA WEATHERING | | | | | | | |
| BOR DEPTH (m) | LE-GEND | ROCK DESCRIPTION | RUN NO. | RUN DEPTH (m) | CORE DIA. (mm) | (m) | (%) | I | II | III | IV | V | I | II | III | IV | V | DISCONTINUITY DESCRIPTION | (%) | CORE RECO. (%) |
| 81 | | **AGLOMERA**<br>Gri,yeşilimsi kimi düzeyler pembemsi ve alacalı.<br>Genel olarak taze ve dayanımlı.İnce kalsit damarları gözlenmekte. | 15 | 82.00 | 54 mm | | | | | | | | | | | | | Genel olarak masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | 100 | 100 |
| 82 | | | 16 | 84.00 | | | | | | | | | | | | | | | 100 | 100 |
| 83 | | | | | | | | | | | | | | | | | | | | |
| 84 | | | 17 | 86.00 | | | | | | | | | | | | | | | 100 | 100 |
| 85 | | | | | | | | | | | | | | | | | | | | |
| 86 | | | 18 | 88.00 | | | | | | | | | | | | | | | 100 | 100 |
| 87 | | | | | | | | | | | | | | | | | | | | |
| 88 | | | 19 | 90.00 | | | | | | | | | | | | | | | 100 | 100 |
| 89 | | | | | | | | | | | | | | | | | | | | |
| 90 | | | 20 | 92.00 | | | | | | | | | | | | | | | 100 | 100 |
| 91 | | | | | | | | | | | | | | | | | | | | |
| 92 | | | 21 | 94.00 | | | | | | | | | | | | | | | 100 | 100 |
| 93 | | | | | | | | | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 8/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | 22 | 96.00 | 54 mm | | | | | | 100 | 100 |
| 96 | | | | | | | | | | | | |
| 97 | | | 23 | 98.00 | | | | | | | 100 | 100 |
| 98 | | | | | | | | | | | | |
| 99 | | | 24 | 100.00 | | | | | | | 100 | 100 |
| 100 | | **AGLOMERA**<br>Gri,yeşilimsi kimi düzeyler pembemsi ve alacalı.<br>Genel olarak taze ve dayanımlı.İnce kalsit damarları gözlenmekte. | | | | | | | | Genel olarak masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit sıvalı. | | |
| 101 | | | 25 | 102.00 | | | | | | | 100 | 100 |
| 102 | | | | | | | | | | | | |
| 103 | | | 26 | 104.00 | | | | | | | 100 | 100 |
| 104 | | | | | | | | | | | | |
| 105 | | | 27 | 106.00 | | | | | | | 100 | 100 |
| 106 | | | | | | | | | | | | |
| 107 | | | 28 | 108.00 | | | | | | | 100 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK9

SAYFA / PAGE NO : 9/9

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 6/9'da. | 29 | 109.00 | ▲ 54 mm ▼ | | | | | Tanımlama Sayfa 6/9'da. | 100 | 100 |
| 109 | | KUYU SONU 109.00m. | | | | | | | | | | |
| 110 | | | | | | | | | | | | |
| 111 | | | | | | | | | | | | |
| 112 | | | | | | | | | | | | |
| 113 | | | | | | | | | | | | |
| 114 | | | | | | | | | | | | |
| 115 | | | | | | | | | | | | |
| 116 | | | | | | | | | | | | |
| 117 | | | | | | | | | | | | |
| 118 | | | | | | | | | | | | |
| 119 | | | | | | | | | | | | |
| 120 | | | | | | | | | | | | |
| 121 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK10<br>SAYFA / PAGE NO : 1/8 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 191.97 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 1 | KOORD. / COORD. N-S (y) : 401619 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (x) : 4539478 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 24+200 | 12.60 | 14/02/01 | | |
| BASL. TAR. / START DATE :06.12.2000 | SAPMA / OFFSET (m) : EKSEN | 4.95 | 17.02.2001 | 11.30 | |
| BİTİŞ TAR. / FINISH DATE : 10.01.2001 | DERİNLİK / DEPTH (m) : 108.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00m-10.00m arasında<br>Sondaj Karotsuz Açıldı. | | | | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Bülent Güngör | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 2/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **KİLTAŞI** | 1 | 11.00 | 54 mm | NW | | | | | 97 | 89 |
| 11 | | Karotsuz açıldı. | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | 20.00 | | | | | | | | |
| 20 | | **KİLTAŞI** | 2 | | 54 mm | | | | | | 99 | 99 |
| 21 | | | | 21.00 | | | | | | | | |
| 22 | | Karotsuz açıldı. | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 3/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | 30.00 | | | | | | | | |
| | | **KİLTAŞI** | 3 | | 54 mm | NW | | | | | 70 | 97 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | Karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 4/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | **KİLTAŞI** | 4 | | 54 mm | | | | | | 55 | 100 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | Karotsuz açıldı. | | | | | | | | | | |
| 44 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | **KİLTAŞI** | 5 | | 54 mm | | | | | | 37 | 94 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 5/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 56 | | Karotsuz açıldı. | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | | | 60.00 | | | | | | | | |
| | | **FİLİŞ** Kiltaşı+Kireçtaşı | 6 | | 54 mm | | | | | | 72 | 98 |
| 61 | | | | 61.00 | | | | | | | | |
| 62 | | Karotsuz açıldı. | | | | | | | | | | |
| 63 | | | | 63.00 | | | | | | | | |
| | | | 7 | | | | | | | | 52 | 98 |
| | | **KUMTAŞI+KİLTAŞI** | | 64.00 | | | | | | | | |
| 64 | | Açık gri yeşilimsi renkli orta ve çok ayrışmalı orta zayıf-zayıf, ince marn bantlı. | | | 54 mm | | | | | Ayrışma nedeniy-le süreksizlik göz-lenemedi. | | |
| 65 | | | 8 | | | | | | | | 35 | 78 |
| | | | | 66.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 6/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | 9 | | | | | | | | 63 | 96 |
| | | | | 68.00 | | | | | | | | |
| 68 | | Tanımlama Sayfa 5/8'de. | 10 | | | | | | | Tanımlama Sayfa 5/8'de. | 35 | 99 |
| 69 | | | | 70.00 | | | | | | | | |
| 70 | | | 11 | | | | | | | | 52 | 95 |
| 71 | | | | | 54 mm | | | | | | | |
| | | | | 72.00 | | | | | | | | |
| 72 | | | 12 | 72.50 | | | | | | | 44 | 90 |
| 73 | | | 13 | | | | | | | | 60 | 100 |
| | | | | 74.00 | | | | | | | | |
| 74 | | | 14 | | | | | | | | 68 | 100 |
| 75 | | **KİREÇTAŞI** Beyaz renkli az ayrışmalı ve orta dayanımlı. Seyrekçe orta derecede ayrışmış ve orta zayıf-zayıf. Yer yer ince damarlı. (Bordo renkli tüf çizgileri gözlenmekte. | | | | | | | | Süreksizlik yüzeyleri pürüzlü ve yer yer kalsit dolgulu. Genel olarak süreksizlik düzlemleri bordo renkli tüf ile sıvalı. | | |
| 76 | | | | 76.00 | | | | | | | | |
| 77 | | | 15 | | | | | | | | 88 | 100 |
| | | | | 78.00 | | | | | | | | |
| 78 | | | 16 | 78.50 | | | | | | | 26 | 90 |
| 79 | | | 17 | | | | | | | | 85 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK10

SAYFA / PAGE NO : 7/8

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | | | 18 | 82.00 | 54 mm | | | | | | 89 | 99 |
| 82 | | | 19 | 84.00 | | | | | | | 98 | 100 |
| 83 | | | | | | | | | | | | |
| 84 | | | 20 | 86.00 | | | | | | | 90 | 100 |
| 85 | | | | | | | | | | | | |
| 86 | | **KİREÇTAŞI** Beyaz renkli az ayrışmalı ve orta dayanımlı. Seyrekçe orta derecede ayrışmış ve orta zayıf-zayıf. Yer yer ince damarlı. (Bordo renkli tüf çizgileri gözlenmekte. | 21 | 88.00 | | | | | | Genelde masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve kalsit ve / veya bordo renkli tüf sıvalı. | 100 | 100 |
| 87 | | | | | | | | | | | | |
| 88 | | | 22 | 90.00 | | | | | | | 100 | 100 |
| 89 | | | | | | | | | | | | |
| 90 | | | 23 | 92.00 | | | | | | | 100 | 100 |
| 91 | | | | | | | | | | | | |
| 92 | | | 24 | 94.00 | | | | | | | 65 | 100 |
| 93 | | **TÜF** Bordo renkli çok ayrışmış, zayıf - çok zayıf. | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | SONDAJ / BORING NO : T1-SK10<br>SAYFA / PAGE NO : 8/8 | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T1-SK11 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/11 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 220.89 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL - 1 | KOORD. / COORD. N-S (y) : 401897 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4539292 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 24+450 | 10.60m | 04.04.2001 | | |
| BASL. TAR. / START DATE :15.01.2001 | SAPMA / OFFSET (m) : Eksen | | | | |
| BİTİŞ TAR. / FINISH DATE :18.03.2001 | DERİNLİK / DEPTH (m) : 143.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | 0.00-83.00m arasında sondaj karotsuz açıldı. | | | | | | | | | | |
| 5 | | | | | 54 mm | NW | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Bülent Güngör | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 2/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Açık kahverenkli az killi, kumlu Siltaşı yer yer çakıltaşı içermekte. | 1 | 11.00 | 54 mm | NW | | | | | 64 | 97 |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | 20.00 | | | | | | | | |
| | | Açık kahverenkli az killi, kumlu Siltaşı yer yer çakıltaşı içermekte. | 2 | 21.00 | | | | | | | - | 94 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 3/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-83.00m arasında sondaj karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | Yeşilimsi kahverenkli orta derecede ayrışmış KİLTAŞI. | 3 | 30.00<br>31.00 | 54 mm | NW | | | | | 63 | 98 |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 4/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | Yeşilimsi kahverenkli orta derecede ayrışmış KİLTAŞI. | 4 | | | | | | | | 90 | 100 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | 54 mm | NW | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | Yeşilimsi kahverenkli orta derecede ayrışmış KİLTAŞI. | 5 | | | | | | | | 70 | 100 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 5/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 56 | | 0.00-83.00m arasında sondaj karotsuz açıldı. | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | 54 mm | NW | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | | | 60.00 | | | | | | | | |
| | | Yeşilimsi kahverenkli orta derecede ayrışmış KİLTAŞI. | 6 | 61.00 | | | | | | | 85 | 100 |
| 61 | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 6/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | ▲ | | | | | | | |
| 68 | | | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| 70 | | Yeşilimsi kahverenkli orta derecede ayrışmış KİLTAŞI. | 7 | 70.00 71.00 | | | | | | | 80 | 98 |
| 71 | | | | | | | | | | | | |
| 72 | | | | | 54 mm | | | | | | | |
| 73 | | 0.00-83.00m arasında sondaj karotsuz açıldı. | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 7/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **FİLİŞ**<br>Yeşilimsi gri renkli fliş. | 8 | 81.00 | ▲ | | | | | | 85 | 98 |
| 81 | | | | | | | | | | | | |
| 82 | | | | 83.00 | | | | | | | | |
| 83 | | | 9 | | | | | | | | 100 | 100 |
| 84 | | | | 85.00 | | | | | | | | |
| 85 | | **FİLİŞ SERİSİ**<br>Yeşilimsi gri renkli, kumtaşı ve marn ara bantlı, yer yer kireç taşı blokları kesen KİLTAŞI. | 10 | | | | | | | | 95 | 100 |
| 86 | | | | 87.00 | 54 mm | | | | | Seyrekçe gözlenen katman düzlemleri kil dolgulu. | | |
| 87 | | | 11 | | | | | | | | 35 | 75 |
| 88 | | 85.00-88.00m arası kirli beyaz renkli, aglomera özellikli iri ve köşeli daneler içeren KUMTAŞI. | | 89.00 | | | | | | | | |
| 89 | | | 12 | | | | | | | | 80 | 90 |
| 90 | | | | 91.00 | | | | | | | | |
| 91 | | | 13 | | | | | | | | 63 | 83 |
| 92 | | | | 93.00 | | | | | | | | |
| 93 | | | 14 | | ▼ | | | | | | 33 | 76 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 8/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | 14 | 95.00 | 54 mm | | | | | | 33 | 76 |
| 96 | | | 15 | 97.00 | | | | | | | 34 | 75 |
| 97 | | | 16 | 99 | | | | | | | 65 | 80 |
| 99 | | | 17 | 101.00 | | | | | | | 85 | 70 |
| 101 | | | 18 | 103.00 | | | | | | | 15 | 60 |
| 102 | | | | | | | | | | | | |
| 103 | | Tanımlama Sayfa 7/11'de. | 19 | 105.00 | | | | | | Tanımlama Sayfa 7/11'de. | 50 | 83 |
| 104 | | | | | | | | | | | | |
| 105 | | | 20 | 107.00 | | | | | | | 15 | 70 |
| 106 | | | | | | | | | | | | |
| 107 | | | 21 | | | | | | | | 70 | 100 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 9/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 109 | | Tanımlama Sayfa 7/11'de. | 22 | 109.00 | 54 mm | | | | | Tanımlama Sayfa 7/11'de. | 15 | 80 |
| | | | 23 | 110.00 | | | | | | | 28 | 70 |
| 110 | | | 24 | | | | | | | | 50 | 75 |
| 111 | | | | 111.00 | | | | | | | 26 | 75 |
| 112 | | | 25 | | | | | | | | | |
| 113 | | | 26 | 113.00 | | | | | | | 55 | 75 |
| 114 | | | | | | | | | | | | |
| 115 | | | 27 | 115.00 | | | | | | Genelde masif, seyrekçe gözlenen süreksizlik düzlemleri pürüzlü. | 20 | 66 |
| 116 | | **AGLOMERA** Pembemsi gri renkli genelde taze ve dayanımlı belirgin özellikli AGLOMERA. | | | | | | | | | | |
| 117 | | | 28 | 117.00 | | | | | | | 95 | 100 |
| 118 | | | | | | | | | | | | |
| 119 | | | 29 | 119.00 | | | | | | | 45 | 80 |
| 120 | | | | | | | | | | | | |
| 121 | | | 30 | 121.00 | | | | | | | 93 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK11

SAYFA / PAGE NO : 10/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 30 | 123.00 | ▲ | | | | | | 93 | 100 |
| 123 | | | | | | | | | | | | |
| 124 | | | 31 | 125.00 | | | | | | | 65 | 86 |
| 125 | | | | | | | | | | | | |
| 126 | | | 32 | 127.00 | | | | | | | 90 | 95 |
| 127 | | | | | | | | | | | | |
| 128 | | Tanımlama Sayfa 9/11'de. | 33 | 129.00 | 54 mm | | | | | Tanımlama Sayfa 9/11'de. | 95 | 98 |
| 129 | | | | | | | | | | | | |
| 130 | | | 34 | 131.00 | | | | | | | 95 | 98 |
| 131 | | | | | | | | | | | | |
| 132 | | | 35 | 133.00 | | | | | | | 85 | 95 |
| 133 | | | | | | | | | | | | |
| 134 | | | 36 | 135.00 | | | | | | | 90 | 98 |
| 135 | | | | | | | | | | | | |
| | | | 37 | | ▼ | | | | | | 90 | 93 |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | | SONDAJ / BORING NO : T1-SK11<br>SAYFA / PAGE NO : 11/11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER. | GÖS-TERİM | KAYAÇ TANIMLAMASI | MAN. NO. | MAN. DER. | KAR ÇAPI | MUH. BOR. DER. CAS. DEP | DOL. SUYU KAY. CIR. LOSS | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES | | | | | | | | | | | SÜREKSİZLİK TANIMLAMASI | RQD | KAROT YÜZ. |
| | | | | | | | | DAYANIM STRENGTH | | | | | AYRIŞMA WEATHERING | | | | | | | |
| BOR DEPTH (m) | LE-GEND | ROCK DESCRIPTION | RUN NO. | RUN DEPTH (m) | CORE DIA. (mm) | (m) | (%) | I | II | III | IV | V | I | II | III | IV | V | DISCONTINUITY DESCRIPTION | (%) | CORE RECO. (%) |
| 137 | | Koyu gri renkli yer yer yeşilimsi, pembemsi taze ve dayanımlı aglomera. | 37 | 137.00 | 54 mm | | | | | | | | | | | | | Süreksizlik düzlemleri pürüzlü ve seyrekçe kalsit sıvalı. | 90 | 93 |
| 138 | | | 38 | 139.00 | | | | | | | | | | | | | | | 100 | 100 |
| 139 | | | | | | | | | | | | | | | | | | | | | |
| 140 | | | 39 | 141.00 | | | | | | | | | | | | | | | 93 | 95 |
| 141 | | | 40 | | | | | | | | | | | | | | | | 93 | 95 |
| 142 | | | | | | | | | | | | | | | | | | | | | |
| 143 | | KUYU SONU 143.00m. | | | | | | | | | | | | | | | | | | | |
| 144 | | | | | | | | | | | | | | | | | | | | | |
| 145 | | | | | | | | | | | | | | | | | | | | | |
| 146 | | | | | | | | | | | | | | | | | | | | | |
| 147 | | | | | | | | | | | | | | | | | | | | | |
| 148 | | | | | | | | | | | | | | | | | | | | | |
| 149 | | | | | | | | | | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK12<br>SAYFA / PAGE NO : 1/11 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :239.88 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL- 1 | KOORD. / COORD. N-S (y) : 402008 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4539070 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 24+750 | 19.80m | 27.04.2001 | | |
| BASL. TAR. / START DATE : 02.02.2001 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE 15.04.2001 | DERİNLİK / DEPTH (m) : 148.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH<br>I II III IV V | <br>AYRIŞMA WEATHERING<br>I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00-103.00m arasında<br>Sondaj Karotsuz açıldı. | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Dursun Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA WEATHERING | | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 2/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Kahverenkli ince kireçtaşı daneleri içeren KİL - MARN | 1 | 11.00 | 54 mm | NW | | | | | - | 73 |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | 20.00 | | | | | | | | |
| 20 | | Açık gri gri renkli çok kırıklı parçalı bazalt ve aglomera blokları orta çok ayrışmış orta zayıf zayıf. Kırık yüzeyleri kil sıvalı ve paslı. | 2 | 21.00 | | | | | | | - | 35 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 3/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-103.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| | | | | 30.00 | | | | | | | | |
| 30 | | Açık gri gri renkli çok kırıklı parçalı bazalt ve aglomera blokları orta çok ayrışmış orta zayıf zayıf. Kırık yüzeyleri kil sıvalı ve paslı. | 3 | 31.00 | 54 mm | NW | | | | | 10 | 39 |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | 0.00-103.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 4/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | Açık gri gri renkli çok kırıklı parçalı bazalt ve aglomera blokları orta çok ayrışmış orta zayıf zayıf. Kırık yüzeyleri kil sıvalı ve paslı. | 4 | | | | | | | | - | 40 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | 54 mm | NW | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | Açık gri gri renkli çok kırıklı parçalı bazalt ve aglomera blokları orta çok ayrışmış orta zayıf zayıf. Kırık yüzeyleri kil sıvalı ve paslı. | 5 | | | | | | | | - | 60 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 5/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | 0.00-103.00m arasında Sondaj Karotsuz açıldı. | | | | NW | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | 54 mm | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | Açık gri gri renkli çok kırıklı parçalı bazalt ve aglomera blokları orta çok ayrışmış orta zayıf zayıf. Kırık yüzeyleri kil sıvalı ve paslı. | 6 | 60.00 61.00 | | | | | | - | 48 |
| 61 | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | 0.00-103.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 65 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 6/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | | | | | | | | |
| 68 | | | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| | | | | 70.00 | | | | | | | | |
| 70 | | Açık gri renkli, taze ve az ayrış-mış, orta dayanımlı, AGLOMERA | 7 | | | | | | | | - | 81 |
| | | | | 71.00 | | | | | | | | |
| 71 | | | | | | | | | | | | |
| 72 | | | | | 54 mm | | | | | | | |
| 73 | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 7/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Açık gri renkli, taze ve az ayrış-mış, orta dayanımlı, AGLOMERA | 8 | 81.00 | ▲ | | | | | | 30 | 87 |
| 81 | | 0.00-103.00m arasında Sondaj Karotsuz açıldı. | | | 54 mm | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | Yeşilimsi gri renkli kireçtaşı bloğu içeren büt. ayrışmalı ve çok zayıf KİLTAŞI. Seyrekçe kireçtaşı içermekte. | 9 | 90.00<br>91.00 | | | | | | | - | 40 |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | ▼ | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 8/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | | | | | | | | | | |
| 96 | | | | | | | | | | | | |
| 97 | | | | | | | | | | | | |
| 98 | | | | | | | | | | | | |
| 99 | | | | | | | | | | | | |
| 100 | | Yeşilimsi gri renkli kireçtaşı bloğu içeren büt. ayrışmalı ve çok zayıf KİLTAŞI. Seyrekçe kireçtaşı içermekte. | 10 | 100.00<br>101.00 | 54 mm | | | | | | - | 32 |
| 101 | | | | | | | | | | | | |
| 102 | | | | 103.00 | | | | | | | | |
| 103 | | KİLTAŞI<br>Yeşilimsi gri renkli, orta ayrışmalı ve zayıf. | 11 | 104.00 | | | | | | | - | 42 |
| 104 | | | 12 | 105.00 | | | | | | | - | 32 |
| 105 | | | 13 | 106.00 | | | | | | | - | 34 |
| 106 | | | 14 | 107.00 | | | | | | | 14 | 49 |
| 107 | | | 15 | 108.00 | | | | | | | 20 | 81 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 9/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 16 | 109.00 | ▲ | | | | | | - | 52 |
| 109 | | | 17 | 110.00 | | | | | | | 22 | 58 |
| 110 | | ÇAKILTAŞI<br>Kahverengimsi gri renkli ve ince ve iri çakıl içermekte. Az - orta ayrışmalı ve orta zayıf. | | | | | | | | Çok kırıklı | | |
| 111 | | | 18 | 112.00 | | | | | | | 36 | 75 |
| 112 | | | 19 | | | | | | | | | |
| 113 | | Açık gri renkli taze ve dayanımlı. | | 114.00 | | | | | | | 37 | 84 |
| 114 | | KİREÇTAŞI<br>Açık gri, taze ve dayanımlı. | 20 | | 54 mm | | | | | Düzensiz çatlaklı ve çok kırıklı. | 28 | 83 |
| 115 | | | | 116.00 | | | | | | | | |
| 116 | | | 21 | | | | | | | | 29 | 73 |
| 117 | | | | 118.00 | | | | | | | | |
| 118 | | | 22 | | | | | | | | 34 | 75 |
| 119 | | KİLTAŞI<br>Yeşilimsi gri renkli, orta ayrışmalı ve orta zayıf. | | 120.00 | | | | | | | | |
| 120 | | | 23 | | | | | | | | 58 | 92 |
| 121 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 10/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 123 | | | 24 | | | | | | | | 75 | 88 |
| 124 | | Tanımlama Sayfa 9/11'de. | | 124.00 | | | | | | | | |
| 125 | | | 25 | | | | | | | Tanımlama Sayfa 9/11'de. | 88 | 91 |
| 126 | | | | 126.00 | | | | | | | | |
| 127 | | | 26 | | | | | | | | 55 | 85 |
| 128 | | | | 128.00 | 54 mm | | | | | | | |
| 129 | | | 27 | | | | | | | | 83 | 92 |
| 130 | | | | 130.00 | | | | | | | | |
| 131 | | Pembemsi çok açık gri renk-li, genel olarak taze ve seyrek-çe az ayrışmış, orta dayanım-lı- dayanımlı AGLOMERA. | 28 | | | | | | | | 28 | 86 |
| 132 | | | | 132.00 | | | | | | | | |
| 133 | | | 29 | | | | | | | Süreksizlik düz-lemleri pürüzlü ve paslı. | 100 | 100 |
| 134 | | | | 134.00 | | | | | | | | |
| 135 | | | 30 | | | | | | | | 90 | 94 |
| | | | | 136.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK12

SAYFA / PAGE NO : 11/11

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 137 | | Tanımlama Sayfa 10/11'de | 31 | 138.00 | ▲ 54 mm | | | | | Tanımlama Sayfa 10/11'de | 98 | 99 |
| 138 | | | 32 | | | | | | | | 95 | 99 |
| 139 | | | | 140.00 | | | | | | | | |
| 140 | | | 33 | | | | | | | | 75 | 98 |
| 141 | | | | 142.00 | | | | | | | | |
| 142 | | Gri yeşilimsi kimi düzeyler pembemsi ve alacalı. Taze ve dayanımlı. AGLOMERA. | 34 | | | | | | | Genelde masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve yer yer kalsit sıvalı. | 98 | 98 |
| 143 | | | | 144.00 | | | | | | | | |
| 144 | | | 35 | | | | | | | | 100 | 100 |
| 145 | | | | 146.00 | | | | | | | | |
| 146 | | | 36 | | | | | | | | 100 | 100 |
| 147 | | | | 148.00 | | | | | | | | |
| 148 | | KUYU SONU 148.00m. | | | | | | | | | | |
| 149 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK13<br>SAYFA / PAGE NO : 1/13 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :311.40 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL - 1 | KOORD. / COORD. N-S (y) : 402 291 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4538706 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 25+225 | 24.40m | 04.04.2001 | | |
| BASL. TAR. / START DATE : 18.01.2001 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE 21.02.2001 | DERİNLİK / DEPTH (m) : 169.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00-124.00m arasında<br>Sondaj Karotsuz açıldı. | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | ---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Fahri Çınar | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 2/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sarımsı Kahverengi SİLT TAŞI | 1 | 11.00 | 54 mm | NW | | | | | 60 | 100 |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | Koyu Gri renkli az ayrışmalı orta dayanımlı AGLOMERA. | 2 | 20.00 21.00 | | | | | | | 65 | 100 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 3/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-124.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | NW | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| | | | | 30.00 | | | | | | | | |
| 30 | | Pembemsi gri renkli bordo renkli tüf hamur maddeli az-orta derecede ayrışmış orta dayanımlı AGLOMERA. | 3 | | 54 mm | | | | | | 40 | 95 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 4/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | 54 mm | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | Koyu gri renkli az ayrışmış orta dayanımlı volkanik KUMTAŞI. | 4 | | | | | | | | 85 | 98 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | Yeşilimsi açık gri renkli orta derecede ayrışmış orta zayıf KİLTAŞI. | 5 | | | | | | | | 100 | 100 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | SONDAJ / BORING NO : T1-SK13<br>SAYFA / PAGE NO : 5/13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER.<br>BOR DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I | II | III | IV | V | AYRIŞMA WEATHERING I | II | III | IV | V | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
| 53<br>54<br>55<br>56<br>57<br>58<br>59<br>60<br>61<br>62<br>63<br>64<br>65 | | 0.00-124.00m arasında Sondaj Karotsuz açıldı.<br><br>Koyu gri renkli bazaltik aglomera. Taze ve dayanımlı. | 6 | 60.00<br>61.00 | 54 mm | | | | | | | | | | | | | | 90 | 98 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 6/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | | | | | | | | |
| 68 | | | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| | | | | 70.00 | | | | | | | | |
| 70 | | Koyu gri renkli, taze ve daya-nımlı bazaltik AGLOMERA. | 7 | | | | | | | | 100 | 100 |
| | | | | 71.00 | | | | | | | | |
| 71 | | | | | | | | | | | | |
| 72 | | | | | 54 mm | | | | | | | |
| 73 | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 7/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Koyu gri - siyah renkli taze ve dayanımlı ince kalsit damarlı bazaltik AGLOMERA. | 8 | 81.00 | 54 mm | | | | | | 100 | 100 |
| 81 | | | | | | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | 0.00-124.00m arasında Sondaj Karotsuz açldı. | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | 90.00 | | | | | | | | |
| | | Yeşilimsi gri renkli orta derecede ayrışmış ve orta zayıf KİLTAŞI. | 9 | 91.00 | | | | | | | 65 | 75 |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 8/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | | | ▲ | | | | | | | |
| 96 | | | | | | | | | | | | |
| 97 | | | | | | | | | | | | |
| 98 | | | | | | | | | | | | |
| 99 | | | | | | | | | | | | |
| | | | | 100.00 | | | | | | | | |
| 100 | | Yeşilimsi gri renkli orta dere-cede ayrışmış ve orta zayıf KİLTAŞI. | 10 | | 54 mm | | | | | | 50 | 100 |
| | | | | 101.00 | | | | | | | | |
| 101 | | | | | | | | | | | | |
| 102 | | | | | | | | | | | | |
| 103 | | | | | | | | | | | | |
| 104 | | | | | | | | | | | | |
| 105 | | | | | | | | | | | | |
| 106 | | | | | | | | | | | | |
| 107 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 9/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 109 | | | | | | | | | | | | |
| | | | | 110.00 | | | | | | | | |
| 110 | | Açık gri renkli az ayrışmalı ve orta dayanımlı (küçük benekli) AGLOMERA. | 11 | | | | | | | | 100 | 100 |
| | | | | 111.00 | | | | | | | | |
| 111 | | | | | | | | | | | | |
| 112 | | | | | | | | | | | | |
| 113 | | | | | | | | | | | | |
| 114 | | 0.00-124.00m arasında Sondaj karotsuz açıldı. | | | 54 mm | | | | | | | |
| 115 | | | | | | | | | | | | |
| 116 | | | | | | | | | | | | |
| 117 | | | | | | | | | | | | |
| 118 | | | | | | | | | | | | |
| 119 | | | | | | | | | | | | |
| | | | | 120.00 | | | | | | | | |
| 120 | | Yeşilimsi Gri renkli az-orta derecede ayrışmış, orta zayıf KİLTAŞI. | 12 | | | | | | | | 80 | 87 |
| | | | | 121.00 | | | | | | | | |
| 121 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 10/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 123 | | | | | ▲ | | | | | | | |
| 124 | | | 13 | 124.00 | | | | | | | 100 | 100 |
| | | | | 125.00 | | | | | | | | |
| 125 | | | 14 | | | | | | | | 100 | 100 |
| | | | | 126.00 | | | | | | | | |
| 126 | | | 15 | | | | | | | | 90 | 98 |
| 127 | | | | | | | | | | | | |
| | | | | 128.00 | | | | | | | | |
| 128 | | | 16 | | 54 mm | | | | | | 88 | 98 |
| 129 | | | | | | | | | | | | |
| | | | | 130.00 | | | | | | | | |
| 130 | | | 17 | | | | | | | | 86 | 99 |
| | | | | 131.00 | | | | | | | | |
| 131 | | Yeşilimsi açık gri renkli az-orta ayrışmalı orta zayıf ve zayıf dayanımlı KİLTAŞI. | 18 | | | | | | | Ayrışma nedeniyle süreksizlik göz-lenemedi. | 90 | 100 |
| 132 | | | 19 | 132.00 | | | | | | | 90 | 100 |
| | | | | 133.00 | | | | | | | | |
| 133 | | | 20 | | | | | | | | 80 | 100 |
| | | | | 134.00 | | | | | | | | |
| 134 | | | 21 | | | | | | | | 60 | 100 |
| | | | | 135.00 | | | | | | | | |
| 135 | | | 22 | | ▼ | | | | | | 97 | 99 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 11/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 137 | | Tanımlama Sayfa 10/13'de. | 23 | 137.00 | 54 mm | | | | | Ayrışma nedeniy-le süreksizlik gözlenemedi. | 95 | 100 |
| | | | 24 | 138.00 | | | | | | | 90 | 98 |
| 138 | | | 25 | 139.00 | | | | | | | 50 | 99 |
| 139 | | | 26 | 140.00 | | | | | | | 97 | 100 |
| 140 | | | 27 | 141.00 | | | | | | | 75 | 100 |
| 141 | | | 28 | 142.00 | | | | | | | 70 | 98 |
| 142 | | | 29 | 144.00 | | | | | | | 75 | 100 |
| 143 | | | | | | | | | | | | |
| 144 | | | 30 | 146.00 | | | | | | | 100 | 100 |
| 145 | | | | | | | | | | | | |
| 146 | | | 31 | 147.00 | | | | | | | 95 | 98 |
| 147 | | | 32 | 148.00 | | | | | | | 75 | 98 |
| 148 | | | 33 | 149.00 | | | | | | | 85 | 90 |
| 149 | | | 34 | 150.00 | | | | | | | 80 | 92 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK13

SAYFA / PAGE NO : 12/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 35 | 151.00 | ▲ | | | | | | 40 | 76 |
| 151 | | Tanımlama Sayfa 10/13'de. | 36 | 152.00 | | | | | | Tanımlama Sayfa 11/13'de. | - | 70 |
| 152 | | 151.00-154.70m arasında Kirli beyaz renkli az ayrışmış kireçtaşı blokları gözlenmek-te. | 37 | 153.00 | | | | | | | 10 | 70 |
| 153 | | | 38 | 154.00 | | | | | | | 70 | 83 |
| 154 | | | 39 | 155.00 | | | | | | | 22 | 68 |
| 155 | | Bordo renkli az killi kumlu TÜF. | 40 | 156.00 | | | | | | Ayrışma nedeniy-le süreksizlik gözlenemedi. | 70 | 100 |
| 156 | | | 41 | 157.00 | | | | | | | 20 | 80 |
| 157 | | | 42 | 158.00 | 54 mm | | | | | | - | 76 |
| 158 | | | 43 | 159.00 | | | | | | | 14 | 73 |
| 159 | | | 44 | 160.00 | | | | | | | - | 47 |
| 160 | | Tanımlama Sayfa 13/13'de. | 45 | 161.00 | | | | | | | - | 43 |
| 161 | | | 46 | 162.00 | | | | | | Tanımlama Sayfa 13/15'de. | 16 | 58 |
| 162 | | | 47 | 163.00 | | | | | | | 12 | 66 |
| 163 | | | 48 | | ▼ | | | | | | 80 | 85 |

| TEMELSON | KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T1-SK13 |
|---|---|---|
| | | SAYFA / PAGE NO : 13/13 |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 49 | 165.00 | ▲ | | | | | | 40 | 66 |
| 165 | | | 50 | 166.00 | | | | | | Süreksizlik düz-lemleri pürüzlü ve kil sıvalı. | 33 | 67 |
| 166 | | Gri renkli az-orta derecede ayrışmış orta dayanımlı, ince kalsit damarlı AGLOMERA | 51 | 177.00 | 54 mm | | | | | | 30 | 68 |
| 167 | | | 52 | 168.00 | | | | | | | 35 | 98 |
| 168 | | | 53 | | ▼ | | | | | | 60 | 100 |
| 169 | | KUYU SONU 169.00m | | | | | | | | | | |
| 170 | | | | | | | | | | | | |
| 171 | | | | | | | | | | | | |
| 172 | | | | | | | | | | | | |
| 173 | | | | | | | | | | | | |
| 174 | | | | | | | | | | | | |
| 175 | | | | | | | | | | | | |
| 176 | | | | | | | | | | | | |
| 177 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T1-SK14 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/13 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :274.59 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL - 1 | KOORD. / COORD. N-S (y) : 402513 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4538403 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 25+600 | 10.80m | 21.05.2001 | | |
| BASL. TAR. / START DATE :27.3.2001 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE 20.05.2001 | DERİNLİK / DEPTH (m) : 165.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.00-120.00m arasında Sondaj Karotsuz açıldı. | | | 54 mm | NW | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXELLENT | | |

| AYRI?MA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|
| I : BÜT. AYRIŞMALI COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI HIGHLY WEATH | | | |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI SLIGHTLY WEAT. | | | |
| V : TAZE FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 2/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Gri renkli taze ve az ayrış-malı orta dayanımlı BAZALT. | 1 | 11.00 | 54 mm | NW | | | | | 18 | 83 |
| 20 | | Gri renkli az-orta derecede ayrışmış, orta zayıf BAZALT. | 2 | 20.00<br>21.00 | | | | | | | 26 | 75 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 3/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-120.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | 30.00 | | | | | | | | |
| | | Gri renkli taze ve az ayrışmalı, orta dayanımlı bazalt. | 3 | | 54 mm | NW | | | | | 45 | 98 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | 0.00-120.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 4/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | Gri renkli taze - az ayrışmalı, orta dayanımlı - dayanımlı BAZALT. | 4 | | | | | | | | 90 | 92 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | 54 mm | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | Gri renkli az ayrışmalı, orta dayanımlı BAZALT. | 5 | | | | | | | | 78 | 82 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 5/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | ▲ | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | 0.00-120.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | 54 mm | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | Açık gri renkli orta çok ayrış-mış, zayıf KİLTAŞI. Yer yer ince ve iri çakıl içer-mekte. | 6 | 60.00 61.00 | | | | | | | - | 73 |
| 61 | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | 0.00-120.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 65 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 6/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | | | | | | | | |
| 68 | | | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| | | | | 70.00 | | | | | | | | |
| 70 | | Açık gri renkli orta çok ayrış-mış, zayıf KİLTAŞI. Yer yer ince ve iri çakıl içer-mekte. | 7 | | | | | | | | 27 | 77 |
| | | | | 71.00 | | | | | | | | |
| 71 | | | | | | | | | | | | |
| 72 | | | | | 54 mm | | | | | | | |
| 73 | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 7/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Grimsi kahverenkli orta - çok ayrışmış, orta zayıf KİLTAŞI. Yer yer ince çakıl içermekte. | 8 | 81.00 | ▲ | | | II | III | | 50 | 74 |
| 81 | | | | | | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | 0.00-120.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | 54 mm | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | 90.00 | | | | | | | | |
| | | Grimsi kahverenkli orta - çok ayrışmış, orta zayıf KİLTAŞI. Yer yer ince çakıl içermekte. | 9 | 91.00 | | | | II | III | | 35 | 75 |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 8/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | | | ▲ | | | | | | | |
| 96 | | | | | | | | | | | | |
| 97 | | | | | | | | | | | | |
| 98 | | | | | | | | | | | | |
| 99 | | | | | | | | | | | | |
| 100 | | Grimsi kahverenkli orta - çok ayrışmış, orta zayıf KİLTAŞI. Yer yer ince çakıl içermekte. | 10 | 100.00<br>101.00 | 54 mm | | | | | | - | 70 |
| 101 | | | | | | | | | | | | |
| 102 | | | | | | | | | | | | |
| 103 | | | | | | | | | | | | |
| 104 | | | | | | | | | | | | |
| 105 | | | | | | | | | | | | |
| 106 | | | | | | | | | | | | |
| 107 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 9/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 109 | | | | 110.00 | 54 mm | | | | | | | |
| 110 | | Grimsi kahverenkli orta çok ayrışmış, orta zayıf yer yer ince ve çakıl içeren KİLTAŞI. | 11 | 111.00 | | | | | | | 30 | 72 |
| 111 | | | | | | | | | | | | |
| 112 | | | | | | | | | | | | |
| 113 | | | | | | | | | | | | |
| 114 | | | | | | | | | | | | |
| 115 | | | | | | | | | | | | |
| 116 | | | | | | | | | | | | |
| 117 | | | | | | | | | | | | |
| 118 | | | | | | | | | | | | |
| 119 | | | | 120.00 | | | | | | | | |
| 120 | | Tanımlama Sayfa 10/13'de<br><br>121.60-122.00m arası Beyazımsı gri renkli taze ve dayanımlı kireçtaşı. | 12 | | | | | | | | 48 | 97 |
| 121 | | | | 122.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 10/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 123 | | Gri renkli kum içeren orta derecede ayrışmış orta zayıf, zayıf AGLOMERA | 13 | | | | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | - | 75 |
| 124 | | | 14 | 124.00 | | | | | | | 13 | 75 |
| 125 | | | | | | | | | | | | |
| 126 | | Grimsi kahverenkli seyrekçe ince ve iri çakıl içeren orta derecede ayrışmış, orta zayıf - zayıf KİLTAŞI. | 15 | 126.00 | 54 mm | | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | 35 | 86 |
| 127 | | | | | | | | | | | | |
| 128 | | | 16 | 128.00 | | | | | | | 20 | 87 |
| 129 | | | | | | | | | | | | |
| 130 | | | 17 | 130.00 | | | | | | | 20 | 80 |
| 131 | | | | | | | | | | | | |
| 132 | | | 18 | 132.00 | | | | | | | 25 | 97 |
| 133 | | | | | | | | | | | | |
| 134 | | | 19 | 134.00 | | | | | | | 75 | 94 |
| 135 | | | | | | | | | | | | |
| | | | | 136.00 | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 11/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 137 | | | 20 | | | | | | | | 55 | 93 |
| | | | | 138.00 | | | | | | | | |
| 138 | | Tanımlama Sayfa 10/13'de | | | | | | | | | | |
| | | | 21 | | | | | | | Ayrışma nedeniyle süreksizlik gözle-nemedi. | 55 | 83 |
| 139 | | | | | | | | | | | | |
| | | | | 140.00 | | | | | | | | |
| 140 | | | 22 | | | | | | | | | |
| 141 | | 141.00-142.00m arası Koyu gri renkli bazalt bloğu. | | | | | | | | | 7 | 78 |
| | | | | 142.00 | | | | | | | | |
| 142 | | | | | | | | | | | | |
| | | | 23 | | 54 mm | | | | | | - | 83 |
| 143 | | | | | | | | | | | | |
| | | | | 144.00 | | | | | | | | |
| 144 | | FLİŞ Açık gri renkli kumtaşı ara katmanlı, yer yer kireçtaşı parça ve blokları içeren az-orta derecede ayrışmış, orta zayıf KİLTAŞI. | | | | | | | | | | |
| | | | 24 | | | | | | | Ayrışma nedeniyle süreksizlik gözle-nemedi. | 27 | 92 |
| 145 | | | | | | | | | | | | |
| | | | | 146.00 | | | | | | | | |
| 146 | | | | | | | | | | | | |
| | | | 25 | | | | | | | | 58 | 98 |
| 147 | | | | | | | | | | | | |
| | | | | 148.00 | | | | | | | | |
| 148 | | | | | | | | | | | | |
| | | | 26 | | | | | | | | 45 | 94 |
| 149 | | | | | | | | | | | | |
| | | | | 150.00 | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK14

SAYFA / PAGE NO : 12/13

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 11/13'de. | | | 54 mm | | | | | Tanımlama Sayfa 11/13'de. | 55 | 99 |
| 151 | | | 27 | 152.00 | | | | | | | | |
| 152 | | Açık gri renkli taze ve az ayrışmalı orta dayanımlı, dayanımlı AGLOMERA. | | | | | | | | | | |
| 153 | | | 28 | 154.00 | | | | | | Kırık düzlemleri pürüzlü ve seyrekçe kil sıvalı. | 25 | 98 |
| 154 | | Gri renkli taze ve az ayrışmalı orta dayanımlı, dayanımlı AGLOMERA. | 29 | | | | | | | | | |
| 155 | | | | | | | | | | | 95 | 100 |
| 156 | | | | 156.00 | | | | | | | | |
| 157 | | | 30 | | | | | | | | 95 | 100 |
| 158 | | | | 158.00 | | | | | | | | |
| 159 | | | 31 | | | | | | | | 99 | 99 |
| 160 | | Gri, yeşilimsi, kimi düzeyler pembemsi ve alacalı. Taze ve dayanımlı. AGLOMERA. | | 160.00 | | | | | | | | |
| 161 | | | 32 | | | | | | | Masif, seyrekçe gözlenen eklem düzlemleri pürüzlü ve seyrekçe kalsit sıvalı. | 100 | 100 |
| 162 | | | | 162.00 | | | | | | | | |
| 163 | | | 33 | | | | | | | | 100 | 100 |

| TEMELSON | KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T1-SK14 |
|---|---|---|
| | | SAYFA / PAGE NO : 13/13 |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 12/13'de. | 34 | 165.00 | 54 mm | | | | | Tanımlama Sayfa 12/13'de. | 100 | 100 |
| 165 | | KUYU SONU 165.00m. | | | | | | | | | | |
| 166 | | | | | | | | | | | | |
| 167 | | | | | | | | | | | | |
| 168 | | | | | | | | | | | | |
| 169 | | | | | | | | | | | | |
| 170 | | | | | | | | | | | | |
| 171 | | | | | | | | | | | | |
| 172 | | | | | | | | | | | | |
| 173 | | | | | | | | | | | | |
| 174 | | | | | | | | | | | | |
| 175 | | | | | | | | | | | | |
| 176 | | | | | | | | | | | | |
| 177 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T1-SK15 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/10 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :250.41 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL | KOORD. / COORD. N-S (y) : 402719.148 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4538120.850 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 25+950 | 35.50m | 27.04.2001 | | |
| BASL. TAR. / START DATE :20.03.2001 | SAPMA / OFFSET (m) : Eksen | | | | |
| BİTİŞ TAR. / FINISH DATE 23.04.2001 | DERİNLİK / DEPTH (m) : 134.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | 0.00-89.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 5 | | | | | 54 mm | NW | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Yusuf Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 2/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SİLTAŞI-AGLOMERA | 1 | 11.00 | 54 mm | NW | | | | | 40 | 99 |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | 20.00 | | | | | | | | |
| | | Beyazımsı gri renkli orta ayrış-mış ve orta zayıf yer yer killi ve kumlu AGLOMERA. | 2 | 21.00 | | | | | | | 100 | 100 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 3/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-89.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | 30.00 | | | | | | | | |
| | | Beyazımsı gri renkli orta ayrış-mış ve orta zayıf yer yer killi ve kumlu AGLOMERA. | 3 | 31.00 | 54 mm | NW | | | | | 26 | 95 |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | 0.00-89.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 4/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | Çok açık gri renkli taze ve az ayrışmalı dayanımlı-orta dayanımlı. AGLOMERA | 4 | | | | | | | | 28 | 83 |
| | | | | 41.00 | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | 54 mm | NW | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | Çok açık gri renkli taze ve az ayrışmalı dayanımlı-orta dayanımlı. AGLOMERA | 5 | | | | | | | | 62 | 98 |
| | | | | 51.00 | | | | | | | | |
| 51 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 5/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | | | ▲ | | | | | | | |
| 54 | | | | | | | | | | | | |
| 55 | | 0.00-89.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 56 | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | |
| 58 | | | | | 54 mm | | | | | | | |
| 59 | | | | | | | | | | | | |
| 60 | | Çok açık gri renkli taze ve az ayrışmalı dayanımlı-orta dayanımlı. AGLOMERA | 6 | 60.00 61.00 | | | | | | | 65 | 95 |
| 61 | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | |
| 63 | | | | | | | | | | | | |
| 64 | | 0.00-89.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 65 | | | | | ▼ | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 6/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | | | | | | | | | | |
| 68 | | | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| | | | | 70.00 | | | | | | | | |
| 70 | | Çok açık gri renkli taze ve az ayrışmalı dayanımlı-orta dayanımlı. AGLOMERA | 7 | | | | | | | | 81 | 91 |
| | | | | 71.00 | | | | | | | | |
| 71 | | | | | | | | | | | | |
| 72 | | | | | 54 mm | | | | | | | |
| 73 | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 7/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Çok açık gri renkli taze ve az ayrışmalı dayanımlı-orta dayanımlı. AGLOMERA | 8 | 81.00 | ▲ | | | | | | 90 | 92 |
| 81 | | 0.00-89.00m arasında Sondaj Karotsuz açldı. | | | 54 mm | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | 89.00 | | | | | | | | |
| 90 | | Çok açık gri renkli, taze ve az ayrışmalı - orta dayanımlı. AGLOMERA. | 9 | 91.00 | | | | | | Süreksizlik düzlemleri çok pürüzlü yer yer kil seyrekçe kalsit sıvalı oksidosyon gözlenmekte. | 88 | 100 |
| 91 | | | 10 | | | | | | | | 55 | 88 |
| 92 | | | | 93.00 | | | | | | | | |
| 93 | | Tanımlama Sayfa 8/10'da. | 11 | | ▼ | | | | | Tanımlama Sayfa 8/10'da | - | 69 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 8/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | | | 12 | | | | | | | | 40 | 83 |
| 96 | | | 13 | 96.00 | | | | | | | 100 | 100 |
| 97 | | | | 98.00 | | | | | | | | |
| 98 | | | 14 | | | | | | | | 98 | 98 |
| 99 | | Koyu gri renkli, yer yer ince kalsit damarlı ve seyrekçe gözlenen gaz boşluklarında kalsit dolgulu genel olarak taze seyrekçe az ayrışmalı, dayanımlı - orta dayanımlı BAZALT. | | 100.00 | 54 mm | | | | | Süreksizlik düzlemleri pürüzlü ve yer yer kalsit sıvalı. Süreksizlik eğimleri genel olarak düzeye yakın. | | |
| 100 | | | | | | | | | | | | |
| 101 | | | 15 | | | | | | | | 100 | 100 |
| 102 | | | | 102.00 | | | | | | | | |
| 103 | | | 16 | | | | | | | | 60 | 93 |
| 104 | | | | 104.00 | | | | | | | | |
| 105 | | | 17 | | | | | | | | 25 | 83 |
| 106 | | | | 106.00 | | | | | | | | |
| 107 | | | 18 | | | | | | | | 46 | 91 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 9/10

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 109 | | Tanımlama Sayfa 8/10'da. | 19 | 110.00 | 54 mm | | | | | Tanımlama Sayfa 8/10'da. | 95 | 97 |
| 110 | | | 20 | | | | | | | | 70 | 98 |
| 111 | | 111.45m<br>Yeşilimsi gri renkli, çok ayrışmış ve zayıf KİLTAŞI. İnce ve iri çakıl içermekte parçalı ve kırıklı gri renkli Bazalt ile karışık. | | 112.00 | | | | | | | | |
| 112 | | | | | | | | | | | 9 | 77 |
| 113 | | | 21 | | | | | | | | | |
| 114 | | 113.75m<br>Gri renkli, taze ve dayanımlı BAZALT. | 22 | 114.00 | | | | | | | 95 | 98 |
| 115 | | | | | | | | | | Süreksizlik düzlemleri az pürüzlü ve yer yer kalsit sıvalı. | | |
| 116 | | | 23 | 116.00 | | | | | | | 100 | 100 |
| 117 | | 118.00.40-118.60m arası kiltaşı. | | | | | | | | | | |
| 118 | | Yeşilimsi gri renkli çok-bütünüyle ayrışmalı zayıf-çok zayıf KİLTAŞI | 24 | 118.00 | | | | | | | 44 | 83 |
| 119 | | 119.10m<br>Yeşilimsi gri renkli çok-bütünüyle ayrışmalı zayıf-çok zayıf KİLTAŞI | | 120.00 | | | | | | | | |
| 120 | | 121.25-121.65m arası Beyazımsı açık gri renkli kireçtaşı<br>120.45-120.80m arası kireçtaxı parçaları içermekte. | 25 | | | | | | | | 30 | 88 |
| 121 | | | | 122.00 | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK15

SAYFA / PAGE NO : 10/110

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 9/10'da. | | | ▲ | | | | | Tanımlama Sayfa 9/10'da. | | |
| 122.40m | | | | | | | | | | | | |
| 123 | | | 26 | | | | | | | | 28 | 80 |
| 124 | | | | 124.00 | | | | | | | | |
| 125 | | | 27 | | | | | | | | 95 | 97 |
| | | Gri renkli, seyrekçe ince kalsit damarlı taze ve dayanımlı BAZALT. | | 126.00 | | | | | | Süreksizlik düzlemleri az pürüzlü yer yer kalsit sıvalı. | | |
| 126 | | | 28 | | | | | | | | 100 | 100 |
| 127 | | | | 128.00 | | | | | | | | |
| 128 | | | | | 54 mm | | | | | | | |
| 129 | | | 29 | | | | | | | | 100 | 100 |
| 130 | | | | 130.00 | | | | | | | | |
| 131 | | | 30 | | | | | | | | 100 | 100 |
| 132 | | | | 132.00 | | | | | | | | |
| 133 | | | 31 | | | | | | | | 100 | 100 |
| | | | | 134.00 | ▼ | | | | | | | |
| 134 | | KUYU SONU 134.00m. | | | | | | | | | | |
| 135 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T1-SK16 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/7 |

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :209.67 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG:TÜNEL | KOORD. / COORD. N-S (y) : 402866.720 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537919.052 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+200 | Kuyuda | 02.05.2001 | | |
| BASL. TAR. / START DATE :20.04.2001 | SAPMA / OFFSET (m) : Eksen | su yok. | | | |
| BİTİŞ TAR. / FINISH DATE 02.05.2001 | DERİNLİK / DEPTH (m) : 82.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | 0.00-37.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 5 | | | | | 54 mm | NW | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Yusuf Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 2/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Beyazımsı açık gri renkli az ayrışmalı orta dayanımlı. AGLOMERA. | 1 | 11.00 | 54 mm | NW | | | | | 88 | 97 |
| 11 | | 0.00-37.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | 20.00 | | | | | | | | |
| | | Açık kahverenkli , siyah bazalt parçaları ve ince ve iri çakıl içeren SİLTTAŞI- KİLTAŞI. | 2 | 21.00 | | | | | | | - | 50 |
| 21 | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 3/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | 0.00-37.00m arasında Sondaj Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| | | | | 30.00 | | | | | | | | |
| 30 | | Genel olarak Gri, koyu gri - renkli, genelde bazalt blokla-rı, seyrekçe kireçtaşı parçala-rı içeren kiltaşı ara katmanlı ardalanma. | 3 | | 54 mm | NW | | | | | - | 75 |
| | | | | 31.00 | | | | | | | | |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | 0.00-37.00m arası sondaj karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | Tanımlama Sayfa 4/7'de. | | 37.00 | | | | | | Tanımlama Sayfa 4/7'de. | | |
| | | | 4 | 38.00 | | | | | | | - | 75 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 4/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Genel olarak gri, seyrekçe bordo renkli, seyrekçe ince kalsit damarları içeren yer yer kiltaşı ara katmanlı az-orta derecede ayrışmış orta zayıf AGLOMERA. | 5 | 39.00 | 54 mm | NW | | | | | 32 | 81 |
| 40 | | | 6 | 41.00 | | | | | | | 32 | 79 |
| 41 | | | 7 | 43.00 | | | | | | Süreksizlik düzlemleri pürüzlü ve yer yer kalsit sıvalı. | 38 | 67 |
| 42 | | 39.49-40.86m arası. Siyah renkli bazaltik tüf. | | | | | | | | | | |
| 43 | | | 8 | 45.00 | | | | | | | 58 | 97 |
| 44 | | 44.60m | | | | | | | | | | |
| 45 | | Koyu gri - siyah renkli seyrekçe ince kalsit damarlı az orta ayrışmalı. orta zayıf-zayıf KİLTAŞI + SİLTTAŞI. | 9 | 47.00 | | | | | | Süreksizlik düzlemleri boşluklu ve kalsit dolgulu. | 100 | 100 |
| 46 | | | | | | | | | | | | |
| 47 | | | 10 | 49.00 | | | | | | | 78 | 97 |
| 48 | | 48.80m | | | | | | | | | | |
| 49 | | Tanımlama Sayfa 5/7'de. | 11 | 51.00 | | | | | | Tanımlama Sayfa 5/7'de. | 65 | 98 |
| 50 | | | | | | | | | | | | |
| 51 | | | 12 | | | | | | | | 78 | 98 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 5/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 12 | 53.00 | 54 mm | | | | | | 78 | 98 |
| 53 | | **AGLOMERA + KUMTAŞI+ KİLTAŞI** Ardalanması. | 13 | | | | | | | | 65 | 99 |
| 54 | | **AGlomera:** Gri renkli, seyrekçe ince kalsit damarlı az-orta derece-de ayrışmış. | | 55.00 | | | | | | | | |
| 55 | | | | | | | | | | | 75 | 100 |
| 56 | | **Kiltaşı:** Yeşilimsi gri renkli çok ayrış-mış, zayıf. | 14 | 57.00 | | | | | | | | |
| 57 | | **Kumtaşı:** Koyu gri renkli, az killi. | 15 | | | | | | | | 70 | 100 |
| 58 | | | | 59.00 | | | | | | | | |
| 59 | | 59.10m-60.75m arası Bordo renkli aglomera. | 16 | | | | | | | | 44 | 95 |
| 60 | | | | 61.00 | | | | | | | | |
| 61 | | Gri renkli seyrekçe ince da-marlı taze ve dayanımlı BAZALT. | 17 | | | | | | | | 93 | 96 |
| 62 | | 61.60-62.40m arası. Koyu gri renkli SİLTTAŞI. | | 63.00 | | | | | | | | |
| 63 | | | 18 | | | | | | | | 68 | 94 |
| 64 | | Tanımlama Sayfa 6/7'de. | | 65.00 | | | | | | Tanımlama Sayfa 6/7'de. | | |
| 65 | | | 19 | | | | | | | | 95 | 98 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 6/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AGLOMERA<br>64.35-67.50m arası<br>pembemsi gri | 19 | 67.00 | 54 mm | | | | | | 95 | 98 |
| 67 | | 67.50-71.50m arası<br>Koyu gri renkli | 20 | 69.00 | | | | | | | 95 | 99 |
| 68 | | | | | | | | | | | | |
| 69 | | | 21 | | | | | | | | 63 | 96 |
| 70 | | | | | | | | | | | | |
| 71 | | 71.50-73.60m arası<br>Açık gri renkli ve killi orta derecede ayrışmalı ve orta zayıf aglomera. | 22 | 71.00 | | | | | | Genel olarak süreksizlik düzlemleri pürüzlü, yer yer kalsit sıvalı ve seyrekçe kil sıvalı. | 53 | 95 |
| 72 | | | | | | | | | | | | |
| 73 | | 73.60-82.00m arası<br>Açık bordo renkli taze-az ayrışmış ve dayanımlı-orta dayanımlı aglomera. Yer yer kalsit dolgu gözlenmekte. | 23 | 73.00 | | | | | | | 68 | 98 |
| 74 | | | | | | | | | | | | |
| 75 | | | 24 | 75.00 | | | | | | | 95 | 98 |
| 76 | | | | | | | | | | | | |
| 77 | | | 25 | 77.00 | | | | | | | 98 | 100 |
| 78 | | | | | | | | | | | | |
| 79 | | | 26 | 79.00 | | | | | | | 90 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK16

SAYFA / PAGE NO : 7/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 6/7'de. | 26 | 81.00 | 54 mm | | | | | | 90 | 100 |
| 81 | | | 27 | 82.00 | | | | | | Tanımlama Sayfa 6/7'de. | 95 | 100 |
| 82 | | KUYU SONU 82.00m. | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T1-SK17 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/4 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :174.83 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL | KOORD. / COORD. N-S (y) : 402934.628 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537844.826 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+200 | 23.90 | 14.05.2001 | | |
| BASL. TAR. / START DATE :04.05.2001 | SAPMA / OFFSET (m) : Eksen(SOL TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE 12.05.2001 | DERİNLİK / DEPTH (m) : 48.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.00-3.00m arası Sondaj karotsuz açıldı. | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | 3.00 | | | | | | | | |
| 4 | | | 1 | | | | | | | | - | 39 |
| 5 | | | | 5.00 | 54 mm | NW | | | | | | |
| | | | 2 | | | | | | | | 42 | 98 |
| 6 | | Bordomsu gri renkli genel olarak taze ve dayanımlı, bazaltik AGLOMERA. | | 6.00 | | | | | | Süreksizlik düz-lemleri ve kırık yüzeyleri pürüzlü ve kil sıvalı. Oksidasyon göz-lenmekte. | | |
| 7 | | | 3 | | | | | | | | 17 | 70 |
| | | 3.00-5.00m ve 7.00-8.30m araları parçalı. | | 8.00 | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | 4 | | | | | | | | 54 | 84 |
| 10 | | | | 10.00 | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | Bülent Güngör | Mustafa Akıncı |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXELLENT | | |

| AYRI?MA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|
| I : BÜT. AYRIŞMALI COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI HIGHLY WEATH | | | |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI SLIGHTLY WEAT. | | | |
| V : TAZE FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK17

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 5 | 12.00 | 54 mm | NW | | | | | 6 | 61 |
| 12 | | | 6 | 14.00 | | | | | | | 23 | 77 |
| 13 | | Açık kahverengimsi gri renkli parçalı ve kırıklı çok ayrışmalı ve zayıf AGLOMERA. | | | | | | | | | | |
| 14 | | Marn ve kum içermekte. | 7 | 16.00 | | | | | | Ayrışma nedeniy-le süreksizlik göz-lenemedi. Kırık yüzeyleri pürüzlü ve paslı. | 14 | 77 |
| 15 | | | | | | | | | | | | |
| 16 | | | 8 | 17.00 | | | | | | | - | 83 |
| 17 | | | 9 | 18.00 | | | | | | | - | 68 |
| 18 | | | 10 | 19.00 | | | | | | | - | 60 |
| 19 | | | 11 | 20.00 | | | | | | | - | 87 |
| 20 | | | 12 | 22.00 | | | | | | | 92 | 97 |
| 21 | | Tanımlama Sayfa 3/4'de. | | | | | | | | Tanımlama Sayfa 3/4'de. | | |
| 22 | | | 13 | 24.00 | | | | | | | 55 | 89 |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK17

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 14 | 26.00 | 54 mm | | | | | | 45 | 83 |
| 26 | | | 15 | 28.00 | | | | | | | 35 | 82 |
| 27 | | 20.00-23.00m arası Bordomsu gri, genelde gri renkli taze-az ayrışmalı orta dayanımlı-dayanımlı AGLOMERA. | | | | | | | | | | |
| 28 | | | 16 | 30.00 | | | | | | Süreksizlik düz-lemleri ve kırık yüzeyleri pürüzlü ve kil sıvalı yer yer paslı. | 12 | 60 |
| 29 | | 23.00-23.20m arasında Bej renkli ince çakıl daneleri içeren kumtaşı ara katmanlı. | | | | | | | | | | |
| 30 | | | 17 | 32.00 | | | | | | | 23 | 78 |
| 31 | | 34.00-36.00 ve 36.50.38.00m ve 23.20-31.50m arası az-orta derecede ayrışmalı. orta zayıf. | | | | | | | | | | |
| 32 | | | 18 | 34.00 | | | | | | | 93 | 96 |
| 33 | | | | | | | | | | | | |
| 34 | | | 19 | 36.00 | | | | | | | 23 | 72 |
| 35 | | | | | | | | | | | | |
| 36 | | | 20 | 38.00 | | | | | | | 38 | 75 |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK17

SAYFA / PAGE NO : 4/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 3/4'de. | | | | | | | | Tanımlama Sayfa 3/4'de. | | |
| | | | 21 | | | | | | | | 70 | 83 |
| 39 | | | | 40.00 | | | | | | | | |
| 40 | | | 22 | | | | | | | | 47 | 95 |
| 41 | | | | 42.00 | | | | | | | | |
| 42 | | Gri renkli taze ve dayanımlı seyrekçe ince kalsit damarlı BAZALT. | 23 | | | | | | | | 95 | 99 |
| 43 | | | | 44.00 | | | | | | Süreksizlik düz-lemleri az pürüzlü ve yer yer kalsit sıvalı. | | |
| 44 | | | 24 | | 54 mm | | | | | | 100 | 100 |
| 45 | | | | 46.00 | | | | | | | | |
| 46 | | | 25 | | | | | | | | 100 | 100 |
| 47 | | | | | | | | | | | | |
| 48 | | KUYU SONU 48.00m | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T1-SK18<br>SAYFA / PAGE NO : 1/4 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) :171.22 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL | KOORD. / COORD. N-S (y) : 402916.870 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537831.840 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+300 | 20.95 | 04.06.2001 | | |
| BASL. TAR. / START DATE :27.04.2001 | SAPMA / OFFSET (m) :EKSEN (SAĞ TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE 04.05.2001 | DERİNLİK / DEPTH (m) : 45.00 | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH<br>I II III IV V | <br>AYRIŞMA WEATHERING<br>I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | Bitkisel Toprak | | | | | | | | | - | 55 |
| | | | 1 | 1.00 | | | | | | | | |
| 1 | | | 2 | 2.00 | | | | | | | - | 65 |
| 2 | | Kahverenkli seyrekçe ince çakıl taneleri içeren kumlu-siltli KİLTAŞI. | 3 | 3.00 | | | | | | | - | 65 |
| 3 | | | 4 | 4.00 | | | | | | | - | 55 |
| 4 | | | 5 | 5.00 | 54 mm | NW | | | | | - | 70 |
| 5 | | | 6 | 6.00 | | | | | | | - | 75 |
| 6 | | Pembemsi gri renkli taze-az ayrışmalı orta dayanımlı dayanımlı seyrekçe andezit ve bazalt blokları içeren **AGLOMERA** | 7 | 8.00 | | | | | | Kırık yüzeyleri pürüzlü olup kil sıvalı. Oksidasyon gözlenmemekte olup renk değişimi var. | 34 | 82 |
| 8 | | 5.00-9.00m arası orta derecede ayrışmış orta zayıf. | 8 | | | | | | | | | |
| 9 | | | | | | | | | | | 29 | 75 |
| 10 | | | | 10.00 | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK<br>II : ZAYIF WEAK<br>III : ORTA ZAYIF MOD. WEAK<br>IV : O. DAYANIMLI MOD. STRONG<br>V : DAYANIMLI STRONG | 25-50 : ZAYIF POOR<br>50-75 : ORTA FAIR<br>75-90 : İYİ GOOD<br>90-100 : ÇOK İYİ EXELLENT | Bülent Güngör | Mustafa Akıncı |

| AYRI?MA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|
| I : BÜT. AYRIŞMALI COMP. WEATHERED<br>II : ÇOK AYRIŞMALI HIGHLY WEATH<br>III : ORTA DER. AYR. MOD. WEATHERED<br>IV : AZ AYRIŞMALI SLIGHTLY WEAT.<br>V : TAZE FRESH | 1 2 3 M | B.Caner Kandemir | KGM |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK18

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 9 | 12.00 | 54 mm | | | | | | 57 | 95 |
| 12 | | | 10 | 14.00 | | | | | | | 70 | 84 |
| 14 | | | 11 | 16.00 | | | | | | | 95 | 98 |
| 15 | | Tanımlama Sayfa 1/4'de. | | | | | | | | Süreksizlik düz-lemleri pürüzlü ve kil sıvalı. | | |
| 16 | | | 12 | 18.00 | | | | | | | 65 | 88 |
| 17 | | | | | | | | | | | | |
| 18 | | | 13 | 20.00 | | | | | | | 95 | 100 |
| 19 | | | | | | | | | | | | |
| 20 | | | 14 | 22.00 | | | | | | | 95 | 98 |
| 21 | | | | | | | | | | | | |
| 22 | | | 15 | 24.00 | | | | | | | 29 | 83 |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK18

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | 25.10-25.50m arası kumtaşı bazaltı kiltaşı. | 16 | 26.00 | 54 mm | | | | | | 38 | 94 |
| 26 | | | 17 | 28.00 | | | | | | Tanımlama Sayfa 2/4'de | 90 | 95 |
| 28 | | Tanımlama Sayfa 1/4'de | 18 | 30.00 | | | | | | | 95 | 98 |
| 30 | | | 19 | 32.00 | | | | | | | 95 | 99 |
| 32 | | | 20 | 34.00 | | | | | | | 41 | 92 |
| 34 | | **AGLOMERA+KİLTAŞI** Ardalanması | 21 | 36.00 | | | | | | Kırık düzlemleri pürüzlü ve kil sıvalı. Yer yer Oksidasyon sonucu renk değişimi gözlenmekte. | 8 | 89 |
| 35 | | **Aglomera:** Gri renkli kırıklı parçalı yer yer killi orta derecede ayrışmalı, orta zayıf | | | | | | | | | | |
| 36 | | KİLTAŞI: Yeşilimsi gri renkli. | 22 | 38.00 | | | | | | | 60 | 92 |
| 37 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T1-SK18

SAYFA / PAGE NO : 4/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | 38.40-39.80m arası Koyu gri-siyah renkli taze ve dayanımlı gaz boşluklu bazalt bloğu. | 23 | 40.00 | 54 mm | | | | | | 66 | 96 |
| 40 | | | 24 | | | | | | | Tanımlama Sayfa 3/4'de. | 35 | 96 |
| 41 | | | | 42.00 | | | | | | | | |
| 42 | | Tanımlama Sayfa 3/4'de | 25 | | | | | | | | 29 | 95 |
| 43 | | | | 44.00 | | | | | | | | |
| 44 | | | 26 | | | | | | | | 10 | 93 |
| 45 | | KUYU SONU 45.00m. | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

## THE ÖCELİ (T-2) TUNNEL

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T2-SK1

SAYFA / PAGE NO : 1/3

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 145.96 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (x) : 4 536 364 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (y) : 404 346 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 28+400 | | | | |
| BASL. TAR. / START DATE : 18.05.2000 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE : 23.05.2000 | DERİNLİK / DEPTH (m) : 35.00 | | | | |

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | **BİTKİSEL TOPRAK** | | | | | | | | | | |
| 1 | | **KİLTAŞI (Neojen)** Kahverengi, sarımsı, açık gri, çok bütünüyle ayrışmalı ve zayıf - çok zayıf. | 1 | 1.50 | | NW | | | | Ayrışma nedeniyle süreksizlik gözlenmemiştir. | 60 | 100 |
| 2 | | | 2 | 3.00 | | | | | | | 46 | 57 |
| 3 | | **AGLOMERA** Sarımsı, açık gri, çok ayrışmalı ve zayıf. | 3 | 4.00 | 54 | | | | | Düzensiz kırıklı ve çok çatlaklı, süreksizlik düzlemleri paslı. | 0 | 60 |
| 4 | | | 4 | 5.00 | | | | | | | 0 | 56 |
| 5 | | | 5 | 6.00 | | | | | | | 0 | 89 |
| 6 | | | 6 | 7.00 | | | | | | | 0 | 63 |
| 7 | | | 7 | 8.00 | | | | | | | 0 | 82 |
| 8 | | **AGLOMERA** Açık gri, az -orta ayrışmalı ve orta dayanımlı - orta zayıf | 8 | 9.00 | | | | | | | 38 | 100 |
| 9 | | | 10 | | | | | | | | 41 | 89 |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | ZİHNİ EFE | MUSTAFA AKINCI |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXCELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMIŞ | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMIŞ | HIGHLY WEATHERED | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | H.A. TİRYAKİ | |
| IV : AZ AYRIŞMIŞ | SLIGHTLY WEATHERED | | | |
| V : TAZE | FRESH | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BOREING NO : T2-SK1<br>SAYFA / PAGE NO : 2/3 |
|---|---|

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama sayfa 1/3 de. | 11 | 11.00 | 54 | | | | | Tanımlama Sayfa 1/3'de. | 65 | 97 |
| | | | 12 | 12.00 | | | | | | | 55 | 98 |
| 12 | | | 13 | 12.50 | | | | | | | 40 | 46 |
| 13 | | | 14 | 14.00 | | | | | | | 59 | 69 |
| 14 | | | 15 | 15.50 | | | | | | Çok seyrek gözlenen eklem düzlemleri paslı ve kalsit sıvalı.Kimi düzeyler çok kırıklı. | 49 | 96 |
| 15 | | | 16 | 16.00 | | | | | | | 70 | 100 |
| 16 | | | 17 | 17.00 | | | | | | | 83 | 94 |
| 17 | | | 18 | 18.00 | | | | | | | 78 | 88 |
| 18 | | | 19 | 18.50 | | | | | | | 30 | 100 |
| 19 | | **AGLOMERA**<br>Açık - koyu gri, koyu yeşilimsi, breşik dokulu az ayrışmalı ve orta dayanımlı, seyrekçe orta ayrışmalı ve orta zayıf tüf düzeyleri ile yanal - düşey geçişli. | 20 | 20.00 | | | | | | | 67 | 97 |
| 20 | | | 21 | 21.50 | | | | | | | 63 | 100 |
| | | | 22 | 22.00 | | | | | | | 52 | 100 |
| 22 | | | 23 | 23.00 | | | | | | | 93 | 99 |
| 23 | | | 24 | | | | | | | | 97 | 100 |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | | | | | SONDAJ / BOREING NO :T2-SK1<br>SAYFA / PAGE NO : 3/3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER.<br>BORE DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | | | | | AYRIŞMA WEATHERING I II III IV V | | | | | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ.<br>CORE RECO. (%) |
| 25 | | Tanımlama sayfa 2/3'de. | 25 | 25.50 | 54 | | | | | | | | | | | | | | 73 | 99 |
| 26 | | | 26 | 26.00 | | | | | | | | | | | | | | | 60 | 98 |
| 27 | | | 27 | 27.50 | | | | | | | | | | | | | | | 90 | 100 |
| 28 | | | 28 | 28.00 | | | | | | | | | | | | | | Genelde masif, çok seyrekçe gözlenen eklem düzlemleri kalsit sıvalı. | 68 | 100 |
| 29 | | **TÜF**<br>Koyu Gri, siyah renkli, az ayrışmalı ve orta zayıf, çoğu düzeylerde, az ayrışmalı ve orta dayanımlı AGLOMERA ile yanal - düşey geçişli. | 29 | 29.00 | | | | | | | | | | | | | | | 90 | 99 |
| 30 | | | 30 | 30.00 | | | | | | | | | | | | | | | 73 | 100 |
| 31 | | | 31 | 30.50 | | | | | | | | | | | | | | | 60 | 100 |
| 32 | | | 32 | 32.00 | | | | | | | | | | | | | | | 90 | 100 |
| 33 | | | 33 | 33.50 | | | | | | | | | | | | | | | 100 | 100 |
| 34 | | | 34 | 34.00 | | | | | | | | | | | | | | | 100 | 100 |
| 35 | | | 35 | 35.00 | | | | | | | | | | | | | | | 96 | 100 |
| 36 | | KUYU SONU 35.00 m. | | | | | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T2-SK4

SAYFA / PAGE NO : 1/4

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 157.64 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (x) : 4 536 589 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (y) : 403 877 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 27+875 | | | | |
| BASL. TAR. / START DATE : 12.05.2000 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE : 18.05.2000 | DERİNLİK / DEPTH (m) : 40.00 | | | | |

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | **BİTKİSEL TOPRAK** | | | | | | | | | | |
| 1 | | | 1 | 1.50 | | NW | | | | | 46 | 63 |
| 2 | | **KİLTAŞI (Neojen)** Koyu Kahverengi, çok- bütünüyle ayrışmalı, ve zayıf - çok zayıf. | 2 | 3.00 | | | | | | Ayrışma nedeniyle süreksizlik gözlenmedi. | 34 | 64 |
| 3 | | | 3 | 4.50 | | | | | | | 13 | 67 |
| 4 | | | 4 | 6.00 | 54 | | | | | | 74 | 97 |
| 5 | | | 5 | 8.00 | | | | | | | 40 | 97 |
| 6 | | **AGLOMERA** Kahverengi, açık gri, az orta ayrışmalı ve orta dayanımlı- orta zayıf, çoğu düzeylerde orta ayrışmalı ve orta zayıf Tüf ile yanal- düşey geçişli. | 6 | | | | | | | Tanımlama Sayfa 2/4'de. | 43 | 97 |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | İMAM ZİREK | MUSTAFA AKINCI |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXCELLENT | | |

| AYRIŞMA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN- LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|
| I : BÜT. AYRIŞMIŞ COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMIŞ HIGHLY WEATHERED | | | ---------- |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMIŞ SLIGHTLY WEATHERED | | H.A. TİRYAKİ | |
| V : TAZE FRESH | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BOREING NO : T2-SK4

SAYFA / PAGE NO : 2/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama sayfa 1/4'de. | 7 | 12.00 | 54 | | | | | AGLOMERA Düzeylerinde seyrekçe gözlenen geniş eklemler kalsit sıvalı. Tüf düzeyleri çok kırıklı. | 45 | 97 |
| 12 | | | 8 | 13.50 | | | | | | | 73 | 97 |
| 13 | | | 9 | 14.00 | | | | | | | 60 | 100 |
| 14 | | | 10 | 15.00 | | | | | | | 70 | 87 |
| 15 | | | 11 | 16.00 | | | | | | | 46 | 67 |
| 16 | | | 12 | 18.00 | | | | | | | 61 | 89 |
| 17 | | **AGLOMERA** Açık koyu gri, derinlerde siyahımsı orta zayıf kimi düzeylerde orta ayrışmalı ve orta zayıf Tüf ile yanal düşey geçişli. | | | | | | | | | | |
| 18 | | | 13 | 18.50 | | | | | | | 74 | 100 |
| 19 | | | 14 | 20.00 | | | | | | | 72 | 98 |
| 20 | | | 15 | 21.70 | | | | | | | 72 | 86 |
| 21 | | **AGLOMERA** Koyu gri, siyahımsı, breşik dokulu, az orta ayrışmalı ve orta dayanımlı - orta zayıf, kimi düzeylerde orta ayrışmalı ve orta zayıf Tüf ile yanal-düşey geçişli. | 16 | 22.00 | | | | | | | 83 | 100 |
| 22 | | | 17 | 23.50 | | | | | | | 70 | 88 |
| 23 | | | 18 | | | | | | | | 47 | 79 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BOREING NO TK2-SK4

SAYFA / PAGE NO : 3/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | Tanımlama sayfa 2/4 de. | 19 | 25.00 | 54 | | | | | Tanımlama Sayfa 2/4'de. | 50 | 90 |
| | | | 20 | 26.00 | | | | | | | 0 | 77 |
| 26 | | | 21 | 27.00 | | | | | | | 95 | 99 |
| 27 | | | 22 | 28.00 | | | | | | | 90 | 96 |
| 28 | | | 23 | 29.00 | | | | | | | 75 | 94 |
| 29 | | | 24 | 30.00 | | | | | | | 70 | 92 |
| 30 | | | 25 | 31.20 | | | | | | | 65 | 99 |
| 31 | | **AGLOMERA** Açık koyu gri, siyahımsı, az ayrışmalı ve orta dayanımlı. | 26 | 32.00 | | | | | | Seyrekçe, gözlenen geniş eklemler kalsit sıvalı. | 80 | 80 |
| 32 | | | 27 | 34.00 | | | | | | | 80 | 95 |
| 33 | | | 28 | 36.00 | | | | | | | 81 | 100 |
| 34 | | | 29 | | | | | | | | 77 | 100 |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BOREING NO :T2-SK4

SAYFA / PAGE NO : 4/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Tanımlama sayfa 3/4 'de. | 30 | 39.50 | 54 | | | | | Tanımlama sayfa 3/4'de. | 75 | 98 |
| | | | 31 | | | | | | | | - | 100 |
| 40 | | KUYU SONU 40.00 m. | | | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T2-SK3

SAYFA / PAGE NO : 1/3

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 149.53 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (x) : 4 536 469 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (y) : 404 046 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 28+080 | | | | |
| BASL. TAR. / START DATE : 11.05.2000 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE : 18.05.2000 | DERİNLİK / DEPTH (m) : 35.00 | | | | |

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BİTKİSEL TOPRAK** | | | | | | | | | | |
| 1 | | | 1 | 1.50 | | NW | | | | | 53 | 93 |
| 2 | | **KİLTAŞI (Neojen)** Kahverengi, çok-bütünüyle ayrışmalı ve zayıf-çok zayıf. | 2 | 3.00 | | | | | | Ayrışma nede-niyle süreksizlik gözlenmedi. | 40 | 93 |
| 3 | | | 3 | 4.50 | | | | | | | 20 | 87 |
| 5 | | | 4 | 6.00 | 54 | | | | | | 0 | 42 |
| 6 | | **AGLOMERA** Açık gri, az-orta ayrışmalı ve orta dayanımlı-orta zayıf. | 5 | 7.00 | | | | | | Kimi düzeylerde çok kırıklı düzlem-ler paslı. | 33 | 82 |
| 7 | | | 6 | 8.00 | | | | | | | 16 | 90 |
| 8 | | | 7 | 9.00 | | | | | | | 56 | 100 |
| 9 | | | 8 | | | | | | | | 63 | 90 |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | ZİHNİ EFE | MUSTAFA AKINCI |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXCELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMIŞ | COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMIŞ | HIGHLY WEATHERED | | | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | H.A. TİRYAKİ | |
| IV : AZ AYRIŞMIŞ | SLIGHTLY WEATHERED | | | |
| V : TAZE | FRESH | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BOREING NO : T2-SK3

SAYFA / PAGE NO : 2/3

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 9 | 11.50 | | | | | | | 58 | 97 |
| | | | 10 | 12.00 | | | | | | | 20 | 100 |
| 12 | | | 11 | 13.00 | | | | | | | 63 | 94 |
| 13 | | **AGLOMERA** Koyu gri, siyahımsı, az ayrışmalı ve orta dayanımlı çoğu düzeylerde orta ayrış malı ve orta zayıf TÜF ile yanal-düşey geçişli. | 12 | 14.00 | | | | | | AGLOMERA Düzeyleri geniş eklemli,TÜF dü-zeyleri süreksiz kırıklı. Düzlemler paslı ve kalsit sıvalı. | 75 | 95 |
| 14 | | | 13 | 14.50 | | | | | | | 86 | 92 |
| 15 | | | 14 | 16.00 | | | | | | | 71 | 97 |
| 16 | | | 15 | 17.50 | 54 | | | | | | 65 | 97 |
| 17 | | | 16 | 18.00 | | | | | | | 50 | 90 |
| 18 | | | 17 | 19.00 | | | | | | | 60 | 93 |
| 19 | | | 18 | 20.00 | | | | | | | 90 | 100 |
| 20 | | | 19 | 20.50 | | | | | | | 24 | 80 |
| 21 | | | 20 | 22.00 | | | | | | | 56 | 97 |
| 22 | | | 21 | 23.50 | | | | | | | 63 | 97 |
| 23 | | | | | | | | | | | 54 | 100 |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | | | | | SONDAJ / BOREING NO :T2-SK3<br>SAYFA / PAGE NO : 3/3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER.<br>BORE DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | | | | | AYRIŞMA WEATHERING I II III IV V | | | | | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
| 25 | | Tanımlama Sayfa 2/3'de. | 22 | 25.50 | | | | | | | | | | | | | | | | | 80 | 98 |
| | | | 23 | 26.00 | | | | | | | | | | | | | | | | | 0 | 92 |
| 26 | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | 24 | 27.50 | | | | | | | | | | | | | | | | | 63 | 91 |
| | | | 25 | 28.00 | | | | | | | | | | | | | | | | | 40 | 90 |
| 28 | | | 26 | 29.50 | | | | | | | | | | | | | | | | | 80 | 93 |
| 29 | | **AGLOMERA** | | | | | | | | | | | | | | | | | | | | |
| | | Açık - koyu gri, az ayrışmalı ve orta dayanımlı kimi düzeylerde orta ayrışmalı TÜF ile yanal düşey geçişli. | 27 | 30.00 | | | | | | | | | | | | | | | Tanımlama Sayfa 2/3'de. | 46 | 100 |
| 30 | | | 28 | 31.00 | | | | | | | | | | | | | | | | | 70 | 95 |
| 31 | | | 29 | 32.00 | 54 | | | | | | | | | | | | | | | | 17 | 96 |
| 32 | | | 30 | 32.50 | | | | | | | | | | | | | | | | | 40 | 96 |
| 33 | | | 31 | 34.00 | | | | | | | | | | | | | | | | | 42 | 97 |
| 34 | | | 32 | | | | | | | | | | | | | | | | | | 62 | 99 |
| 35 | | KUYU SONU 35.00m. | | | | | | | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO :T2-SK2

SAYFA / PAGE NO : 1/4

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 149.80 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (x) : 4 536 401 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (y) : 404 201 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 28+250 | | | | |
| BASL. TAR. / START DATE : 11.05.2000 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE : 17.05.2000 | DERİNLİK / DEPTH (m) : 40.00 | | | | |

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BİTKİSEL TOPRAK** | | | | | | | | | | |
| 1 | | **KİLTAŞI (Neojen)** Kahverengi, sarımsı, çok - bütünüyle ayrışmalı, zayıf-çok zayıf. | 1 | 1.50 | | NW | | | | Ayrışma nedeni le süreksizlik gözlenemedi. | 62 | 78 |
| 2 | | | 2 | 3.00 | | | | | | | 74 | 81 |
| 3 | | | 3 | 4.50 | | | | | | | 22 | 82 |
| 4 | | | 4 | 6.00 | 54 | | | | | Kimi düzeyler çok çatlaklı ve kırıklı düzlemler paslı. | 60 | 76 |
| 5 | | **AGLOMERA** Açık gri, breşik dokulu, az - orta ayrışmalı ve orta dayanımlı - orta zayıf. | 5 | 7.50 | | | | | | | 55 | 85 |
| 6 | | | 6 | 8.00 | | | | | | | 0 | 74 |
| 7 | | | 7 | 9.00 | | | | | | | 51 | 82 |
| 8 | | | 8 | | | | | | | | 49 | 90 |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | YUSUF YILDIZ | MUSTAFA AKINCI |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXCELLENT | | |

| AYRIŞMA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|
| I : BÜT. AYRIŞMIŞ COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMIŞ HIGHLY WEATHERED | | | ---------- |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMIŞ SLIGHTLY WEATHERED | | H.A. TİRYAKİ | |
| V : TAZE FRESH | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BOREING NO : T2-SK2<br>SAYFA / PAGE NO : 2/4 |
|---|---|

| SOND. DER.<br>BORE DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 9 | 10.60 | | | | | | | 0 | 90 |
| 11 | | | 10 | 12.00 | | | | | | | 45 | 86 |
| 12 | | | | | | | | | | | | |
| 13 | | | 11 | 14.00 | | | | | | | 65 | 85 |
| 14 | | AGLOMERA<br>Açık -koyu gri koyu yeşi-limsi, genelde az ayrışmalı ve orta dayanımlı. Kimi dü-zeylerde az-orta ayrışmalı ve orta zayıf Tüf ile yanal- düşey geçişli,. | 12 | 16.00 | | | | | | | 80 | 93 |
| 16 | | | 13 | 17.00 | | | | | | AGLOMERA<br>Düzeyleri geniş eklemli, TÜF dü-zeyleri yoğun dü-zensiz kırıklı. | 70 | 81 |
| 17 | | | 14 | 18.00 | 54 | | | | | | 81 | 100 |
| 18 | | | 15 | 19.50 | | | | | | | 90 | 100 |
| 19 | | | 16 | 20.00 | | | | | | | 66 | 100 |
| 20 | | | 17 | 20.50 | | | | | | | 24 | 96 |
| 21 | | TÜF<br>Koyu gri, siyah renkli, az ayrışmalı ve orta zayıf. Çoğu düzeylerde, az ayrışmalı ve orta dayanımlı AGLOMERA ile yanal-düşey geçişli. | 18 | 22.00 | | | | | | Tanımlama<br>Sayfa 3/4'de. | 96 | 99 |
| 22 | | | 19 | 23.50 | | | | | | | 83 | 89 |
| 23 | | | 20 | | | | | | | | 0 | 90 |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BOREING NO :T2-SK2<br>SAYFA / PAGE NO : 3/4 |
|---|---|

| SOND. DER.<br>BORE DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 21 | 25.00 | | | | | | | 50 | 100 |
| 25 | | | 22 | 26.00 | | | | | | | 0 | 67 |
| | | Tanımlama Sayfa 2/4'de. | 23 | 26.50 | | | | | | TÜF düzeyleri çok kırıklı, AGLOMERA, düzeyleri geniş ek lemli. | 0 | 80 |
| 26 | | | 24 | 28.00 | | | | | | | 75 | 97 |
| 27 | | | 25 | 29.50 | | | | | | | 61 | 97 |
| 28 | | | 26 | 30.00 | | | | | | | 0 | 88 |
| 29 | | | 27 | 31.50 | 54 | | | | | | 70 | 98 |
| 30 | | | 28 | 32.00 | | | | | | | 80 | 100 |
| 31 | | | 29 | 33.00 | | | | | | | 57 | 100 |
| 32 | | | 30 | 34.00 | | | | | | | 75 | 100 |
| 33 | | AGLOMERA<br>Koyu gri, siyahımsı breşik dokulu, az ayrışmalı ve orta dayanımlı, kimi düzeylerde az ayrışmalı, orta zayıf TÜF ile yanal - düşey geçişli. | 31 | 34.50 | | | | | | TÜF düzeyleri düzensiz kırıklı, AGLOMERA düzeyleri geniş eklemli ve masif. | 100 | 100 |
| 34 | | | 32 | 36.00 | | | | | | | 100 | 100 |
| 35 | | | 33 | 37.50 | | | | | | | 100 | 100 |
| 36 | | | 34 | | | | | | | | 70 | 82 |
| 37 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BOREING NO :T2-SK2

SAYFA / PAGE NO : 4/4

| SOND. DER. BORE DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BORE. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 35 | 39.00 | 54 | | | | | Tanımlama sayfa 3/4'de. | 54 | 100 |
| 39 | | Tanımlama Sayfa 3/4'de. | 36 | | | | | | | | 85 | 100 |
| 40 | | KUYU SONU 40.00 m. | | | | | | | | | | |
| 41 | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T2-SK5 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/4 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 174.97 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG PORTAL (T-2) | KOORD. / COORD. N-S (y) : 403041 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537700 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+475 | 14.50 | 04.04.2001 | | |
| BASL. TAR. / START DATE : 19.02.2001 | SAPMA / OFFSET (m) : EKSEN(SOL TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE : 01.03.2001 | DERİNLİK / DEPTH (m) : 50.00m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | Karotsuz açıldı. | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | 5.00 | 54 mm | | | | | | | |
| | | | 1 | | | | | | | | - | 85 |
| 6 | | | | 6.00 | | | | | | | | |
| 7 | | **BAZALTİK TÜF** | 2 | | | | | | | | 46 | 91 |
| | | Koyu gri, taze - az ayrışmalı ve dayanımlı orta dayanımlı. | | 8.00 | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | 3 | | | | | | | | 85 | 100 |
| 10 | | | | 10.00 | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK5

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama Sayfa 1/4'de. | 4 | | | | | | | Tanımlama Sayfa 1/4'de. | 30 | 42 |
| | | | | 12.00 | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | 5 | | | | | | | | 95 | 100 |
| | | **BAZALTİK TÜF** | | 14.00 | | | | | | | | |
| 14 | | Koyu gri, taze - az ayrışmalı ve dayanımlı orta dayanımlı. | | | | | | | | | | |
| 15 | | | 6 | | | | | | | Masif yapılı, seyrekçe gözlenen süreksizlikler pürüzlü. | 90 | 100 |
| | | | | 16.00 | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | 7 | | 54 mm | | | | | | 90 | 100 |
| | | | | 18.00 | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | **BAZALTİK TÜF+AGLOMERA** Koyu gri yer yer mor renkli,az ayrışmalı ve orta dayanımlı. | 8 | | | | | | | | 100 | 100 |
| | | | | 20.00 | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 21 | | | 9 | | | | | | | | 90 | 100 |
| | | | | 22.00 | | | | | | | | |
| 22 | | **AGLOMERA** Kahverengi, orta ayrışmalı ve orta zayıf. Kimi düzeyler KİLTAŞI arakat-manlı. | | | | | | | | | | |
| 23 | | | 10 | | | | | | | Çok kırıklı. | 30 | 100 |
| | | | | 24.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK5

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 11 | 26.00 | 54 mm | | | | | | 75 | 98 |
| 26 | | | 12 | 28.00 | | | | | | Seyrekçe gözlenen süreksizlikler pürüzlü. | 70 | 100 |
| 28 | | | 13 | 30.00 | | | | | | | 85 | 92 |
| 30 | | | 14 | 32.00 | | | | | | | 80 | 80 |
| 32 | | **ANDEZİTİK TÜF+AGLOMERA** Açık koyu gri, genelde az ayrışmalı ve orta dayanımlı. | 15 | 34.00 | | | | | | | 74 | 87 |
| 34 | | | 16 | 36.00 | | | | | | Çok kırıklı. | 15 | 68 |
| 36 | | | 17 | 38.00 | | | | | | | 15 | 78 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK5

SAYFA / PAGE NO : 4/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | 18 | | | | | | | Çok kırıklı. | 20 | 87 |
| | | | | 40.00 | | | | | | | | |
| 40 | | **ANDEZİTİK TÜF+AGLOMERA** | | | | | | | | | | |
| 41 | | Açık koyu gri, genelde az ayrışmalı ve orta dayanımlı. | 19 | | | | | | | | 95 | 100 |
| | | | | 42.00 | | | | | | | | |
| 42 | | | | | | | | | | | | |
| 43 | | | 20 | | | | | | | Seyrekçe, gözlenen süreksizlikler pürüzlü. | 70 | 75 |
| | | | | 44.00 | | | | | | | | |
| 44 | | | | | 54 mm | | | | | | | |
| 45 | | | 21 | | | | | | | | 38 | 75 |
| | | | | 46.00 | | | | | | | | |
| 46 | | 46.00-48.00m.ler arası, tüfit hamurlu, kireçtaşı çakıllı, | | | | | | | | | | |
| 47 | | karstik ÇAKILTAŞI | 22 | | | | | | | | 95 | 100 |
| | | | | 48.00 | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | 49.00-50.00m ler arası, taze, dayanımlı BAZALT. | 23 | | | | | | | | 90 | 100 |
| 50 | | KUYU SONU (50.00m) | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T2-SK6 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/4 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 179.57 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG PORTAL (T-2) | KOORD. / COORD. N-S (y) : 403023 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537687 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+490 | 26.80 | 04.04.2001 | | |
| BASL. TAR. / START DATE : 13.03.2001 | SAPMA / OFFSET (m) : EKSEN(SAĞ TÜP) | | | | |
| BİTİŞ TAR. / FINISH DATE : 20.03.2001 | DERİNLİK / DEPTH (m) : 50.00m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | Karotsuz açıldı. | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | 5.00 | 54 mm | | | | | | | |
| | | | 1 | 6.00 | | | | | | | 20 | 53 |
| 6 | | | | | | | | | | | | |
| 7 | | **AGLOMERA** Kahverengi, orta ayrışmalı ve orta zayıf. | 2 | 8.00 | | | | | | Çok kırıklı. | 5 | 75 |
| 8 | | | | | | | | | | | | |
| 9 | | | 3 | | | | | | | | 15 | 75 |
| 10 | | | | 10.00 | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK6

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 4 | | | | | | | Seyrekçe düzensiz eklem gözlenmekte. | 80 | 85 |
| 12 | | **BAZALTİK AGLOMERA** Kahverengi, açık gri, az ayrışmalı ve orta dayanımlı. | | 12.00 | | | | | | | | |
| 13 | | | 5 | | | | | | | | 6 | 80 |
| 14 | | | | 14.00 | | | | | | | | |
| 15 | | **KİLTAŞI+MARN** Sarımsı, kahverengi orta ayrışmalı ve orta zayıf. | 6 | | | | | | | | 43 | 82 |
| 16 | | | 7 | 16.00 | | | | | | | 15 | 95 |
| 17 | | | | 17.00 | 54 mm | | | | | | | |
| 18 | | **KİLTAŞI** Gri, az ayrışmalı ve orta dayanımlı. | 8 | 18.00 | | | | | | Çok kırıklı. Kimi düzeylerde ayrışma nedeniyle süreksizlik gözlenemedi. | 15 | 75 |
| 19 | | | 9 | | | | | | | | 25 | 75 |
| 20 | | | | 20.00 | | | | | | | | |
| 21 | | **KİLTAŞI+MARN** Sarımsı, orta ayrışmalı ve orta zayıf. | 10 | | | | | | | | 30 | 75 |
| 22 | | **BAZALTİK TÜF** Açık-koyu gri, genelde taze ve dayanımlı. | | 22.00 | | | | | | | | |
| 23 | | | 11 | | | | | | | Tanımlama Sayfa 3/4'de. | 80 | 90 |
| | | | | 24.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK6

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 12 | 26.00 | 54 mm | | | | | Masif yapılı | 100 | 100 |
| 26 | | 26.15-27.80m ve 28.80-30.35m ler arası az ayrışmalı ve orta dayanımlı. | 13 | 28.00 | | | | | | Kalsit dolgulu | 75 | 85 |
| 28 | | | 14 | 30.00 | | | | | | kırıklı | 60 | 90 |
| 29 | | | | | | | | | | Kalsit dolgulu | | |
| 30 | | | 15 | 32.00 | | | | | | | 70 | 100 |
| 31 | | **BAZALTİK TÜF** Açık-koyu gri, genelde taze ve dayanımlı. | 16 | 34.00 | | | | | | Genelde masif yapılı, eklem düz-lemleri pürüzlü. | 100 | 100 |
| 32 | | | 17 | 36.00 | | | | | | | 100 | 100 |
| 33 | | | 18 | 38.00 | | | | | | | 100 | 100 |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T2-SK7<br>SAYFA / PAGE NO : 1/6 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 205.533 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG:TÜNEL (T-2) | KOORD. / COORD. N-S (y) : 403147 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4537535 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+675 | 09.20 | 04.04.2001 | | |
| BASL. TAR. / START DATE : 03.02.2001 | SAPMA / OFFSET (m) : EKSEN | | | | |
| BİTİŞ TAR. / FINISH DATE :15.02.2001 | DERİNLİK / DEPTH (m) : 68.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 23.00m'ye kadar Sondaj karotsuz açıldı. | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | ---------- | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK7

SAYFA / PAGE NO : 2/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Gri renkli orta derecede ayrışmış orta zayıf AGLOMERA | 1 | 11.00 | 54 mm | NW | | III | III | Çok kırıklı parçalı, kil dolgulu ve pürüzlü. | - | 87 |
| 20 | | Gri - Koyu gri renkli orta derecede ayrışmış ve orta zayıf AGLOMERA ve BAZALT blokları kil dolgulu. | 2 | 20.00 21.00 | | | | III | III | | - | 94 |
| 23 | | Tanımlama Sayfa 3/6'da | 3 | 23.00 | | | | I II | I II | | 54 | 95 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK7

SAYFA / PAGE NO : 3/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 | 25.00 | 54 mm | | | | | | 54 | 95 |
| 25 | | **KİLTAŞI** Gri renkli çok bütünüyle ayrışmalı ve zayıf çok zayıf kiltaşı seyrekçe kum içermekte. | 4 | 27.00 | | | | | | | 20 | 96 |
| 27 | | | 5 | 29.00 | | | | | | | 65 | 85 |
| 28 | | 29.50-38.00m leri arasında ayrışmış aglomera, bazalt ve kireçtaşı blok ve paracıkları içermekte. Kırık yüzeyleri pürüzlü ve kil sıvalı. | | | | | | | | | | |
| 29 | | | 6 | 31.00 | | | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | 13 | 90 |
| 31 | | | 7 | 33.00 | | | | | | | 30 | 88 |
| 33 | | | 8 | 35.00 | | | | | | | 36 | 88 |
| 34 | | | | | | | | | | | | |
| 35 | | Tanımlama Sayfa 4/6'da. | 9 | 37.00 | | | | | | Tanılmama Sayfa 4/6'da. | 93 | 97 |
| 36 | | | | | | | | | | | | |
| 37 | | | 10 | | | | | | | | 93 | 99 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK7

SAYFA / PAGE NO : 4/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10 | 39.00 | 54 mm | | | | | | 93 | 99 |
| 39 | | **AGLOMERA** Koyu Gri renkli az ayrışmış, orta dayanımlı yer yer tüf hamur maddeli Aglomera. | 11 | | | | | | | | 90 | 95 |
| 40 | | | | | | | | | | Seyrekçe gözlenen süreksizlik düzlemleri pürüzlü ve kalsit sıvalı. | | |
| 41 | | | 12 | 41.00 | | | | | | | 98 | 99 |
| 42 | | | | | | | | | | | | |
| 43 | | | | 43.00 | | | | | | | | |
| | | **KİLTAŞI** Grimsi kahverenkli, çok bütünüyle ayrışmış ve zayıf-çok zayıf kiltaşı. | 13 | | | | | | | | 16 | 95 |
| 44 | | | | | | | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | | |
| | | Alt seviyelerde küçük aglomera parçacıkları içermekte. (Çamurtaşı) | | 45.00 | | | | | | | | |
| 45 | | | 14 | | | | | | | | 38 | 75 |
| 46 | | | | | | | | | | | | |
| | | | | 47.00 | | | | | | | | |
| 47 | | | 15 | | | | | | | | 84 | 98 |
| 48 | | Tanımlama Sayfa 5/6'da. | | | | | | | | Tanımlama Sayfa 5/6'da. | | |
| | | | | 49.00 | | | | | | | | |
| 49 | | | 16 | | | | | | | | 84 | 96 |
| 50 | | | | | | | | | | | | |
| | | | | 51.00 | | | | | | | | |
| 51 | | | 17 | | | | | | | | 70 | 98 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK7

SAYFA / PAGE NO : 5/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 17 | 53.00 | | | | | | | 70 | 98 |
| 53 | | | 18 | 55.00 | | | | | | | 78 | 100 |
| 54 | | | | | | | | | | | | |
| 55 | | | 19 | 58.00 | | | | | | | 79 | 100 |
| 56 | | | | | | | | | | | | |
| 57 | | **AGLOMERA** Koyu gri renkli, kimi düzeyler bordo renkli ve alacalı, taze ve dayanımlı, çok seyrekçe az-orta derecede ayrışmış ve orta dayanımlı Aglomera Seyrekçe ince kalsit damarlı. | 20 | 59.00 | 54 mm | | | | | Genelde masif, seyrekçe gözlenen süreksizlikler pürüzlü ve kalsit sıvalı. | 75 | 100 |
| 58 | | | | | | | | | | | | |
| 59 | | | 21 | 61.00 | | | | | | | 73 | 98 |
| 60 | | | | | | | | | | | | |
| 61 | | | 22 | 63.00 | | | | | | | 63 | 100 |
| 62 | | | | | | | | | | | | |
| 63 | | | 23 | 65.00 | | | | | | | 66 | 96 |
| 64 | | | | | | | | | | | | |
| 65 | | | 24 | | | | | | | | 88 | 98 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK7

SAYFA / PAGE NO : 6/6

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | Tanımlama Sayfa 5/6'da. | 24 | 67.00 | 54 mm | | | | | Tanımlama Sayfa 5/6'da. | 88 | 98 |
| | | | 25 | | | | | | | | 100 | 100 |
| 68 | | KUYU SONU 68.00m. | | | | | | | | | | |
| 69 | | | | | | | | | | | | |
| 70 | | | | | | | | | | | | |
| 71 | | | | | | | | | | | | |
| 72 | | | | | | | | | | | | |
| 73 | | | | | | | | | | | | |
| 74 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |
| 78 | | | | | | | | | | | | |
| 79 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T2-SK8<br>SAYFA / PAGE NO : 1/7 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 209.15 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (y) : 403325 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (x) : 4537313 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 26+975 | 3.00 | 14/02/01 | | |
| BASL. TAR. / START DATE :19.02.2000 | SAPMA / OFFSET (m) : EKSEN | 4.95 | 17.02.2001 | 11.40 | |
| BİTİŞ TAR. / FINISH DATE :14.03.2001 | DERİNLİK / DEPTH (m) : 87.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00m-10.00m arasında<br>Sondaj Karotsuz Açıldı. | | | | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Fahri Çınar | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMIALI | COMP. WEATHERED | | | KGM |
| II : ÇOK AYRIŞMIŞMALI | HIGHLY WEATH | | ---------- | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 2/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BAZALTİK TÜF** Koyu gri-siyah renkli az ayrışmalı orta zayıf. | 1 | 11.00 | 54 mm | NW | | | | | 25 | 100 |
| 11 | | Karotsuz açıldı. | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | **BAZALTİK TÜF** | 2 | 20.00 | 54 mm | | | | | | 82 | 90 |
| 21 | | Karotsuz açıldı. | | 21.00 | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 3/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | NW | | | | | | |
| 26 | | Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | **AGLOMERA** | 3 | 30.00<br>31.00 | 54 mm | | | | | | 75 | 100 |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | Karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 4/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Karotsuz açıldı. | | | | | | | | | | |
| | | | | 40.00 | | | | | | | | |
| 40 | | **AGLOMERA** | 4 | | | | | | | | 95 | 100 |
| | | | | 41.00 | | | | | | | | |
| 41 | | Karotsuz açıldı. | | | | | | | | | | |
| | | | | 42.00 | | | | | | | | |
| 42 | | | 5 | | 54 mm | | | | | | 98 | 99 |
| 43 | | | | 44.00 | | | | | | | | |
| 44 | | | 6 | | | | | | | | 85 | 98 |
| 45 | | | | | | | | | | | | |
| 46 | | | 7 | 46.00 | | | | | | | 98 | 100 |
| 47 | | **AGLOMERA** Koyu gri-siyah renkli, taze ve az ayrışmış dayanımlı ve orta dayanımlı. Seyrekçe ince kalsit damarlı. | | | | | | | | Düzlemler pürüzlü ve kimi düzeyler çok çatlaklı ve kırıklı. | | |
| 48 | | 46.50-50.00 m arası ince çakıl daneleri içeren hamur maddesinde tüf arakatmanı gözlendi. | 8 | 48.00 | | | | | | | 98 | 100 |
| 49 | | | | | | | | | | | | |
| 50 | | | 9 | 50.00 | | | | | | | 95 | 100 |
| 51 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 5/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | Tanımlama Sayfa 4/7'de. | 10 | 54.00 | 54 mm | | | | | | 100 | 100 |
| 54 | | | 11 | 56.00 | | | | | | | 95 | 98 |
| 56 | | **BAZALT** Koyu gri renkli taze ve dayanımlı. | 12 | 58.00 | | | | | | | 100 | 100 |
| 58 | | **AGLOMERA** Koyu gri-siyah renkli, taze ve az ayrışmış dayanımlı ve orta dayanımlı. Seyrekçe ince kalsit damarlı. 46.50-50.00 m arası ince çakıl daneleri içeren hamur maddesinde tüf arakatmanı gözlendi. | 13 | 60.00 | | | | | | Düzlemler pürüzlü ve kimi düzeyler çok çatlaklı ve kırıklı. | 92 | 98 |
| 60 | | | 14 | 62.00 | | | | | | | 98 | 98 |
| 62 | | | 15 | 64.00 | | | | | | | 90 | 100 |
| 64 | | | 16 | 66.00 | | | | | | | 82 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 6/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | **BAZALT** Siyah renkli taze ve dayanımlı. | 17 | | 54 mm | | | | | | 55 | 100 |
| 68 | | **VOLKANİK KUMTAŞI** Gri renkli az-orta ayrışmalı ve orta dayanımlı orta zayıf. | | 68.00 | | | | | | | | |
| 69 | | | 18 | | | | | | | | 80 | 100 |
| 70 | | | | 70.00 | | | | | | | | |
| 71 | | | 19 | | | | | | | | 95 | 98 |
| 72 | | **AGLOMERA** Gri renkli ince ve köşeli çakıl daneli az ayrışmalı orta dayanımlı - orta zayıf. | | 72.00 | | | | | | | | |
| 73 | | | 20 | | | | | | | | 98 | 98 |
| 74 | | | | 74.00 | | | | | | Genelde masif, düzlemler pürüzlü kimi düzeyler düzensiz kırıklı. | | |
| 75 | | | 21 | | | | | | | | 95 | 100 |
| 76 | | | | 76.00 | | | | | | | | |
| 77 | | | 22 | | | | | | | | 100 | 100 |
| 78 | | | | 78.00 | | | | | | | | |
| 79 | | | 23 | | | | | | | | 95 | 98 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK8

SAYFA / PAGE NO : 7/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AGLOMERA | | | | | | | | | | |
| 81 | | | 24 | | | | | | | | 82 | 99 |
| | | **KİLTAŞI** Koyu gri renkli orta ayrışmalı ve orta zayıf. | | 82.00 | | | | | | Çok kırıklı | | |
| 82 | | | 25 | | | | | | | | 60 | 75 |
| 83 | | | | | | | | | | | | |
| 84 | | | | 84.00 | 54 mm | | | | | | | |
| | | | 26 | | | | | | | | 65 | 100 |
| 85 | | **AGLOMERA** Gri renkli ince ve köşeli çakıl daneli az ayrışmalı orta daya nımlı - orta zayıf. | | | | | | | | Genelde masif, düzlemler pürüz-lü kimi düzeyler düzensiz kırıklı. | | |
| | | | | 86.00 | | | | | | | | |
| 86 | | | 27 | | | | | | | | 90 | 100 |
| | | | | 87.00 | | | | | | | | |
| 87 | | KUYU SONU 87.00m | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T2-SK9<br>SAYFA / PAGE NO : 1/7 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 192.20 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG :TÜNEL - 2 | KOORD. / COORD. N-S (y) : 403508 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (x) : 4537055 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) :27+280 | 3.00 | 14/02/01 | | |
| BASL. TAR. / START DATE :12.01.2001 | SAPMA / OFFSET (m) : EKSEN | 3.85 | 17.02.2001 | 11.50 | |
| BİTİŞ TAR. / FINISH DATE :30.01.2001 | DERİNLİK / DEPTH (m) : 81.00m | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00m-10.00m arasında<br>Sondaj Karotsuz Açıldı. | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | KAYA KALİTESİ TANIMI - RQD | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|
| I : ÇOK ZAYIF VERY WEAK | 0-25 : ÇOK ZAYIF VERY POOR | ---------- | '---------- |
| II : ZAYIF WEAK | 25-50 : ZAYIF POOR | | |
| III : ORTA ZAYIF MOD. WEAK | 50-75 : ORTA FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI MOD. STRONG | 75-90 : İYİ GOOD | | |
| V : DAYANIMLI STRONG | 90-100 : ÇOK İYİ EXELLENT | | |

| AYRI?MA WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|
| I : BÜT. AYRIŞMALI COMP. WEATHERED | | | KGM |
| II : ÇOK AYRIŞMALI HIGHLY WEATH | | ---------- | ---------- |
| III : ORTA DER. AYR. MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE FRESH | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T2-SK9<br>SAYFA / PAGE NO : 2/7 |
|---|---|

| SOND. DER.<br>BOR DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | <br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BAZALTİK TÜF** | 1 | 11.00 | 54 mm | NW | | | | | 55 | 95 |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | Karotsuz açıldı. | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | 20.00 | | | | | | | | |
| 20 | | **BAZALTİK TÜF** | 2 | 21.00 | | | | | | | 39 | 97 |
| 21 | | | | | | | | | | | | |
| 22 | | Karotsuz açıldı. | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK9

SAYFA / PAGE NO : 3/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | | | | | |
| 26 | | Karotsuz açıldı. | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | 30.00 | | | | | | | | |
| | | **BAZALTİK TÜF** | 3 | | 54 mm | NW | | | | | 90 | 100 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | Karotsuz açıldı. | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | 36.00 | | | | | | | | |
| | | **BAZALTİK TÜF** | | | | | | | | | | |
| 37 | | Koyu gri renkli az orta ayrışmalı, orta zayıf. İnce kil ve marn bantlı, seyrekçe kumtaşı arakatmanlı. | 4 | | | | | | | Kimi yüzeyler kırıklı. | 93 | 96 |
| | | | | 38.00 | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK9

SAYFA / PAGE NO : 4/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 5 | 39.00 | 54 mm | NW | | | | | 70 | 100 |
| 39 | | | 6 | | | | | | | | 85 | 98 |
| | | **BAZALTİK TÜF** | | 40.00 | | | | | | | | |
| 40 | | Tanımlama Sayfa 3/7'de | 7 | | | | | | | Tanımlama Sayfa 3/7'de. | 65 | 100 |
| 41 | | | | | | | | | | | | |
| | | | | 42.00 | | | | | | | | |
| 42 | | | | | | | | | | | | |
| | | | 8 | | | | | | | | 67 | 98 |
| 43 | | | | | | | | | | | | |
| | | | | 44.00 | | | | | | | | |
| 44 | | | 9 | | | | | | | | 77 | 92 |
| 45 | | | | | | | | | | | | |
| | | | | 46.00 | | | | | | | | |
| 46 | | | | | | | | | | Seyrekçe gözlene-bilen düzlemler kil dolgulu. | | |
| | | **KUMTAŞI + ÇAKILTAŞI** | 10 | | | | | | | | 80 | 85 |
| 47 | | Gri renkli az-orta ayrışma-lı, orta dayanımlı- orta zayıf çakıltaşı iri ve köşeli daneler içermektedir. | | | | | | | | | | |
| | | | | 48.00 | | | | | | | | |
| 48 | | | 11 | | | | | | | | 65 | 98 |
| 49 | | | | | | | | | | | | |
| | | | | 50.00 | | | | | | | | |
| 50 | | | | | | | | | | | | |
| | | **KİLTAŞI** | 12 | | | | | | | Tanımlama Sayfa 5/7'de | 48 | 93 |
| 51 | | Tanımlama Sayfa 5/7'de. | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK9

SAYFA / PAGE NO : 5/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | | | 13 | 54.00 | 54 mm | NW | | | | | 70 | 85 |
| 54 | | | | | | | | | | | | |
| 55 | | **KİLTAŞI**<br>Koyu gri renkli çok ayrışmalı-bütünüyle ayrışmalı ve zayıf çok zayıf kimi düzeylerde çamurtaşı arakatmanlı. | 14 | | | | | | | | 70 | 84 |
| 56 | | | | 56.00 | | | | | | Ayrışma nedeni ile süreksizlik gözlenemedi. | | |
| 57 | | | 15 | | | | | | | | 25 | 75 |
| 58 | | | 16 | 58.00 | | | | | | | - | 18 |
| 59 | | | 17 | 59.00 | | | | | | | 33 | 95 |
| 60 | | | | 60.00 | | | | | | | | |
| 61 | | | 18 | | | | | | | | 42 | 75 |
| 62 | | | | 62.00 | | | | | | | | |
| 63 | | **AGLOMERA**<br>Açık gri renkli genelde az ayrışmalı ve orta dayanımlı. (Seyrekçe kimi düzeylerde kırıklı). | 19 | | | | | | | Genel olarak masif yapılı, gözlenilen eklem düzlemleri pürüzlü, paslı ve kalsit sıvalı. | 72 | 82 |
| 64 | | | | 64.00 | | | | | | | | |
| 65 | | | 20 | | | | | | | | 51 | 84 |
| | | | | 66.00 | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK9

SAYFA / PAGE NO : 6/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67 | | | 21 | 68.00 | ▲ | | | | | | 75 | 87 |
| 68 | | | 22 | | | | | | | | 51 | 92 |
| 69 | | | | 70.00 | | | | | | | | |
| 70 | | | 23 | | | | | | | | 80 | 100 |
| 71 | | **AGLOMERA** Açık gri renkli genelde az ayrışmalı ve orta dayanımlı. (Seyrekçe kimi düzeylerde kırıklı). | | 72.00 | 54 mm | | | | | | | |
| 72 | | | 24 | | | | | | | Genel olarak masif yapılı, gözlenilen eklem düzlemleri pürüzlü, paslı ve kalsit sıvalı. | 90 | 100 |
| 73 | | | | 74.00 | | | | | | | | |
| 74 | | | 25 | | | | | | | | 73 | 100 |
| 75 | | | | 76.00 | | | | | | | | |
| 76 | | | 26 | | | | | | | | 100 | 100 |
| 77 | | | | 78.00 | | | | | | | | |
| 78 | | | 27 | | | | | | | | 80 | 100 |
| 79 | | | | | ▼ | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK9

SAYFA / PAGE NO : 7/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 6/7'de. | 28 | 81.00 | 54 mm | | | | | Tanımlama Sayfa 6/7'de. | 100 | 100 |
| 81 | | KUYU SONU 81.00m | | | | | | | | | | |
| 82 | | | | | | | | | | | | |
| 83 | | | | | | | | | | | | |
| 84 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| 87 | | | | | | | | | | | | |
| 88 | | | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T2-SK10<br>SAYFA / PAGE NO : 1/7 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 182.09 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
| SOND. YERİ / BORING LOG : TÜNEL - 2 | KOORD. / COORD. N-S (y) : 403664 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE : CRAELIUS | KOORD. / COORD. E-W (x) : 4536829 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 27+550 | 10.80 | 06.01.2001 | | |
| BASL. TAR. / START DATE : 03.12.2000 | SAPMA / OFFSET (m) : EKSEN | 11.30 | 17.02.2001 | 10.30 | |
| BİTİŞ TAR. / FINISH DATE : 17.12.2000 | DERİNLİK / DEPTH (m) : 88.00 m. | | | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | | 0.00 m-10.00m arasında<br>Karotsuz açıldı. | | | 54 mm | NW | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | ---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Fahri Çınar | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK10

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| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **FİLİŞ** Kahverenkli, orta çok ayrışmalı. | 1 | 11.00 | 54 mm | | | | | | 88 | 98 |
| 11 | | 11.00-20.00m arası karotsuz açıldı. | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | **TÜF** Koyu gri siyah renkli, az ayrışmalı. | 2 | 20.00 21.00 | | | | | | | 95 | 99 |
| 21 | | 21.00-30.00 m arası karotsuz açıldı. | | | | | | | | | | |
| 22 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK10

SAYFA / PAGE NO : 3/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | 21.00-30.00m arası karotsuz açıldı. | | | | | | | | | | |
| 26 | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| | | | | 30.00 | | | | | | | | |
| 30 | | **FİLİŞ** Kumtaşı silt marn tüf ardalanması. | 3 | | 54 mm | | | | | | 55 | 100 |
| 31 | | | | 31.00 | | | | | | | | |
| 32 | | 31.00-40.00m arası karotsuz açıldı. | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | | | | | | | | | | | | | | | | | | | | | | SONDAJ / BORING NO : T2-SK10<br>SAYFA / PAGE NO : 4/7 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOND. DER.<br>BOR DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BOR. DER.<br>CAS. DEP (m) | DOL. SUYU KAY.<br>CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | | | | | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>AYRIŞMA WEATHERING I II III IV V | | | | | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
| 39 | | 31.00-40.00m arası karotsuz açıldı. | | | | | | | | | | | | | | | | | | | | | |
| 40 | | **FİLİŞ**<br>Kumtaşı silt marn tüf ardalanması. | 4 | 40.00<br>41.00 | | | | | | | | | | | | | | | | | 66 | 100 |
| 41<br>42 | | 41.00-43.00m arası karotsuz açıldı. | 5 | 43.00 | | | | | | | | | | | | | | | | | | |
| 43 | | | 6 | 43.50 | | | | | | | | | | | | | | | | | 48 | 48 |
| 44 | | | 7 | 45.00 | | | | | | | | | | | | | | | | | 70 | 75 |
| 45 | | | 8 | | 54 mm | | | | | | | | | | | | | | | Çamurtaşı ve tüf düzeylerinde ayrışma nedeni ile süreksizlik gözlenemedi. | 85 | 100 |
| 46<br>47 | | Bazaltik Tüf, kiltaşı, volkanik kumtaşı, Aglomera ardalanması<br>(44.20-44.50 arasında çamurtaşı gözlenmekte)<br>Koyu gri siyah renkli tüf, volkanik kumtaşı ardalanması, ince marn ardalanmalı. | 9 | 47.00 | | | | | | | | | | | | | | | | Aglomera genelde masif görünümlü. | 90 | 100 |
| 48<br>49 | | Seyrekçe tüf hamur maddeli, bütünüyle ayrışmış aglomera görülmekte. | 10 | 49.00 | | | | | | | | | | | | | | | | | 95 | 100 |
| 50<br>51 | | | 11 | 51.00 | | | | | | | | | | | | | | | | | 40 | 87 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK10

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| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 12 | 53.00 | | | | | | | 63 | 94 |
| 53 | | | 13 | | | | | | | | 60 | 94 |
| 54 | | | | 55.00 | | | | | | | | |
| 55 | | | 14 | 56.00 | | | | | | | 85 | 98 |
| 56 | | | 15 | 57.00 | | | | | | | 95 | 97 |
| 57 | | | 16 | 58.00 | | | | | | Çamurtaşı ve tüf düzeylerinde ayrışma nedeni ile süreksizlik gözlenemedi. | 80 | 88 |
| 58 | | Bazaltik Tüf, kiltaşı, volkanik kumtaşı, Aglomera ardalanması | 17 | 59.00 | | | | | | | 51 | 89 |
| 59 | | (44.20-44.50 arasında çamurtaşı gözlenmekte) | 18 | 60.00 | | | | | | Aglomera genelde masif görünümlü. | 60 | 90 |
| 60 | | Koyu gri siyah renkli tüf, volkanik kumtaşı ardalanması, ince marn ardalanmalı. | 19 | 61.00 | 54 mm | | | | | | 100 | 100 |
| 61 | | Seyrekçe tüf hamur maddeli, bütünüyle ayrışmış aglomera görülmekte. | 20 | 63.00 | | | | | | | 90 | 95 |
| 63 | | | 21 | 65.00 | | | | | | | 44 | 82 |
| 65 | | | 22 | | | | | | | | 72 | 96 |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK10

SAYFA / PAGE NO : 6/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 67.00 | | | | | | | 72 | 96 |
| 67 | | | 23 | | | | | | | | | |
| 68 | | Bazaltik Tüf, kiltaşı, volkanik kumtaşı, Aglomera ardalanması (44.20-44.50 arasında çamurtaşı gözlenmekte) | | 69.00 | | | | | | | 71 | 93 |
| 69 | | Koyu gri siyah renkli tüf, volkanik kumtaşı ardalanması, ince marn ardalanmalı. | 24 | 70.00 | | | | | | Çamurtaşı ve tüf düzeylerinde ayrışma nedeni ile süreksizlik gözlenemedi. | 98 | 98 |
| 70 | | Seyrekçe tüf hamur maddeli, bütünüyle ayrışmış aglomera görülmekte. | 25 | 71.00 | | | | | | Aglomera genelde masif görünümlü. | 33 | 82 |
| 71 | | | 26 | | | | | | | | | |
| 72 | | | | 73.00 | | | | | | | 85 | 94 |
| 73 | | | 27 | | | | | | | | | |
| 74 | | | | | 54 mm | | | | | | 69 | 95 |
| 75 | | **AGLOMERA** | | 75.00 | | | | | | | | |
| 76 | | Koyu gri renkli ince kalsit damarlı genelde taze, seyrekçe az ayrışmış. | 28 | | | | | | | | 95 | 95 |
| 77 | | (Derine inildikçe hamur maddesinde bazalt oranı artmakta). | | 77.00 | | | | | | Süreksizlik yüzeyleri pürüzlü ve oksidosyon gözlenmekte. | | |
| 78 | | | 29 | | | | | | | | 93 | 98 |
| 79 | | | | 79.00 | | | | | | | | |
| | | | 30 | | | | | | | | 56 | 96 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK10

SAYFA / PAGE NO : 7/7

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 6/7'de | | | | | | | | Tanımlama Sayfa 6/7'de | | |
| | | | | 81.00 | | | | | | | 96 | 96 |
| 81 | | | | | | | | | | | | |
| | | | 31 | | | | | | | Süreksizlik yüzeyleri pürüzlü ve kalsit dolgulu. ( Kalsit dolgu, camsı ve parlak sünger görünümünde gaz boşluklu. | 100 | 100 |
| 82 | | | | | | | | | | | | |
| | | | | 83.00 | | | | | | | | |
| 83 | | **BAZALT** | | | | | | | | | | |
| | | Gri renkli yer yer çok ince kalsit damarlı, seyrekçe gaz boşluklu, taze ve dayanımlı | | | 54 mm | | | | | | | |
| | | | 32 | | | | | | | | 97 | 100 |
| 84 | | | | | | | | | | | | |
| 85 | | | | 85.00 | | | | | | | | |
| | | | | | | | | | | | 96 | 100 |
| | | | 33 | | | | | | | | | |
| 86 | | | | | | | | | | | | |
| | | | | 87.00 | | | | | | | | |
| 87 | | | | | | | | | | | | |
| | | | 34 | | | | | | | | 100 | 100 |
| | | | | 88.00 | | | | | | | | |
| 88 | | KUYU SONU 88.00m. | | | | | | | | | | |
| 89 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 91 | | | | | | | | | | | | |
| 92 | | | | | | | | | | | | |
| 93 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO :T2-SK11<br>SAYFA / PAGE NO : 1/4 |
|---|---|---|

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 137.66 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG :PORTAL (T-2) | KOORD. / COORD. N-S (y) : 404397 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRAELIUS | KOORD. / COORD. E-W (x) : 4536367 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 28+450 | 17.30 | 06.01.2001 | | |
| BASL. TAR. / START DATE : 12.12.2000 | SAPMA / OFFSET (m) :EKSEN (SOL TÜP) | 16.85 | 17.02.2001 | 10.15 | |
| BİTİŞ TAR. / FINISH DATE : 20.12.2000 | DERİNLİK / DEPTH (m) : 45.00m | 15.80 | 04.06.2001 | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | **KİLTAŞI**<br>Sarımsı açık kahverenkli, çok bütünüyle ayrışmalı ve çok zayıf. | 1 | 1.50 | | | | | | | 36 | 100 |
| 2 | | **KUMTAŞI**<br>Kahverenkli orta ayrışmalı orta-zayıf; siltli seyrekçe karbonat içermekte. | 2 | 2.00 | | | | | | | - | 82 |
| | | | 3 | 3.00 | | | | | | | 18 | 74 |
| 3 | | | 4 | 4.00 | | NW | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | 75 | 98 |
| 4 | | **VOLKANİK KUMTAŞI**<br>Sarımsı Kahverenkli orta ayrışmış, orta zayıf, marn ara katmanlı. | 5 | 6.00 | 54 mm | | | | | | 6 | 89 |
| 6 | | | | | | | | | | | | |
| 7 | | **AGLOMERA**<br>Kahverenkli gri renkli az- orta ayrışmış, orta zayıf. | 6 | 8.00 | | | | | | Çatlaklı ve kırıklı. Çatlak ve kırık yüzeyleri pürüzlü ve kil sıvalı, yaslı. | 60 | 93 |
| 8 | | Oksidosyon nedeniyle renk değişmesi meydana gelmiş. (6.00 - 6.45m. olan BAZALT) | 7 | | | | | | | | 28 | 83 |
| 10 | | | | 10.00 | | | | | | | | |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRIŞMA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY KGM |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | ---------- | ---------- |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | | |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | B.Caner Kandemir | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK11

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama Sayfa 1/4'de. | 8 | | | | | | | çok kırıklı | 30 | 93 |
| | | | | 12.00 | | | | | | | | |
| 12 | | | 9 | | | | | | | | 72 | 96 |
| 13 | | | | 14.00 | | | | | | | | |
| 14 | | | 10 | | | | | | | | | |
| 15 | | **AGLOMERA+TÜF+ VOLKANİK KUMTAŞI** Genelde koyu gri, siyahımsı, az ayrışmaşı ve orta dayanım-lı. | | | | | | | | | 32 | 72 |
| 16 | | Tüf düzeylerinde, seyrekçe orta ayrışmalı ve orta zayıf. | | 16.00 | 54 mm | | | | | | | |
| 17 | | (11.75-12.00)(12.00-13.00) (13.45-14.00) metreleri arası açık gri bazalt. | 11 | | | | | | | Kimi düzeyler çok çatlaklı ve düzen-siz kırıklı düzlem-ler pürüzlü. | 30 | 72 |
| 18 | | | | 18.00 | | | | | | | | |
| 19 | | | 12 | | | | | | | | 50 | 84 |
| 20 | | | | 20.00 | | | | | | | | |
| 21 | | | 13 | | | | | | | | 58 | 81 |
| | | **21.00m-39.00m arasında VOLKANİK KOMTAŞI+TÜF** | | 22.00 | | | | | | | | |
| 22 | | Koyu gri, siyahımsı, genelde az ayrışmalı ve orta dayanımlı. | 14 | | | | | | | | 64 | 91 |
| 23 | | | | 24.00 | | | | | | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK11

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 15 | 26.00 | | | | | | | 58 | 89 |
| 26 | | | 16 | 28.00 | | | | | | | 90 | 100 |
| 27 | | | 17 | 30.00 | | | | | | Kimi düzeyler çok çatlaklı ve düzensiz kırıklı. Düzlemler pürüzlü. | 59 | 87 |
| 28 | | | 18 | 32.00 | | | | | | | 74 | 88 |
| 29 | | **21.00m-39.00m arasında VOLKANİK KOMTAŞI+TÜF** Koyu gri, siyahımsı, genelde az ayrışmalı ve orta dayanımlı. | 19 | 34.00 | 54 mm | | | | | | 85 | 97 |
| 30 | | | 20 | 36.00 | | | | | | | 72 | 89 |
| 31 | | | 21 | 38.00 | | | | | | | 53 | 80 |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | |

TEMELSON

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK11

SAYFA / PAGE NO : 4/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tanımlama Sayfa 3/4'de. | | | | | | | | | | |
| 39 | | | 22 | | | | | | | | 25 | 77 |
| | | | | 40.00 | | | | | | | | |
| 40 | | | 23 | | | | | | | | 40 | 95 |
| 41 | | **AGLOMERA** Açık koyu gri, bazaltik düzeyler taze ve dayanımlı, öteki düzeyler az ayrışmalı ve orta dayanımlı. | | | 54 mm | | | | | Kimi düzeyler çok çatlaklı ve kırıklı. Düzlemler pürüzlü. | | |
| 42 | | | | 42.00 | | | | | | | | |
| 43 | | | 24 | | | | | | | | 38 | 99 |
| | | | | 44.00 | | | | | | | | |
| 44 | | | 25 | | | | | | | | 35 | 80 |
| 45 | | KUYU SONU (45.00 m) | | | | | | | | | | |
| 46 | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

| TEMELSON | ORDU ÇEVREYOLU | SONDAJ / BORING NO :T2-SK12 |
|---|---|---|
| | KAYA SONDAJ LOGU / ROCK BORING LOG | SAYFA / PAGE NO : 1/4 |

| YÜKLENİCİ / CONTRACTOR : TEMELSON | ZEM. KOTU / GROU. EL. (m) : 139.67 | YERALTI SUYU DURUMU-GROUND WATER DATA | | | |
|---|---|---|---|---|---|
| SOND. YERİ / BORING LOG: PORTAL (T-2) | KOORD. / COORD. N-S (y) : 404394 | DERİNLİK | TARİH | SAAT | AÇIKLAMA |
| MAKİNA TİPİ / RIG TYPE :CRALEIUS | KOORD. / COORD. E-W (x) : 4536345 | DEPTH (m) | DATE | HOUR | REMARKS |
| SOND. MET. / DRIL. METH. : ROTARY | İSTASYON / STATION (km) : 28+450 | 14.70 | 14/12/00 | | |
| BASL. TAR. / START DATE : 21.12.2000 | SAPMA / OFFSET (m) :EKSE(SAĞ TÜP) | 11.70 | 17.02.2001 | 12.00 | |
| BİTİŞ TAR. / FINISH DATE : 10.01.2001 | DERİNLİK / DEPTH (m) : 47.00m. | 10.75 | 04.06.2001 | | |

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERİNDE ÖZELLİKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | Karotsuz açıldı. | 1 | 2.00 | | | | | | | 60 | 93 |
| 2 | | **KUMTAŞI+MARN ARDALANMASI** Kahverenkli çok, ayrışmalı ve çok zayıf-zayıf. | 2 | 4.00 | | | | | | | 25 | 85 |
| 4 | | Kumtaşı - açık gri, kahve renkli orta derecede ayrışmış, orta zayıf. | 3 | 6.00 | 54 mm | NW | | | | Ayrışma nedeniyle süreksizlik gözlenemedi. | 24 | 73 |
| 6 | | | 4 | 8.00 | | | | | | | 47 | 88 |
| 8 | | | 5 | 10.00 | | | | | | | 32 | 88 |

| DAYANIMLILIK - STRENGTH | | KAYA KALİTESİ TANIMI - RQD | | SONDÖR-DRILLER | KONTROL-CHECKED |
|---|---|---|---|---|---|
| I : ÇOK ZAYIF | VERY WEAK | 0-25 : ÇOK ZAYIF | VERY POOR | ---------- | '---------- |
| II : ZAYIF | WEAK | 25-50 : ZAYIF | POOR | | |
| III : ORTA ZAYIF | MOD. WEAK | 50-75 : ORTA | FAIR | Hasan Yıldız | Mustafa Akıncı |
| IV : O. DAYANIMLI | MOD. STRONG | 75-90 : İYİ | GOOD | | |
| V : DAYANIMLI | STRONG | 90-100 : ÇOK İYİ | EXELLENT | | |

| AYRI?MA | WEATHERING | ÖLÇEK - SCALE : | LOGU YAPAN-LOGGED BY | ONAY - APPROVED BY |
|---|---|---|---|---|
| I : BÜT. AYRIŞMALI | COMP. WEATHERED | | | KGM |
| II : ÇOK AYRIŞMALI | HIGHLY WEATH | | ---------- | ---------- |
| III : ORTA DER. AYR. | MOD. WEATHERED | 1 2 3 M | | |
| IV : AZ AYRIŞMALI | SLIGHTLY WEAT. | | B.Caner Kandemir | |
| V : TAZE | FRESH | | | |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK12

SAYFA / PAGE NO : 2/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | Tanımlama Sayfa 1/4'de. | 6 | 11.00 | 54 mm | NW | | | | Tanımlama Sayfa 1/4'de. | 75 | 100 |
| 12 | | | 7 | 12.00 | | | | | | | 10 | 97 |
| 13 | | | 8 | 14.00 | | | | | | | 26 | 85 |
| 14 | | | 9 | 16.00 | | | | | | | 55 | 84 |
| 16 | | **AGLOMERA** Gri koyu gri renkli, genelde az ayrışmalı ve orta dayanımlı. | 10 | 18.00 | | | | | | | 42 | 86 |
| 18 | | | 11 | 20.00 | | | | | | Kimi düzeyler çok çatlaklı ve kırıklı. Oksidasyondan dolayı renk değişimi gözlenmekte. Düzlemler paslı ve pürüzlü. | 98 | 100 |
| 20 | | | 12 | 22.00 | | | | | | | 90 | 100 |
| 22 | | **BAZALTİK TÜF+ AGLOMERA** Koyu gri, siyah renkli, az ayrışmalı ve orta dayanımlı. Aglomera ile geçişli | 13 | 24.00 | | | | | | | 100 | 100 |

T E M E L S O N

KAYA SONDAJ LOGU / ROCK BORING LOG

SONDAJ / BORING NO : T2-SK12

SAYFA / PAGE NO : 3/4

| SOND. DER. BOR DEPTH (m) | GÖS-TERİM LE-GEND | KAYAÇ TANIMLAMASI ROCK DESCRIPTION | MAN. NO. RUN NO. | MAN. DER. RUN DEPTH (m) | KAR ÇAPI CORE DIA. (mm) | MUH. BOR. DER. CAS. DEP (m) | DOL. SUYU KAY. CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI DISCONTINUITY DESCRIPTION | RQD (%) | KAROT YÜZ. CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | | | 14 | 26.00 | 54 mm | | | | | | 100 | 100 |
| 26 | | | 15 | 28.00 | | | | | | | 90 | 100 |
| 28 | | | 16 | 30.00 | | | | | | | 25 | 93 |
| 30 | | **BAZALTİK TÜF+ AGLOMERA** Koyu gri, siyah renkli, az ayrışmalı ve orta dayanımlı. Aglomera ile geçişli | 17 | 32.00 | | | | | | Tüf düzeyleri çok kırıklı. Düzlemler pürüzlü. | 49 | 91 |
| 32 | | | 18 | 34.00 | | | | | | | 100 | 100 |
| 34 | | | 19 | 36.00 | | | | | | | 80 | 88 |
| 36 | | | 20 | 38.00 | | | | | | | 85 | 97 |
| 37 | | **VOLKANİK KUMTAŞI** Koyu gri renkli, ince daneli, az ayrışmış ve orta dayanımlı. | | | | | | | | | | |

| TEMELSON<br>KAYA SONDAJ LOGU / ROCK BORING LOG | SONDAJ / BORING NO : T2-SK12<br>SAYFA / PAGE NO : 4/4 |
|---|---|

| SOND. DER.<br>BOR DEPTH (m) | GÖS-TERİM<br>LE-GEND | KAYAÇ TANIMLAMASI<br>ROCK DESCRIPTION | MAN. NO.<br>RUN NO. | MAN. DER.<br>RUN DEPTH (m) | KAR ÇAPI<br>CORE DIA. (mm) | MUH. BOR. DER.<br>CAS. DEP (m) | DOL. SUYU KAY.<br>CIR. LOSS (%) | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES<br>DAYANIM STRENGTH I II III IV V | YERYNDE ÖZELLYKLER IN-SITU PROPERTIES<br>AYRIŞMA WEATHERING I II III IV V | SÜREKSİZLİK TANIMLAMASI<br>DISCONTINUITY DESCRIPTION | RQD<br>(%) | KAROT YÜZ.<br>CORE RECO. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | Tanımlama Sayfa 3/4'de | 21 | | | | | | | Tanımlama Sayfa 3/4'de. | 100 | 100 |
| 40 | | | | 40.00 | | | | | | | | |
| 41 | | | 22 | | | | | | | | 100 | 100 |
| 42 | | **BAZALTİK TÜF**<br>Koyu gri siyah renkli, az ayrış-mış ve orta dayanımlı, sey-rekçe volkanik kumtaşı ara-katmanlı.<br>Tüf içerisinde köşeli çakıl da-neleri içeren Aglomera kat-manlarıda gözlenmekte. | | 42.00 | 54 mm | | | | | | | |
| 43 | | | 23 | | | | | | | Genelde masif görünümlü, kimi düzeyler düzensiz kırıklı. | 100 | 100 |
| 44 | | | | 44.00 | | | | | | | | |
| 45 | | | 24 | | | | | | | | 95 | 100 |
| 46 | | | | 46.00 | | | | | | | | |
| | | | 25 | 47.00 | | | | | | | 60 | 100 |
| 47 | | KUYU SONU (47.00m) | | | | | | | | | | |
| 48 | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | |

# APPENDIX – C
# NGI Q SYSTEM CHARTS

ENGINEERING CLASSIFICATION OF ROCK MASSES FOR THE DESIGN OF TUNNEL SUPPORTS

TABLE: 1) DESCRIPTIONS AND RATINGS FOR THE PARAMETERS RQD, Jn, AND Jr

1. ROCK QUALITY DESIGNATION

| | |
|---|---|
| A. Very poor ..... | 0-25 |
| B. Poor ..... | 25-50 |
| C. Fair ..... | 50-75 |
| D. Good ..... | 75-90 |
| E. Excellent ..... | 90-100 |

Note:

(i) Where RQD is reported or measured as $\leq 10$ (including 0) a nominal value of 10 is used to evaluate Q in eg.(1)

(ii) RQD intervals of 5,i.e.100, 95, 90, etc. are sufficiently accurate

2. JOINT SET NUMBER

| | |
|---|---|
| A. Massive, no or few joints.. | 0.5-1.0 |
| B. One joint set ..... | 2 |
| C. One joint set plus random . | 3 |
| D. Two joint sets ..... | 4 |
| E. Two joint sets plus random | 6 |
| F. Three joint sets ..... | 9 |
| G. Three joint sets plus random | 12 |
| H. Four or more joint sets, random, heavily jointed, "sugar cube", etc. ..... | 15 |
| J. Crushed rock, earthlike .. | 20 |

Note:

(i) For intersections use (3.0 X Jn)

(ii) For portals use (2.0 X Jn)

3. JOINT ROUGHNESS NUMBER (Jr)

| | |
|---|---|
| (a) Rock wall contact and (b) Rock wall contact before 10 cms shear | |
| A. Discontinuous joints ..... | 4 |
| B. Rough or irregular, undulating | 3 |
| C. Smooth undulating ..... | 2 |
| D. Slickensided, undulating ..... | 1.5 |
| E. Rough or irregular, planar... | 1.5 |

Note:

(i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m

(ii) Jr=0.5 can be used for planar slickensided joints having lineations are favourably orientated.

TABLE: 1) CONTINUED

F. Smooth, planar ..... 1.0

G. Slickensided, planar ..... 0.5

(c) No rock wall contact when sheared

H. Zone containing clay minerals thick enough to prevent rock wall contact 1.0 (nominal)

J. Sandy, gravelly or crushed zone thick enough to prevent rock wall contact ..... 1.0 (nominal)

TABLE: 2) DESCRIPTIONS AND RATINGS FOR THE PARAMETERS Ja AND Jw

| 4. JOINT ALTERATION NUMBER (Ja) | | $\varphi r$ (approx.) |
|---|---|---|
| (a) Rock wa contact | | |
| A. Tightly healed, hard, non-softening, impermeable filling i.e. quartz or epidote | 0.75 | (-) |
| B. Unaltered joint walls, surface staining only | 1.0 | ($25^o$-$35^o$) |
| C. Slightly altered joint walls. Nonsoftening mineral coatings, sandy particles, clay-free disintegrated rock etc. | 2.0 | ($25^o$-$30^o$) |
| D. Silty-, or sandy-clay coatings, small clay-fraction (non-softening) | 3.0 | ($20^o$-$25^o$) |
| E. Softening or low friction clay mineral coatings, i.e.kaolinite mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1-2 mm or less in thickness) | 4.0 | ($8^o$-$16^o$) |
| (b) Rock wall contact before 10 cms shear | | |
| F. Sandy particles, clay-free disintegrated rock etc. | 4.0 | ($25^o$-$30^o$) |

Note:

(i) Values of $(\varphi)r$ are intended as an approximate guide to the mineralogical properties of the alteration products, if present.

TABLE: 2) CONTINUED

| | | |
|---|---|---|
| G. Strongly over-consolidated, non-softening clay mineral fillings (Continuous, < 5 mm in thickness) | 6.0 | ($16^o$-$24^o$) |
| H. Medium or low over-consolidation, softening, clay mineral fillings. (Continuous, < 5 mm in thickness) | 8.0 | ($12^o$-$16^o$) |
| J. Swelling clay fillings, i.e. montmorillonite (Continuous, < 5 mm in thickness). Value of Ja depends on percent of swelling clay-size particles, and access to water etc. | 8.0-12.0 | ($6^o$-$12^o$) |
| (c) No rock wall contact when sheared | | |
| K,L,M. Zones or bands of disintegrated or crushed rock and clay (see G, H, J for description of clay condition) | 6.0-8.0 or 8.0-12.0 | ($6^o$-$24^o$) |
| N. Zones or bands of silty- or sandy clay, small clay fraction (non-softening) | 5.0 | |
| O,P, R. Thick, continuous zones or bands of clay (see G,H,J for description of clay condition) | 10.0-13.0 or 13.0-20.0 | ($6^o$-$24^o$) |

| 5. JOINT WATER REDUCTION FACTOR | (Jw) | Approx,water pressure ($kg/cm^2$) |
|---|---|---|
| A. Dry excavations or minor inflow i.e. < 5 l/min locally | 1.0 | < 1 |
| B. Medium inflow or pressure occasional outwash of joint fillings | 0.66 | 1.0-2.5 |
| C. Large inflow or high pressure in competent rock with unfilled joints | 0.5 | 2.5-10.0 |
| D. Large inflow or high pressure, considerable outwash of joint fillings. | 0.33 | 2.5-10.0 |
| E. Exceptionally high inflow or water pressure at blasting, decaying with time | 0.2-0.1 | >10.0 |
| F. Exceptionally high inflow or water pressure continuing without noticeable decay | 0.1-0.05 | 10.0 |

Note:

(i) Factors C to F are crude estimates. Increase Jw if drainage measures are installed

(ii) Special problems caused by ice formation are not considered.

TABLE: 3) DESCRIPTIONS AND RATINGS FOR THE PARAMETER SRF

6. STRESS REDUCTION FACTOR

| | | | | |
|---|---|---|---|---|
| | (a) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated | | | Note: (i) Reduce these values of SRF by 25-50 % If the relevant shear zones only influence but do not intersect the excavation |
| A | Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth) | | 10.0 | |
| B. | Single weakness zones containing clay, or chemically disintegrated rock (depth of excavation $\leq$ 50 m) | | | |
| C. | Single weakness zones containing clay, or chemically disintegrated rock (depth of excavation $>$ 50 m) | | 2.5 | |
| D. | Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth) | | | |
| E. | Single shear zones in competent rock (clay free) (depth of excavation $\leq$ 50 m) | | | |
| F. | Single shear zones in competent rock (clay free) (depth of excavation $>$ 50 m) | | | |
| G. | Loose open joints, heavily jointed or "sugar cube" etc. (any depth) | | 5.0 | (ii) For strongly aniso ropic stress field (if measured): when $5 \leq \sigma_1/\sigma_3 \leq 10$, reduce $\sigma_c$ and $\sigma_t$ to $0.8\sigma_c$ and $0.8\sigma_t$ |
| | (b) Competent rock, rock stress problems | $\sigma_c/\sigma_1$ | $\sigma_t/\sigma_1$ | |
| H. | Low stress, near surface | $>200$ | $>13$ | 2.5 |
| J. | Medium stress | 200-10 | 13-0.66 | 1.0 |
| K. | High stress, very tight structure (Usually favourable to stability, may be unfavourable to wall stability) | 10-5 | 0.66-0.33 | 0.5-2.0 |
| | Mild rock burst (massive rock) | 5-2.5 | 0.33-0.16 | 5-10 |

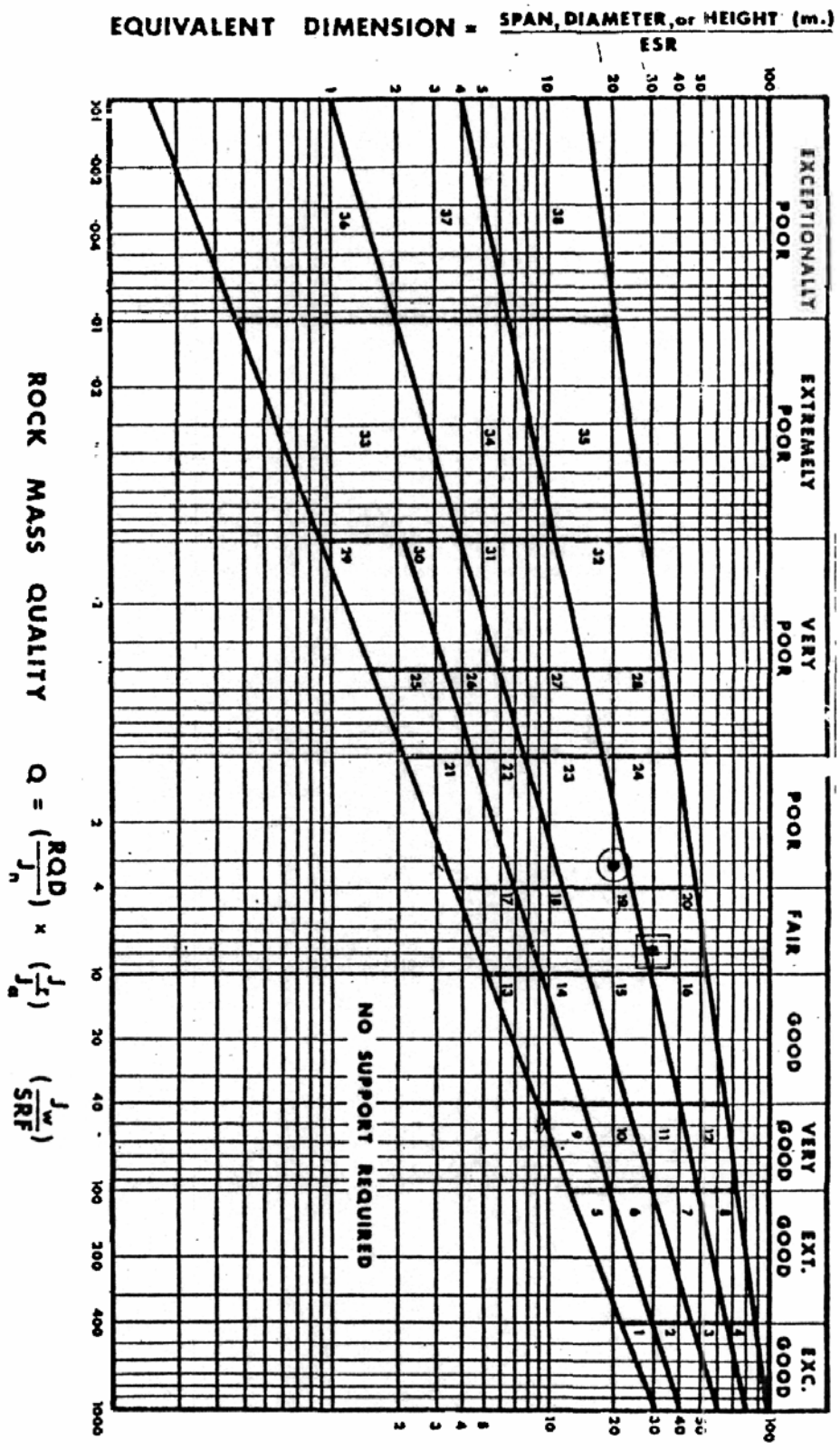
When $\sigma_1/\sigma_3 > 10$, reduce $\sigma_c$ and $\sigma_t$ to $0.6\sigma_c$ and $0.6\sigma_t$ where: $\sigma_c$= unconfined compression strength,

$\sigma_t$= tensile strength (point load), $\sigma_1$ and $\sigma_3$ = major and minor principal stresses

TABLE: 3) CONTINUED

| | | | | |
|---|---|---|---|---|
| M | Heavy rock burst (massive rock) | $< 2.5$ | $< 0.16$ | 10-20 |
| | (c) Squeezing rock; plastic flow of incompetent rock under the influence of high rock pressures | | | |
| N. | Mild squeezing rock pressure | | | 5-10 |
| O. | Heavy squeezing rock pressure | | | 10-20 |
| | (d) Swelling rock; chemical swelling activity depending on presence of water | | | |
| P. | Mild swelling rock pressure | | | |
| R. | Heavy swelling rock pressure | | | 10-15 |

(iii) Few case records available where depth of crown below surface is less than span width. Suggest SRF increase from 2.5 to 5 for such cases (see H)


EQUIVALENT DIMENSION = SPAN, DIAMETER, or HEIGHT (m.) / ESR
ROCK MASS QUALITY Q = (RQD/Jn) x (Jr/Ja) (Jw/SRF)
EXCEPTIONALLY POOR
EXTREMELY POOR
VERY POOR
POOR
FAIR
GOOD
VERY GOOD
EXT. GOOD
EXC. GOOD
NO SUPPORT REQUIRED

☆ Authors estimates of support. Insufficient case records available for reliable estimation of support requirements.

The type of support to be used in categories 1 to 8 will depend on the blasting technique. Smooth wall blasting and thorough barring-down may remove the need for support. Roughwall blasting may result in the need for single applications of shotcrete, especially where the excavation height is > 25 m. Future case records should differentiate categories 1 to 8.

Key to Support Tables:

sb = spot bolting
B = systematic bolting
(utg= untensioned, grouted.

TABLE: 4 ) SUPPORT MEASURES FOR ROCK MASSES OF "EXCEPTIONAL", "EXTREMELY GOOD", "VERY GOOD", AND "GOOD" QUALITY (Q RANGE: 1000-10)

| Support Category | Q | Conditional Factors RQD/Jn | Jr/Jn | SPAN/ESR (m) | P kg/cm$^2$ (approx) | SPAN/ESR (m) | Type of support | Note see Table 8 |
|---|---|---|---|---|---|---|---|---|
| 1☆ | 1000-400 | - | - | - | <0.01 | 20-40 | sb (utg) | - |
| 2☆ | 1000-400 | - | - | - | <0.01 | 30-60 | sb (utg) | - |
| 3☆ | 1000-400 | - | - | - | <0.01 | 46-80 | sb (utg) | - |
| 4 | 1000-400 | - | - | - | <0.01 | 65-100 | sb (utg) | - |
| 5☆ | 400-100 | - | - | - | 0.05 | 12-30 | sb (utg) | - |
| 6☆ | 400-100 | - | - | - | 0.05 | 19-45 | sb (utg) | - |
| 7☆ | 400-100 | - | - | - | 0.05 | 30-65 | sb (utg) | - |
| 8 | 400-100 | - | - | - | 0.05 | 48-88 | sb (utg) | - |
| 9 | 100-40 | ⩾ 20 | - | - | 0.25 | 8.5-19 | sb (utg) | |
| | | < 20 | - | - | | | B (utg)2.5-3 m | |
| 10 | 100-40 | ⩾ 30 | - | - | 0.25 | 14-30 | B (utg) 2-3 m | |
| | | < 30 | - | - | | | B (utg)1.5-2 m | |
| | | | | | | | + clm | |
| 11☆ | 100-40 | ⩾ 30 | - | - | 0.25 | 23-48 | B (tg) 2-3 m | |
| | | < 30 | - | - | | | B (tg)1.5-2 m | |
| | | | | | | | + clm | |
| 12☆ | 100-40 | ⩾ 30 | - | - | 0.25 | 40-72 | B (tg) 2-3 m. | |
| | | < 30 | - | - | | | B (tg)1.5-2 m | |
| | | | | | | | + clm | |
| 13 | 40-10 | ⩾ 10 | ⩾ 1.5 | - | 0.5 | 5-14 | sb (utg) | I |
| | | ⩾ 10 | < 1.5 | - | | | B (utg)1.5-2 m | I |
| | | < 10 | ⩾ 1.5 | - | | | B (utg)1.5-2 m | I |
| | | < 10 | < 1.5 | - | | | B (utg)1.5-2 m | I |
| | | | | | | | + S 2-3 cm | |
| 14 | 40-10 | ⩾ 10 | | ⩾ 15 | 0.5 | 9-23 | B (tg)1.5-2 m | I,II |
| | | | | | | | + clm | |
| | | | | ⩾ 15 | | | B (tg)1.5-2 m | I,II |
| | | | | | | | + S(mr) 5-10cm | |
| | | | | < 15 | | | B (urg)1.5-2 m | I,III |
| | | | | | | | + clm | |
| 15 | 40-10 | > 10 | | | 0.5 | 15-40 | B (tg)1.5-2 m | I,II,IV |
| | | | | | | | + clm | |
| | | ⩽ 10 | | | | | B (tg)1.5-2 m | I,II,IV |
| | | | | | | | + S(mr) 5-10 cm | |
| 16☆ See Note XII | 40-10 | > 15 | | | 0.5 | 30-65 | B (tg)1.5-2 m | I,V,VI |
| | | | | | | | + clm | |
| | | ⩽ 15 | | | | | B (tg) 1.5-2 m | I,V,VI |
| | | | | | | | + S (mr) 10-15 cm | |

TABLE: 5 ) SUPPORT MEASURES FOR ROCK MASSES OF "FAIR" AND "POOR" QUALITY

(Q range: 10-1)

| Support category | Q | Conditional factors RQD/Jn | Jr/Ja | SPAN/ ESR | P $Kg/cm^2$ (approx.) | SPAN/ ESR/ (m) | Type of support | Note See Table 8 |
|---|---|---|---|---|---|---|---|---|
| 17 | 10-4 | > 30 | - | - | 1.0 | 3.5-9 | sb (utg) | I |
| | | ⩾ 10, ⩽ 30 | - | - | | | B (utg)1-1.5 m | I |
| | | < 10 | - | ⩾ 6 m | | | B (utg)1-1.5 m +S 2-3 cm | I |
| | | < 10 | - | < 6 m | | | S 2-3 cm | I |
| 18 | 10-4 | > 5 | - | ⩾ 10 m | 1.0 | 7-15 | B (tg) 1-1.5 m +clm | I,III |
| | | > 5 | - | < 10 m | | | B (utg)1-1.5 m +clm | I |
| | | ⩽ 5 | - | ⩾ 10 m | | | B (tg)1-1.5 m +S 2-3 cm | I,III |
| | | ⩽ 5 | - | < 10 m | | | B (utg)1-1.5 m +S 2-3 cm | I |
| 19 | 10-4 | | | ⩾ 20 m | 1.0 | 12-29 | B (tg)1-2 m +S (mr)10-15 cm | I,II,IV |
| | | | | < 20 m | | | B (tg)1-1.5 m +S (mr)5-10 cm | I,II |
| 20☆ See Note XII | 10-4 | - | - | ⩾ 35 m | 1.0 | 24-52 | B (tg)1-2 m +S (mr)20-25 cm | I,V,VI |
| | | - | - | < 35 m | | | B (tg)1-2 m +S (mr)10-20 cm | I,II,IV |
| 21 | 4-1 | ⩾ 12.5 | ⩽ 0.75 | - | 1.5 | 2.1-6.5 | B (utg) 1 m +S 2-3 cm | I |
| | | ⩾ 12.5 | ⩽ 0.75 | - | | | S 2.5-5 cm | I |
| | | - | > 0.75 | - | | | B (utg) 1 m | I |
| 22 | 4-1 | > 10, < 30 | > 1.0 | - | 1.5 | 4.5-11.5 | B (utg) 1 m+clm | |
| | | ⩽ 10 | > 1.0 | - | | | S 2.5-7.5 cm | |
| | | < 30 | ⩽ 1.0 | - | | | B (utg) 1 m +S (mr) 2.5-5 cm | |
| | | ⩾ 30 | - | - | | | B (utg) 1 m | I |
| 23 | 4-1 | - | - | ⩾ 15 m | 1.5 | 8-24 | B (tg) 1-1.5 m +S (mr) 10-15 cm | I,II,IV, VII |
| | | - | - | < 15 m | | | B (utg) 1-1.5 +S (mr) 5-10 m | I |
| 24☆ See note XII | 4-1 | - | - | ⩾ 30 m | 1.5 | 18-46 | B (tg) 1-1.5 m +S (mr) 15-30 cm | I,V,VI |
| | | - | - | < 30 m | | | B (tg) 1-1.5 m +S (mr) 10-15 cm | I,II,IV |

☆ Authors' estimates of support. Insufficient case records available for reliable estimation of support requirements.

(tg) = Tensioned, (expanding shell type for competent rock masses grouted post-tensioned in very poor quality rock masses; see Note XI)
S = Shotcrete
(mr) = Mesh reinforced
clm = Chain link mesh
CCA = Cast concrete arch
(sr) = Steel reinforced

Bolt spacings are given in metres (m). Shotcrete, or cast concrete arch thickness is given in centimetres (cm).

TABLE: 6) SUPPORT MEASURES FOR ROCK MASSES OF "VERY POOR" QUALITY (Q RANGE: 1.0-0.

| Support Category | Q | Conditional factors RQD/Jn | Jr/Ja | SPAN/ESR (m) | P kg/cm$^2$ (approx.) | SPAN/ESR (m) | Type of support | Note See Table 8 |
|---|---|---|---|---|---|---|---|---|
| 25 | 1.0-0.4 | > 10 | > 0.5 | | 2.25 | 1.5-4.2 | B (utg) 1 m+mr or clm | I |
| | | ⩽ 10 | > 0.5 | | | | B (utg) 1 m+S (mr) 5 cm | I |
| | | | ⩽ 0.5 | | | | B (tg) 1 m+S (mr) 5 cm | I |
| 26 | 1.0-0.4 | | | | 2.25 | 3.2-7.5 | B (tg) 1 m +S (mr) 5-7.5 cm | VIII,X,XI |
| | | | | | | | B (utg) 1 m+S 2.5-5 cm | I,IX |
| 27 | 1.0-0.4 | | | ⩾ 12 m | 2.25 | 6-18 | B (tg) 1 m +S (mr) 7.5-10 cm | I,IX |
| | | | | < 12 m | | | B (utg) 1 m +S (mr) 5-7.5 cm | I,IX |
| | | | | ⩾ 12 m | | | CCA 20-40 cm +B (tg) 1 m | VIII,X,XI |
| | | | | < 12 m | | | S (mr) 10-20 cm +B (tg) 1 m | VIII,X,XI |
| 28 ☆ See Note XII | 1.0-0.4 | | | ⩾ 30 m | 2.25 | 15-38 | B (tg) 1 m +S (mr) 30-40 cm | I,IV,V,IX |
| | | | | ⩾ 20, < 30 | | | B (tg) 1 m +S (mr) 20-30 cm | I,II,IV,IX |
| | | | | < 20 m | | | B (gt) 1 m +S (mr) 15-20 cm | I,II,IX |
| | | | | | | | CCA (sr) 30-100 cm +B (tg) 1 m | IV,VIII,X,XI |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 29 ☆ | 0.4-0. | > 5 | > 0.25 | 3.0 | .0-3.1 | B (utg) 1 m+S 2-3 cm | |
| | | ⩽ 5 | > 0.25 | | | B (utg) 1 m+S (mr) 5 cm | |
| | | | ⩽ 0.25 | | | B (tg) 1 m+S(mr) 5 cm | |
| 30 ☆ | 0.4-0.1 | ⩾ 5 | | 3.0 | 2.2-6 | B (tg) 1 m+S 2.5-5 cm | IX |
| | | < 5 | | | | S (mr) S-7.5 cm | IX |
| | | | | | | B (tg) 1 m | VIII,X,XI |
| | | | | | | +S (mr) 5-7.5 cm | |
| 31 | 0.4-0.1 | > 4 | | 3.0 | 4-14.5 | B (tg) 1 m | IX |
| | | | | | | +S (mr) 5-12.5 cm | |
| | | ⩽ 4,⩾ 1.5 | | | | S (mr) 7.5-25 cm | IX |
| | | < 1.5 | | | | CCA 20-40 cm | IX,XI |
| | | | | | | +B (tg) 1 m | |
| | | | | | | CCA (sr) 30-50 cm | VIII,X,XI |
| | | | | | | +B (tg) 1 m | |
| 32 | 0.4-0.1 | | ⩾ 20 m | 3.0 | 11-34 | B (tg) 1 m | II,IV,IX,XI |
| See | | | | | | +S (mr) 40-60 cm | |
| Note XII | | | < 20 m | | | B (tg) 1 m | III,IV,IX,XI |
| | | | | | | +S (mr) 20-40 cm | |
| | | | | | | CCA (sr) 40-120 cm | IV,VIII,X,XI |
| | | | | | | +B (tg) 1 m | |

☆ Authors' estimates of support. Insufficient case records available for confident prediction of support requirements.

TABLE: 7) SUPPORT MEASURES FOR ROCK MASSES OF "EXTREMELY POOR" AND "EXCEPTIONALLY POOR" QUALITY
(Q range: 0.1-0.001)

| Support Category | Q | Conditional Factors RQD/Jn | Jr/Ja | SPAN/ESR (m) | P Kg/cm$^2$ (approx.) | SPAN/ESR (m) | Type of Support | Note See Table 8 |
|---|---|---|---|---|---|---|---|---|
| 33 ☆ | 0.1-0.01 | ⩾ 2 | - | - | 6 | 1.0-3.9 | B (tg) 1 m +S (mr) 2.5-5 cm | IX |
| | | < 2 | - | - | | | S (mr) 5-10 cm | IX |
| | | - | - | - | | | S (mr) 7.5-15 cm | VIII,X |
| 34 | 0.1-0.01 | ⩾ 2 | ⩾ 0.25 | | 6 | 2.0-11 | B (tg) 1 m +S (mr) 5-7.5 cm | IX |
| | | < 2 | ⩾ 0.25 | | | | S (mr) 7.5-15 cm | IX |
| | | - | < 0.25 | | | | S (mr) 15-25 cm | IX |
| | | - | - | | | | CCA (sr) 20-60 cm +B (tg) 1 m | VIII,X,XI |
| 35 See Note XII | 0.1-0.01 | | | ⩾ 15 m | 6 | 6.5-28 | B (tg) 1 m +S (mr) 30-100 cm | II,IX,XI |
| | | | | ⩾ 15 m | | | CCA (sr) 60-200 cm +B (tg) 1 m | VIII,X,XI,II |
| | | | | < 15 m | | | B (tg) 1 m +S (mr) 20-75 cm. | IX,XI,III |
| | | | | < 15 m | | | CCA (sr) 40-150 cm +B (tg) 1 m | VIII,X,XI,III |
| 36 ☆ | 0.01-0.001 | - | - | - | 12 | 1.0-2.0 | S (mr) 10-20 cm | IX |
| | | - | - | - | | | S (mr) 10-20 cm +B (tg) 0.5-1.0 m | VIII,X,XI |
| 37 | 0.01-0.001 | - | - | - | 12 | 1.0-6.5 | S (mr) 20-60 cm | IX |
| | | - | - | - | | | S (mr) 20-60 cm +B (tg) 0.5-1.0 m | VIII,X,XI |
| 38 See Note XIII | 0.01-0.001 | | | ⩾ 10 m | 12 | 4.0-20 | CCA (sr) 100-300 cm | IX |
| | | | | ⩾ 10 m | | | CCA (sr) 100-300 cm +B (tg) 1 m | VIII,X,II,XI |
| | | | | ⩾ 10 m | | | S (mr) 70-200 cm | IX |
| | | | | < 10 m | | | S (mr) 70-200 cm +B (tg) 1 m | VIII,X,III,XI |

☆ Authors' estimates of support. Insufficient case records available for confident prediction of support requirements.

TABLE 8) *Supplementary Notes for Support Tables*

I. For cases of heavy rock bursting or "popping", tensioned bolts with enlarged bearing plates often used, with spacing of about 1 m (occasionally down to 0.8 m). Final support when "popping" activity ceases.

II. Several bolt lengths often used in same excavation, i. e. 3, 5 and 7 m.

III. Several bolt lengths often used in same excavation, i. e. 2, 3 and 4 m.

IV. Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 2—4 m.

V. Several bolt lengths often used in some excavations, i. e. 6, 8 and 10 m.

VI. Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 4—6 m.

VII. Several of the older generation power stations in this category employ systematic or spot bolting with areas of chain link mesh, and a free span concrete arch roof (25—40 cm) as permanent support.

VIII. Cases involving swelling, for instance montmorillonite clay (with access of water). Room for expansion behind the support is used in cases of heavy swelling. Drainage measures are used where possible.

IX. Cases not involving swelling clay or squeezing rock.

X. Cases involving squeezing rock. Heavy rigid support its generally used as permanent support.

XI. According to the authors' experience, in cases of swelling or squeezing, the temporary support required before concrete (or shotcrete) arches are formed may consist of bolting (tensioned shell-expansion type) if the value of $RQD/J_n$ is sufficiently high (i. e. $> 1.5$), possibly combined with shotcrete. If the rock mass is very heavily jointed or crushed (i. e. $RQD/J_n < 1.5$, for example a "sugar cube" shear zone in quartzite), then the temporary support may consist of up to several applications of shotcrete. Systematic bolting (tensioned) may be added after casting the concrete (or shotcrete) arch to reduce the uneven loading on the concrete, but it may not be effective when $RQD/J_n < 1.5$, or when a lot of clay is present, unless the bolts are grouted before tensioning. A sufficient length of anchored bolt might also be obtained using quick setting resin anchors in these extremely poor quality rockmasses. Serious occurrences of swelling and/or squeezing rock may require that the concrete arches are taken right up to the face, possibly using a shield as temporary shuttering. Temporary support of the working face may also be required in these cases.

XII. For reasons of safety the multiple drift method will often be needed during excavation and supporting of roof arch. Categories 16, 20, 24, 28, 32, 35 ($SPAN/ESR > 15$ m only).

XIII. Multiple drift method usually needed during excavation and support of arch, walls and floor in cases of heavy squeezing. Category 38 ($SPAN/ESR > 10$ m only).

# APPENDIX – D
# Q FLOW CHARTS AND CLASSEX OUTPUTS

# Q – FLOW CHARTS

## THE BOZTEPE (T-1) TUNNEL

T1-1

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=43.5 calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 3

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.10m

SET-2: 0.15m

SET-3: 0.20m

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ■ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ■ | ☐ | ☐ |
| (ii) Discontinuous | ☐ | ■ | ■ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ■ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ■ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | SET-2 | SET-3 |
|---|---|---|
| A | A | A |
| B | B | B |
| C | C | C |
| D | D | D |
| E | E | E |
| F | F | F |
| G | G | G |
| H | H | H |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | ■ | □ | ■ |
| (ii) Perpendicular | □ | ■ | □ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ■ | □ |
| (ii) Out | □ | □ | ■ |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ■ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ☐ | ■ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level : 50 m

9. STRENGTH of INTACT ROCK (UCS) :25 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT: 9 m

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 14. SWELLING CLAY : | YES | ☐ | NO | ■ | UNSURE | ☐ |

T1-2

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=96: calculated from discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.35m

SET-2: 0.35m

SET-3: ----

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ☐ | ☐ | ☐ |
| (ii) Discontinuous | ■ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

5.5 DESCRIPTION of ALTERATION

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| A | ☐ | ☐ | ☐ |
| B | ■ | ■ | ☐ |
| C | ☐ | ☐ | ☐ |
| D | ☐ | ☐ | ☐ |
| E | ☐ | ☐ | ☐ |
| F | ☐ | ☐ | ☐ |
| G | ☐ | ☐ | ☐ |
| H | ☐ | ☐ | ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | ☐ | ■ | ☐ |
| (ii) | Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ☐ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ■ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :80m

9. STRENGTH of INTACT ROCK (UCS) :30 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T1-3

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=65.5: calculated from discontinuity spacings )

2. NUMBER OF DISCONTINUITY:2

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.12m

SET-2: 0.15m

SET-3:

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ■ | ☐ | ☐ |
| (ii) Discontinuous | ☐ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | SET-2 | SET-3 |
|---|---|---|
| A ☐ | A ☐ | A ☐ |
| B ☐ | B ☐ | B ☐ |
| C ■ | C ■ | C ☐ |
| D ☐ | D ☐ | D ☐ |
| E ☐ | E ☐ | E ☐ |
| F ☐ | F ☐ | F ☐ |
| G ☐ | G ☐ | G ☐ |
| H ☐ | H ☐ | H ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | ☐ | ■ | ☐ |
| (ii) Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ☐ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ■ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :120m

9. STRENGTH of INTACT ROCK (UCS) :35 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T1-4

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=60: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.10m

SET-2:0.15m

SET-3:…..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ■ | ☐ | ☐ |
| (ii) Discontinuous | ☐ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | | SET-2 | | SET-3 | |
|---|---|---|---|---|---|
| A | ☐ | A | ☐ | A | ☐ |
| B | ☐ | B | ☐ | B | ☐ |
| C | ■ | C | ■ | C | ☐ |
| D | ☐ | D | ☐ | D | ☐ |
| E | ☐ | E | ☐ | E | ☐ |
| F | ☐ | F | ☐ | F | ☐ |
| G | ☐ | G | ☐ | G | ☐ |
| H | ☐ | H | ☐ | H | ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | ☐ | ■ | ☐ |
| (ii) | Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :170m

9. STRENGTH of INTACT ROCK (UCS) : 20 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T1-5

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=67.6: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.13m

SET-2: 0.15m

SET-3:…..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ▭ |
| (ii) 1.00-5.00 | ▭ | ▭ | ▭ |
| (iii) > 5.00 | ▭ | ▭ | ▭ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ▭ | ▭ | ▭ |
| (ii) Discontinuous | ■ | ■ | ▭ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ▭ |
| (ii) Planar | ▭ | ▭ | ▭ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ▭ |
| (ii) Smooth | ▭ | ▭ | ▭ |
| (iii) Slickensided | ▭ | ▭ | ▭ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | SET-2 | SET-3 |
|---|---|---|
| A ☐ | A ☐ | A ☐ |
| B ☐ | B ☐ | B ☐ |
| C ■ | C ■ | C ☐ |
| D ☐ | D ☐ | D ☐ |
| E ☐ | E ☐ | E ☐ |
| F ☐ | F ☐ | F ☐ |
| G ☐ | G ☐ | G ☐ |
| H ☐ | H ☐ | H ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | ☐ | ■ | ☐ |
| (ii) Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :60m

9. STRENGTH of INTACT ROCK (UCS) : 30 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T1-Pn

FLOW CHART (Q CLASSIFICATION

1. DRILL CORE --- DIRECTLY ( RQD= 54.5: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 3

3. PORTAL OR INTERSECTION

3.1. PORTAL ■ 3.2. TUNNEL □

4. SPACING OF JOINTS :

SET-1: 0.15

SET-2: 0.15

SET-3: 0.20

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | □ | □ | □ |
| (ii) 1.00-5.00 | ■ | ■ | ■ |
| (iii) > 5.00 | □ | □ | □ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ■ | □ | □ |
| (ii) Discontinuous | □ | ■ | ■ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ■ |
| (ii) Planar | □ | □ | □ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ■ |
| (ii) Smooth | □ | □ | □ |
| (iii) Slickensided | □ | □ | □ |

5.5 DESCRIPTION of ALTERATION

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| A | ☐ | ☐ | ☐ |
| B | ☐ | ☐ | ☐ |
| C | ■ | ■ | ■ |
| D | ☐ | ☐ | ☐ |
| E | ☐ | ☐ | ☐ |
| F | ☐ | ☐ | ☐ |
| G | ☐ | ☐ | ☐ |
| H | ☐ | ☐ | ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | ☐ | ■ | ☐ |
| (ii) | Perpendicular | ■ | ☐ | ■ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ■ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ■ 5.8.2. TUNNEL □

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | □ | □ |
| (ii) 30-60 | 20-45 | □ | ■ | □ |
| (iii) 60-90 | 45-90 | □ | □ | ■ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET: 1

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | |
|---|---|---|---|
| None □ | < 10 □ | 10-25 □ | 25-125 □ |
| None □ | Minor □ | Medium ■ | Large □ |

8. STRESS PARAMETER

(i) Directly □

(ii) Depth Relation ■

-Depth to tunnel level : 35 m

9. STRENGTH of INTACT ROCK (UCS) : 25MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY □

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9m

14. SWELLING CLAY : YES □ NO ■ UNSURE □

T1-Px

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=49: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 3

3. PORTAL OR INTERSECTION

3.1. PORTAL ■ 3.2. TUNNEL □

4. SPACING OF JOINTS :

SET-1: 0.15m

SET-2: 0.15m

SET-3: 0.15m

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ▭ | ▭ | ▭ |
| (ii) 1.00-5.00 | ▬ | ▬ | ▬ |
| (iii) > 5.00 | ▭ | ▭ | ▭ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ▭ | ▭ | ▭ |
| (ii) Discontinuous | ▬ | ▬ | ▬ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ▭ | ▭ | ▭ |
| (ii) Planar | ▬ | ▬ | ▬ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ▬ | ▬ | ▬ |
| (ii) Smooth | ▭ | ▭ | ▭ |
| (iii) Slickensided | ▭ | ▭ | ▭ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | SET-2 | SET-3 |
|---|---|---|
| A | A | A |
| B | B | B |
| C | C | C |
| D | D | D |
| E | E | E |
| F | F | F |
| G | G | G |
| H | H | H |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | | | |
| (ii) Perpendicular | | | |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | | | |
| (ii) Out | | | |

5.8. DIP AMOUNT

5.8.1. PORTAL ■ 5.8.2. TUNNEL □

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | □ | □ |
| (ii) 30-60 | 20-45 | □ | ■ | □ |
| (iii) 60-90 | 45-90 | □ | □ | ■ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | |
|---|---|---|---|
| None □ | < 10 □ | 10-25 □ | 25-125 □ |
| None □ | Minor □ | Medium ■ | Large □ |

8. STRESS PARAMETER

(i) Directly □

(ii) Depth Relation ■

-Depth to tunnel level : 35 m

9. STRENGTH of INTACT ROCK (UCS) : 25MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT □ 11.2. TEMPORARY □

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES □ NO ■ UNSURE □

## THE ÖCELİ (T-2) TUNNEL

T2-1

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=63: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.11m

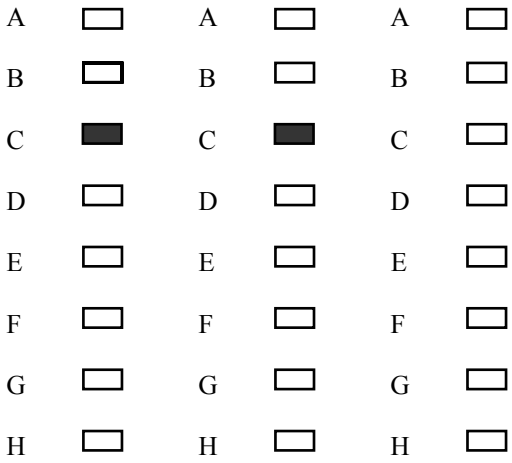
SET-2: 0.15m

SET-3: …..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ▭ |
| (ii) 1.00-5.00 | ▭ | ▭ | ▭ |
| (iii) > 5.00 | ▭ | ▭ | ▭ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ▭ | ▭ | ▭ |
| (ii) Discontinuous | ■ | ■ | ▭ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ▭ |
| (ii) Planar | ▭ | ▭ | ▭ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ▭ |
| (ii) Smooth | ▭ | ▭ | ▭ |
| (iii) Slickensided | ▭ | ▭ | ▭ |

| 5.5 DESCRIPTION of ALTERATION | SET-1 | SET-2 | SET-3 |
|---|---|---|---|




(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | | | |
| (ii) Perpendicular | | | |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | | | |
| (ii) Out | | | |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level : 65 m

9. STRENGTH of INTACT ROCK (UCS) :20 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T2-2

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=88.5: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.25m

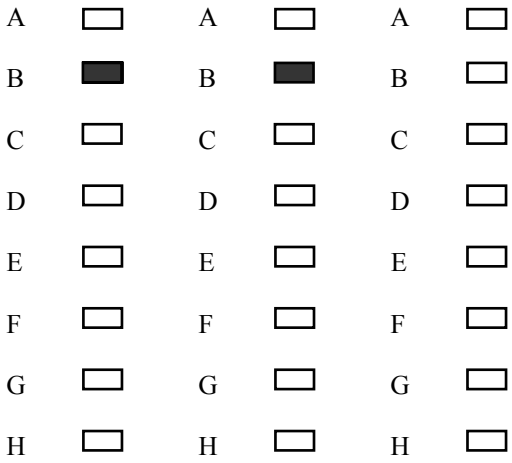
SET-2: 0.25m

SET-3: …..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ■ | ☐ | ☐ |
| (ii) Discontinuous | ☐ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

| 5.5 DESCRIPTION of ALTERATION | SET-1 | SET-2 | SET-3 |
|---|---|---|---|




(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | | | |
| (ii) Perpendicular | | | |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | | | |
| (ii) Out | | | |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :75 m

9. STRENGTH of INTACT ROCK (UCS) :30 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T2-3

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=76.5: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.15m

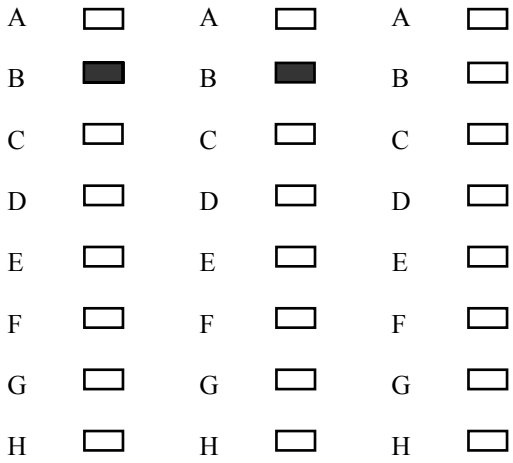
SET-2: 0.20m

SET-3: …..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ☐ | ☐ | ☐ |
| (ii) Discontinuous | ■ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

| 5.5 DESCRIPTION of ALTERATION | SET-1 | SET-2 | SET-3 |
|---|---|---|---|




(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | | | |
| (ii) | Perpendicular | | | |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | | | |
| (ii) Out | | | |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :60 m

9. STRENGTH of INTACT ROCK (UCS) :20 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

14. SWELLING CLAY : YES ☐ NO ■ UNSURE ☐

T2-4

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=82: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ☐ 3.2. TUNNEL ■

4. SPACING OF JOINTS :

SET-1: 0.20m

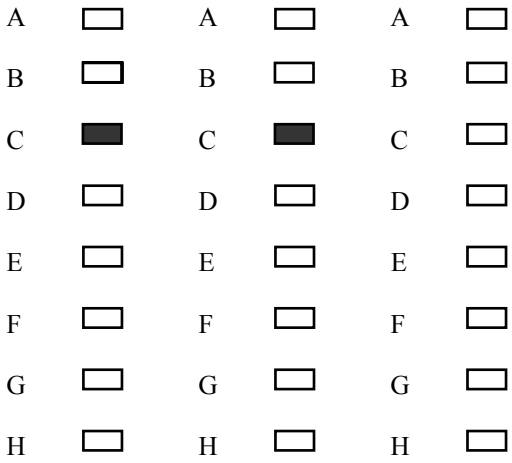
SET-2: 0.20m

SET-3: …..

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE ( mm ) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ■ | ■ | ☐ |
| (ii) 1.00-5.00 | ☐ | ☐ | ☐ |
| (iii) > 5.00 | ☐ | ☐ | ☐ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ☐ | ☐ | ☐ |
| (ii) Discontinuous | ■ | ■ | ☐ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ☐ |
| (ii) Planar | ☐ | ☐ | ☐ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ☐ |
| (ii) Smooth | ☐ | ☐ | ☐ |
| (iii) Slickensided | ☐ | ☐ | ☐ |

| 5.5 DESCRIPTION of ALTERATION | SET-1 | SET-2 | SET-3 |
|---|---|---|---|




(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | | | |
| (ii) | Perpendicular | | | |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | | | |
| (ii) Out | | | |

5.8. DIP AMOUNT

5.8.1. PORTAL ☐ 5.8.2. TUNNEL ■

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | ☐ | ☐ |
| (ii) 30-60 | 20-45 | ☐ | ☐ | ☐ |
| (iii) 60-90 | 45-90 | ☐ | ■ | ☐ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | ☐ | < 10 | ☐ | 10-25 | ☐ | 25-125 | ☐ |
| None | ☐ | Minor | ■ | Medium | ☐ | Large | ☐ |

8. STRESS PARAMETER

(i) Directly ☐

(ii) Depth Relation ■

-Depth to tunnel level :60 m

9. STRENGTH of INTACT ROCK (UCS) :15 MPa

10. ESR : 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY ☐

12. SPAN DIAMETER : 12 m

13. HEIGHT : 9 m

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 14. SWELLING CLAY : | YES | ☐ | NO | ■ | UNSURE | ☐ |

T2-Px

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=60: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ■ 3.2. TUNNEL □

4. SPACING OF JOINTS:

SET-1: 0.10m

SET-2: 0.15m

SET-3…

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE (mm) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ▭ | ▭ | ▭ |
| (ii) 1.00-5.00 | ■ | ■ | ▭ |
| (iii) > 5.00 | ▭ | ▭ | ▭ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ▭ | ▭ | ▭ |
| (ii) Discontinuous | ■ | ■ | ▭ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | ▭ |
| (ii) Planar | ▭ | ▭ | ▭ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | ▭ |
| (ii) Smooth | ▭ | ▭ | ▭ |
| (iii) Slickensided | ▭ | ▭ | ▭ |

5.5 DESCRIPTION of ALTERATION

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| A | ☐ | ☐ | ☐ |
| B | ☐ | ☐ | ☐ |
| C | ■ | ■ | ☐ |
| D | ☐ | ☐ | ☐ |
| E | ☐ | ☐ | ☐ |
| F | ☐ | ☐ | ☐ |
| G | ☐ | ☐ | ☐ |
| H | ☐ | ☐ | ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | ☐ | ■ | ☐ |
| (ii) | Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ■ 5.8.2. TUNNEL □

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | □ | □ |
| (ii) 30-60 | 20-45 | □ | □ | □ |
| (iii) 60-90 | 45-90 | □ | ■ | □ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | □ | < 10 | □ | 10-25 | □ | 25-125 | □ |
| None | □ | Minor | □ | Medium | ■ | Large | □ |

8. STRESS PARAMETER

(i) Directly □

(ii) Depth Relation ■

-Depth to tunnel level : 35m

9. STRENGTH of INTACT ROCK (UCS) : 10 MPa
10. ESR: 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY □

12. SPAN DIAMETER: 12 m

13. HEIGHT: 9 m
14. SWELLING CLAY: YES □ NO ■ UNSURE □

T2-Pna

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=60: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ■ 3.2. TUNNEL □

4. SPACING OF JOINTS:

SET-1: 0.10m

SET-2: 0.15m

SET-3…

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE (mm) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | □ | □ | □ |
| (ii) 1.00-5.00 | ■ | ■ | □ |
| (iii) > 5.00 | □ | □ | □ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | □ | □ | □ |
| (ii) Discontinuous | ■ | ■ | □ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ■ | ■ | □ |
| (ii) Planar | □ | □ | □ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ■ | ■ | □ |
| (ii) Smooth | □ | □ | □ |
| (iii) Slickensided | □ | □ | □ |

5.5 DESCRIPTION of ALTERATION

| SET-1 | SET-2 | SET-3 |
|---|---|---|
| A ☐ | A ☐ | A ☐ |
| B ☐ | B ☐ | B ☐ |
| C ■ | C ■ | C ☐ |
| D ☐ | D ☐ | D ☐ |
| E ☐ | E ☐ | E ☐ |
| F ☐ | F ☐ | F ☐ |
| G ☐ | G ☐ | G ☐ |
| H ☐ | H ☐ | H ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Parallel | ☐ | ■ | ☐ |
| (ii) Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ■ 5.8.2. TUNNEL □

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | □ | □ |
| (ii) 30-60 | 20-45 | □ | □ | □ |
| (iii) 60-90 | 45-90 | □ | ■ | □ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | □ | < 10 | □ | 10-25 | □ | 25-125 | □ |
| None | □ | Minor | □ | Medium | ■ | Large | □ |

8. STRESS PARAMETER

(i) Directly □

(ii) Depth Relation ■

-Depth to tunnel level : 35m

9. STRENGTH of INTACT ROCK (UCS) : 10 MPa
10. ESR: 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY □

12. SPAN DIAMETER: 12 m

13. HEIGHT: 9 m
14. SWELLING CLAY: YES □ NO ■ UNSURE □

T2-Pnb

FLOW CHART (Q CLASSIFICATION )

1. DRILL CORE --- DIRECTLY ( RQD=60: calculated from the discontinuity spacings)

2. NUMBER OF DISCONTINUITY: 2+Random

3. PORTAL OR INTERSECTION

3.1. PORTAL ■ 3.2. TUNNEL □

4. SPACING OF JOINTS:

SET-1: 0.10m

SET-2: 0.15m

SET-3…

5. COMMON RUN FOR EACH JOINT

| 5.1. APERTURE (mm) : | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) < 1.0 | ▭ | ▭ | ▭ |
| (ii) 1.00-5.00 | ▬ | ▬ | ▭ |
| (iii) > 5.00 | ▭ | ▭ | ▭ |
| 5.2. CONTINUITY | | | |
| (i) Continuous | ▭ | ▭ | ▭ |
| (ii) Discontinuous | ▬ | ▬ | ▭ |
| 5.3. ROUGHNESS | | | |
| (i) Undulating | ▬ | ▬ | ▭ |
| (ii) Planar | ▭ | ▭ | ▭ |
| 5.4. ROUGHNESS (Definition) | | | |
| (i) Rough irregular | ▬ | ▬ | ▭ |
| (ii) Smooth | ▭ | ▭ | ▭ |
| (iii) Slickensided | ▭ | ▭ | ▭ |

5.5 DESCRIPTION of ALTERATION

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| A | ☐ | ☐ | ☐ |
| B | ☐ | ☐ | ☐ |
| C | ■ | ■ | ☐ |
| D | ☐ | ☐ | ☐ |
| E | ☐ | ☐ | ☐ |
| F | ☐ | ☐ | ☐ |
| G | ☐ | ☐ | ☐ |
| H | ☐ | ☐ | ☐ |

(See table below)

TABLE 5.5.1-Joint alteration number (Ja)

| Description of Gouge | Joint Alteration Number for Joint Separation of < 1.0 mm | 1.0-5.0 mm | > 5.0 mm |
|---|---|---|---|
| A. Tightly healed , hard , non-softening impermeable filling | 0.75 | | |
| B. Unaltered joint walls, surface staining only | 1.0 | | |
| C. Slightly altered, non-softening, non-cohesive rock mineral or crushed rock filling | 2.0 | 4.0 | 6.0 |
| D. Non-softening, slightly clayey non-cohesive filling | 3.0 | 6.0 | 10.0 |
| E. Non-softening , strongly over-consolidated clay mineral filling with or without crushed rock | 3.0 | 6.0 | 10.0 |
| F. Softening or low friction clay mineral coatings and small quantities of swelling clays | 4.0 | 8.0 | 13.0 |
| G. Softening moderately over-consolidated clay mineral filling, with or without crushed rock | 4.0 | 8.0 | 13.0 |
| H. Shattered or micro-shattered (swelling) clay gauge, with or without crushed rock | 5.0 | 10.0 | 18.0 |

5.6. ORIENTATION of DISCONTINUITY

| | | SET-1 | SET-2 | SET-3 |
|---|---|---|---|---|
| (i) | Parallel | ☐ | ■ | ☐ |
| (ii) | Perpendicular | ■ | ☐ | ☐ |

5.7. DIP WITH RESPECT TO TUNNEL

| | SET-1 | SET-2 | SET-3 |
|---|---|---|---|
| (i) Into | ■ | ☐ | ☐ |
| (ii) Out | ☐ | ■ | ☐ |

5.8. DIP AMOUNT

5.8.1. PORTAL ■ 5.8.2. TUNNEL □

| | | | | |
|---|---|---|---|---|
| (i) 15-30 | 0-20 | ■ | □ | □ |
| (ii) 30-60 | 20-45 | □ | □ | □ |
| (iii) 60-90 | 45-90 | □ | ■ | □ |

6. CHOOSE THE MOST UNFAVORABLE JOINT SET

7. GROUNDWATER CONDITIONS

7.1. INFLOW ( l/m for 10 m. of tunnel length)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| None | □ | < 10 | □ | 10-25 | □ | 25-125 | □ |
| None | □ | Minor | □ | Medium | ■ | Large | □ |

8. STRESS PARAMETER

(i) Directly □

(ii) Depth Relation ■

-Depth to tunnel level : 35m

9. STRENGTH of INTACT ROCK (UCS) : 60 MPa
10. ESR: 1.00

11. SUPPORT TYPE

11.1. PERMANENT ■ 11.2. TEMPORARY □

12. SPAN DIAMETER: 12 m

13. HEIGHT: 9 m
14. SWELLING CLAY: YES □ NO ■ UNSURE □

# CLASSEX OUTPUTS

# THE BOZTEPE (T-1) TUNNEL

```
 CLASSEX RESULTS
-----------------


**************  Q-SYSTEM OUTPUT ---> T1-1  *************

The UCS is about  25 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 6.89 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS.  Barton
suggests that a high stress environment creates a very tight
structure usually favourable to roof stability, but it may be
unfavourable to wall stability.  Stacey and Page suggest that there
should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

          Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-1
     ---------------------------------------------------------------

                  ROCK MASS QUALITY: POOR with a Q of 2.0

          ROOF 'Q' USED : 2.0 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 2.8 m (ESR = 1), from De vs Q
                         :  3.1 m (ESR = 1), from plot of actual
                           unsupported excavation spans vs Q
   MAX POSSIBLE ROOF SPAN: roof spans > 41.9 m above limits of
applicability
         SUPPORT PRESSURE:  51.9 kPa (Equation_3)
                 Emean -->  2.73 GPa (Serafim_and_Pereira_1983)

          WALL 'Q' USED :   5 with a factor of 2.5 x original Q
  MAX UNSUPPORTED WALL HT: 4.0 m, from De vs Q
     MAX POSSIBLE WALL HT: wall heights > 47.6 m above limits of
applicability

               Q-SYSTEM PARAMETERS ----> T1-1
   ---------------------------------------------------------------

        43.5    3.0     1.0                    TUNNEL_SECTION
    Q = ---- X ---- X ------                     SPAN =12m
         9.0    2.0    3.617              WALL HEIGHT = 9 m
                                                 ESR =   1
                        ************
                          Q = 2.0
                        ************        ROCK MASS = HOMOGENEOUS
                                          ROCK QUALITY = POOR
   RQD = 43.5
    Jn =  9.0                 BLOCK SIZE (RQD/ORIG Jn) =  4.833 units
    Jr =  3.0       INTER-BLOCK SHEAR STRENGTH (Jr/Ja) =  1.500
    Ja =  2.0             APPARENT FRICTION ANGLE (ír) =   56.3ø
    Jw =  1.0                   ACTIVE STRESS (Jw/SRF) =  0.276
   SRF =  3.617

          Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-1
     ---------------------------------------------------------------

     ROCK MASS QUALITY: POOR with a Q of 2.0
            CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of
                        12m
```

```
-----------------------------------------------------------------
      SUPPORT CATEGORY: 23B
      SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 -
                        1.5 m
                        Shotcrete reinforced with weldmesh, 50 - 100
                        mm thick
                        Mean Bolt Length =  3.80 m

 NOTES from Barton, Lien and Lunde
----------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts
with enlarged bearing plates are often used, with spacings of about
1 m (occasionally 0.8 m).  Final support when 'popping' activity
ceases.~


 NOTES from Hoek and Brown
--------------------------
NOTE C: Weldmesh, consisting of steel wires set on a square pattern
and
welded at each intersection, should be used for the reinforcement of
shotcrete since it allows easy access of the shotcrete to the rock.
Chainlink mesh should never be used for this purpose since the
shotcrete
cannot penetrate all the spaces between the wires and air pockets
are
formed with consequent rusting of the wire.  When choosing weldmesh,
it is
important that the mesh can be handled by one or two men working
from the
top of a high-lift vehicle and hence the mesh should not be too
heavy.
Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x
100 x 4.2
weldmesh) are used for reinforcing shotcrete.~

           Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-1
     -----------------------------------------------------------------

     ROCK MASS QUALITY: POOR with a Q of 2.0
            CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of
                        12m
-----------------------------------------------------------------

      SUPPORT CATEGORY: 23B
      SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 -
                        1.5 m
                        Shotcrete reinforced with weldmesh, 50 - 100
                        mm thick
                        Mean Bolt Length =  3.80 m

 NOTES from Barton, Lien and Lunde
----------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts
with enlarged bearing plates are often used, with spacings of about
1 m (occasionally 0.8 m).  Final support when 'popping' activity
ceases.~
```

```
 NOTES from Hoek and Brown
--------------------------
NOTE C: Weldmesh, consisting of steel wires set on a square pattern
and welded at each intersection, should be used for the
reinforcement of shotcrete since it allows easy access of the
shotcrete to the rock. Chainlink mesh should never be used for this
purpose since the shotcrete cannot penetrate all the spaces between
the wires and air pockets are formed with consequent rusting of the
wire.  When choosing weldmesh, it is important that the mesh can be
handled by one or two men working from the top of a high-lift
vehicle and hence the mesh should not be too heavy. Typically, 4.2
mm wires set at 100 mm intervals (designated 100 x 100 x 4.2
weldmesh) are used for reinforcing shotcrete.~


          Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-1
     ------------------------------------------------------------------

            'Q' USED : 5 with a factor of 2.5 x original Q
           CRITICAL Q: need Q >= 42.0 for unsupported WALL span of
                       9 m
------------------------------------------------------------------------

    SUPPORT CATEGORY: 18D
    SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of
                       1 - 1.5 m
                      Shotcrete applied directly to rock, 20 - 30 mm
                       thick
                      Mean Bolt Length =  3.35 m

 NOTES from Barton, Lien and Lunde
----------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts
with enlarged bearing plates are often used, with spacings of about
1 m (occasionally 0.8 m).  Final support when 'popping' activity
ceases.~


************************ RQD SUPPORT SYSTEM *********************

The roof span of 12m is within the valid range of spans (6-12 m) for
the RQD support recommendation system.

     SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER
DEERE)
   ------------------------------------------------------------------
                             RQD = Poor @ 43.5%
       TUNNELER'S CLASSIFICATION = Shattered, Very Blocky & Seamy
             CONSTRUCTION METHOD = Tunnel Boring Machine
                       ROCK LOAD =    12 --> 19.20 m

 ALTERNATIVE SUPPORT SYSTEMS:

    STEEL SETS (2): Medium circular sets on 0.92 m to 1.22 m centre
    ROCK BOLTS (3): Pattern, 0.92 m to 1.53 m centre
        SHOTCRETE : 10.2 cm to 15.3 cm on crown and sides
                    Combine with bolts
```

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to
100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in
good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 2.0, POOR ROCK
******

Bieniawski: Correlations from Civil Engineering Tunnels

RMR = 9 (lnQ) + 44
= 50.2, FAIR_ROCK, CLASS III
******

Abad: Correlation from Coal Mine Roadways in Spain

RMR = 10.5 (lnQ) + 42
= 49.2, FAIR_ROCK, CLASS III
******

Rutledge: Correlation from Tunneling Projects in New Zealand

RMR = 13.5 (logQ) + 43
= 47.0, FAIR_ROCK, CLASS III
******

Rutledge: RSR = 13.3 (logQ) + 46.5
= 50.5
******

Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 29.3
******

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T1-2 **********

The UCS is about 30 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 5.28 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS. Barton suggests that a high stress environment creates a very tight structure usually favourable to roof stability, but it may be unfavourable to wall stability. Stacey and Page suggest that there should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-2

ROCK MASS QUALITY: GOOD with a Q of 18.8

ROOF 'Q' USED : 18.8 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 6.6 m (ESR = 1), from De vs Q
: 13.8 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 57.3 m above limits of applicability
SUPPORT PRESSURE: 6.1 kPa (Equation_4)
Emean --> 31.85 GPa (25logQ)

WALL 'Q' USED : 94 with a factor of 5 x original Q
MAX UNSUPPORTED WALL HT: 12.2 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 71.8 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T1-2

$$Q = \frac{96.1}{4.0} \times \frac{4.0}{1.0} \times \frac{1.0}{5.099}$$

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 18.8
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = GOOD

RQD = 96.1
Jn = 4.0 BLOCK SIZE (RQD/ORIG Jn) = 24.035 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 4
Ja = 1.0 APPARENT FRICTION ANGLE (ír) = 76.0ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.196
SRF = 5.099

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-2

ROCK MASS QUALITY: GOOD with a Q of 18.8
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

```
-----------------------------------------------------------------------
   SUPPORT CATEGORY: 14C
   SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of
                     1.5 - 2 m
                     Chainlink mesh anchored to bolts and
                     intermediate points
                     Mean Bolt Length =  3.80 m

 NOTES from Barton, Lien and Lunde
---------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts
with enlarged bearing plates are often used, with spacings of about
1 m (occasionally 0.8 m).  Final support when 'popping' activity
ceases.~

NOTE 4: Several bolt lengths often used in same excavation.
        i.e. 2, 3, and 4 m.~


 NOTES from Hoek and Brown
--------------------------
NOTE B: Chainlink mesh is sometimes used to catch small pieces of
rock which can become loose with time.  It should be attached to the
rock at intervals of between 1 and 1.5 m and short grouted pins can
be used between bolts.  Galvanised chainlink mesh should be used
where it is intended to be permanent, eg. in an underground
powerhouse.~


           Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-2
     ------------------------------------------------------------------

             'Q' USED : 94 with a factor of 5 x original Q
            CRITICAL Q: need Q >= 42.0 for unsupported WALL span of
                        9 m
-----------------------------------------------------------------------

      SUPPORT CATEGORY: Below_unsupported_span_line
      SUPPORT MEASURES: No support required

      De --->    9. If De is greater than 7 and you wish to be
conservative, support category 9 is the closest to your situation.
It recommends systematic bolting with untensioned grouted dowels
spaced at 2.5-3.0 m.

************************ RQD SUPPORT SYSTEM ***********************

The roof span of 12m is within the valid range of spans (6-12 m) for
the RQD support recommendation system.

     SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER
DEERE)
   ------------------------------------------------------------------
                             RQD = Excellent @ 96.1% (1)
       TUNNELER'S CLASSIFICATION = Intact
             CONSTRUCTION METHOD = Tunnel Boring Machine
                       ROCK LOAD = 0 --> 2.40 m

 ALTERNATIVE SUPPORT SYSTEMS:
```

```
                  STEEL SETS (2): None to occasional light set
                  ROCK BOLTS (3): None to occasional
                      SHOTCRETE : None to occasional application

NOTES: (1) In EXCELLENT rock the support requirement will be, in
          general, minimal but will be dependent upon joint
          geometry, tunnel
           diameter and relative orientations of joints and tunnel.
       (2) Lagging requirements will usually be zero in EXCELLENT
            rock.
       (3) Mesh requirements usually zero in EXCELLENT rock

                          CORRELATIONS WITH Q-VALUES
                        ------------------------------

    Barton: Q = 18.8, GOOD ROCK
              ******
Bieniawski: Correlations from Civil Engineering Tunnels
----------  RMR = 9 (lnQ) + 44
              = 70.4, GOOD_ROCK, CLASS II
               ******
      Abad: Correlation from Coal Mine Roadways in Spain
      ----  RMR = 1O.5 (lnQ) + 42
              =  72.8, GOOD_ROCK, CLASS II
               ******
  Rutledge: Correlation from Tunneling Projects in New Zealand
  --------  RMR = 13.5 (logQ) + 43
              = 60.2, GOOD_ROCK, CLASS II
               ******
  Rutledge: RSR = 13.3 (logQ) + 46.5
  --------      = 63.4
               ******
 Rib Ratio (RR) = (88OO/(RSR + 3O)) - 8O
              = 14.2
               ******
```

```
 CLASSEX RESULTS
-----------------


**************  Q-SYSTEM OUTPUT ---> T1-3  *************

The UCS is about  35 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 4.22 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING
(Barton). Stacey and Page suggest that some spalling from the
surface may occur parallel to å1, and that 'heavier' support is
usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

          Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-3
     ---------------------------------------------------------------

                  ROCK MASS QUALITY: POOR with a Q of 3.6

          ROOF 'Q' USED : 3.6 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 3.5 m (ESR = 1), from De vs Q
                        :  4.6 m (ESR = 1), from plot of actual
                           unsupported excavation spans vs Q
   MAX POSSIBLE ROOF SPAN: roof spans > 45.5 m above limits of
                           applicability
         SUPPORT PRESSURE:  14.2 kPa (Equation_4)
                 Emean --> 13.90 GPa (25logQ)

          WALL 'Q' USED :   9 with a factor of 2.5 x original Q
  MAX UNSUPPORTED WALL HT: 5.0 m, from De vs Q
     MAX POSSIBLE WALL HT: wall heights > 51.7 m above limits of
                           applicability

               Q-SYSTEM PARAMETERS ----> T1-3
   ---------------------------------------------------------------

        65.5    3.0     1.0                    TUNNEL_SECTION
    Q = ---- X ---- X ------                      SPAN =12m
         4.0    2.0    6.772              WALL HEIGHT = 9 m
                                                  ESR =   1
                        ************
                          Q = 3.6
                        ************         ROCK MASS = HOMOGENEOUS
                                           ROCK QUALITY = POOR
   RQD = 65.5
    Jn =  4.0                 BLOCK SIZE (RQD/ORIG Jn) = 16.375 units
    Jr =  3.0       INTER-BLOCK SHEAR STRENGTH (Jr/Ja) =  1.500
    Ja =  2.0             APPARENT FRICTION ANGLE (ír) =   56.3ø
    Jw =  1.0                   ACTIVE STRESS (Jw/SRF) =  0.147
   SRF =  6.772

          Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-3
     ---------------------------------------------------------------

     ROCK MASS QUALITY: POOR with a Q of 3.6
            CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of
                        12m
```

```
-----------------------------------------------------------------------
      SUPPORT CATEGORY: 23B
      SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 -
                        1.5 m
                        Shotcrete reinforced with weldmesh, 50 - 100
                        mm thick
                        Mean Bolt Length =  3.80 m

 NOTES from Barton, Lien and Lunde
-----------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts with enlarged bearing plates are often used, with spacings of
about 1 m (occasionally 0.8 m).  Final support when 'popping'
activity ceases.~


 NOTES from Hoek and Brown
---------------------------
NOTE C: Weldmesh, consisting of steel wires set on a square pattern
and welded at each intersection, should be used for the
reinforcement of shotcrete since it allows easy access of the
shotcrete to the rock. Chainlink mesh should never be used for this
purpose since the shotcrete cannot penetrate all the spaces between
the wires and air pockets are formed with consequent rusting of the
wire.  When choosing weldmesh, it is important that the mesh can be
handled by one or two men working from the

           Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-3
     ------------------------------------------------------------

     ROCK MASS QUALITY: POOR with a Q of 3.6
            CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of
                        12m
-----------------------------------------------------------------------

      SUPPORT CATEGORY: 23B
      SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 -
                        1.5 m
                        Shotcrete reinforced with weldmesh, 50 - 100
                        mm thick
                        Mean Bolt Length =  3.80 m

 NOTES from Barton, Lien and Lunde
-----------------------------------
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned
bolts with enlarged bearing plates are often used, with spacings of
about 1 m (occasionally 0.8 m).  Final support when 'popping'
activity ceases.~


 NOTES from Hoek and Brown
---------------------------
NOTE C: Weldmesh, consisting of steel wires set on a square pattern
and welded at each intersection, should be used for the
reinforcement of shotcrete since it allows easy access of the
shotcrete to the rock. Chainlink mesh should never be used for this
purpose since the shotcrete cannot penetrate all the spaces between
the wires and air pockets are formed with consequent rusting of the
wire.  When choosing weldmesh, it is important that the mesh can be
handled by one or two men working from the top of a high-lift
vehicle and hence the mesh should not be too heavy.
```

Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-3

'Q' USED : 9 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9 m

SUPPORT CATEGORY: 17B
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 - 1.5 m
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

RQD = Fair @ 65.5%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 3.6, POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 55.5, FAIR_ROCK, CLASS III
******

```
     Abad: Correlation from Coal Mine Roadways in Spain
     ----  RMR = 10.5 (lnQ) + 42
               =  55.4, FAIR_ROCK, CLASS III
                ******
 Rutledge: Correlation from Tunneling Projects in New Zealand
 --------  RMR = 13.5 (logQ) + 43
               = 50.5, FAIR_ROCK, CLASS III
                ******
 Rutledge: RSR = 13.3 (logQ) + 46.5
 --------      = 53.8
                ******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
               = 25.0
                ******
```

```
 CLASSEX RESULTS
-----------------


**************  Q-SYSTEM OUTPUT ---> T1-4  *************

The UCS is about  20 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 1.76 is between 1.5 and 2.
Thus, the GMU is considered to be one capable of HEAVY ROCK BURSTING
(Barton).  Stacey and Page suggest that the openings within this
range are very dangerous and difficult to keep open, and support is
heavy and costly.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

          Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-4
     ---------------------------------------------------------------

                  ROCK MASS QUALITY: VERY_POOR with a Q of 1.0

          ROOF 'Q' USED : 1.0 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 2.1 m (ESR = 1), from De vs Q
                        : 2 m (ESR = 1), from plot of actual
                          unsupported excavation spans vs Q
   MAX POSSIBLE ROOF SPAN: roof spans > 38.0 m above limits of
                          applicability
         SUPPORT PRESSURE:  21.7 kPa (Equation_4)
                 Emean -->  2.33 GPa (Serafim_and_Pereira_1983)

          WALL 'Q' USED : 2.5 with a factor of 2.5 x original Q
  MAX UNSUPPORTED WALL HT: 3.0 m, from De vs Q
    MAX POSSIBLE WALL HT: wall heights > 43.2 m above limits of
                          applicability

               Q-SYSTEM PARAMETERS ----> T1-4
   ---------------------------------------------------------------

        60.0    3.0     1.0                    TUNNEL_SECTION
    Q = ---- X ---- X ------                      SPAN =12m
         4.0    2.0   21.126              WALL HEIGHT = 9 m
                                                 ESR =   1
                       ************
                         Q = 1.0
                       ************        ROCK MASS = HOMOGENEOUS
                                         ROCK QUALITY = VERY_POOR
   RQD = 60.0
    Jn =  4.0                 BLOCK SIZE (RQD/ORIG Jn) = 15.000 units
    Jr =  3.0       INTER-BLOCK SHEAR STRENGTH (Jr/Ja) =  1.500
    Ja =  2.0             APPARENT FRICTION ANGLE (ír) =   56.3ø
    Jw =  1.0                   ACTIVE STRESS (Jw/SRF) =  0.047
   SRF = 21.126

          Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-4
     ---------------------------------------------------------------

     ROCK MASS QUALITY: VERY_POOR with a Q of 1.0
            CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of
                        12m
-------------------------------------------------------------------
```

SUPPORT CATEGORY: 27A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 75 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---

NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-4

'Q' USED : 2.5 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 22A
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---

NOTE A: In Scandinavia, the use of 'perfobolts' is common. These are perforated hollow tubes which are filled with grout and inserted into drillholes. The grout is extruded to fill the annular space around the tube when a piece of reinforcing rod is pushed into the grout filling the tube. Obviously, there is no way in which these

devices can be tensioned although it is common to thread the end of the reinforcing rod and place a normal bearing plate or washer and nut on this end. In North America the use of 'perfobolts' is rare. In mining applications a device known as a 'split set' or 'friction set (developed by Scott) has become popular. This is a split tube which is forced into a slightly smaller diameter hole than the outer diameter of the tube. The friction between the steel tube and the rock, particularly when the steel rusts, acts in much the same way as the grout around a reinforcing rod. For temporary support, these devices are very effective.~ In Australian mines, untensioned grouted reinforcing is installed by pumping thick grout into drillholes and then simply pushing a piece of threaded reinforcing rod into the grout. The grout is thick enough to remain in an up-hole during emplacement of the rod.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 60.0%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 1.0, VERY_POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 44, FAIR_ROCK, CLASS III
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 10.5 (lnQ) + 42
= 42, FAIR_ROCK, CLASS III
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 43, FAIR_ROCK, CLASS III
******
Rutledge: RSR = 13.3 (logQ) + 46.5

```
 --------       = 46.5
                  ******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
               = 35.0
                  ******
```

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T1-5 **********

The UCS is about 40 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 5.71 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS. Barton suggests that a high stress environment creates a very tight structure usually favourable to roof stability, but it may be unfavourable to wall stability. Stacey and Page suggest that there should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-5

ROCK MASS QUALITY: FAIR with a Q of 4.9

ROOF 'Q' USED : 4.9 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 3.9 m (ESR = 1), from De vs Q
: 5.7 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 47.5 m above limits of applicability
SUPPORT PRESSURE: 9.6 kPa (Equation_4)
Emean --> 17.25 GPa (25logQ)

WALL 'Q' USED : 12.2 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 5.6 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 54.0 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T1-5

$$Q = \frac{67.6}{6.0} \times \frac{4.0}{2.0} \times \frac{1.0}{4.575}$$

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 4.9
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = FAIR

RQD = 67.6
Jn = 6.0 BLOCK SIZE (RQD/ORIG Jn) = 11.269 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 2
Ja = 2.0 APPARENT FRICTION ANGLE (ír) = 63.5ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.218
SRF = 4.575

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-5

ROCK MASS QUALITY: FAIR with a Q of 4.9
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 18A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 4: Several bolt lengths often used in same excavation. i.e. 2, 3, and 4 m.~

NOTES from Hoek and Brown

NOTE A: In Scandinavia, the use of 'perfobolts' is common. These are perforated hollow tubes which are filled with grout and inserted into drillholes. The grout is extruded to fill the annular space around the tube when a piece of reinforcing rod is pushed into the grout filling the tube. Obviously, there is no way in which these devices can be tensioned although it is common to thread the end of the reinforcing rod and place a normal bearing plate or washer and nut on this end. In North America the use of 'perfobolts' is rare. In mining applications a device known as a 'split set' or 'friction set (developed by Scott) has become popular. This is a split tube which is forced into a slightly smaller diameter hole than the outer diameter of the tube. The friction between the steel tube and the rock, particularly when the steel rusts, acts in much the same way as the grout around a reinforcing rod. For temporary support, these devices are very effective.~ In Australian mines, untensioned grouted reinforcing is installed by pumping thick grout into drillholes and then simply pushing a piece of threaded reinforcing rod into the grout. The grout is thick enough to remain in an up-hole during emplacement of the rod.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-5

'Q' USED : 12.2 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 13A
SUPPORT MEASURES: Spot reinforcement with untensioned grouted dowels.
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

```
************************ RQD SUPPORT SYSTEM ***********************

The roof span of 12m is within the valid range of spans (6-12 m) for
the RQD support recommendation system.

     SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER
DEERE)
   ------------------------------------------------------------------
------
                              RQD = Fair @ 67.6%
       TUNNELER'S CLASSIFICATION = Blocky & Seamy
             CONSTRUCTION METHOD = Tunnel Boring Machine
                       ROCK LOAD =  4.80 -->    12 m

 ALTERNATIVE SUPPORT SYSTEMS:

    STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
    ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
        SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
       (2) Lagging requirements will range from up to 25% in good
           rock to
           100% in very poor rock.
       (3) Mesh requirements will range from occasional mesh (or
           straps) in
           good rock to 100% mesh in very poor rock.

                           CORRELATIONS WITH Q-VALUES
                         ------------------------------

    Barton: Q = 4.9, FAIR ROCK
                ******
Bieniawski: Correlations from Civil Engineering Tunnels
----------  RMR = 9 (lnQ) + 44
                = 58.3, FAIR_ROCK, CLASS III
                 ******
      Abad: Correlation from Coal Mine Roadways in Spain
      ----  RMR = 10.5 (lnQ) + 42
                =  58.6, FAIR_ROCK, CLASS III
                 ******
  Rutledge: Correlation from Tunneling Projects in New Zealand
  --------  RMR = 13.5 (logQ) + 43
                = 52.3, FAIR_ROCK, CLASS III
                 ******
  Rutledge: RSR = 13.3 (logQ) + 46.5
  --------      = 55.6
                 ******
 Rib Ratio (RR) = (8800/(RSR + 30)) - 80
                = 22.8
                 ******
```

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T1-Pn **********

The UCS is about 25 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 9.75 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS. Barton suggests that a high stress environment creates a very tight structure usually favourable to roof stability, but it may be unfavourable to wall stability. Stacey and Page suggest that there should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-Pn

ROCK MASS QUALITY: VERY_POOR with a Q of 0.64

ROOF 'Q' USED : 0.64 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 1.8 m (ESR = 1), from De vs Q
: 1.4 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 35.7 m above limits of applicability
SUPPORT PRESSURE: 75.8 kPa (Equation_3)
Emean --> 2.11 GPa (Serafim_and_Pereira_1983)

WALL 'Q' USED : 1.6 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 2.5 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 40.6 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T1-Pn

$$Q = \frac{54.5}{18} \times \frac{3.0}{4.0} \times \frac{0.66}{2.311}$$

PORTAL SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 0.64
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = VERY_POOR

RQD = 54.5
Jn = 18 BLOCK SIZE (RQD/ORIG Jn) = 6.055 units
Jr = 3.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 0.750
Ja = 4.0 APPARENT FRICTION ANGLE (ír) = 36.9ø
Jw = 0.66 ACTIVE STRESS (Jw/SRF) = 0.285
SRF = 2.311

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-Pn

ROCK MASS QUALITY: VERY_POOR with a Q of 0.64
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 27A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 75 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-Pn

'Q' USED : 1.6 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 23B
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Shotcrete reinforced with weldmesh, 50 - 100 mm thick
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock.

Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 54.5%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 0.64, VERY_POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 39.9, POOR_ROCK, CLASS IV
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 10.5 (lnQ) + 42
= 37.3, POOR_ROCK, CLASS IV
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 40.3, FAIR_ROCK, CLASS III
******
Rutledge: RSR = 13.3 (logQ) + 46.5
-------- = 43.9
******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 39.0
******

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T1-Px **********

The UCS is about 25 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 9.75 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS. Barton suggests that a high stress environment creates a very tight structure usually favourable to roof stability, but it may be unfavourable to wall stability. Stacey and Page suggest that there should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T1-Px

ROCK MASS QUALITY: VERY_POOR with a Q of 0.77

ROOF 'Q' USED : 0.77 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 1.9 m (ESR = 1), from De vs Q
: 1.6 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 36.7 m above limits of applicability
SUPPORT PRESSURE: 53.5 kPa (Equation_3)
Emean --> 2.20 GPa (Serafim_and_Pereira_1983)

WALL 'Q' USED : 1.9 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 2.7 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 41.6 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T1-Px

$$Q = \frac{49}{18} \times \frac{4.0}{4.0} \times \frac{0.66}{2.311}$$

PORTAL SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 0.77
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = VERY_POOR

RQD = 49
Jn = 18 BLOCK SIZE (RQD/ORIG Jn) = 5.444 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 1
Ja = 4.0 APPARENT FRICTION ANGLE (ír) = 45.0ø
Jw = 0.66 ACTIVE STRESS (Jw/SRF) = 0.285
SRF = 2.311

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T1-Px

ROCK MASS QUALITY: VERY_POOR with a Q of 0.77
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 27A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 75 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T1-Px

'Q' USED : 1.9 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 22C
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 25 - 50 mm thick
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between

the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Poor @ 49%
TUNNELER'S CLASSIFICATION = Shattered, Very Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 12 --> 19.20 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Medium circular sets on 0.92 m to 1.22 m centre
ROCK BOLTS (3): Pattern, 0.92 m to 1.53 m centre
SHOTCRETE : 10.2 cm to 15.3 cm on crown and sides
Combine with bolts

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to
100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in
good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 0.77, VERY_POOR ROCK
******

Bieniawski: Correlations from Civil Engineering Tunnels
RMR = 9 (lnQ) + 44
= 41.6, FAIR_ROCK, CLASS III
******

Abad: Correlation from Coal Mine Roadways in Spain
RMR = 10.5 (lnQ) + 42
= 39.2, POOR_ROCK, CLASS IV
******

Rutledge: Correlation from Tunneling Projects in New Zealand
RMR = 13.5 (logQ) + 43
= 41.4, FAIR_ROCK, CLASS III
******

Rutledge: RSR = 13.3 (logQ) + 46.5
= 44.9
******

Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 37.4
******

## THE ÖCELİ (T-2) TUNNEL

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-1 **********

The UCS is about 20 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 4.28 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING (Barton). Stacey and Page suggest that some spalling from the surface may occur parallel to å1, and that 'heavier' support is usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ---->

ROCK MASS QUALITY: POOR with a Q of 3.1

ROOF 'Q' USED : 3.1 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 3.3 m (ESR = 1), from De vs Q
: 4.2 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 44.5 m above limits of applicability
SUPPORT PRESSURE: 11.2 kPa (Equation_4)
Emean --> 12.28 GPa (25logQ)

WALL 'Q' USED : 7.7 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 4.7 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 50.6 m above limits of applicability

Q-SYSTEM PARAMETERS ---->

$$Q = \frac{63}{6.0} \times \frac{4.0}{2.0} \times \frac{1.0}{6.734}$$

**********
Q = 3.1
**********

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1
ROCK MASS = HOMOGENEOUS
ROCK QUALITY = POOR

RQD = 63
Jn = 6.0 BLOCK SIZE (RQD/ORIG Jn) = 10.500 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 2
Ja = 2.0 APPARENT FRICTION ANGLE (ír) = 63.5ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.148
SRF = 6.734

Q-SYSTEM RECOMMENDED ROOF SUPPORT ---->

ROCK MASS QUALITY: POOR with a Q of 3.1
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 23B
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Shotcrete reinforced with weldmesh, 50 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ---->

'Q' USED : 7.7 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9 m

SUPPORT CATEGORY: 18B
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 - 1.5 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE A: In Scandinavia, the use of 'perfobolts' is common. These are perforated hollow tubes which are filled with grout and inserted into drillholes. The grout is extruded to fill the annular space around the tube when a piece of reinforcing rod is pushed into the grout filling the tube. Obviously, there is no way in which these devices can be tensioned although it is common to thread the end of

the reinforcing rod and place a normal bearing plate or washer and nut on this end. In North America the use of 'perfobolts' is rare. In mining applications a device known as a 'split set' or 'friction set (developed by Scott) has become popular. This is a split tube which is forced into a slightly smaller diameter hole than the outer diameter of the tube. The friction between the steel tube and the rock, particularly when the steel rusts, acts in much the same way as the grout around a reinforcing rod. For temporary support, these devices are very effective.~ In Australian mines, untensioned grouted reinforcing is installed by pumping thick grout into drillholes and then simply pushing a piece of threaded reinforcing rod into the grout. The grout is thick enough to remain in an up-hole during emplacement of the rod.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 63%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 3.1, POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 54.1, FAIR_ROCK, CLASS III
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 10.5 (lnQ) + 42
= 53.8, FAIR_ROCK, CLASS III
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 49.6, FAIR_ROCK, CLASS III
******
Rutledge: RSR = 13.3 (logQ) + 46.5
-------- = 53.0

```
                  ******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
               = 26.0
                  ******
```

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-2 **********

The UCS is about 30 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 5.61 is between 5 and 1O.
Thus, the GMU is considered to be one of HIGH STRESS. Barton suggests that a high stress environment creates a very tight structure usually favourable to roof stability, but it may be unfavourable to wall stability. Stacey and Page suggest that there should be no particular stability problems.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-2

ROCK MASS QUALITY: GOOD with a Q of 12.5

ROOF 'Q' USED : 12.5 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 5.6 m (ESR = 1), from De vs Q
: 10.5 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 54.1 m above limits of applicability
SUPPORT PRESSURE: 7.0 kPa (Equation_4)
Emean --> 27.42 GPa (25logQ)

WALL 'Q' USED : 62.5 with a factor of 5 x original Q
MAX UNSUPPORTED WALL HT: 10.4 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 67.8 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-2

$$Q = \frac{88.5}{6.0} \times \frac{4.0}{1.0} \times \frac{1.0}{4.711}$$

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 12.5
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = GOOD

RQD = 88.5
Jn = 6.0 BLOCK SIZE (RQD/ORIG Jn) = 14.766 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 4
Ja = 1.0 APPARENT FRICTION ANGLE (ír) = 76.0ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.212
SRF = 4.711

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-2

ROCK MASS QUALITY: GOOD with a Q of 12.5
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

SUPPORT CATEGORY: 14C
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1.5 - 2 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally O.8 m). Final support when 'popping' activity ceases.~

NOTE 4: Several bolt lengths often used in same excavation.
i.e. 2, 3, and 4 m.~

NOTES from Hoek and Brown
---

NOTE B: Chainlink mesh is sometimes used to catch small pieces of rock which can become loose with time. It should be attached to the rock at intervals of between 1 and 1.5 m and short grouted pins can be used between bolts. Galvanised chainlink mesh should be used where it is intended to be permanent, eg. in an underground powerhouse.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-2

'Q' USED : 62.5 with a factor of 5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9 m

SUPPORT CATEGORY: Below_unsupported_span_line
SUPPORT MEASURES: No support required

De ---> 9. If De is greater than 7 and you wish to be conservative, support category 9 is the closest to your situation. It recommends systematic bolting with untensioned grouted dowels spaced at 2.5-3.0 m.

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

RQD = Good @ 88.5% (1)
TUNNELER'S CLASSIFICATION = Massive, moderately blocky
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 0 --> 4.80 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Occasional light sets to pattern on 1.53 m to 1.83 m centre
ROCK BOLTS (3): Occasional to pattern on 1.53 m to 1.83 m centre
SHOTCRETE : None to occasional application, 5.1 cm to 7.6 cm.

NOTES: (1) In GOOD ROCK the support requirement will be, in general, minimal but will be dependent upon joint geometry, tunnel diameter and relative orientations of joints and tunnel.
(2) Lagging requirements will range from up to 25% in GOOD ROCK to 1OO% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in GOOD ROCK to 1OO% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 12.5, GOOD ROCK
******

Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 66.7, GOOD_ROCK, CLASS II
******

Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 1O.5 (lnQ) + 42
= 68.5, GOOD_ROCK, CLASS II
******

Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 57.8, FAIR_ROCK, CLASS III
******

Rutledge: RSR = 13.3 (logQ) + 46.5
-------- = 61.0
******

Rib Ratio (RR) = (88OO/(RSR + 3O)) - 8O
= 16.7
******

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-3 **********

The UCS is about 20 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 4.62 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING (Barton). Stacey and Page suggest that some spalling from the surface may occur parallel to å1, and that 'heavier' support is usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-3

ROCK MASS QUALITY: FAIR with a Q of 8.3

ROOF 'Q' USED : 8.3 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 4.8 m (ESR = 1), from De vs Q
: 8.0 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 51.1 m above limits of applicability
SUPPORT PRESSURE: 8.0 kPa (Equation_4)
Emean --> 22.97 GPa (25logQ)

WALL 'Q' USED : 20.7 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 6.8 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 58.1 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-3

$$Q = \frac{76.5}{6.0} \times \frac{4.0}{1.0} \times \frac{1.0}{6.095}$$

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 8.3
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = FAIR

RQD = 76.5
Jn = 6.0 BLOCK SIZE (RQD/ORIG Jn) = 12.750 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 4
Ja = 1.0 APPARENT FRICTION ANGLE (ír) = 76.0ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.164
SRF = 6.095

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-3

ROCK MASS QUALITY: FAIR with a Q of 8.3
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

SUPPORT CATEGORY: 18A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally O.8 m). Final support when 'popping' activity ceases.~

NOTE 4: Several bolt lengths often used in same excavation.
i.e. 2, 3, and 4 m.~

NOTES from Hoek and Brown
---

NOTE A: In Scandinavia, the use of 'perfobolts' is common. These are perforated hollow tubes which are filled with grout and inserted into drillholes. The grout is extruded to fill the annular space around the tube when a piece of reinforcing rod is pushed into the grout filling the tube. Obviously, there is no way in which these devices can be tensioned although it is common to thread the end of the reinforcing rod and place a normal bearing plate or washer and nut on this end. In North America the use of 'perfobolts' is rare. In mining applications a device known as a 'split set' or 'friction set (developed by Scott) has become popular. This is a split tube which is forced into a slightly smaller diameter hole than the outer diameter of the tube. The friction between the steel tube and the rock, particularly when the steel rusts, acts in much the same way as the grout around a reinforcing rod. For temporary support, these devices are very effective.~ In Australian mines, untensioned grouted reinforcing is installed by pumping thick grout into drillholes and then simply pushing a piece of threaded reinforcing rod into the grout. The grout is thick enough to remain in an up-hole during emplacement of the rod.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-3

'Q' USED : 20.7 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 13A
SUPPORT MEASURES: Spot reinforcement with untensioned grouted dowels.
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---

NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally O.8 m). Final support when 'popping' activity ceases.~

```
************************ RQD SUPPORT SYSTEM ***********************

The roof span of 12m is within the valid range of spans (6-12 m) for
the RQD support recommendation system.

     SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER
DEERE)
   ---------------------------------------------------------------
                              RQD = Good @ 76.5% (1)
       TUNNELER'S CLASSIFICATION = Massive, moderately blocky
             CONSTRUCTION METHOD = Tunnel Boring Machine
                       ROCK LOAD = 0 --> 4.80 m

 ALTERNATIVE SUPPORT SYSTEMS:

  STEEL SETS (2): Occasional light sets to pattern on 1.53 m to 1.83
                  m centre
  ROCK BOLTS (3): Occasional to pattern on 1.53 m to 1.83 m centre
      SHOTCRETE : None to occasional application, 5.1 cm to 7.6 cm.

NOTES: (1) In GOOD ROCK the support requirement will be, in general,
           minimal but will be dependent upon joint geometry, tunnel
           diameter and relative orientations of joints and tunnel.
       (2) Lagging requirements will range from up to 25% in GOOD
           ROCK to
           1OO% in very poor rock.
       (3) Mesh requirements will range from occasional mesh (or
           straps) in
           GOOD ROCK to 1OO% mesh in very poor rock.

                          CORRELATIONS WITH Q-VALUES
                        ------------------------------

    Barton: Q = 8.3, FAIR ROCK
                ******
Bieniawski: Correlations from Civil Engineering Tunnels
----------  RMR = 9 (lnQ) + 44
                = 63.0, GOOD_ROCK, CLASS II
                 ******
      Abad: Correlation from Coal Mine Roadways in Spain
      ----  RMR = 1O.5 (lnQ) + 42
                =  64.2, GOOD_ROCK, CLASS II
                 ******
  Rutledge: Correlation from Tunneling Projects in New Zealand
  --------  RMR = 13.5 (logQ) + 43
                = 55.4, FAIR_ROCK, CLASS III
                 ******
  Rutledge: RSR = 13.3 (logQ) + 46.5
  --------      = 58.7
                 ******
 Rib Ratio (RR) = (88OO/(RSR + 3O)) - 8O
                = 19.2
                 ******
```

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-4 **********

The UCS is about 15 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 3.47 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING (Barton). Stacey and Page suggest that some spalling from the surface may occur parallel to å1, and that 'heavier' support is usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-4

ROCK MASS QUALITY: POOR with a Q of 3.0

ROOF 'Q' USED : 3.0 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 3.2 m (ESR = 1), from De vs Q
: 4.1 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 44.3 m above limits of applicability
SUPPORT PRESSURE: 11.3 kPa (Equation_4)
Emean --> 11.92 GPa (25logQ)

WALL 'Q' USED : 7.5 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 4.6 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 50.4 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-4

$$Q = \frac{82}{6.0} \times \frac{4.0}{2.0} \times \frac{1.0}{8.909}$$

TUNNEL_SECTION
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 3.0
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = POOR

RQD = 82
Jn = 6.0 BLOCK SIZE (RQD/ORIG Jn) = 13.666 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 2
Ja = 2.0 APPARENT FRICTION ANGLE (ír) = 63.5ø
Jw = 1.0 ACTIVE STRESS (Jw/SRF) = 0.112
SRF = 8.909

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-4

ROCK MASS QUALITY: POOR with a Q of 3.0
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

SUPPORT CATEGORY: 23B
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Shotcrete reinforced with weldmesh, 50 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-4

'Q' USED : 7.5 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9 m

SUPPORT CATEGORY: 18B
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 - 1.5 m
Chainlink mesh anchored to bolts and intermediate points
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE A: In Scandinavia, the use of 'perfobolts' is common. These are perforated hollow tubes which are filled with grout and inserted into drillholes. The grout is extruded to fill the annular space around the tube when a piece of reinforcing rod is pushed into the grout filling the tube. Obviously, there is no way in which these devices can be tensioned although it is common to thread the end of

the reinforcing rod and place a normal bearing plate or washer and nut on this end. In North America the use of 'perfobolts' is rare. In mining applications a device known as a 'split set' or 'friction set (developed by Scott) has become popular. This is a split tube which is forced into a slightly smaller diameter hole than the outer diameter of the tube. The friction between the steel tube and the rock, particularly when the steel rusts, acts in much the same way as the grout around a reinforcing rod. For temporary support, these devices are very effective.~ In Australian mines, untensioned grouted reinforcing is installed by pumping thick grout into drillholes and then simply pushing a piece of threaded reinforcing rod into the grout. The grout is thick enough to remain in an up-hole during emplacement of the rod.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Good @ 82% (1)
TUNNELER'S CLASSIFICATION = Massive, moderately blocky
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 0 --> 4.80 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Occasional light sets to pattern on 1.53 m to 1.83 m centre
ROCK BOLTS (3): Occasional to pattern on 1.53 m to 1.83 m centre
SHOTCRETE : None to occasional application, 5.1 cm to 7.6 cm.

NOTES: (1) In GOOD ROCK the support requirement will be, in general, minimal but will be dependent upon joint geometry, tunnel diameter and relative orientations of joints and tunnel.
(2) Lagging requirements will range from up to 25% in GOOD ROCK to 1OO% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in GOOD ROCK to 1OO% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

---

Barton: Q = 3.0, POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 53.8, FAIR_ROCK, CLASS III
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 1O.5 (lnQ) + 42
= 53.5, FAIR_ROCK, CLASS III
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43

```
                = 49.4, FAIR_ROCK, CLASS III
                  ******
 Rutledge: RSR = 13.3 (logQ) + 46.5
 --------       = 52.8
                  ******
Rib Ratio (RR) = (88OO/(RSR + 3O)) - 8O
                = 26.2
                  ******
```

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-Pna **********

The UCS is about 10 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 3.90 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING (Barton). Stacey and Page suggest that some spalling from the surface may occur parallel to å1, and that 'heavier' support is usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-Pna

ROCK MASS QUALITY: VERY_POOR with a Q of 0.42

ROOF 'Q' USED : 0.42 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 1.5 m (ESR = 1), from De vs Q
: 1.1 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 33.7 m above limits of applicability
SUPPORT PRESSURE: 21.8 kPa (Equation_4)
Emean --> 1.92 GPa (Serafim_and_Pereira_1983)

WALL 'Q' USED : 1.0 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 2.1 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 38.0 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-Pna

$$Q = \frac{60.0}{12} \times \frac{4.0}{4.0} \times \frac{0.66}{7.686}$$

PORTAL SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 0.42
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = VERY_POOR

RQD = 60.0
Jn = 12 BLOCK SIZE (RQD/ORIG Jn) = 10.000 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 1
Ja = 4.0 APPARENT FRICTION ANGLE (ír) = 45.0ø
Jw = 0.66 ACTIVE STRESS (Jw/SRF) = 0.085
SRF = 7.686

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-Pna

ROCK MASS QUALITY: VERY_POOR with a Q of 0.42
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 27A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 75 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-Pna

'Q' USED : 1.0 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 27B
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 50 - 75 mm thick
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the

shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 60.0%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 0.42, VERY_POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 36.1, POOR_ROCK, CLASS IV
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 10.5 (lnQ) + 42
= 32.8, POOR_ROCK, CLASS IV
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 37.9, POOR_ROCK, CLASS IV
******
Rutledge: RSR = 13.3 (logQ) + 46.5
-------- = 41.4
******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 43.2
******

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-Pnb **********

The UCS is about 60 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 23.4 is above 1O. Thus, the GMU is considered to be one of MEDIUM STRESS and no particular stress problems are expected.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-Pnb

ROCK MASS QUALITY: POOR with a Q of 2.4

ROOF 'Q' USED : 2.4 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 3.0 m (ESR = 1), from De vs Q
: 3.5 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 43.0 m above limits of applicability
SUPPORT PRESSURE: 12.2 kPa (Equation_4)
Emean --> 9.50 GPa (25logQ)

WALL 'Q' USED : 6 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 4.2 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 48.9 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-Pnb

$$Q = \frac{60.0}{12} \times \frac{4.0}{4.0} \times \frac{0.66}{1.347}$$

PORTAL SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 2.4
**********

ROCK MASS = NON_HOMOGENEOUS
ROCK QUALITY = POOR

RQD = 60.0
Jn = 12 BLOCK SIZE (RQD/ORIG Jn) = 10.000 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 1
Ja = 4.0 APPARENT FRICTION ANGLE (ír) = 45.0ø
Jw = 0.66 ACTIVE STRESS (Jw/SRF) = 0.489
SRF = 1.347

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-Pnb

ROCK MASS QUALITY: POOR with a Q of 2.4
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

---

SUPPORT CATEGORY: 23B
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 - 1.5 m
Shotcrete reinforced with weldmesh, 50 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-Pnb

'Q' USED : 6 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9 m

SUPPORT CATEGORY: 18D
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 - 1.5 m
Shotcrete applied directly to rock, 20 - 30 mm thick
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 60.0%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

Barton: Q = 2.4, POOR ROCK
******

Bieniawski: Correlations from Civil Engineering Tunnels
RMR = 9 (lnQ) + 44
= 51.8, FAIR_ROCK, CLASS III
******

Abad: Correlation from Coal Mine Roadways in Spain
RMR = 10.5 (lnQ) + 42
= 51.1, FAIR_ROCK, CLASS III
******

Rutledge: Correlation from Tunneling Projects in New Zealand
RMR = 13.5 (logQ) + 43
= 48.1, FAIR_ROCK, CLASS III
******

Rutledge: RSR = 13.3 (logQ) + 46.5
= 51.5
******

Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 27.9
******

CLASSEX RESULTS
---

********** Q-SYSTEM OUTPUT ---> T2-Px **********

The UCS is about 10 MPa as determined by UCS.
The strength/stress ratio (åc/å1) of 3.90 is between 2.5 and 5.
Thus, the GMU is considered to be one capable of MILD ROCK BURSTING (Barton). Stacey and Page suggest that some spalling from the surface may occur parallel to å1, and that 'heavier' support is usually required.

For permanent support, the ESR value remains unchanged.
ALL SUPPORT MEASURES LISTED WILL BE FOR PERMANENT SUPPORT.

Q-SYSTEM DESIGN CONSIDERATIONS ----> T2-Px

ROCK MASS QUALITY: VERY_POOR with a Q of 0.42

ROOF 'Q' USED : 0.42 with a factor of 1 x original Q
MAX UNSUPPORTED ROOF SPAN: 1.5 m (ESR = 1), from De vs Q
: 1.1 m (ESR = 1), from plot of actual unsupported excavation spans vs Q
MAX POSSIBLE ROOF SPAN: roof spans > 33.7 m above limits of applicability
SUPPORT PRESSURE: 21.8 kPa (Equation_4)
Emean --> 1.92 GPa (Serafim_and_Pereira_1983)

WALL 'Q' USED : 1.0 with a factor of 2.5 x original Q
MAX UNSUPPORTED WALL HT: 2.1 m, from De vs Q
MAX POSSIBLE WALL HT: wall heights > 38.0 m above limits of applicability

Q-SYSTEM PARAMETERS ----> T2-Px

$$Q = \frac{60.0}{12} \times \frac{4.0}{4.0} \times \frac{0.66}{7.686}$$

PORTAL
SPAN =12m
WALL HEIGHT = 9 m
ESR = 1

**********
Q = 0.42
**********

ROCK MASS = HOMOGENEOUS
ROCK QUALITY = VERY_POOR

RQD = 60.0
Jn = 12 BLOCK SIZE (RQD/ORIG Jn) = 10.000 units
Jr = 4.0 INTER-BLOCK SHEAR STRENGTH (Jr/Ja) = 1
Ja = 4.0 APPARENT FRICTION ANGLE (ír) = 45.0ø
Jw = 0.66 ACTIVE STRESS (Jw/SRF) = 0.085
SRF = 7.686

Q-SYSTEM RECOMMENDED ROOF SUPPORT ----> T2-Px

ROCK MASS QUALITY: VERY_POOR with a Q of 0.42
CRITICAL Q: need Q >= 89.5 for unsupported ROOF span of 12m

SUPPORT CATEGORY: 27A
SUPPORT MEASURES: Tensioned rockbolts on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 75 - 100 mm thick
Mean Bolt Length = 3.80 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

Q-SYSTEM RECOMMENDED WALL SUPPORT ----> T2-Px

'Q' USED : 1.0 with a factor of 2.5 x original Q
CRITICAL Q: need Q >= 42.0 for unsupported WALL span of 9m

SUPPORT CATEGORY: 27B
SUPPORT MEASURES: Untensioned grouted dowels on grid spacing of 1 m
Shotcrete reinforced with weldmesh, 50 - 75 mm thick
Mean Bolt Length = 3.35 m

NOTES from Barton, Lien and Lunde
---
NOTE 2: For cases of heavy rock bursting or 'popping', tensioned bolts with enlarged bearing plates are often used, with spacings of about 1 m (occasionally 0.8 m). Final support when 'popping' activity ceases.~

NOTE 10: Cases not involving swelling clay or squeezing rock.~

NOTES from Hoek and Brown
---
NOTE C: Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of

shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.~

********** RQD SUPPORT SYSTEM **********

The roof span of 12m is within the valid range of spans (6-12 m) for the RQD support recommendation system.

SUPPORT GUIDELINES FOR TUNNELS (6-12 m diam) FROM RQD (AFTER DEERE)

---

RQD = Fair @ 60.0%
TUNNELER'S CLASSIFICATION = Blocky & Seamy
CONSTRUCTION METHOD = Tunnel Boring Machine
ROCK LOAD = 4.80 --> 12 m

ALTERNATIVE SUPPORT SYSTEMS:

STEEL SETS (2): Light to medium sets, 1.53 m to 1.83 m centre
ROCK BOLTS (3): Pattern, 1.22 m to 1.83 m centre
SHOTCRETE : 5.1 cm to 10.2 cm in crown

NOTES: (1) N/A
(2) Lagging requirements will range from up to 25% in good rock to 100% in very poor rock.
(3) Mesh requirements will range from occasional mesh (or straps) in good rock to 100% mesh in very poor rock.

CORRELATIONS WITH Q-VALUES

---

Barton: Q = 0.42, VERY_POOR ROCK
******
Bieniawski: Correlations from Civil Engineering Tunnels
---------- RMR = 9 (lnQ) + 44
= 36.1, POOR_ROCK, CLASS IV
******
Abad: Correlation from Coal Mine Roadways in Spain
---- RMR = 10.5 (lnQ) + 42
= 32.8, POOR_ROCK, CLASS IV
******
Rutledge: Correlation from Tunneling Projects in New Zealand
-------- RMR = 13.5 (logQ) + 43
= 37.9, POOR_ROCK, CLASS IV
******
Rutledge: RSR = 13.3 (logQ) + 46.5
-------- = 41.4
******
Rib Ratio (RR) = (8800/(RSR + 30)) - 80
= 43.2
******

# APPENDIX – E
# A-RMR CALCULATIONS AND CLASSIFICATION CHARTS

# A-RMR CALCULATIONS

**Boztepe (T-1) Tunnel**

**(a) Portal sections**

*Entrance (T1-Pn)*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 25\,MPa)$
Rating $(I_{UCS}) = 4.49$

(2) Rating $(I_{RQD}) = 2.7 + 0.173RQD$ $(RQD = 54.5)$
Rating $(I_{RQD}) = 12.13$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+150}{3} \cong 170\,mm\right)$
Rating $(I_{JS}) = 10.27$

(4) Groundwater conditions (Dripping) $= 4$
(5) Discontinuity conditions $= 14$

$A - RMR = 44.89$
$A - RMR_P = 44.89 - 6.24 = 38.65$ at portal.

Note : The values of sub section (4) and (5) are taken from the related RMR tables in Appendix ***

*Exit (T1-Px)*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 25\,MPa)$
Rating $(I_{UCS}) = 4.49$

(2) Rating $(I_{RQD}) = 2.7 + 0.173RQD$ $(RQD = 49)$
Rating $(I_{RQD}) = 11.18$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+100}{3} \cong 150\,mm\right)$
Rating $(I_{JS}) = 10.03$

(4) Groundwater conditions (Dripping) $= 4$
(5) Discontinuity conditions $= 16$

$A - RMR = 45.70$
$A - RMR_P = 45.70 - 6.24 = 39.46$ at portal.

**(b) Tunnel sections**

*T1-1*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 25\,\text{MPa})$
Rating $(I_{UCS}) = 4.49$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 43.5)$
Rating $(I_{RQD}) = 10.23$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+100}{3} \cong 150\,\text{mm}\right)$
Rating $(I_{JS}) = 10.03$

(4) Groundwater conditions (Wet) $= 7$
(5) Discontinuity conditions $= 19$

$\text{A} - \text{RMR} = 50.75$

*T1-2*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 30\,\text{MPa})$
Rating $(I_{UCS}) = 4.93$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 96.1)$
Rating $(I_{RQD}) = 19.33$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{350+350}{2} \cong 350\,\text{mm}\right)$
Rating $(I_{JS}) = 11.75$

(4) Groundwater conditions (Damp) $= 10$
(5) Discontinuity conditions $= 23.5$

$\text{A} - \text{RMR} = 69.51$

*T1-3*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 35\,\text{MPa})$
Rating $(I_{UCS}) = 5.34$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 65.5)$
Rating $(I_{RQD}) = 14.03$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{120+150}{2} \cong 135\,\text{mm}\right)$
Rating $(I_{JS}) = 9.83$

(4) Groundwater conditions (Wet) = 7
(5) Discontinuity conditions = 17

A – RMR = 53.20

*T1-4*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 20\,\text{MPa})$
Rating $(I_{UCS}) = 4.00$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 60)$
Rating $(I_{RQD}) = 13.08$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100+150}{2} \cong 125\,\text{mm}\right)$
Rating $(I_{JS}) = 9.69$

(4) Groundwater conditions (Damp) = 10
(5) Discontinuity conditions = 14

A – RMR = 50.77

*T1-5*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 40\,\text{MPa})$

Rating $(I_{UCS}) = 5.72$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 67.6)$

Rating $(I_{RQD}) = 14.39$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{130+150}{2} \cong 140\text{mm}\right)$

Rating $(I_{JS}) = 9.90$

(4) Groundwater conditions (Damp) $= 10$

(5) Discontinuity conditions $= 19$

$A - \text{RMR} = 59.01$

**Öceli (T-2) Tunnel**

**(a) Portal sections**

*Entrance (T2-$Pn_a$)*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 10\,\text{MPa})$

Rating $(I_{UCS}) = 2.80$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 60)$

Rating $(I_{RQD}) = 13.08$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100+150}{2} \cong 125\text{mm}\right)$

Rating $(I_{JS}) = 9.69$

(4) Groundwater conditions (Wet) $= 7$

(5) Discontinuity conditions $= 12$

$A - \text{RMR} = 44.57$

$A - \text{RMR}_P = 44.57 - 6.24 = 38.33$ at portal.

Note : The values of (4) and (5) are taken from the related RMR tables.

*Entrance (T2-$Pn_b$)*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 60\,\text{MPa})$
Rating $(I_{UCS}) = 7.05$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 60)$
Rating $(I_{RQD}) = 13.08$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100+150}{2} \cong 125\,\text{mm}\right)$
Rating $(I_{JS}) = 9.69$

(4) Groundwater conditions (Wet) $= 7$
(5) Discontinuity conditions $= 19.50$

$\text{A} - \text{RMR} = 56.32$
$\text{A} - \text{RMR}_P = 56.32 - 6.24 = 50.08$ at portal.

*Exit (T2-Px)*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 10\,\text{MPa})$
Rating $(I_{UCS}) = 2.80$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 60)$
Rating $(I_{RQD}) = 13.08$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100+150}{2} \cong 125\,\text{mm}\right)$
Rating $(I_{JS}) = 9.69$

(4) Groundwater conditions (Dripping) $= 4$
(5) Discontinuity conditions $= 12$

$\text{A} - \text{RMR} = 41.57$
$\text{A} - \text{RMR}_P = 41.57 - 6.24 = 35.33$ at portal.

*T2-1*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 20\,\text{MPa})$
Rating $(I_{UCS}) = 4.00$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 63)$
Rating $(I_{RQD}) = 13.59$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{110+150}{2} \cong 130\text{mm}\right)$
Rating $(I_{JS}) = 9.77$

(4) Groundwater conditions (Wet) = 7
(5) Discontinuity conditions = 20

A − RMR = 54.36

*T2-2*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 30\,\text{MPa})$
Rating $(I_{UCS}) = 4.93$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 88.5)$
Rating $(I_{RQD}) = 18.01$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{250+250}{2} \cong 250\text{mm}\right)$
Rating $(I_{JS}) = 11.04$

(4) Groundwater conditions (Wet) = 7
(5) Discontinuity conditions = 23.5

A − RMR = 64.48

*T2-3*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 20\,\text{MPa})$
Rating $(I_{UCS}) = 4.00$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 76.5)$
Rating $(I_{RQD}) = 15.93$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{150 + 200}{2} \cong 175\text{mm}\right)$
Rating $(I_{JS}) = 10.32$

(4) Groundwater conditions $(\text{Wet}) = 7$
(5) Discontinuity conditions $= 22.5$

$\text{A} - \text{RMR} = 59.75$

*T2-4*

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 15\,\text{MPa})$
Rating $(I_{UCS}) = 3.45$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 82)$
Rating $(I_{RQD}) = 16.89$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200 + 200}{2} \cong 200\text{mm}\right)$
Rating $(I_{JS}) = 10.58$

(4) Groundwater conditions $(\text{Wet}) = 7$
(5) Discontinuity conditions $= 18$

$\text{A} - \text{RMR} = 55.92$

**PORTAL SLOPE SECTIONS**

(a) Boztepe (T-1) Tunnel

*Entrance Portal*

**(i) Volcanics**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 45\,\text{MPa})$
Rating $(I_{UCS}) = 6.08$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 45)$
Rating $(I_{RQD}) = 12.2$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+150}{3} \cong 170\,\text{mm}\right)$
Rating $(I_{JS}) = 10.27$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 48.55$
$\text{A} - \text{RMR}_P = 48.55 - 6.24 = 42.31$ at portal face.

**(ii) Flysch**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 15\,\text{MPa})$
Rating $(I_{UCS}) = 3.45$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 55)$
Rating $(I_{RQD}) = 12.2$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+150}{3} \cong 170\,\text{mm}\right)$
Rating $(I_{JS}) = 10.27$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 45.92$
$\text{A} - \text{RMR}_P = 45.92 - 6.24 = 39.68$ at portal face.

*Exit Portal*

**(i) Volcanics**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 25\,\text{MPa})$
Rating $(I_{UCS}) = 4.49$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 40)$
Rating $(I_{RQD}) = 18.68$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{150+150+150}{3} \cong 150\text{mm}\right)$
Rating $(I_{JS}) = 10.03$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 53.20$
$\text{A} - \text{RMR}_P = 53.20 - 6.24 = 46.96$ at portal face.

**(ii) Flysch**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 15\,\text{MPa})$
Rating $(I_{UCS}) = 3.45$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 55)$
Rating $(I_{RQD}) = 12.2$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{200+150+150}{3} \cong 170\text{mm}\right)$
Rating $(I_{JS}) = 10.27$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 45.92$
$\text{A} - \text{RMR}_P = 45.92 - 6.24 = 39.68$ at portal face.

(a) Öceli (T-2) Tunnel

*Entrance Portal*

**Flysch**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 13\,\text{MPa})$
Rating $(I_{UCS}) = 3.21$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 55)$
Rating $(I_{RQD}) = 12.22$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $(J_S = \frac{100 + 125 + 150}{3} \cong 125\,\text{mm})$
Rating $(I_{JS}) = 9.7$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 45.3$
$\text{A} - \text{RMR}_P = 45.3 - 6.24 = 39.06$ at portal face.

**Left Tube**

**Volcanics**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 10\,\text{MPa})$
Rating $(I_{UCS}) = 2.8$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 64)$
Rating $(I_{RQD}) = 13.77$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $(J_S = \frac{100 + 125 + 150}{3} \cong 125\,\text{mm})$
Rating $(I_{JS}) = 9.7$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 46.27$
$\text{A} - \text{RMR}_P = 46.27 - 6.24 = 40.03$ at portal face.

**Right Tube**

**Volcanics**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 60\,\text{MPa})$
Rating $(I_{UCS}) = 7.05$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 64)$
Rating $(I_{RQD}) = 13.77$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100 + 125 + 150}{3} \cong 125\text{mm}\right)$
Rating $(I_{JS}) = 9.7$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 19$

$\text{A} - \text{RMR} = 59.52$
$\text{A} - \text{RMR}_P = 59.52 - 6.24 = 53.28$ at portal face.

*Exit Portal*

**(i) Volcanics**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 13\,\text{MPa})$
Rating $(I_{UCS}) = 3.21$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 55)$
Rating $(I_{RQD}) = 12.22$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \frac{100 + 125 + 150}{3} \cong 125\text{mm}\right)$
Rating $(I_{JS}) = 9.7$

(4) Groundwater conditions (Dripping) $= 10$
(5) Discontinuity conditions $= 16$

$\text{A} - \text{RMR} = 51.13$
$\text{A} - \text{RMR}_P = 51.13 - 6.24 = 44.89$ at portal face.

**(ii) Flysch**

(1) Rating $(I_{UCS}) = 0.856\sigma_c^{0.515}$ $(U_{CS} = 13\,\text{MPa})$

Rating $(I_{UCS}) = 3.21$

(2) Rating $(I_{RQD}) = 2.7 + 0.173\text{RQD}$ $(\text{RQD} = 55)$

Rating $(I_{RQD}) = 12.22$

(3) Rating $(I_{JS}) = 3.93J_S^{0.187}$ $\left(J_S = \dfrac{100 + 125 + 150}{3} \cong 125\,\text{mm}\right)$

Rating $(I_{JS}) = 9.7$

(4) Groundwater conditions (Dripping) $= 10$

(5) Discontinuity conditions $= 10$

$\text{A} - \text{RMR} = 45.3$

$\text{A} - \text{RMR}_P = 45.3 - 6.24 = 39.06$ at portal face.

# CLASSIFICATION CHARTS

# TUNNEL SECTIONS

## THE BOZTEPE (T-1) TUNNEL

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 – 1

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **46** |
| **A-RMR** = | **50.75** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 – 2

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** | **67.50** |
| **A-RMR** | **69.51** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 – 3

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **49.00** |
| **A-RMR** = | **53.20** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 – 4

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** | **45.50** |
| **A-RMR** | **50.77** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 – 5

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** | **54.00** |
| **A-RMR** | **59.01** |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T1 – Pn

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **41.00** |
| **A-RMR** = | **44.89** |
| **A-RMR$_P$** = | **38.65** |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T1 – Px

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **41.50** |
| **A-RMR** = | **45.70** |
| **A-RMR$_P$** = | **39.46** |

## THE ÖCELİ (T-2) TUNNEL

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 – 1

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 50.00 |
| A-RMR = | 54.36 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T2 – 2

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 61.50 |
| A-RMR = | 64.48 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 – 3

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | Tunnels and mines | | 0 | -2 | -5 | -10 | -12 | | |
| | Foundations | | 0 | -2 | -7 | -15 | -25 | | |
| | Slopes | | 0 | -5 | -25 | -50 | | | |
| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| D. MEANING OF ROCK CLASSES | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| RMR = | 60.50 |
| A-RMR = | 59.75 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T2 – 4

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 52.00 |
| A-RMR = | 55.92 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T2 – Pna

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 42.00 |
| A-RMR = | 44.57 |
| A-RMR$_P$ = | 38.33 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T2 – Pnb

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 54.50 |
| A-RMR = | 56.32 |
| A-RMR$_P$ = | 50.08 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T2 – Px

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| **B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)** | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | | Tunnels and mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| **C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS** | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| **D. MEANING OF ROCK CLASSES** | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| **E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions** | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| **F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING** | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| **RMR =** | **39.00** |
| **A-RMR =** | **41.57** |
| **A-RMR$_P$ =** | **35.33** |

# TUNNEL PORTAL SLOPES

# THE BOZTEPE (T-1) TUNNEL

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 ENTRANCE PORTAL/VOLCANICS AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **50** |
| **A-RMR** = | **48.55** |
| **A-RMR$_P$** = | **42.31** |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T1 ENTRANCE PORTAL/FLYSCH AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **43.00** |
| **A-RMR** = | **45.92** |
| **A-RMR$_P$** = | **39.68** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 ENTRANCE PORTAL/VOLCANICS AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 50 |
| A-RMR = | 48.55 |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T1 ENTRANCE PORTAL/FLYSCH AT SIDE SLOPES

| **A. CLASSIFICATION PARAMETERS AND THEIR RATINGS** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| **B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)** | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | | Tunnels and mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| **C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS** | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| **D. MEANING OF ROCK CLASSES** | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| **E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions** | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| **F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING** | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| **RMR** | **43.00** |
| **A-RMR** | **45.92** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 EXIT PORTAL/VOLCANICS AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **50.00** |
| **A-RMR** = | **53.20** |
| **A-RMR$_P$** = | **46.96** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 ENTRANCE PORTAL/FLYSCH AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** | **43.00** |
| **A-RMR** | **45.92** |
| **A-RMR$_P$** | **39.68** |

# GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

## T1 EXIT PORTAL/VOLCANICS AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** | **50.00** |
| **A-RMR** | **53.20** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T1 EXIT PORTAL/FLYSCH AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | |
|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 43.00 |
| A-RMR = | 45.92 |

## THE ÖCELİ (T-2) TUNNEL

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 LEFT TUBE ENTRANCE PORTAL/VOLCANICS AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | | |
|---|---|---|
| **RMR** | = | **48** |
| **A-RMR** | = | **46.27** |
| **A-RMR$_P$** | = | **40.03** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 RIGHT TUBE ENTRANCE PORTAL/VOLCANICS AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range- uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces Not continuous No separation Unweathered wall rock | Slightly rough surfaces Separation <1 mm Slightly weathered walls | Slightly rough surfaces Separation <1 mm Highly weathered walls | Slickensided surfaces or Gouge <5 mm thick or Separation 1-5 mm Continuous | Soft gouge >5 mm thick or Separation >5 mm Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **53** |
| **A-RMR** = | **59.52** |
| **A-RMR$_P$** = | **53.28** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 ENTRANCE PORTAL/FLYSCH AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 43.00 |
| A-RMR = | 45.3 |
| $A\text{-}RMR_P$ = | 39.06 |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 LEFT TUBE ENTRANCE PORTAL/VOLCANICS AT SIDE SLOPES

| **A. CLASSIFICATION PARAMETERS AND THEIR RATINGS** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| **B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)** | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | | Tunnels and mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| **C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS** | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| **D. MEANING OF ROCK CLASSES** | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| **E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions** | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| **F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING** | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| **RMR** | **48** |
| **A-RMR** | **46.27** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 RIGHT TUBE ENTRANCE PORTAL/VOLCANICS AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 53 |
| A-RMR = | 59.52 |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 ENTRANCE PORTAL/FLYSCH AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 43.00 |
| A-RMR = | 45.3 |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 EXIT PORTAL/VOLCANICS AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | | Tunnels and mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| D. MEANING OF ROCK CLASSES | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| RMR = | 48.00 |
| A-RMR = | 51.13 |
| $A\text{-}RMR_P$ = | 44.89 |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 EXIT PORTAL/FLYSCH AT PORTAL FACE

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | |
| Class Number | I | II | III | IV | V | |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | |

| D. MEANING OF ROCK CLASSES | | | | | |
|---|---|---|---|---|---|
| Class Number | I | II | III | IV | V |
| Average stand-up time | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | |
|---|---|---|---|---|---|
| Discontinuity length (persistence) | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | 6 | 5 | 4 | 1 | 0 |
| Roughness | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | 6 | 4 | 2 | 2 | 0 |
| Weathering | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| **RMR** = | **43.00** |
| **A-RMR** = | **45.3** |
| **A-RMR$_P$** = | **39.06** |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 EXIT PORTAL/VOLCANICS AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal o) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |
| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | | | | |
| Strike and dip orientations | | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable | | |
| Ratings | | Tunnels and mines | 0 | -2 | -5 | -10 | -12 | | |
| | | Foundations | 0 | -2 | -7 | -15 | -25 | | |
| | | Slopes | 0 | -5 | -25 | -50 | | | |
| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | | | | |
| Rating | | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 | | |
| Class Number | | | I | II | III | IV | V | | |
| Description | | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock | | |
| D. MEANING OF ROCK CLASSES | | | | | | | | | |
| Class Number | | | I | II | III | IV | V | | |
| Average stand-up time | | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span | | |
| Cohesion of rock mass (kPa) | | | >400 | 300-400 | 200-300 | 100-200 | <100 | | |
| Friction angle of rock mass (deg) | | | >45 | 35-45 | 25-35 | 15-25 | <15 | | |
| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | | | | | |
| Discontinuity length (persistence) | | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m | | |
| Rating | | | 6 | 4 | 2 | 1 | 0 | | |
| Separation (aperture) | | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm | | |
| Rating | | | 6 | 5 | 4 | 1 | 0 | | |
| Roughness | | | Very rough | Rough | Slightly rough | Smooth | Slickensided | | |
| Rating | | | 6 | 5 | 3 | 1 | 0 | | |
| Infilling (gouge) | | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm | | |
| Rating | | | 6 | 4 | 2 | 2 | 0 | | |
| Weathering | | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed | | |
| Ratings | | | 6 | 5 | 3 | 1 | 0 | | |
| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | | | | | | | |
| Strike perpendicular to tunnel axis | | | | | Strike parallel to tunnel axis. | | | | |
| Drive with dip-Dip 45-90 | | | Drive with dip-Dip 20-45 | | Dip 45-90 | | Dip 20-45 | | |
| Very favourable | | | Favourable | | Very Favourable | | Fair | | |
| Drive against dip-Dip 45-90 | | | Drive against dip-Dip 20-45 | | Dip 0-20-Irrespective of strike | | | | |
| Fair | | | Unfavourable | | Fair | | | | |

| | |
|---|---|
| RMR = | 48.00 |
| A-RMR = | 51.13 |

GEOMECHANICS CLASSIFICATION SYSTEM (After Bieniawski, 1989)

T2 EXIT PORTAL/FLYSCH AT SIDE SLOPES

| A. CLASSIFICATION PARAMETERS AND THEIR RATINGS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | | Range of values | | | | | | |
| 1 | Strength of intact rock material | Point-load strength index | >10 Mpa | 4-10 Mpa | 2-4 Mpa | 1-2 Mpa | For this low range-uniaxial compressive test is preferred | | |
| | | Uniaxial comp. Strength | >250 Mpa | 100-250 Mpa | 50-100 Mpa | 25-50 Mpa | 5-25 Mpa | 1-5 Mpa | <1 Mpa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core Quality RQD | | 90%-100% | 75%-90% | 50%-75% | 25%-50% | <25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities (See E) | | Very rough surfaces<br>Not continuous<br>No separation<br>Unweathered wall rock | Slightly rough surfaces<br>Separation <1 mm<br>Slightly weathered walls | Slightly rough surfaces<br>Separation <1 mm<br>Highly weathered walls | Slickensided surfaces<br>or<br>Gouge <5 mm thick<br>or<br>Separation 1-5 mm<br>Continuous | Soft gouge >5 mm thick<br>or<br>Separation >5 mm<br>Continuous | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground Water | Inflow per 10 m tunnel length (l/m) | None | <10 | 10-25 | 25-125 | >125 | | |
| | | (Joint water press)/ (Major principal σ) | 0 | <0.1 | 0.1-0.2 | 0.2-0.5 | >0.5 | | |
| | | General conditions | Completely dry | Damp | Wet | Dripping | Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

| B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F) | | | | | | |
|---|---|---|---|---|---|---|
| Strike and dip orientations | | Very favourable | Favourable | Fair | Unfavourable | Very Unfavourable |
| Ratings | Tunnels and mines | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | |

| C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS | | | | | | |
|---|---|---|---|---|---|---|
| Rating | | 100<----81 | 80<----61 | 60<----41 | 40<----21 | <21 |
| Class Number | | I | II | III | IV | V |
| Description | | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

| D. MEANING OF ROCK CLASSES | | | | | | |
|---|---|---|---|---|---|---|
| Class Number | | I | II | III | IV | V |
| Average stand-up time | | 20 yrs for 15 m span | 1 year for 10 m span | 1 week for 5 m span | 10 hrs for 2.5 m span | 30 min for 1 m span |
| Cohesion of rock mass (kPa) | | >400 | 300-400 | 200-300 | 100-200 | <100 |
| Friction angle of rock mass (deg) | | >45 | 35-45 | 25-35 | 15-25 | <15 |

| E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions | | | | | | |
|---|---|---|---|---|---|---|
| Discontinuity length (persistence) | | <1 m | 1-3 m | 3-10 m | 10-20 m | >20 m |
| Rating | | 6 | 4 | 2 | 1 | 0 |
| Separation (aperture) | | None | <0.1 mm | 0.1-1.0 mm | 1-5 mm | >5 mm |
| Rating | | 6 | 5 | 4 | 1 | 0 |
| Roughness | | Very rough | Rough | Slightly rough | Smooth | Slickensided |
| Rating | | 6 | 5 | 3 | 1 | 0 |
| Infilling (gouge) | | None | Hard filling<5mm | Hard filling>5mm | Soft filling<5mm | Soft filling>5mm |
| Rating | | 6 | 4 | 2 | 2 | 0 |
| Weathering | | Unweathered | Slightly weathered | Moderately weathered | Highly weathered | Decomposed |
| Ratings | | 6 | 5 | 3 | 1 | 0 |

| F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING | | | |
|---|---|---|---|
| Strike perpendicular to tunnel axis | | Strike parallel to tunnel axis. | |
| Drive with dip-Dip 45-90 | Drive with dip-Dip 20-45 | Dip 45-90 | Dip 20-45 |
| Very favourable | Favourable | Very Favourable | Fair |
| Drive against dip-Dip 45-90 | Drive against dip-Dip 20-45 | Dip 0-20-Irrespective of strike | |
| Fair | Unfavourable | Fair | |

| | |
|---|---|
| RMR = | 43.00 |
| A-RMR = | 45.3 |

# APPENDIX – F
# ROCLAB OUTPUTS

# THE BOZTEPE (T-1) TUNNEL

# T1 – 1

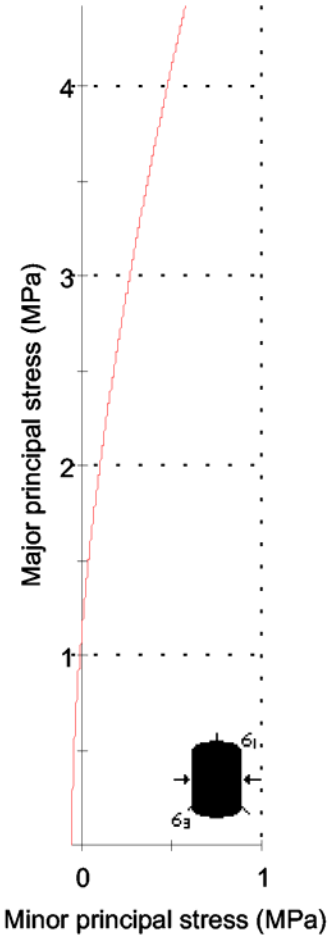
## Analysis of Rock Strength using RocLab

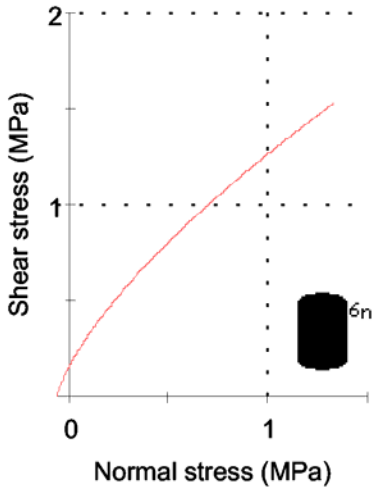
**Hoek-Brown Classification**
intact uniaxial compressive strength = 25 MPa
GSI = 45 mi = 7.1 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 0.996 s = 0.0022 a = 0.508

**Mohr-Coulomb Fit**
cohesion = 0.262 MPa friction angle = 45.29 deg

**Rock Mass Parameters**
tensile strength = -0.056 MPa
uniaxial compressive strength = 1.121 MPa
global strength = 3.311 MPa
modulus of deformation = 3749.47 MPa



**T1 – 2**

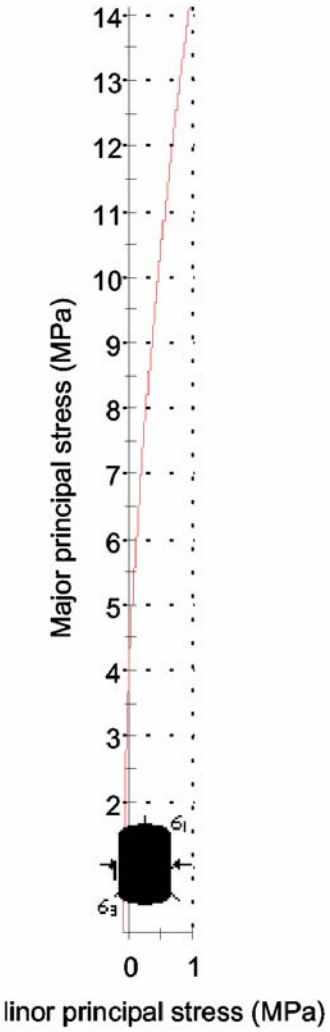
**Analysis of Rock Strength using RocLab**

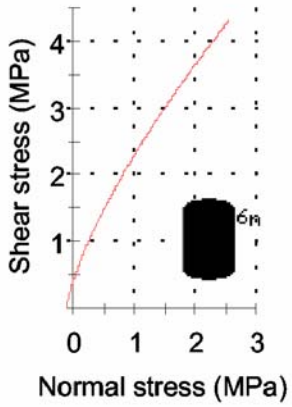
**Hoek-Brown Classification**
intact uniaxial compressive strength = 30 MPa
GSI = 65 mi = 19 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 5.444 s = 0.0205 a = 0.502

**Mohr-Coulomb Fit**
cohesion = 0.698 MPa friction angle = 56.26 deg

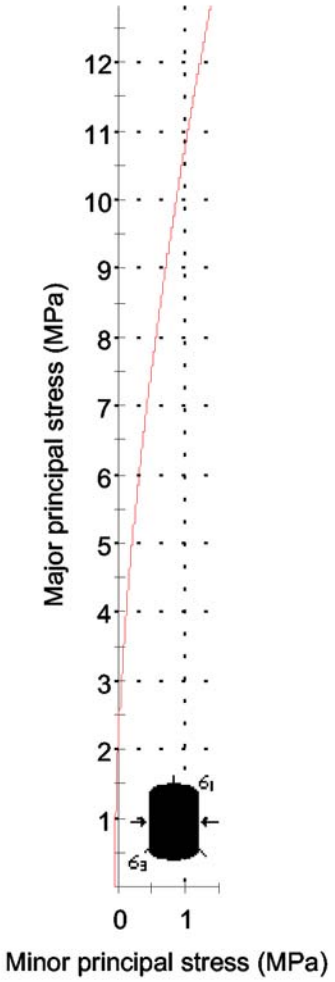
**Rock Mass Parameters**
tensile strength = -0.113 MPa
uniaxial compressive strength = 4.259 MPa
global strength = 9.771 MPa
modulus of deformation = 12988.55 MPa



## T1 – 3

**Analysis of Rock Strength using RocLab**




**Hoek-Brown Classification**

intact uniaxial compressive strength = 35 MPa
GSI = 50 mi = 16 Disturbance factor = 0

**Hoek-Brown Criterion**

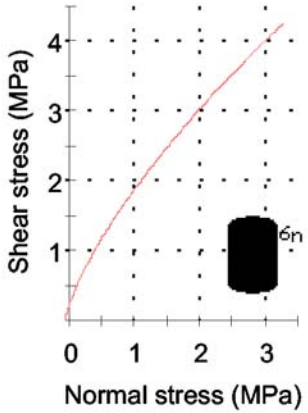
mb = 2.683 s = 0.0039 a = 0.506

**Mohr-Coulomb Fit**

cohesion = 0.609 MPa friction angle = 49.72 deg

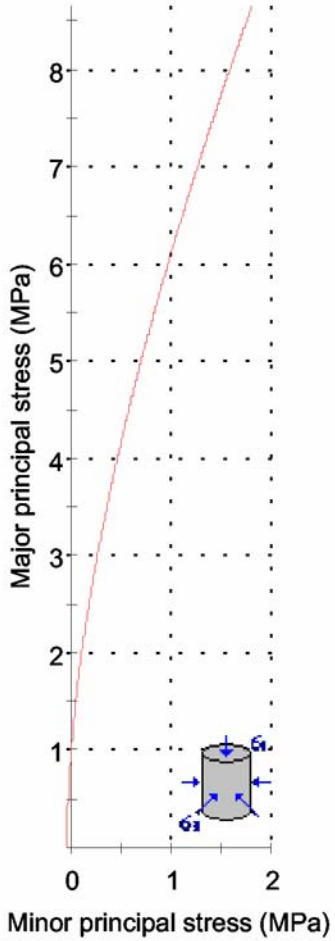
**Rock Mass Parameters**

tensile strength = -0.050 MPa
uniaxial compressive strength = 2.108 MPa
global strength = 7.647 MPa
modulus of deformation = 5916.08 MPa



**T1 – 4**

**Analysis of Rock Strength using RocLab**




**Hoek-Brown Classification**

intact uniaxial compressive strength = 20 MPa

GSI = 46 mi = 9 Disturbance factor = 0

**Hoek-Brown Criterion**

mb = 1.308 s = 0.0025 a = 0.508

**Mohr-Coulomb Fit**

cohesion = 0.475 MPa friction angle = 36.77 deg

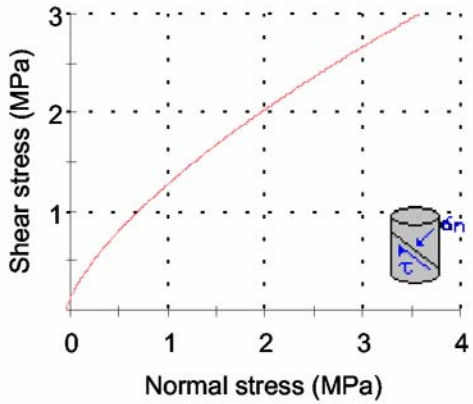
**Rock Mass Parameters**

tensile strength = -0.038 MPa

uniaxial compressive strength = 0.952 MPa

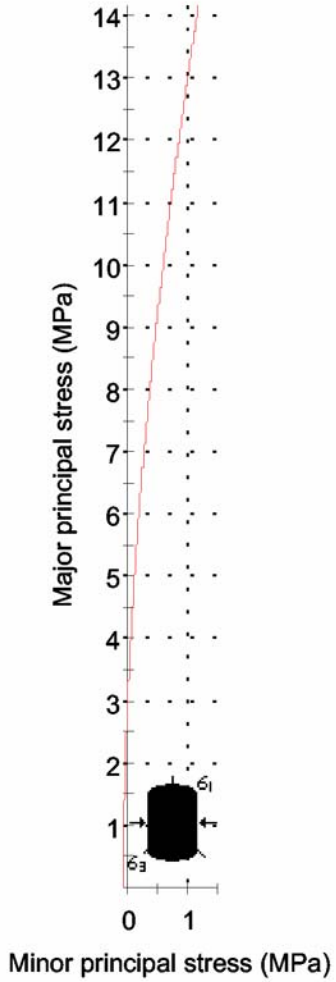
global strength = 3.035 MPa

modulus of deformation = 3552.34 MPa



# T1 – 5

## Analysis of Rock Strength using RocLab




**Hoek-Brown Classification**

intact uniaxial compressive strength = 40 MPa
GSI = 55 mi = 17 Disturbance factor = 0

**Hoek-Brown Criterion**

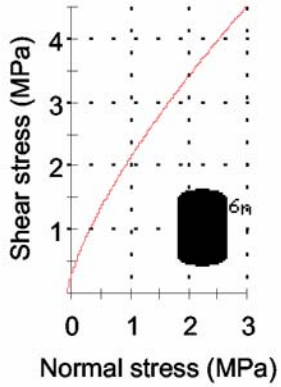
mb = 3.408 s = 0.0067 a = 0.504

**Mohr-Coulomb Fit**

cohesion = 0.669 MPa friction angle = 53.65 deg

**Rock Mass Parameters**

tensile strength = -0.079 MPa
uniaxial compressive strength = 3.218 MPa
global strength = 9.989 MPa
modulus of deformation = 8433.93 MPa



## T1 – Pn

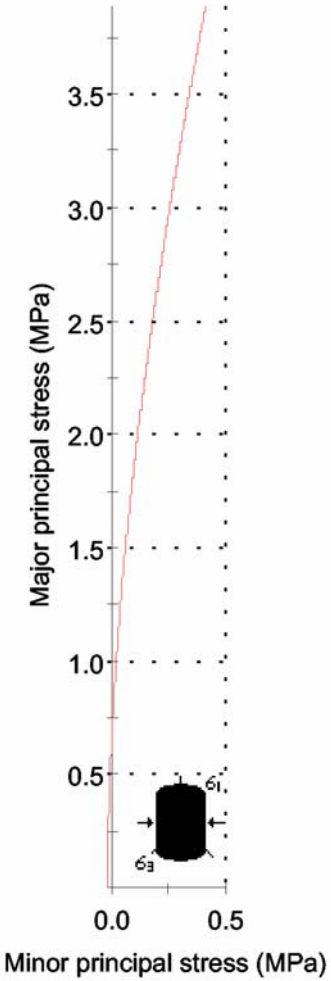
**Analysis of Rock Strength using RocLab**

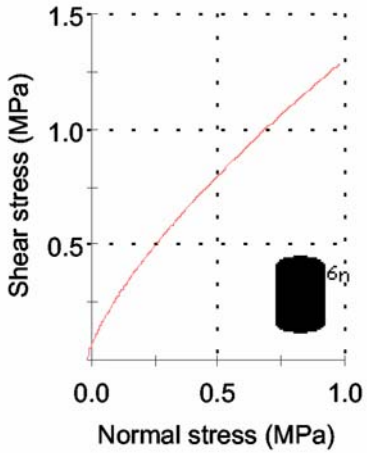
**Hoek-Brown Classification**
intact uniaxial compressive strength = 25 MPa
GSI = 35 mi = 13 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 1.276 s = 0.0007 a = 0.516

**Mohr-Coulomb Fit**
cohesion = 0.177 MPa friction angle = 50.11 deg

**Rock Mass Parameters**
tensile strength = -0.014 MPa
uniaxial compressive strength = 0.602 MPa
global strength = 3.549 MPa
modulus of deformation = 2108.48 MPa



# T1 – Px

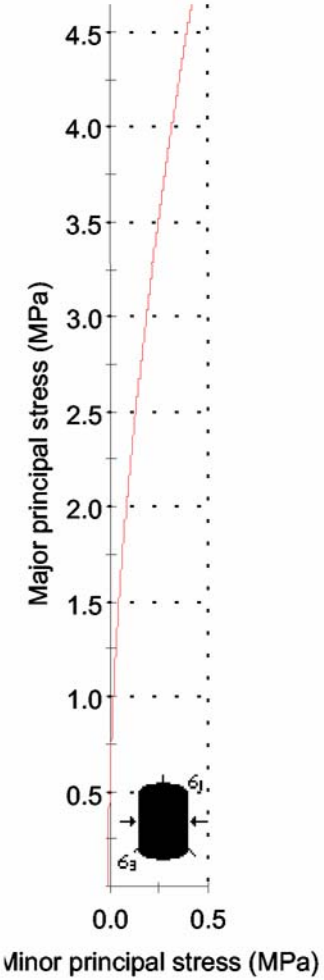
## Analysis of Rock Strength using RocLab

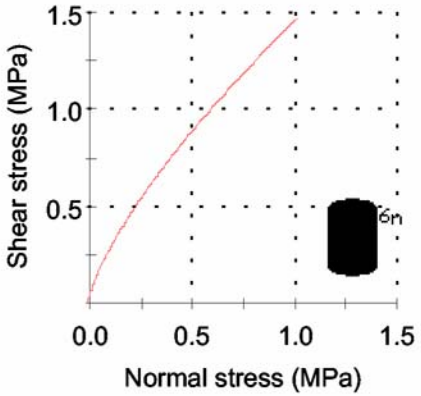
**Hoek-Brown Classification**
intact uniaxial compressive strength = 25 MPa
GSI = 35 mi = 19 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 1.865 s = 0.0007 a = 0.516

**Mohr-Coulomb Fit**
cohesion = 0.192 MPa friction angle = 53.16 deg

**Rock Mass Parameters**
tensile strength = -0.010 MPa
uniaxial compressive strength = 0.602 MPa
global strength = 4.305 MPa
modulus of deformation = 2108.48 MPa



**THE ÖCELİ (T-2) TUNNEL**

# T2 – 1

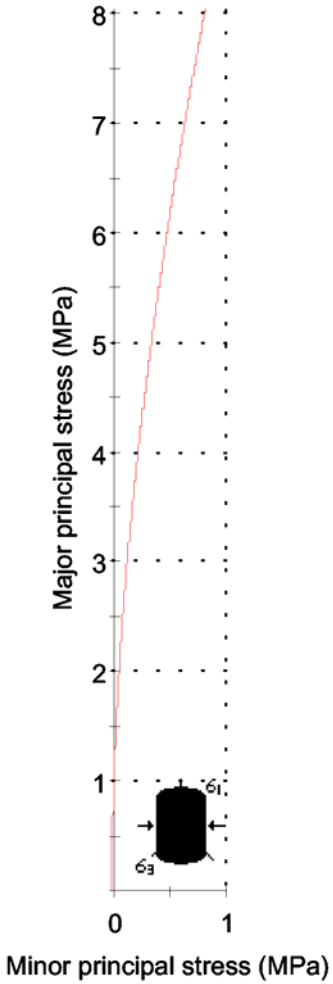
## Analysis of Rock Strength using RocLab

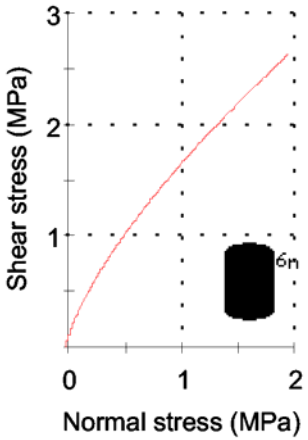
**Hoek-Brown Classification**
intact uniaxial compressive strength = 20 MPa
GSI = 50 mi = 19 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 3.186 s = 0.0039 a = 0.506

**Mohr-Coulomb Fit**
cohesion = 0.366 MPa friction angle = 50.90 deg

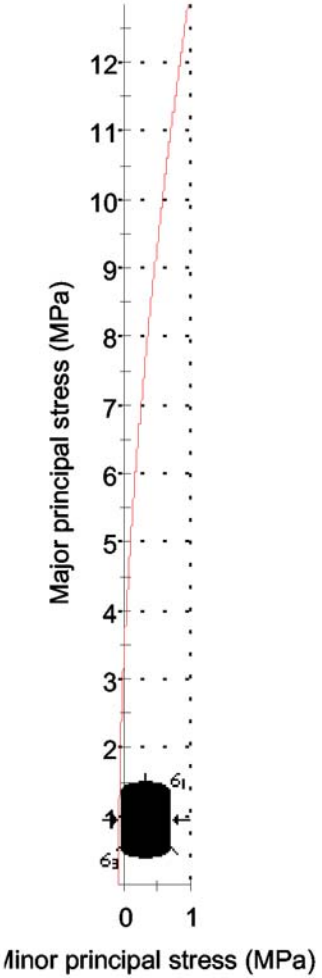
**Rock Mass Parameters**
tensile strength = -0.024 MPa
uniaxial compressive strength = 1.205 MPa
global strength = 4.751 MPa
modulus of deformation = 4472.14 MPa



## T2 – 2

**Analysis of Rock Strength using RocLab**

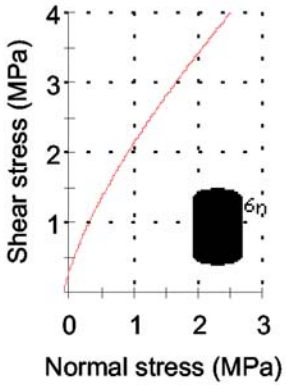



**Hoek-Brown Classification**
intact uniaxial compressive strength = 30 MPa
GSI = 60 mi = 19 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 4.553 s = 0.0117 a = 0.503

**Mohr-Coulomb Fit**
cohesion = 0.604 MPa friction angle = 55.11 deg

**Rock Mass Parameters**
tensile strength = -0.077 MPa
uniaxial compressive strength = 3.210 MPa
global strength = 8.772 MPa
modulus of deformation = 9740.04 MPa



**T12– 3**

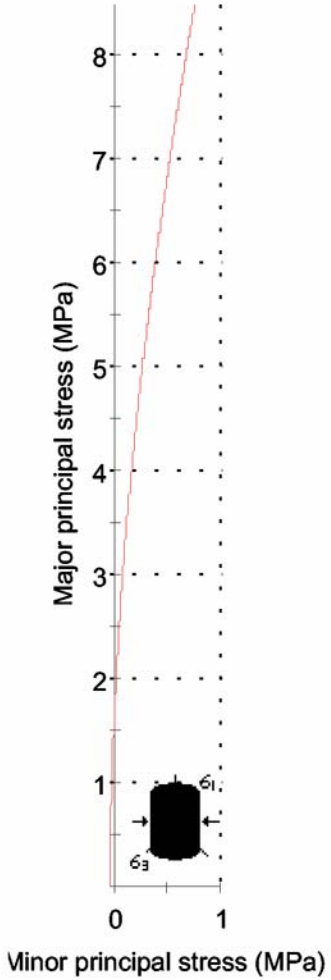
**Analysis of Rock Strength using RocLab**

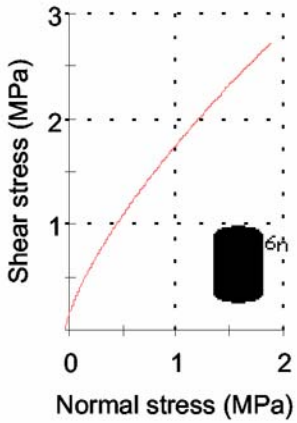
**Hoek-Brown Classification**
intact uniaxial compressive strength = 20 MPa
GSI = 55 mi = 19 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 3.809 s = 0.0067 a = 0.504

**Mohr-Coulomb Fit**
cohesion = 0.389 MPa friction angle = 52.74 deg

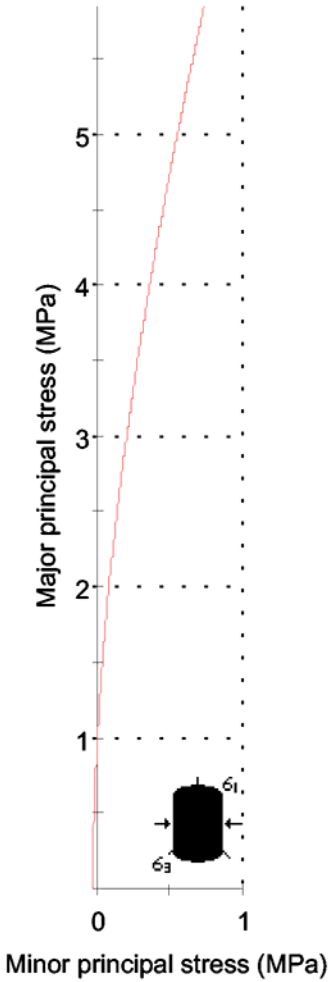
**Rock Mass Parameters**
tensile strength = -0.035 MPa
uniaxial compressive strength = 1.609 MPa
global strength = 5.268 MPa
modulus of deformation = 5963.69 MPa



## T2 – 4

**Analysis of Rock Strength using RocLab**

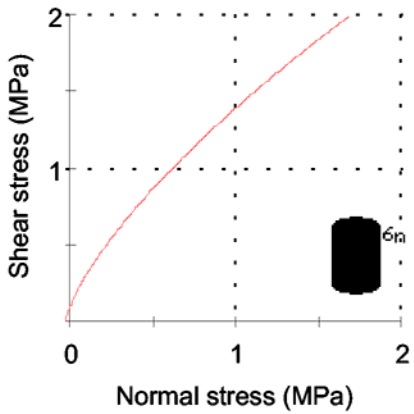



**Hoek-Brown Classification**
intact uniaxial compressive strength = 15 MPa
GSI = 50 mi = 14 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 2.347 s = 0.0039 a = 0.506

**Mohr-Coulomb Fit**
cohesion = 0.291 MPa friction angle = 46.88 deg

**Rock Mass Parameters**
tensile strength = -0.025 MPa
uniaxial compressive strength = 0.903 MPa
global strength = 3.072 MPa
modulus of deformation = 3872.98 MPa



# T2 – Pna

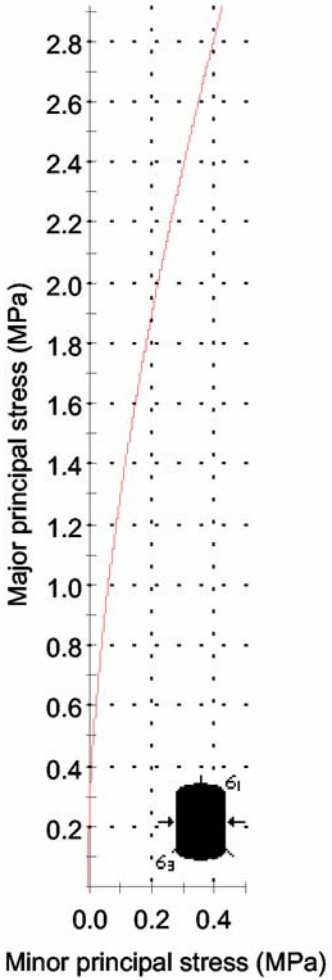
**Analysis of Rock Strength using RocLab**

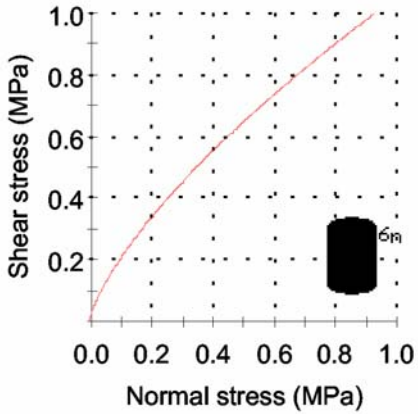
**Hoek-Brown Classification**
intact uniaxial compressive strength = 10 MPa
GSI = 35 mi = 16 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 1.570 s = 0.0007 a = 0.516

**Mohr-Coulomb Fit**
cohesion = 0.137 MPa friction angle = 44.53 deg

**Rock Mass Parameters**
tensile strength = -0.005 MPa
uniaxial compressive strength = 0.241 MPa
global strength = 1.578 MPa
modulus of deformation = 1333.52 MPa



## T2 – Pnb

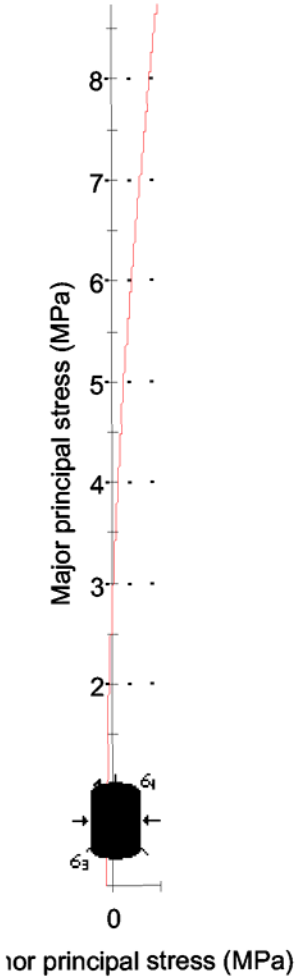
**Analysis of Rock Strength using RocLab**

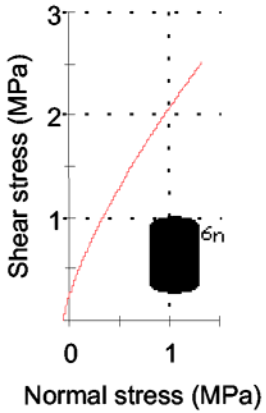
**Hoek-Brown Classification**
intact uniaxial compressive strength = 60 MPa
GSI = 45 mi = 16 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 2.244 s = 0.0022 a = 0.508

**Mohr-Coulomb Fit**
cohesion = 0.394 MPa friction angle = 59.37 deg

**Rock Mass Parameters**
tensile strength = -0.059 MPa
uniaxial compressive strength = 2.690 MPa
global strength = 11.801 MPa
modulus of deformation = 5808.66 MPa



# T2 – Px

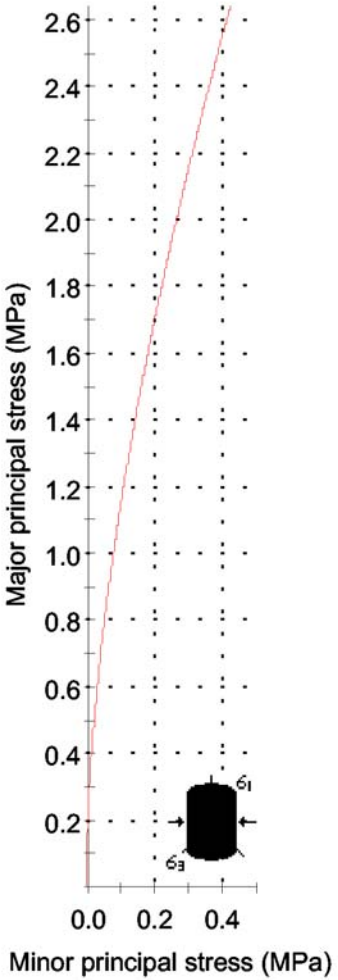
## Analysis of Rock Strength using RocLab

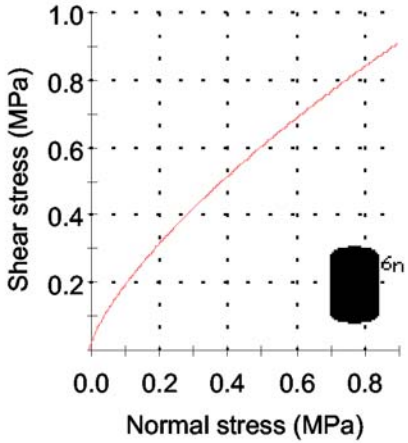
**Hoek-Brown Classification**
intact uniaxial compressive strength = 10 MPa
GSI = 30 mi = 16 Disturbance factor = 0

**Hoek-Brown Criterion**
mb = 1.313 s = 0.0004 a = 0.522

**Mohr-Coulomb Fit**
cohesion = 0.123 MPa friction angle = 42.84 deg

**Rock Mass Parameters**
tensile strength = -0.003 MPa
uniaxial compressive strength = 0.172 MPa
global strength = 1.397 MPa
modulus of deformation = 1000.00 MPa

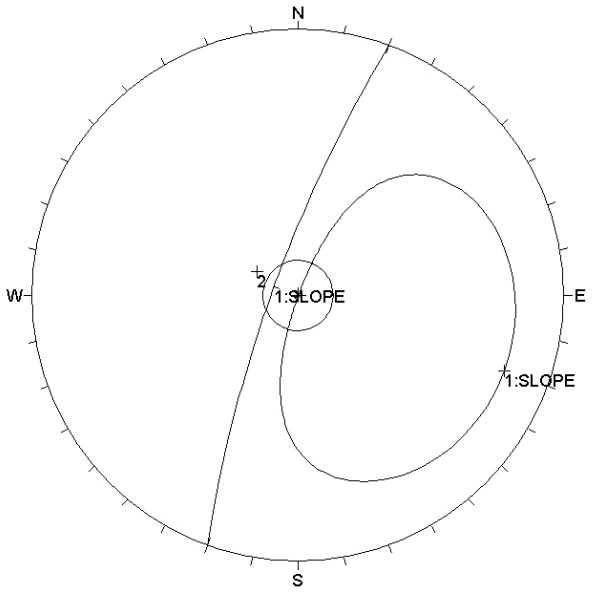


# APPENDIX – G
# KINEMATICAL ANALYSES RESULTS

**PLANE FAILURE**

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL FACE

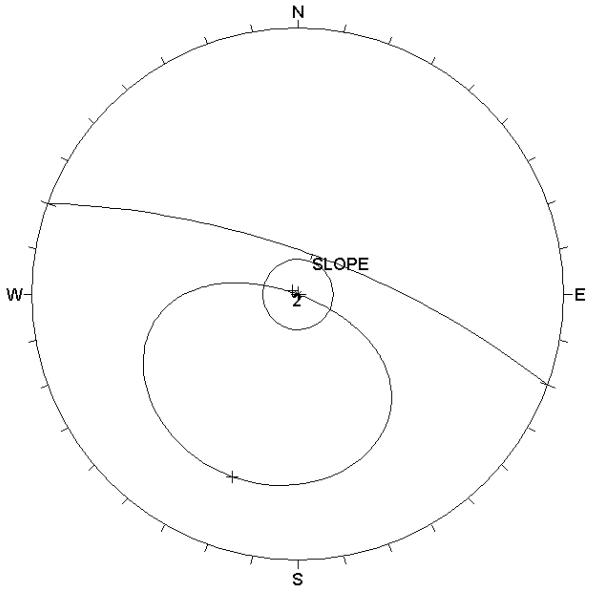



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 290 |
| 2 | 20 / 120 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL / LEFT CUT

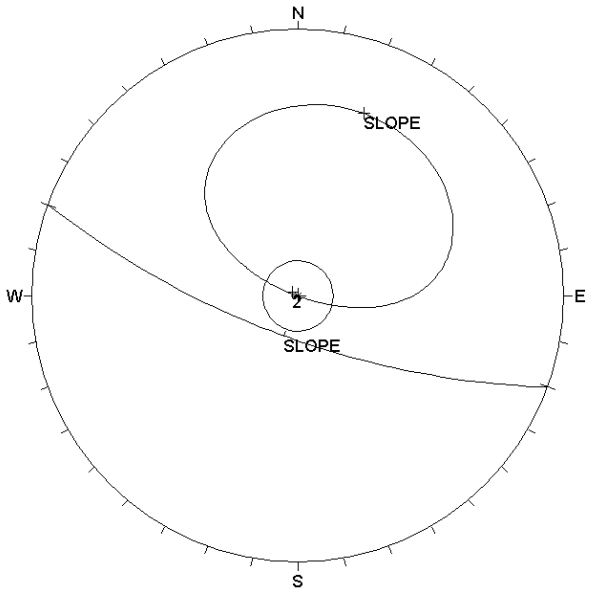



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 020 |
| 2 | 03 / 120 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL / RIGHT CUT

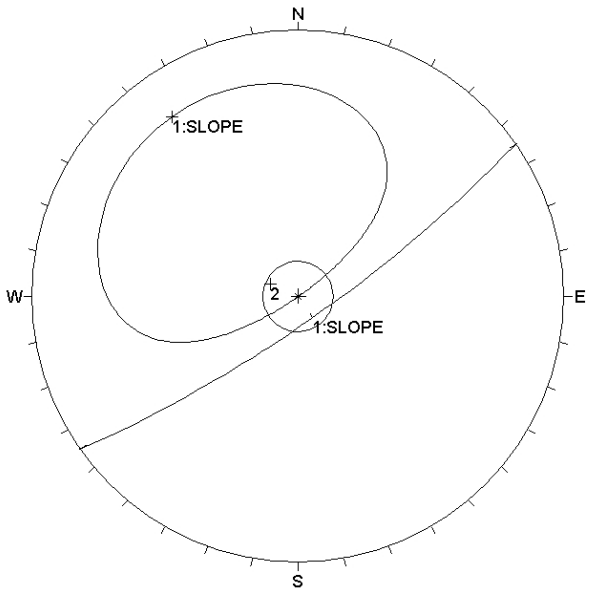



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 03 / 120 |
| 1 | 72 / 200 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE PORTAL FACE

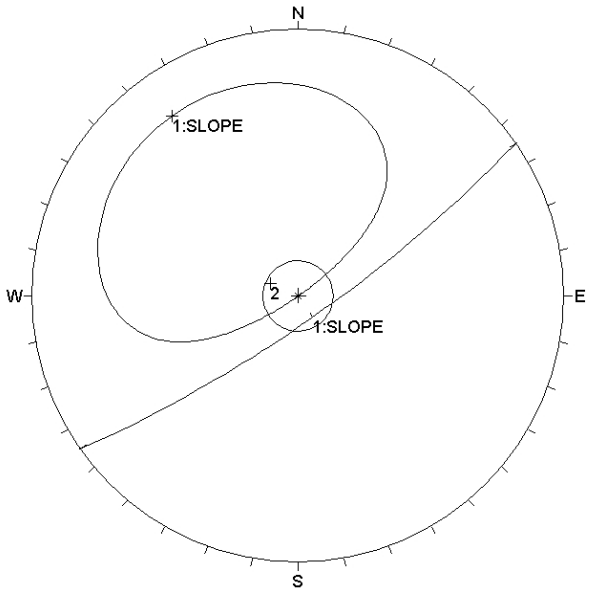



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 145 |
| 2 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / RIGHT TUBE PORTAL FACE

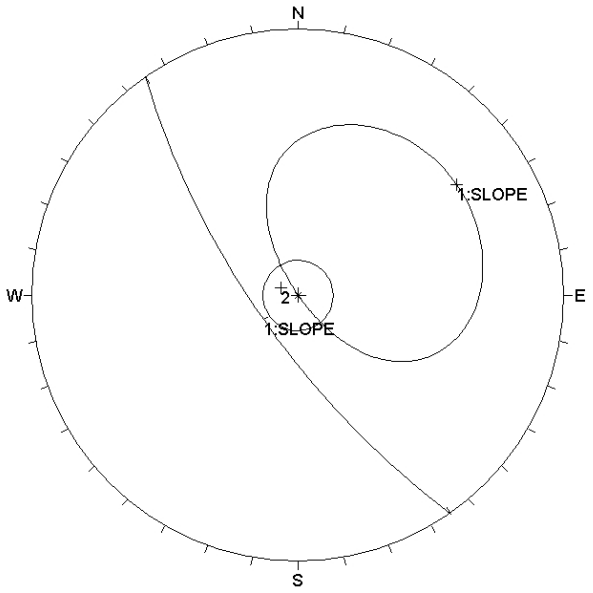



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 145 |
| 2 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE LEFT CUT

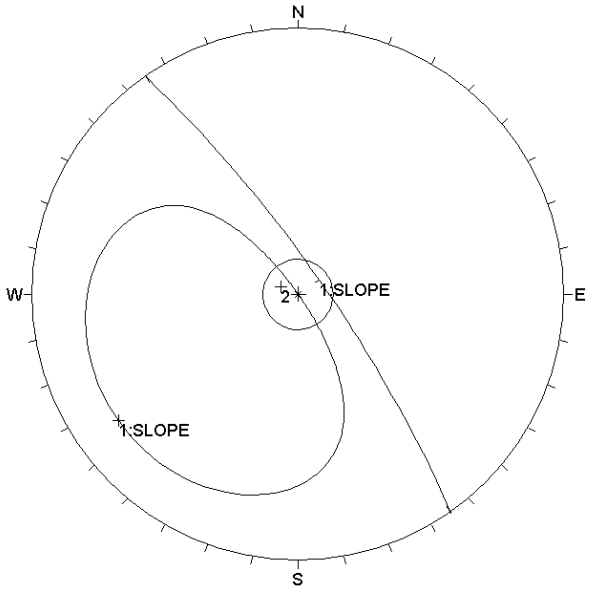



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 235 |
| 2 | 08 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE RIGHT CUT

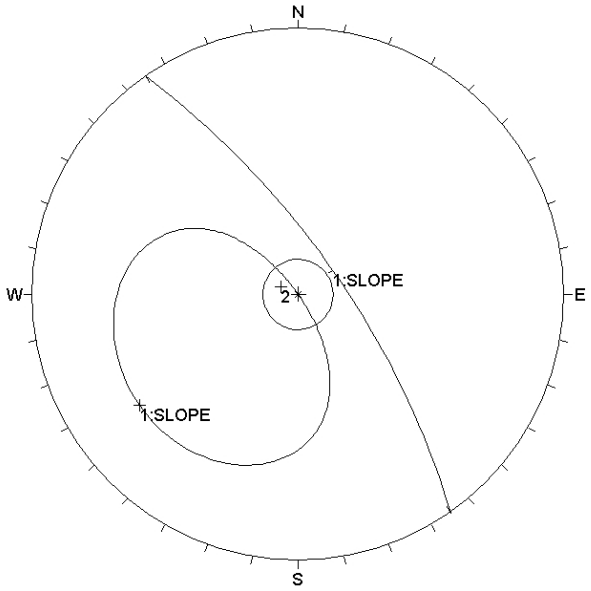



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 08 / 115 |
| 1 | 79 / 055 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / RIGHT TUBE RIGHT CUT

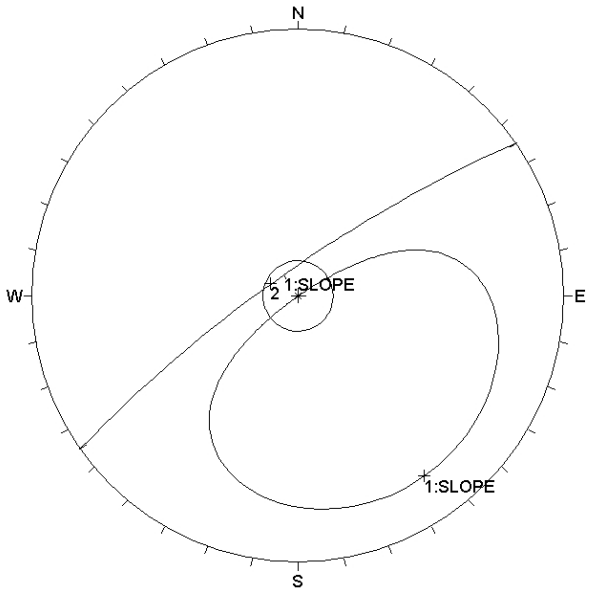



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 08 / 115 |
| 1 | 72 / 055 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / LEFT TUBE PORTAL FACE

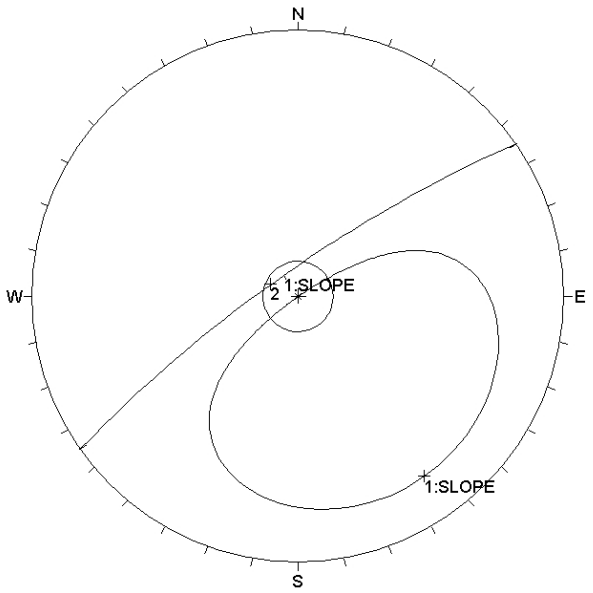



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 13 / 115 |
| 1 | 79 / 325 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE PORTAL FACE

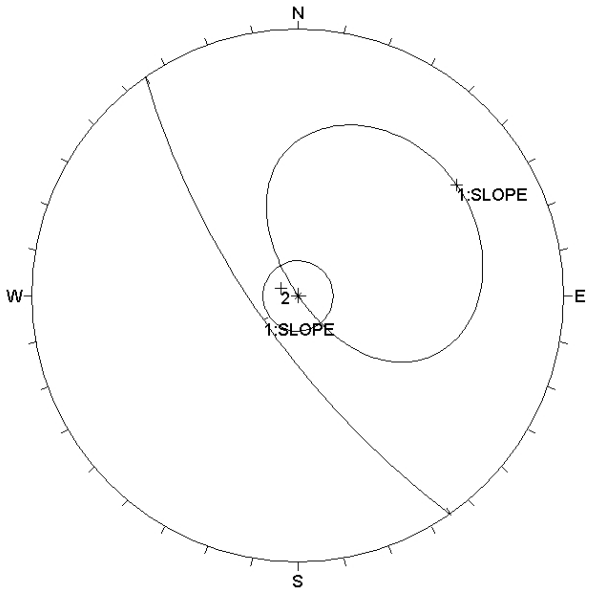



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 13 / 115 |
| 1 | 79 / 325 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / LEFT TUBE LEFT CUT

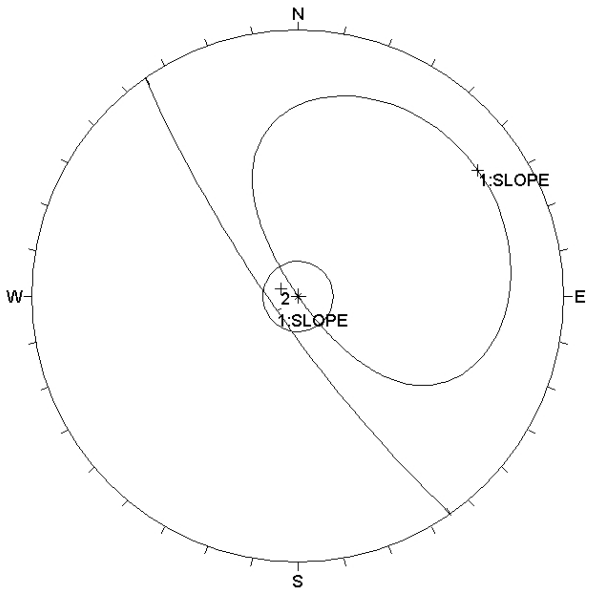



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 235 |
| 2 | 08 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE LEFT CUT

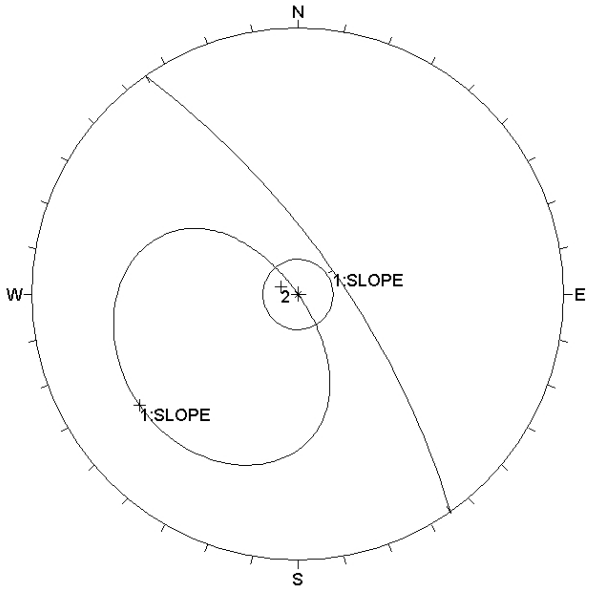



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 08 / 115 |
| 1 | 79 / 235 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE RIGHT CUT

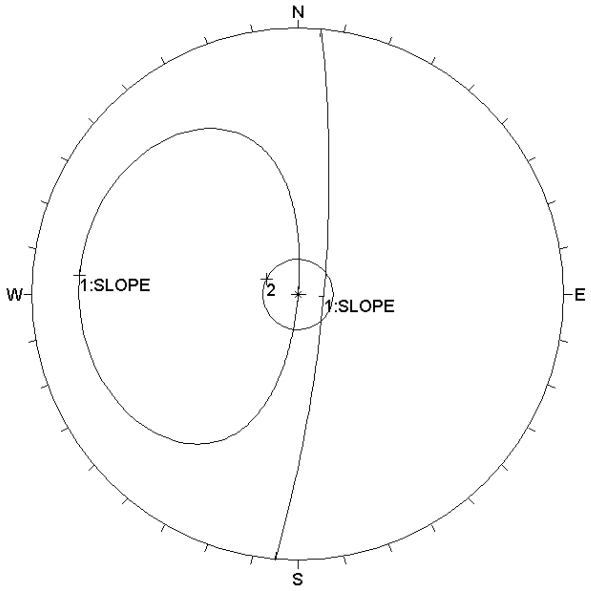



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 08 / 115 |
| 1 | 72 / 055 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE PORTAL FACE

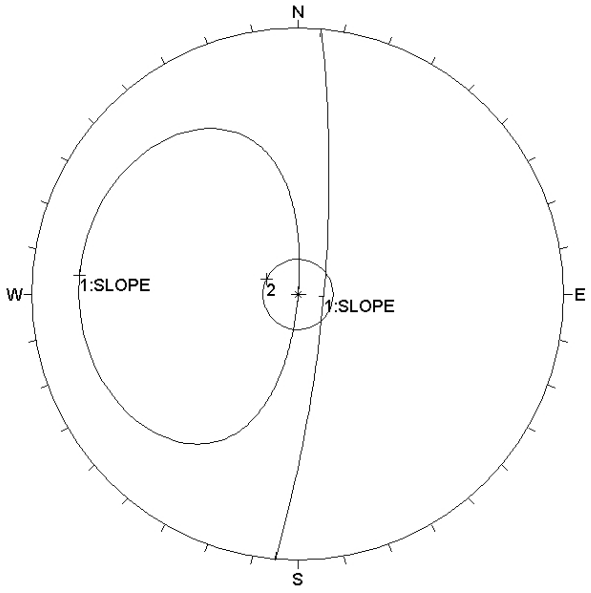



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 095 |
| 2 | 15 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / RIGHT TUBE PORTAL FACE

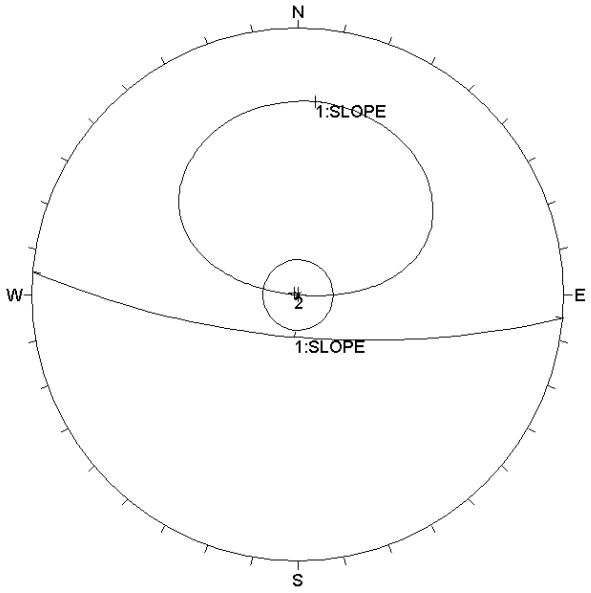



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 095 |
| 2 | 15 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE LEFT CUT

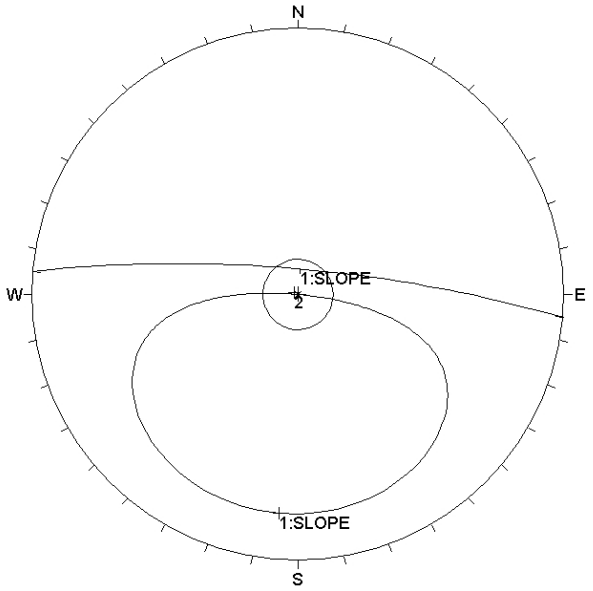



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 185 |
| 2 | 02 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE RIGHT CUT

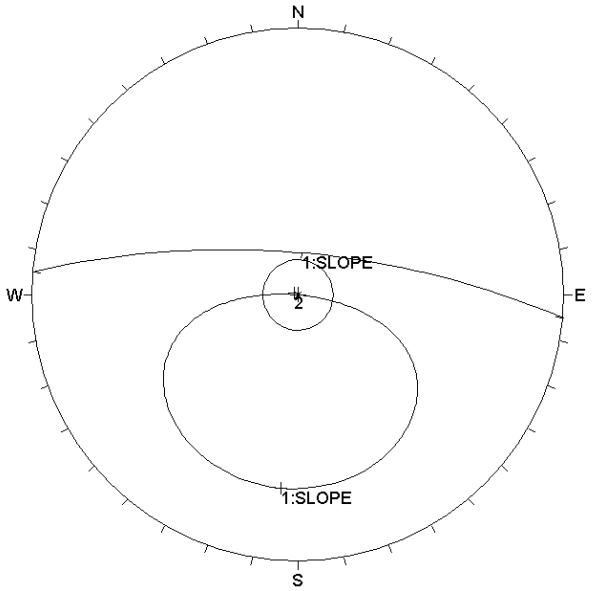



Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 02 / 115 |
| 1 | 79 / 005 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / RIGHT TUBE RIGHT CUT



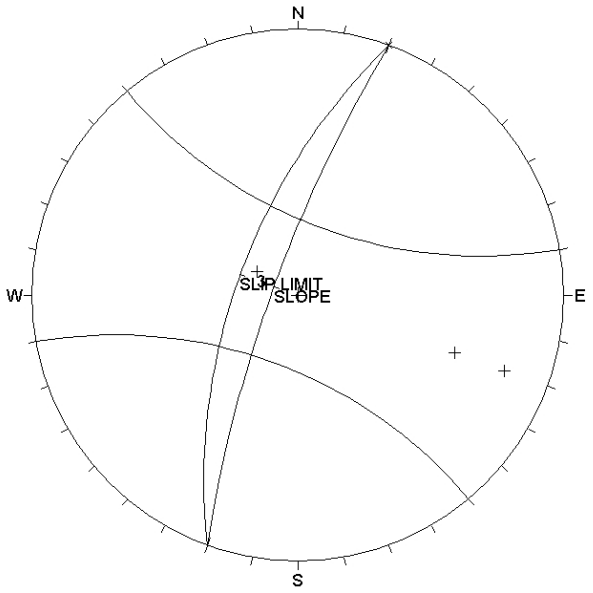

Orientations

| ID | Dip / Direction |
|---|---|
| 2 | 02 / 115 |
| 1 | 72 / 005 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

**TOPPLING**

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL FACE

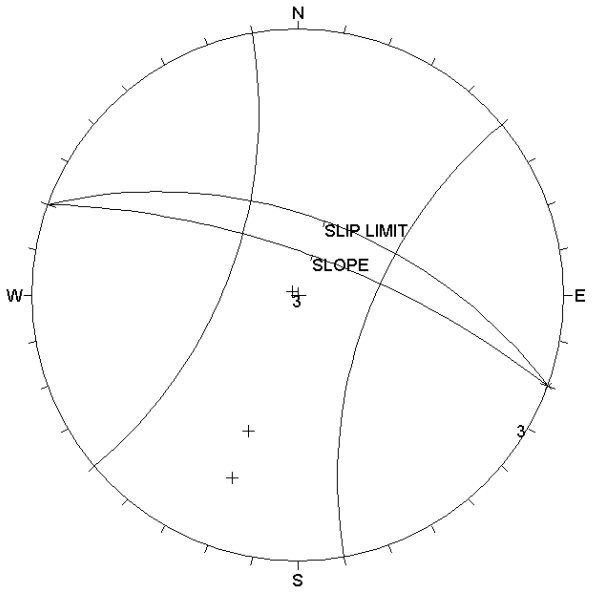



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 290 |
| 2 | 64 / 290 |
| 3 | 20 / 120 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL / LEFT CUT

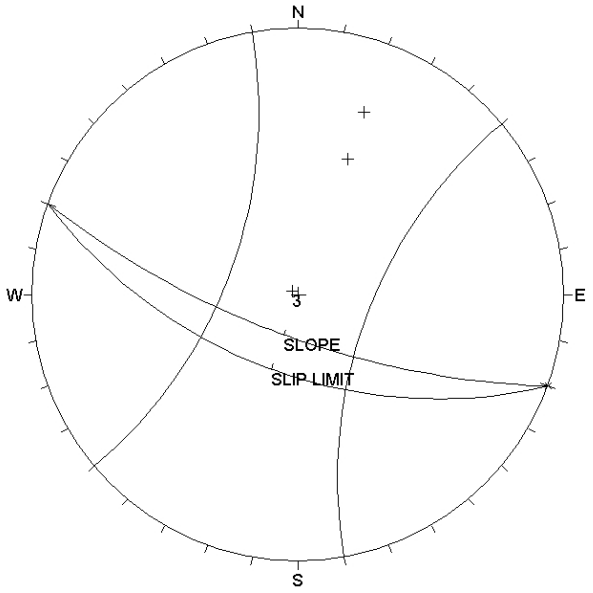



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 020 |
| 2 | 57 / 020 |
| 3 | 03 / 120 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL / RIGHT CUT

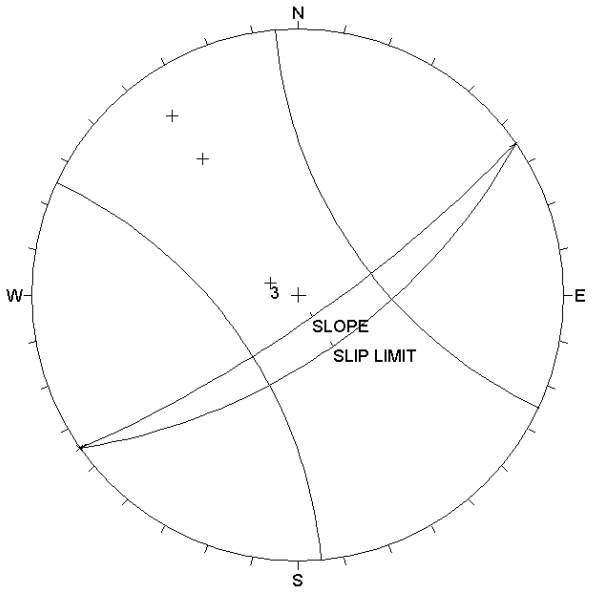



Orientations

| ID | Dip / Direction |
|---|---|
| 3 | 03 / 120 |
| 1 | 72 / 200 |
| 2 | 57 / 200 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE PORTAL FACE

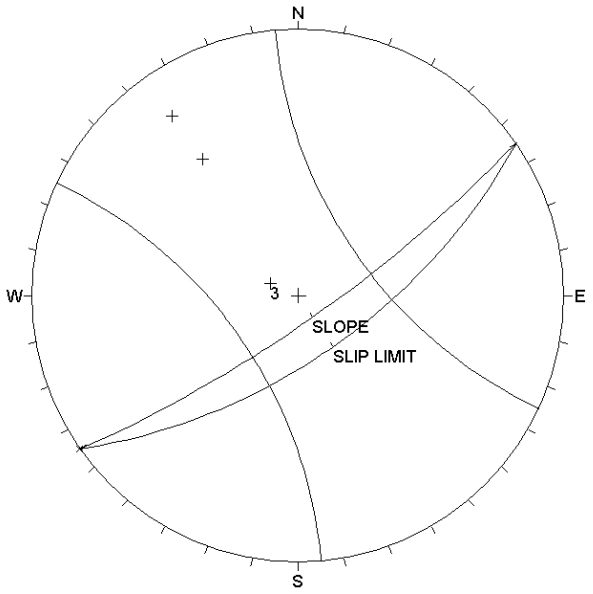



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 145 |
| 2 | 64 / 145 |
| 3 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / RIGHT TUBE PORTAL FACE

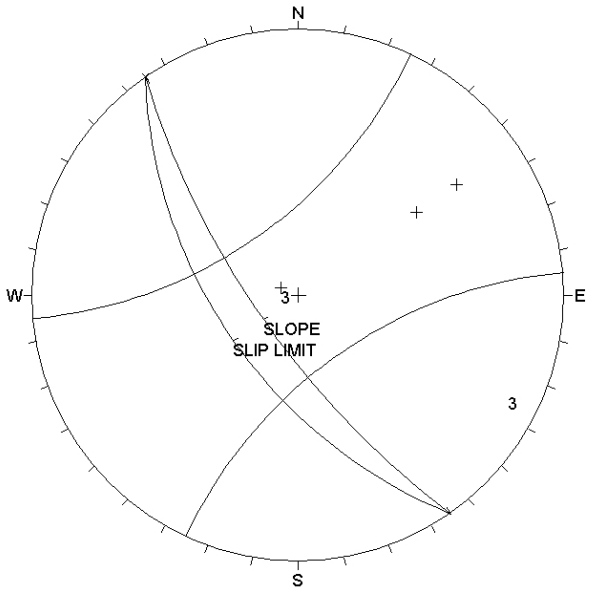



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 145 |
| 2 | 64 / 145 |
| 3 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE LEFT CUT

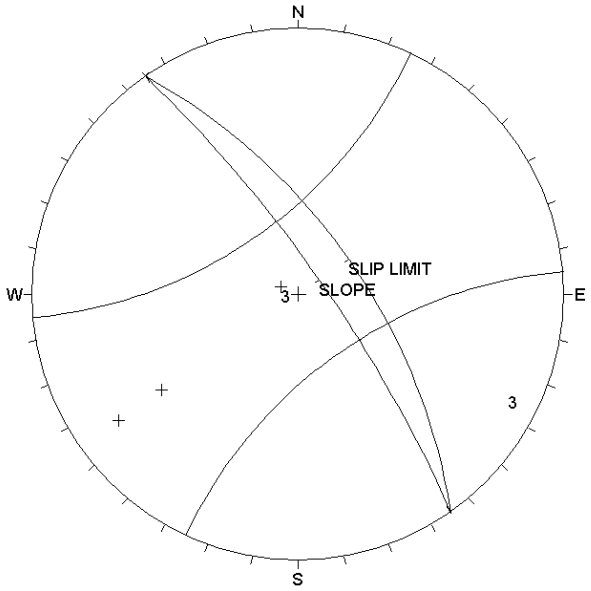



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 235 |
| 2 | 57 / 235 |
| 3 | 08 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / LEFT TUBE RIGHT CUT

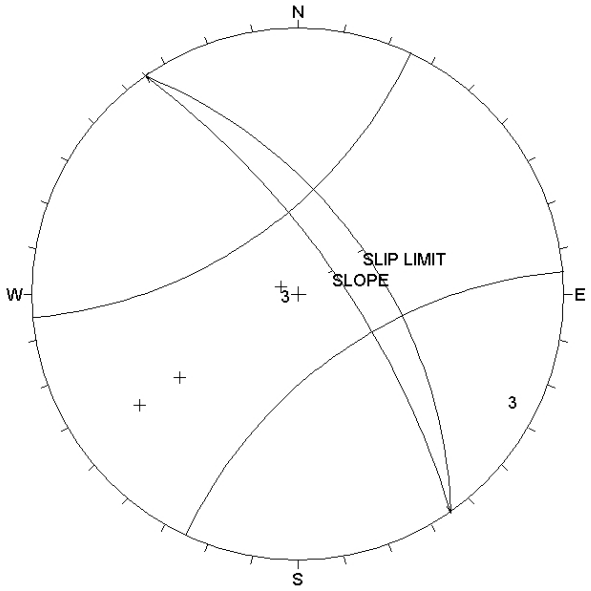



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 055 |
| 2 | 64 / 055 |
| 3 | 08 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## BOZTEPE (T-1) TUNNEL EXIT PORTAL / RIGHT TUBE RIGHT CUT

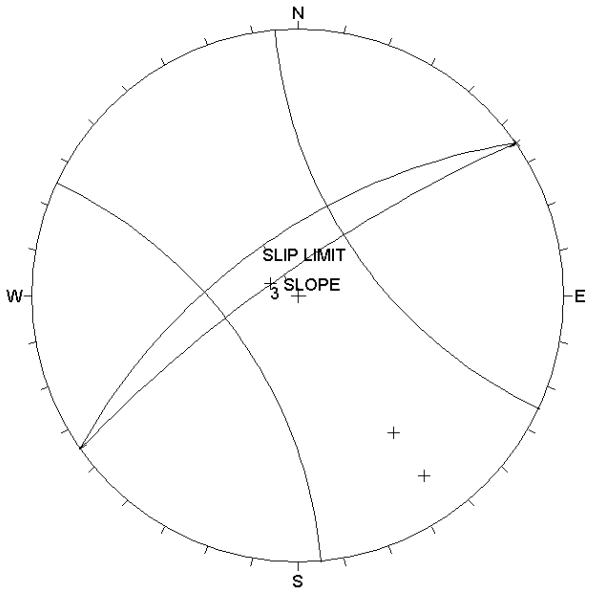



Orientations

| ID | Dip / Direction |
|---|---|
| 3 | 08 / 115 |
| 1 | 72 / 055 |
| 2 | 57 / 055 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / LEFT TUBE PORTAL FACE

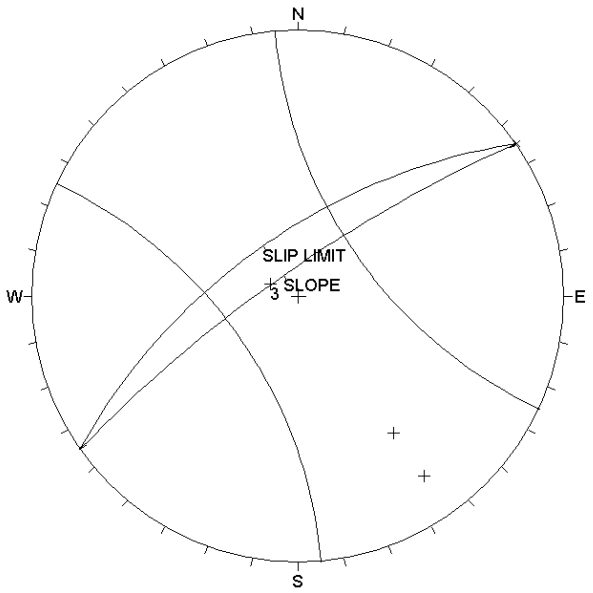



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 325 |
| 2 | 64 / 325 |
| 3 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE PORTAL FACE

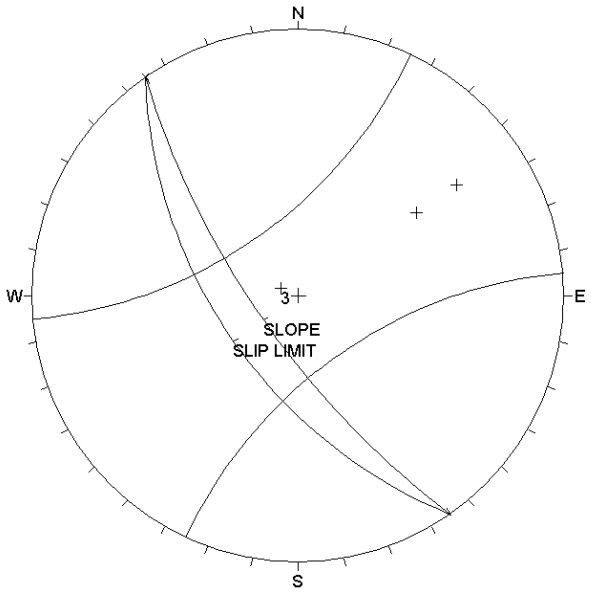



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 325 |
| 2 | 64 / 325 |
| 3 | 13 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / LEFT TUBE LEFT CUT

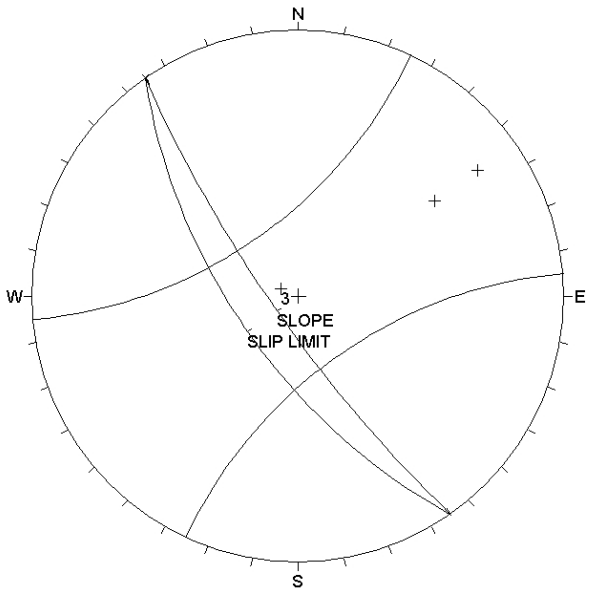



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 235 |
| 2 | 57 / 235 |
| 3 | 08 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE LEFT CUT

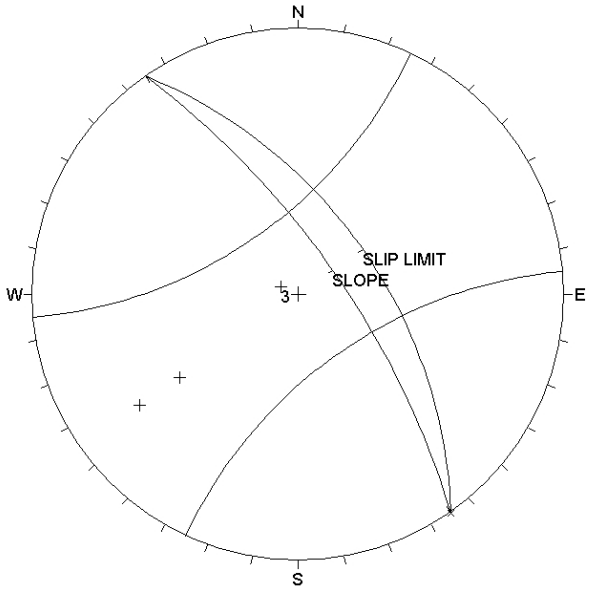



Orientations

| ID | Dip / Direction |
|---|---|
| 3 | 08 / 115 |
| 1 | 79 / 235 |
| 2 | 64 / 235 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL / RIGHT TUBE RIGHT CUT

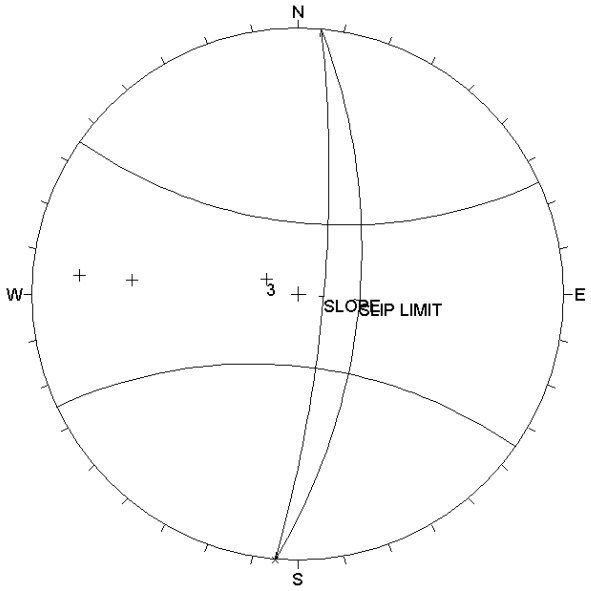



Orientations

| ID | Dip / Direction |
|---|---|
| 3 | 08 / 115 |
| 1 | 72 / 055 |
| 2 | 57 / 055 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE PORTAL FACE

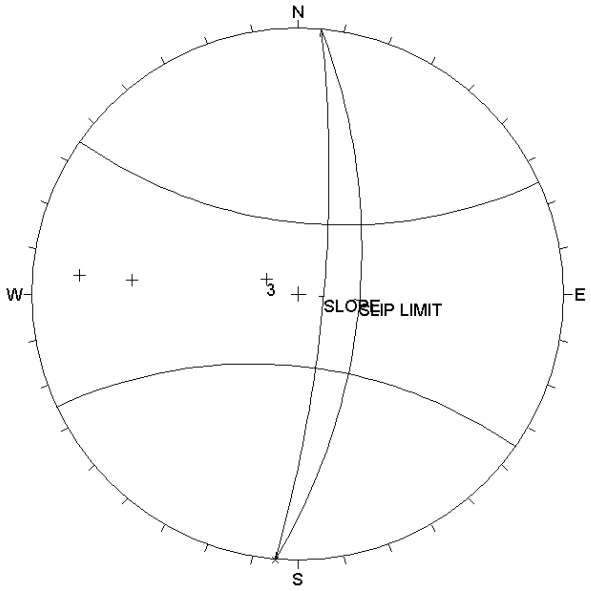



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 095 |
| 2 | 64 / 095 |
| 3 | 15 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / RIGHT TUBE PORTAL FACE

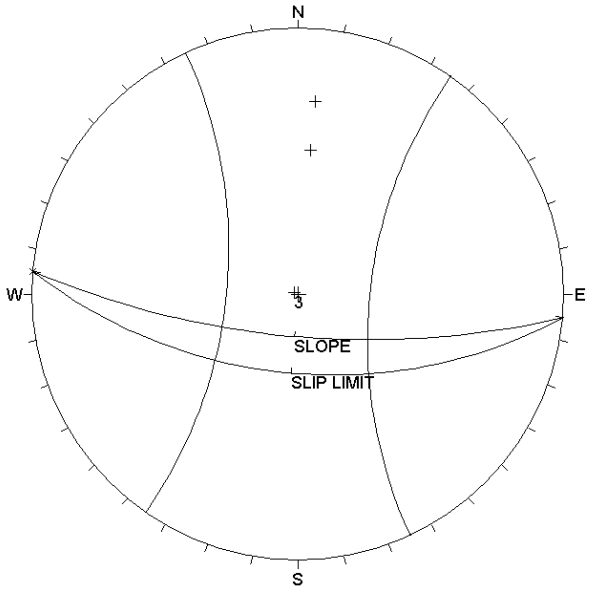



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 79 / 095 |
| 2 | 64 / 095 |
| 3 | 15 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE LEFT CUT

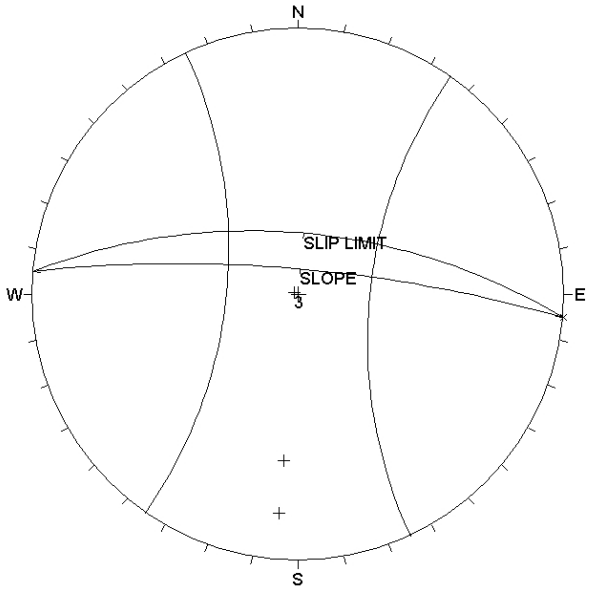



Orientations

| ID | Dip / Direction |
|---|---|
| 1 | 72 / 185 |
| 2 | 57 / 185 |
| 3 | 02 / 115 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / LEFT TUBE RIGHT CUT

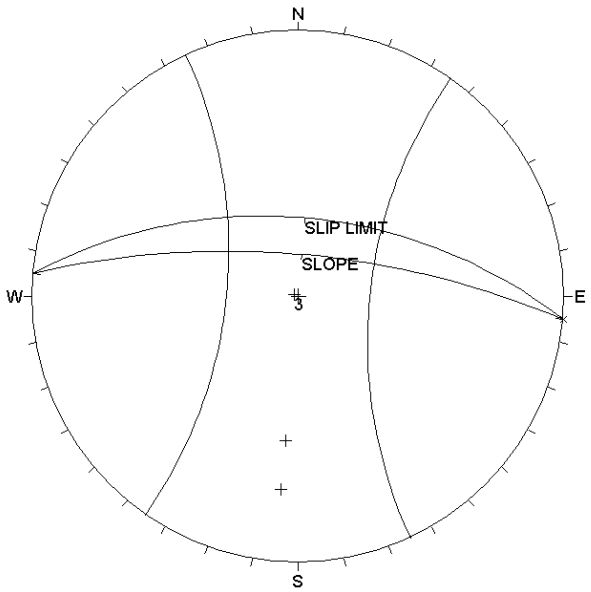



Orientations

| ID | Dip / Direction |
|---|---|
| 3 | 02 / 115 |
| 1 | 79 / 005 |
| 2 | 64 / 005 |

Equal Angle
Lower Hemisphere
0 Poles
0 Entries

## ÖCELİ (T-2) TUNNEL EXIT PORTAL / RIGHT TUBE RIGHT CUT



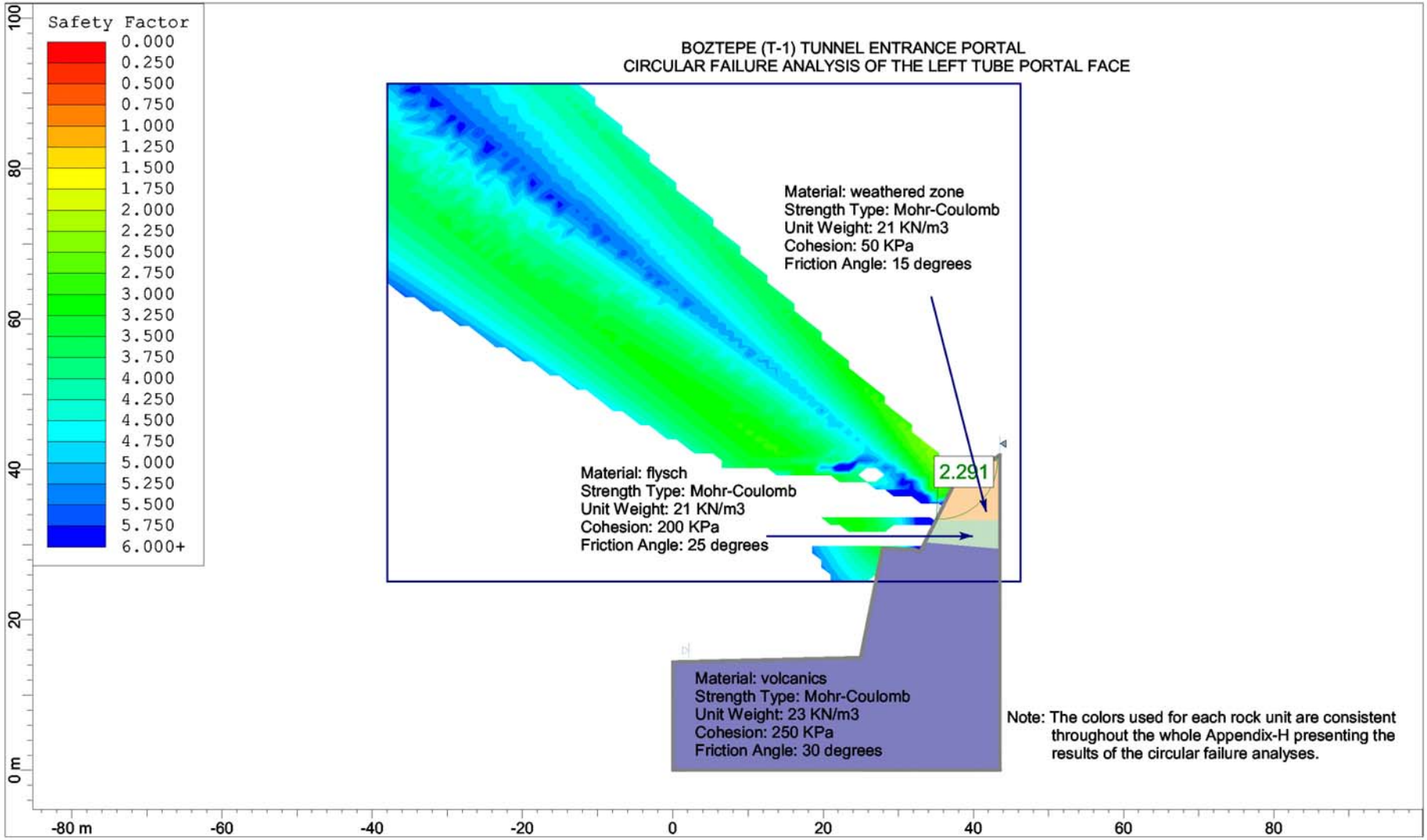

Orientations

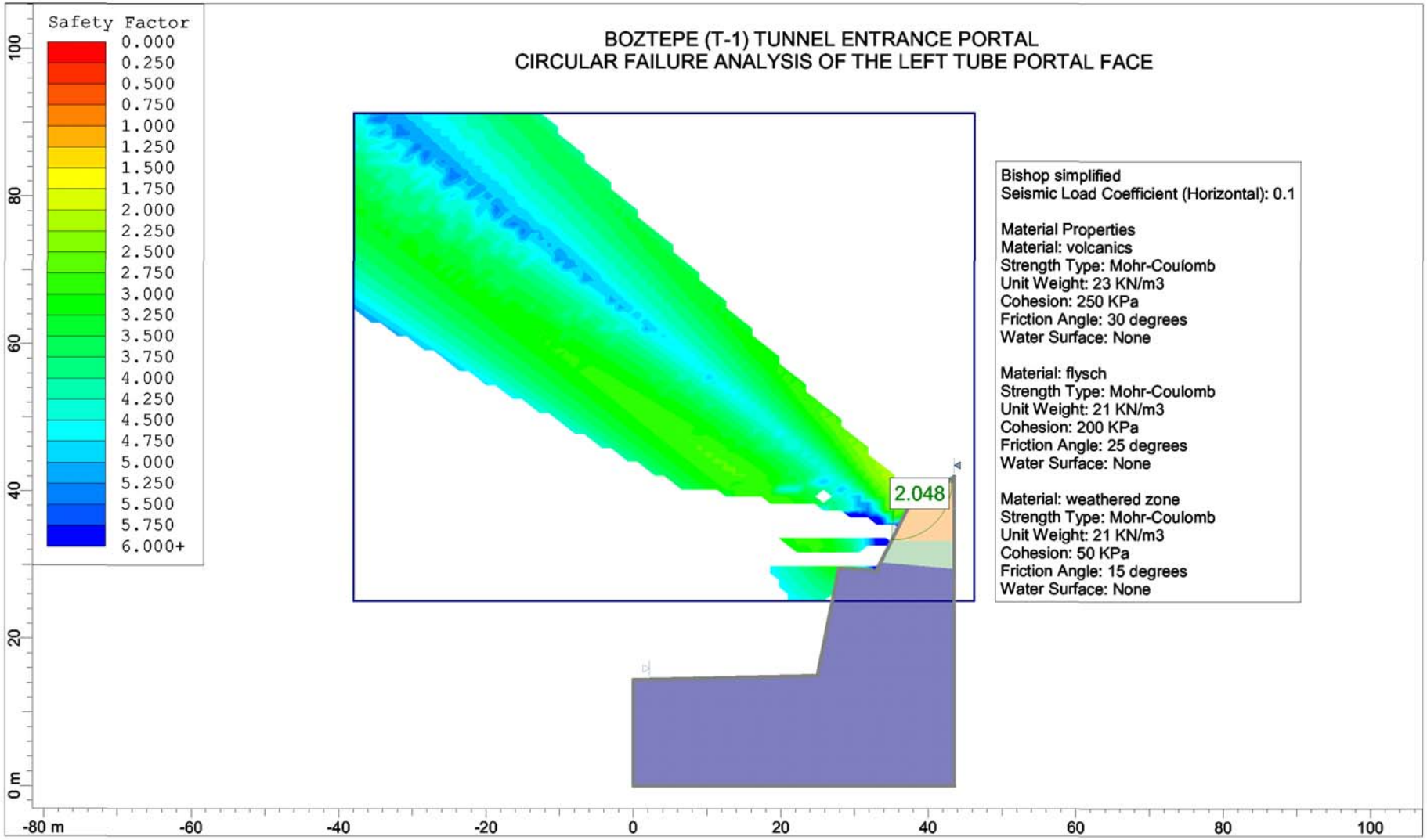
| ID | Dip / Direction |
|---|---|
| 3 | 02 / 115 |
| 1 | 72 / 005 |
| 2 | 57 / 005 |

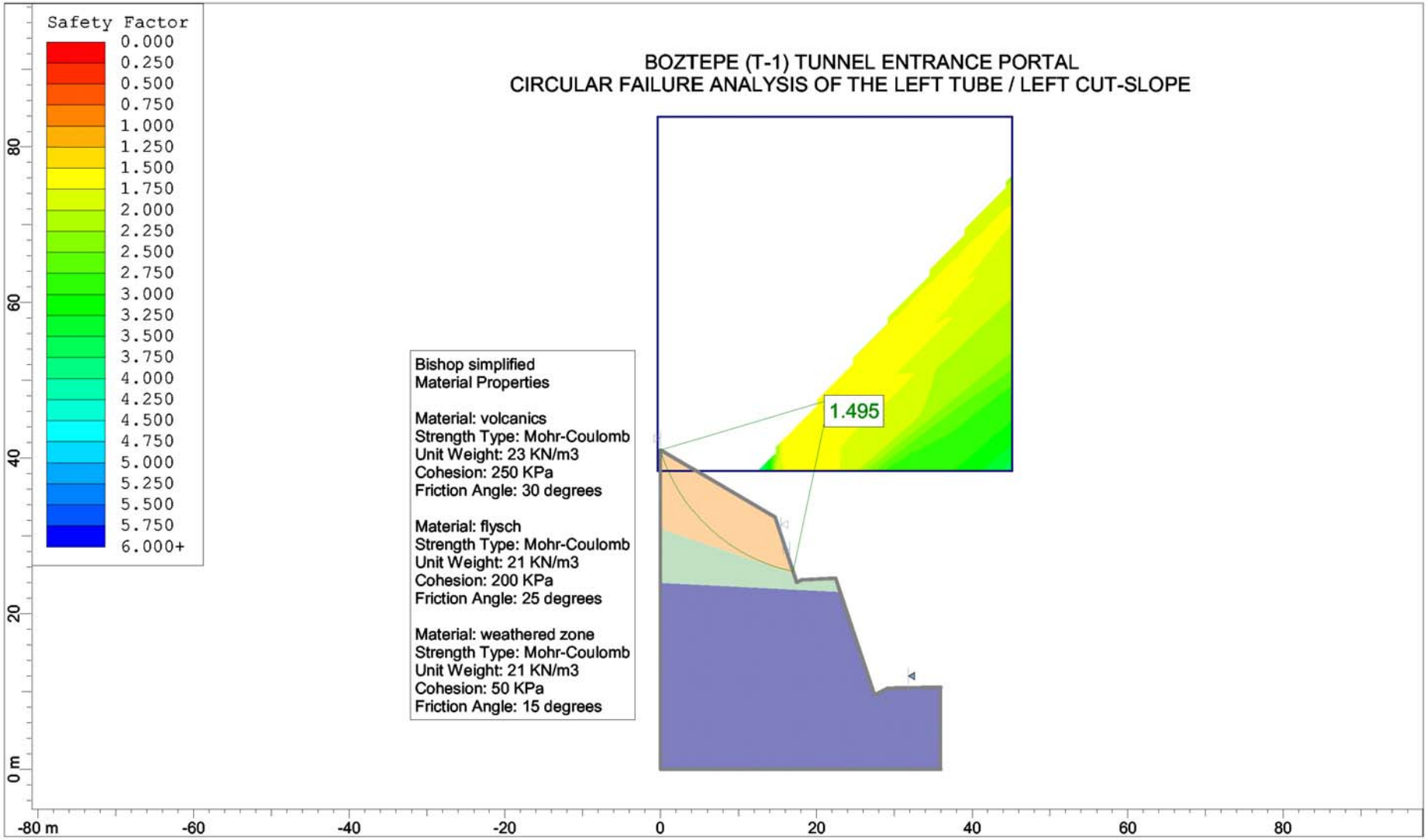
Equal Angle
Lower Hemisphere
0 Poles
0 Entries

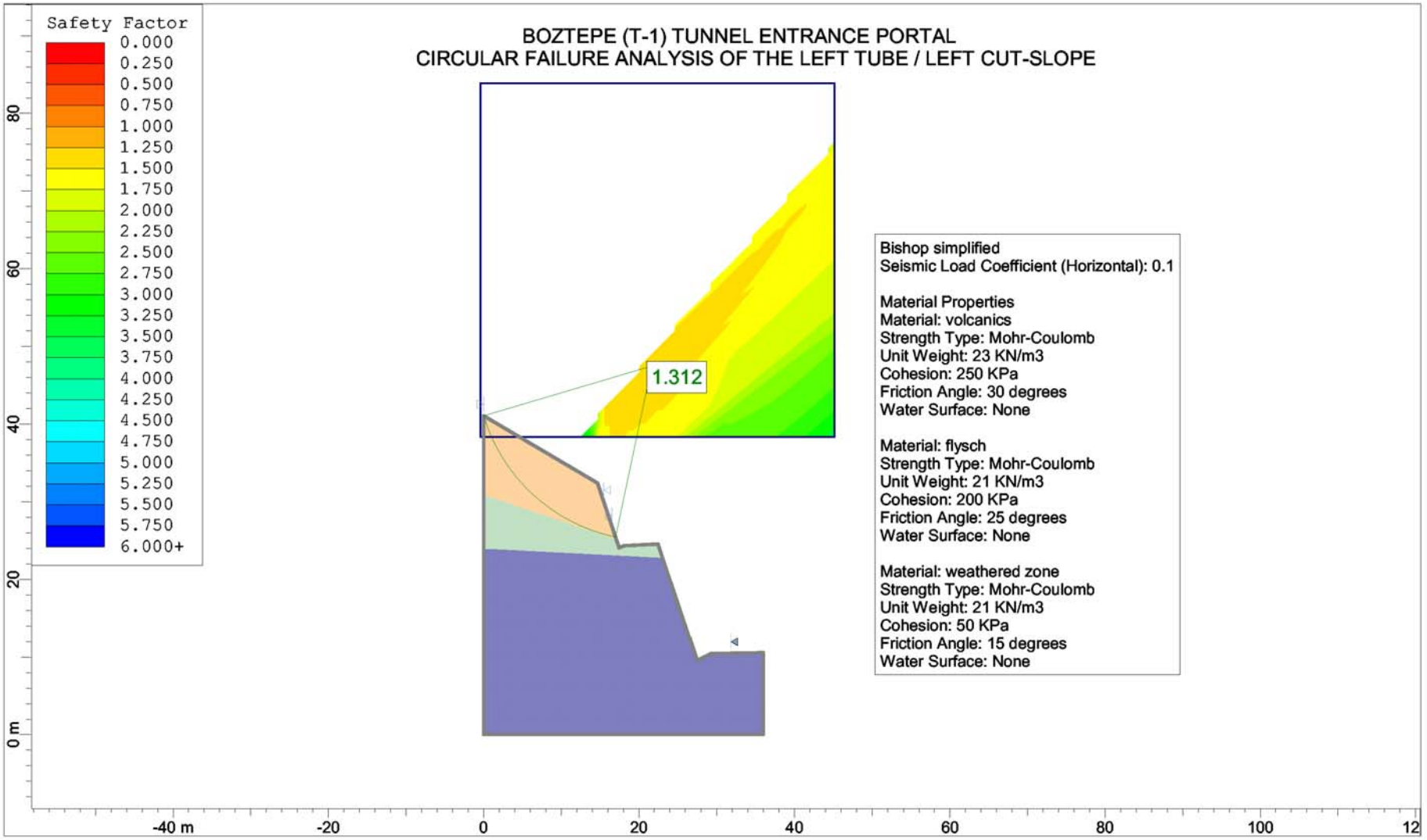
# APPENDIX – H
# CIRCULAR FAILURE ANALYSES RESULTS

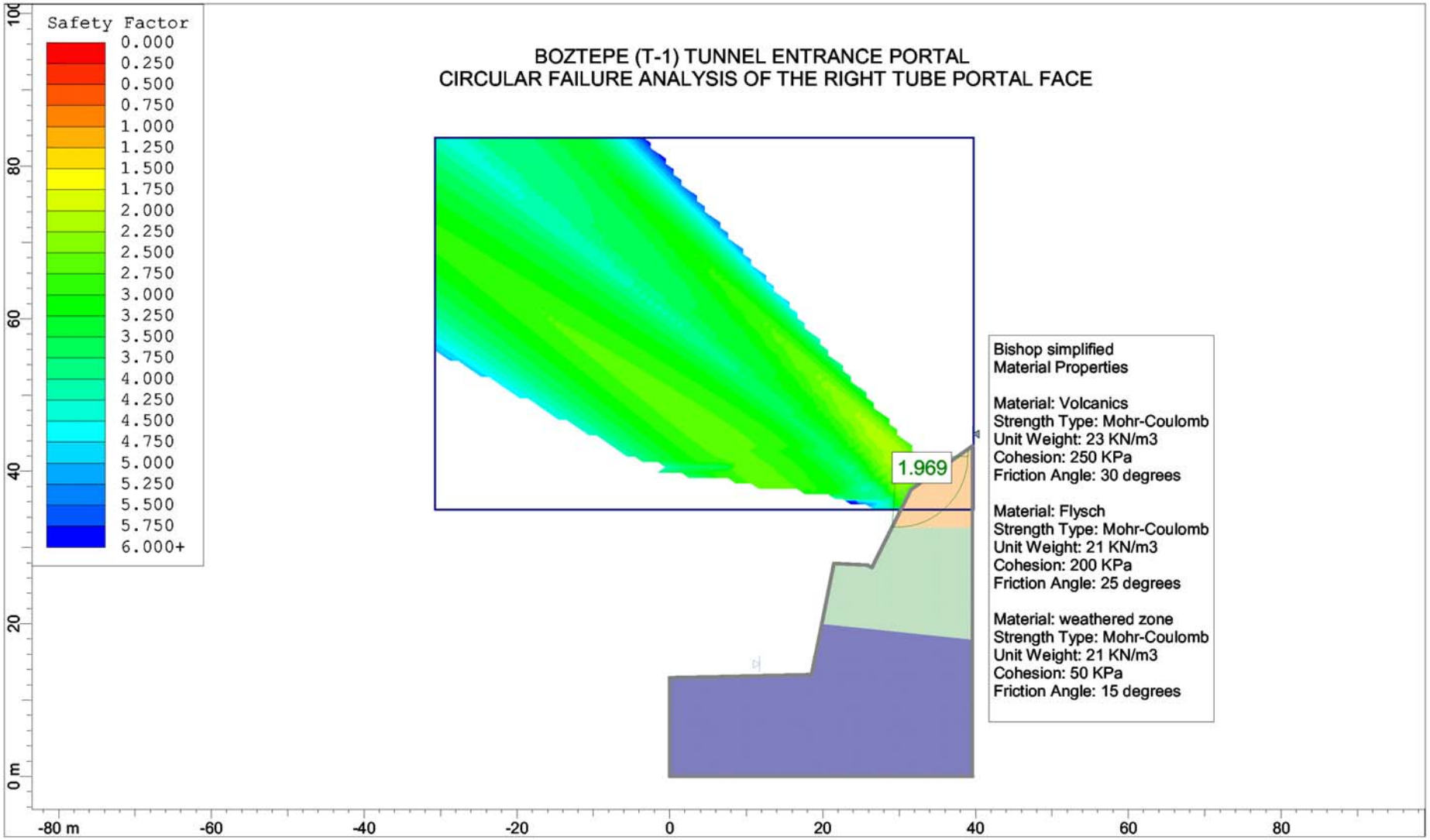
## THE BOZTEPE (T-1) TUNNEL

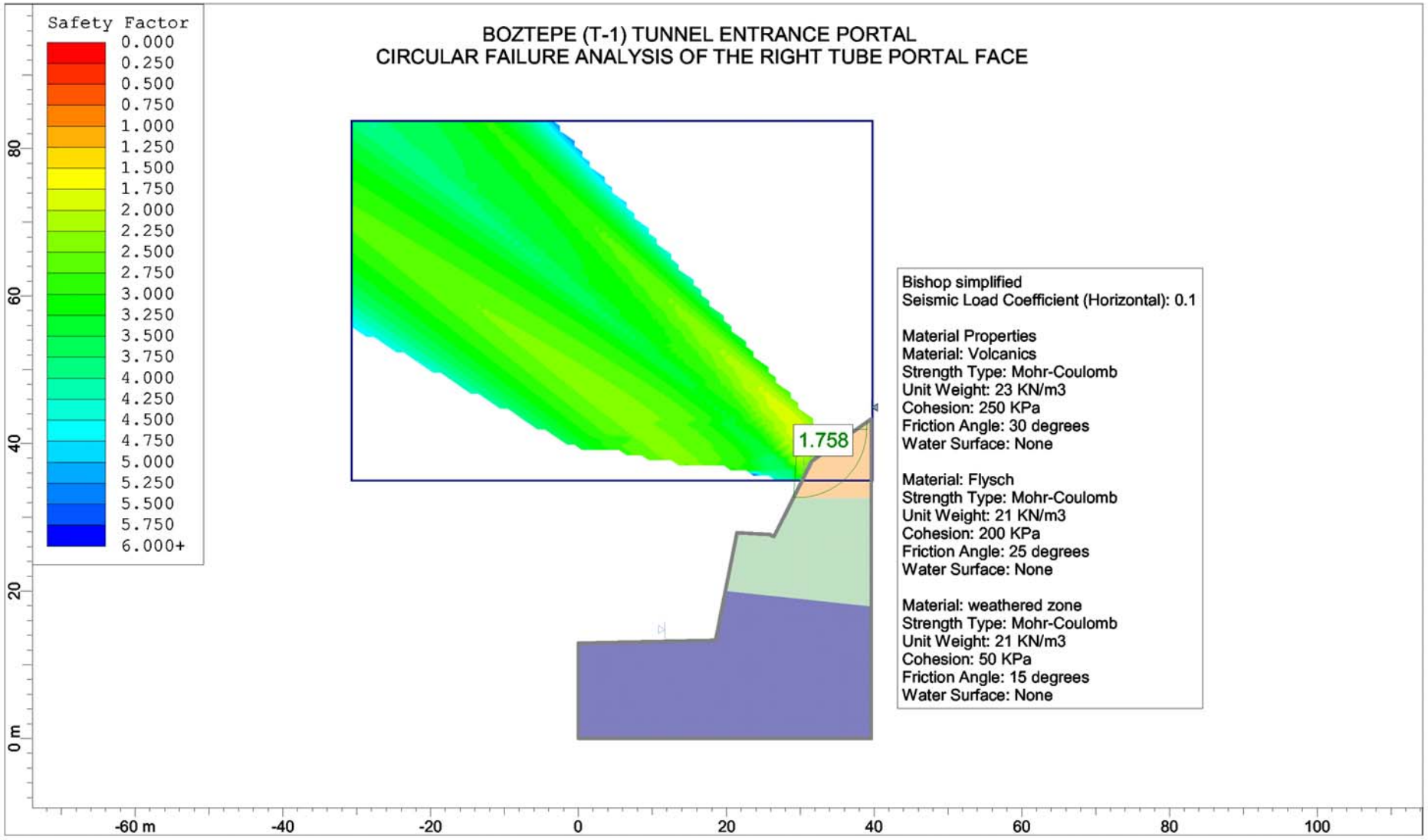

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
2.291
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Note: The colors used for each rock unit are consistent throughout the whole Appendix-H presenting the results of the circular failure analyses.
100
80
60
40
20
0 m
-80 m
-60
-40
-20
0
20
40
60
80

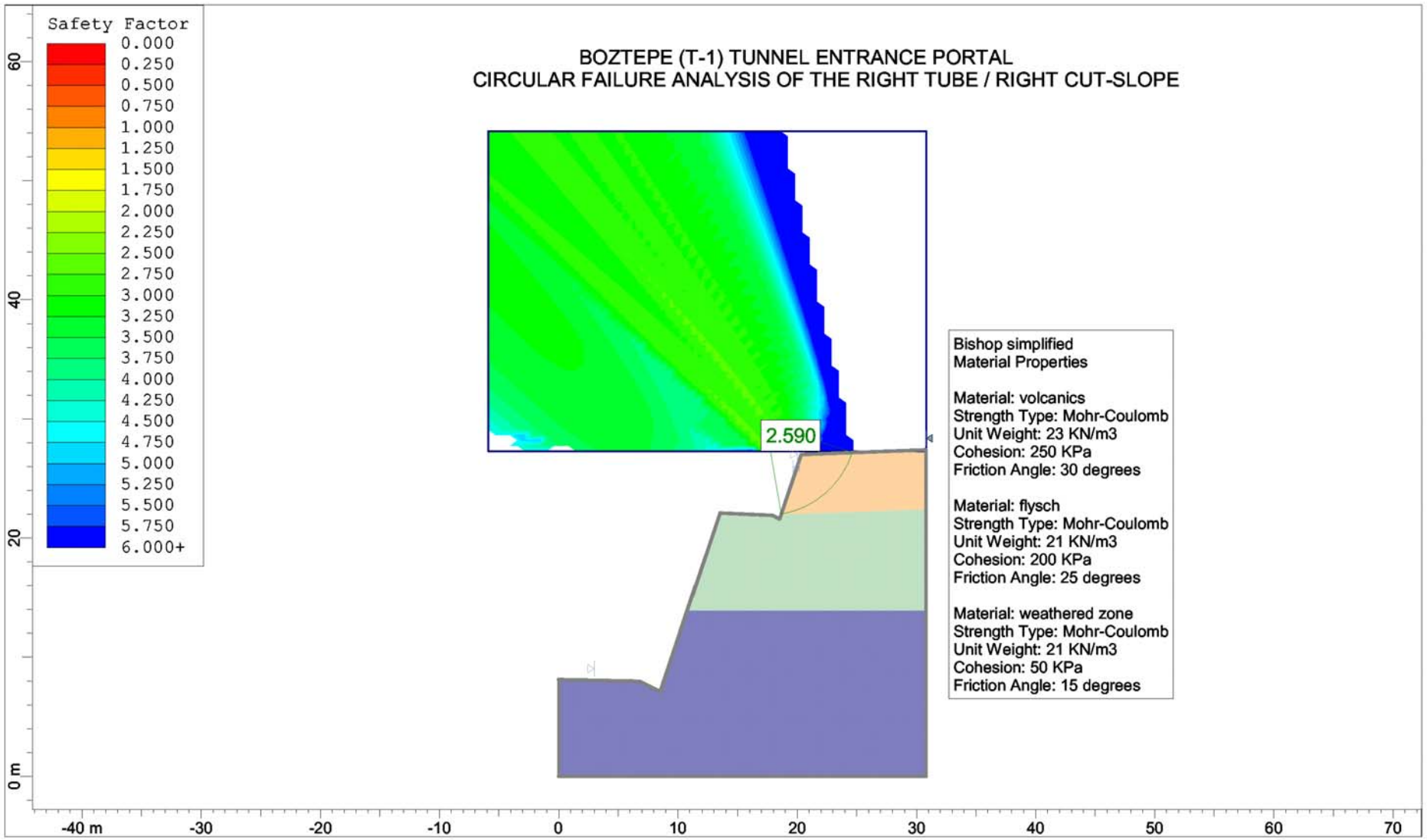

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.048
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
100
80
60
40
20
0 m
-80 m
-60
-40
-20
0
20
40
60
80
100

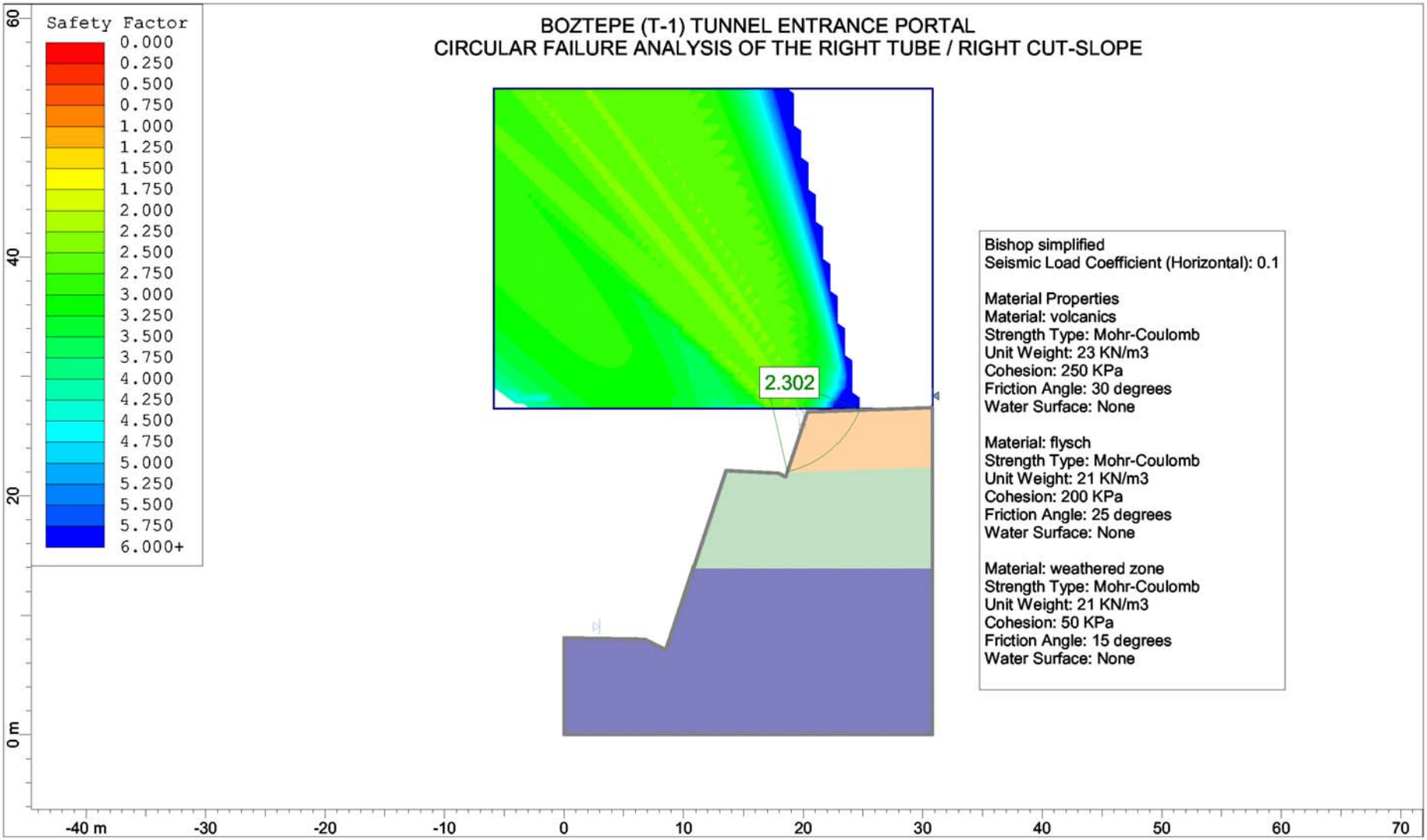

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
1.495
0 m
20
40
60
80
-80 m
-60
-40
-20
0
20
40
60
80

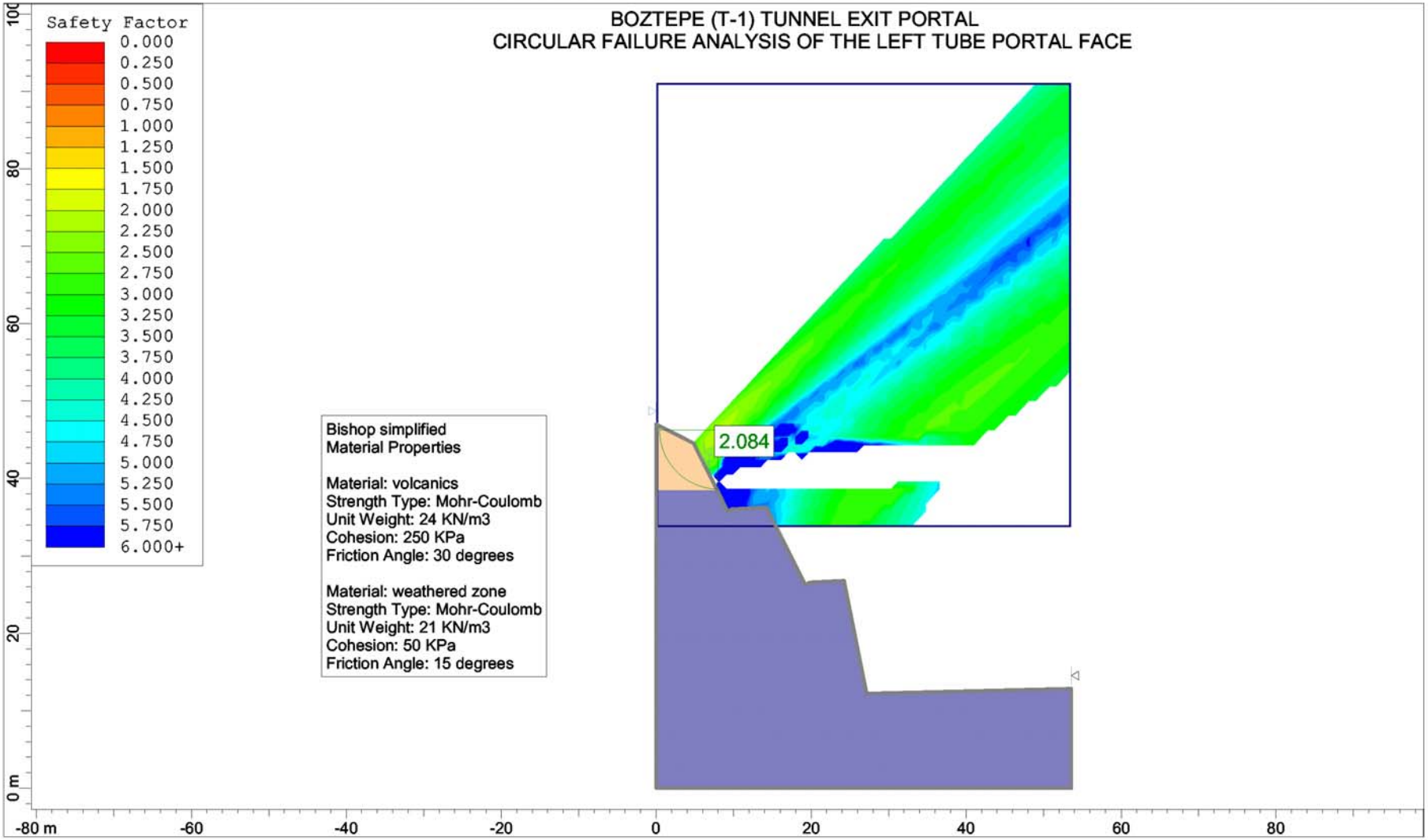

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.312
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
80
60
40
20
0 m
-40 m
-20
0
20
40
60
80
100
12

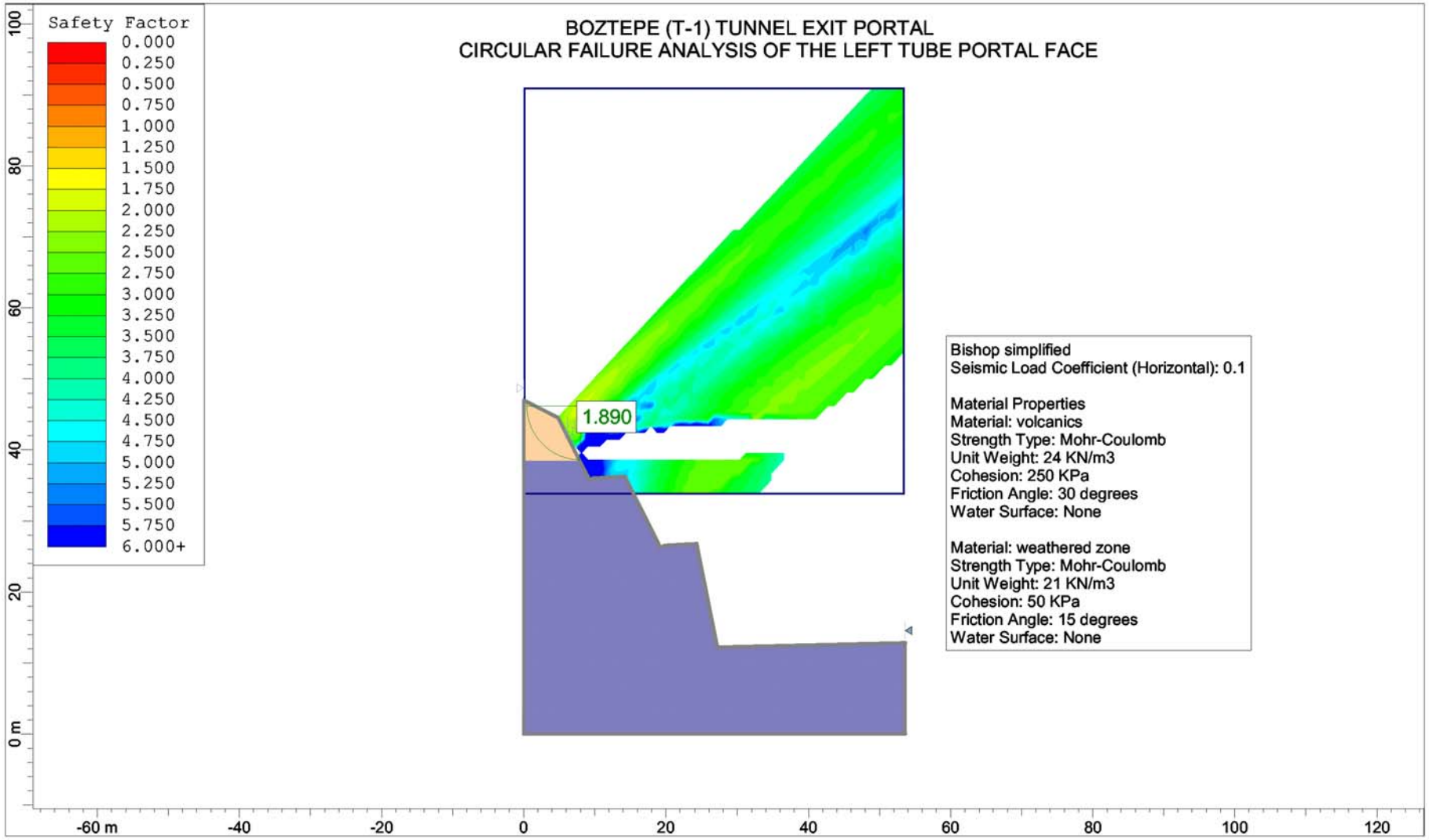

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.969
Bishop simplified
Material Properties
Material: Volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: Flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
100
80
60
40
20
0 m
-80 m
-60
-40
-20
0
20
40
60
80

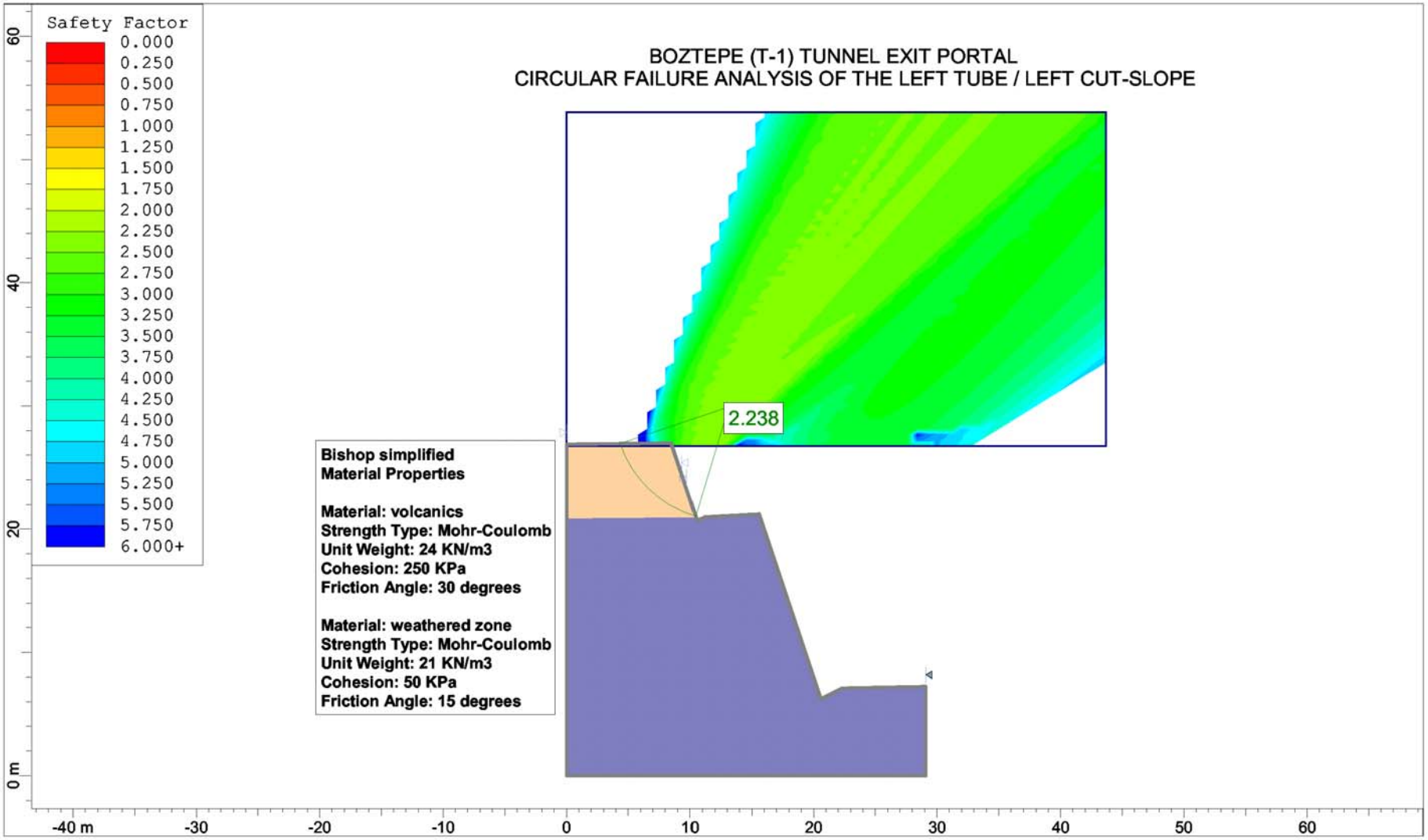

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.758
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: Volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: Flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
0 m
20
40
60
80
-60 m
-40
-20
0
20
40
60
80
100

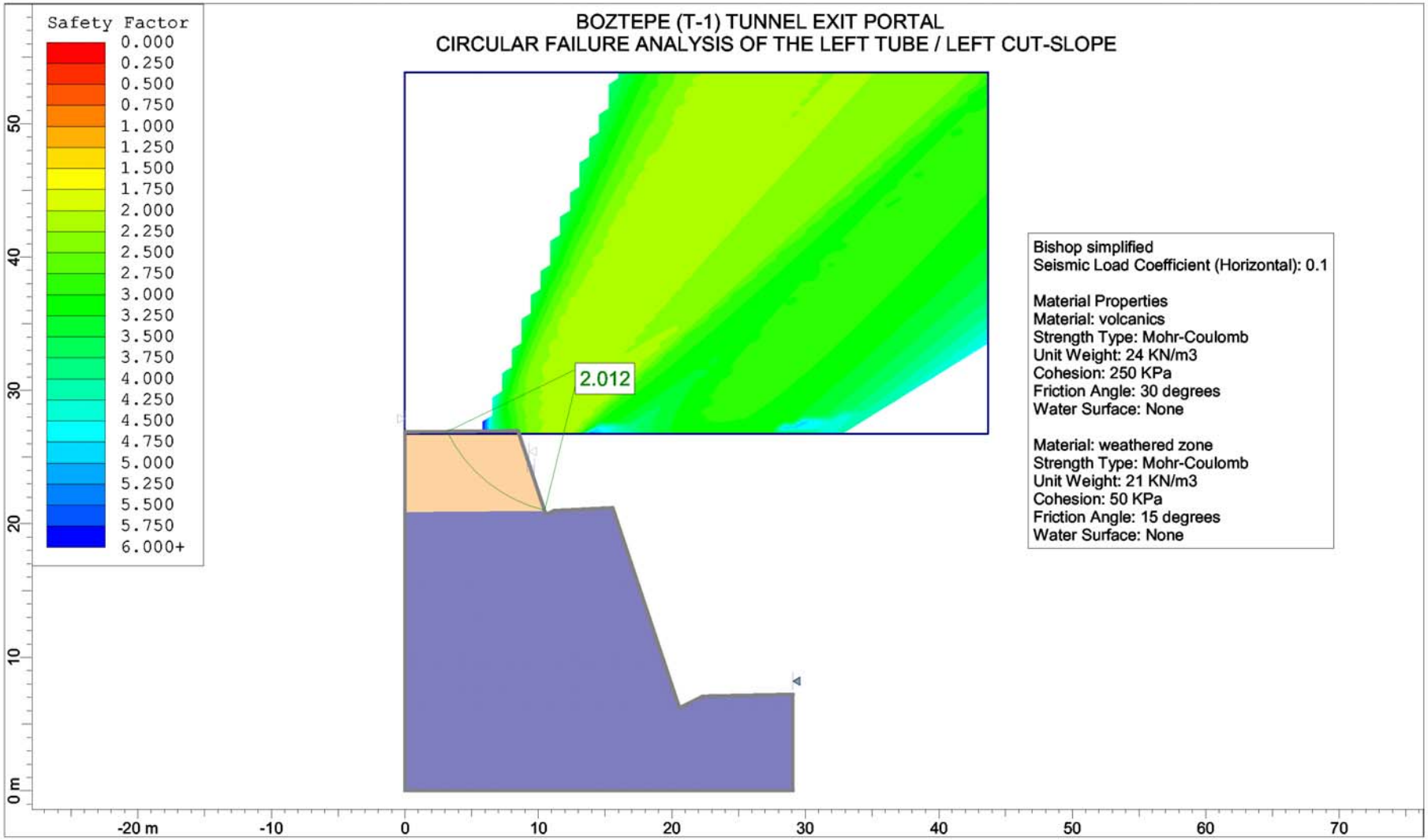

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
2.590
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
60
40
20
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50
60
70

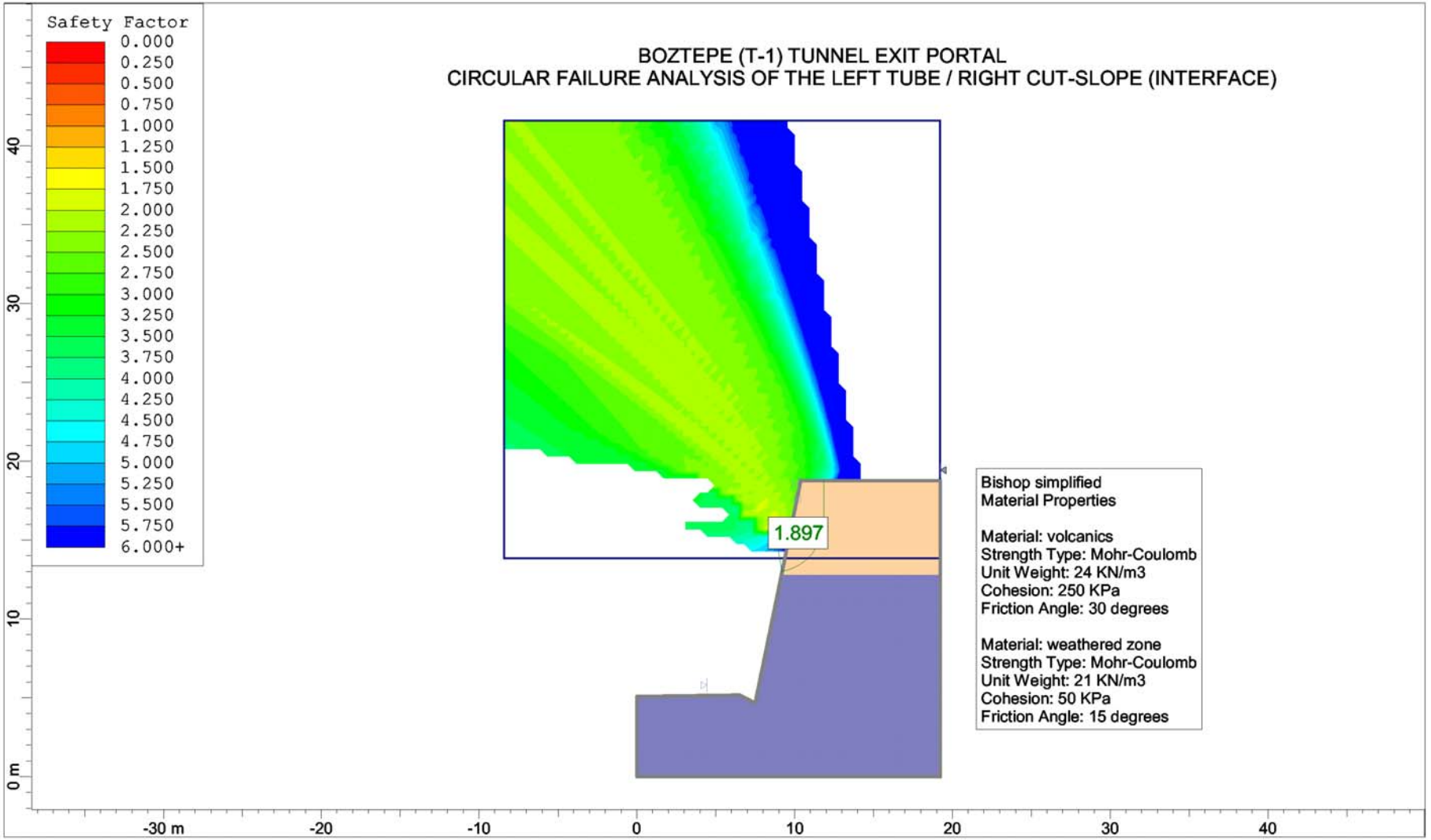

BOZTEPE (T-1) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.302
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
60
40
20
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50
60
70

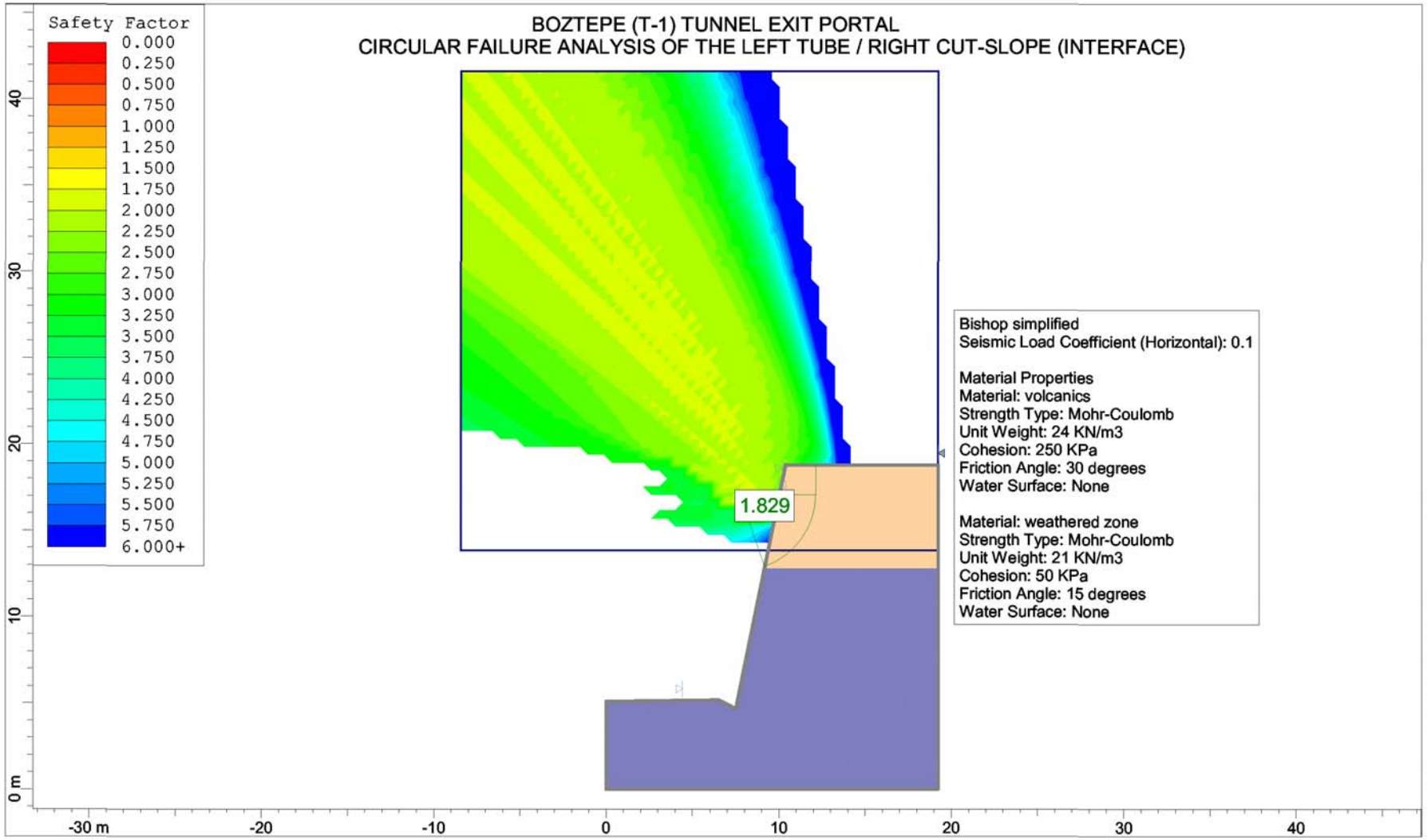

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
2.084
100
80
60
40
20
0 m
-80 m
-60
-40
-20
0
20
40
60
80

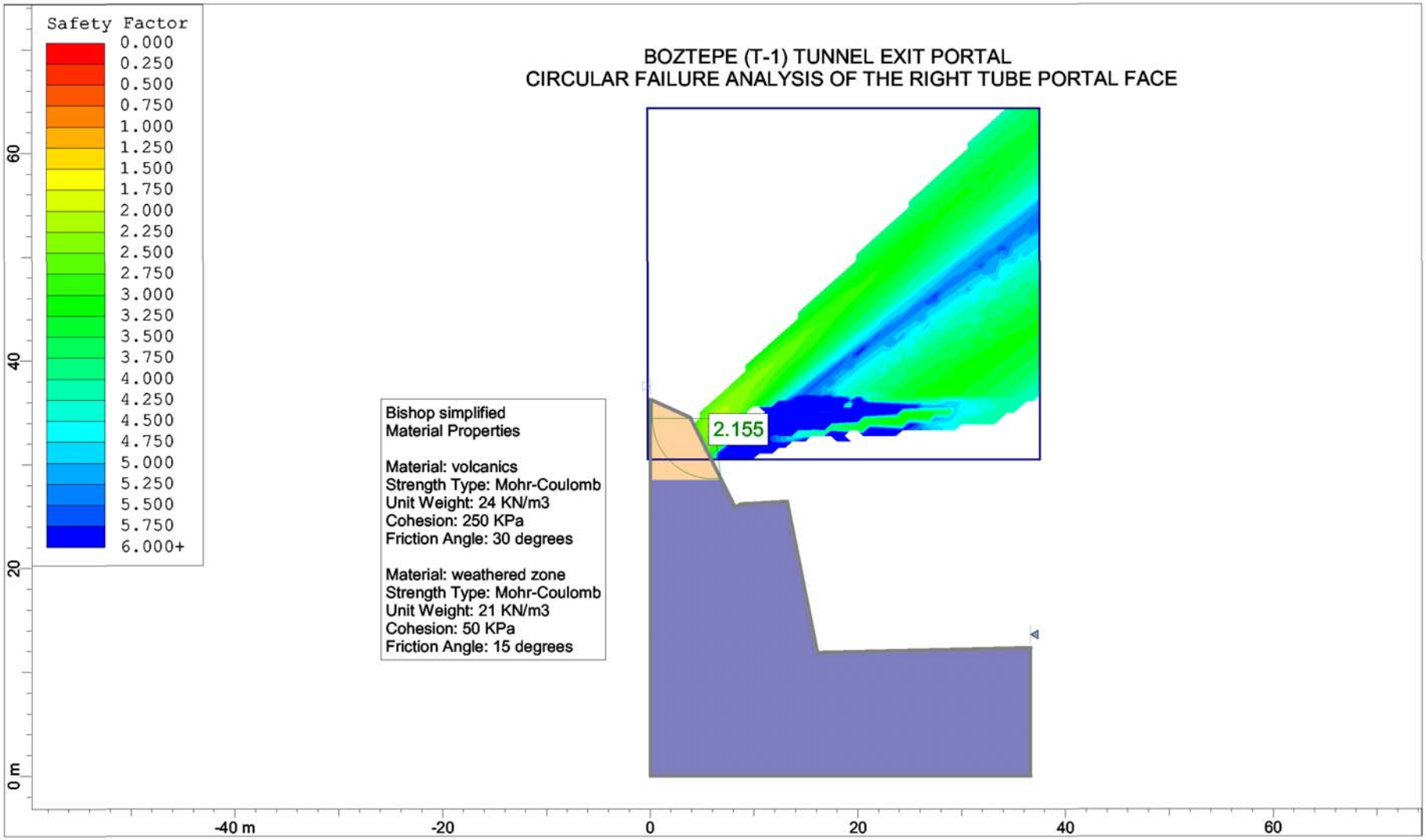

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.890
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
100
80
60
40
20
0 m
-60 m
-40
-20
0
20
40
60
80
100
120

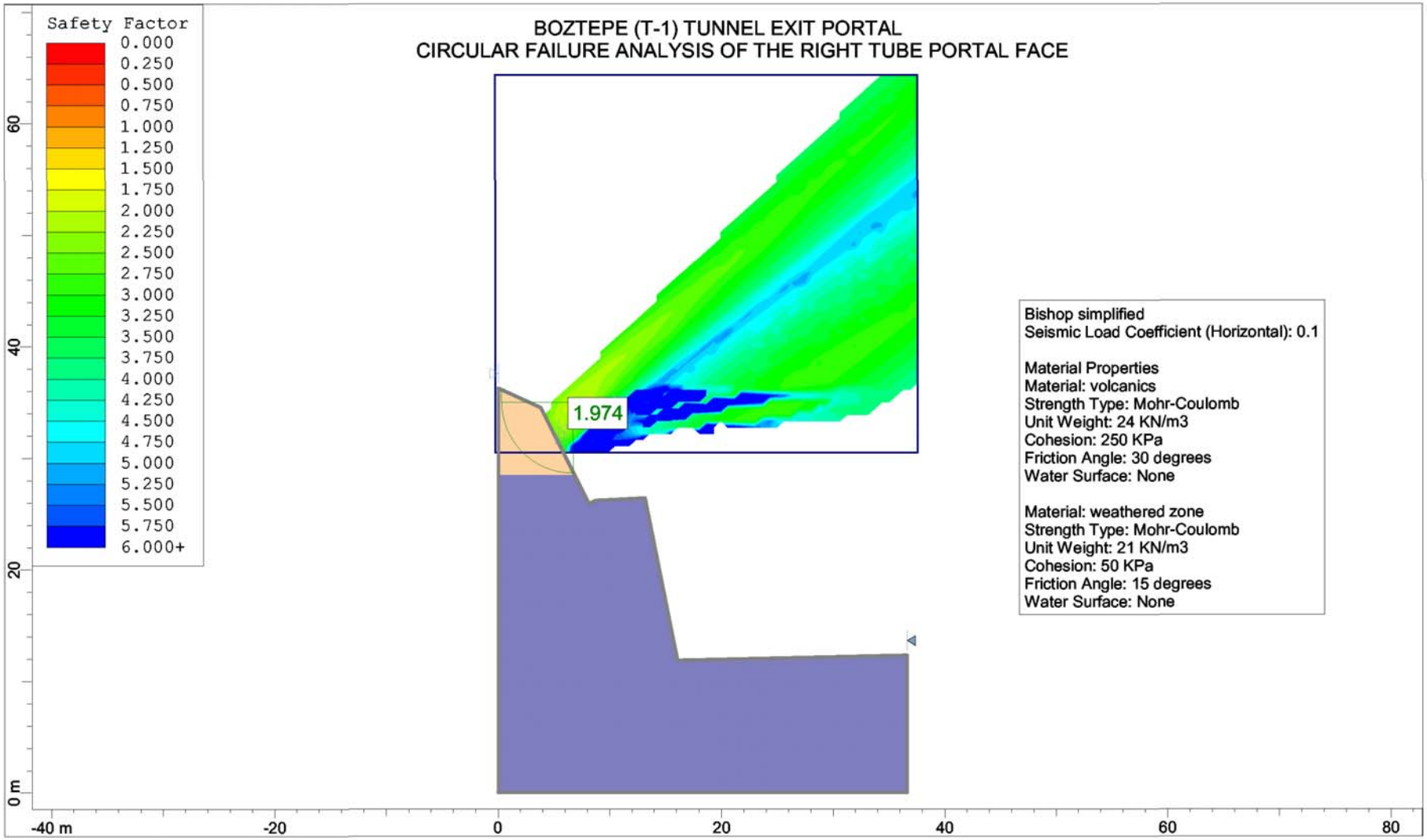

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.238
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
60
40
20
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50
60

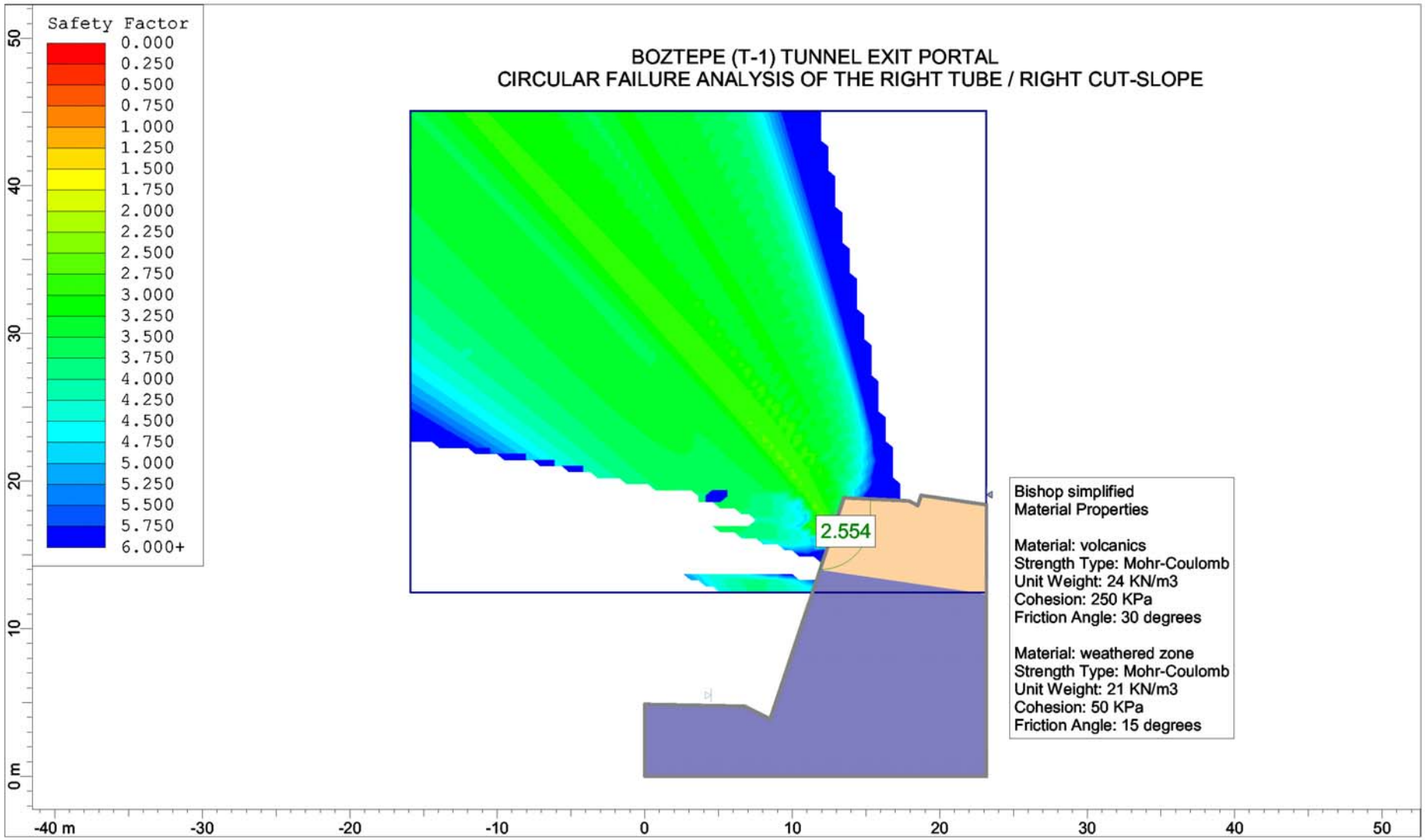

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.012
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
0 m
10
20
30
40
50
-20 m
-10
0
10
20
30
40
50
60
70

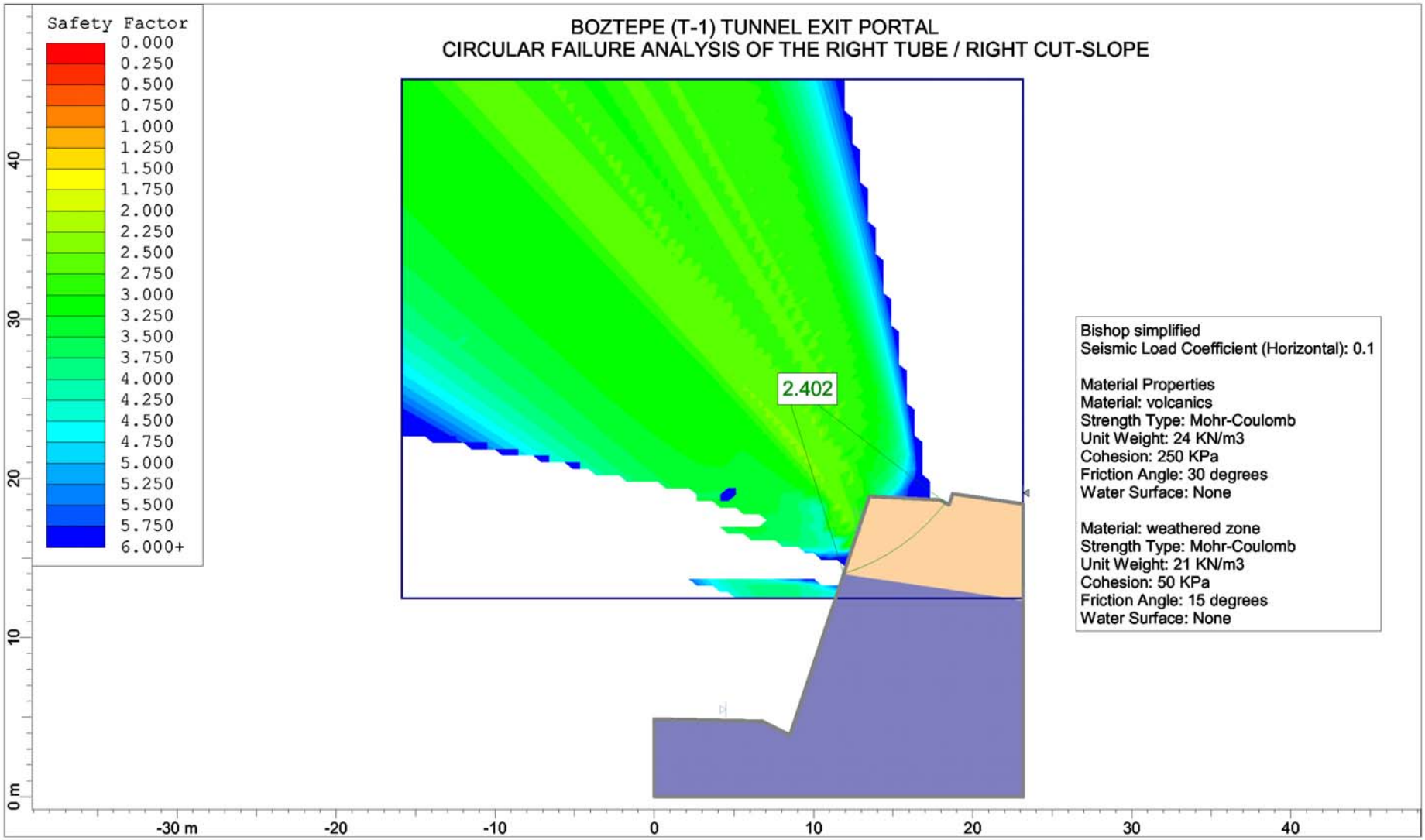

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / RIGHT CUT-SLOPE (INTERFACE)
1.897
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
0 m
10
20
30
40
-30 m
-20
-10
0
10
20
30
40


BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / RIGHT CUT-SLOPE (INTERFACE)
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.829
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
40
30
20
10
0 m
-30 m
-20
-10
0
10
20
30
40

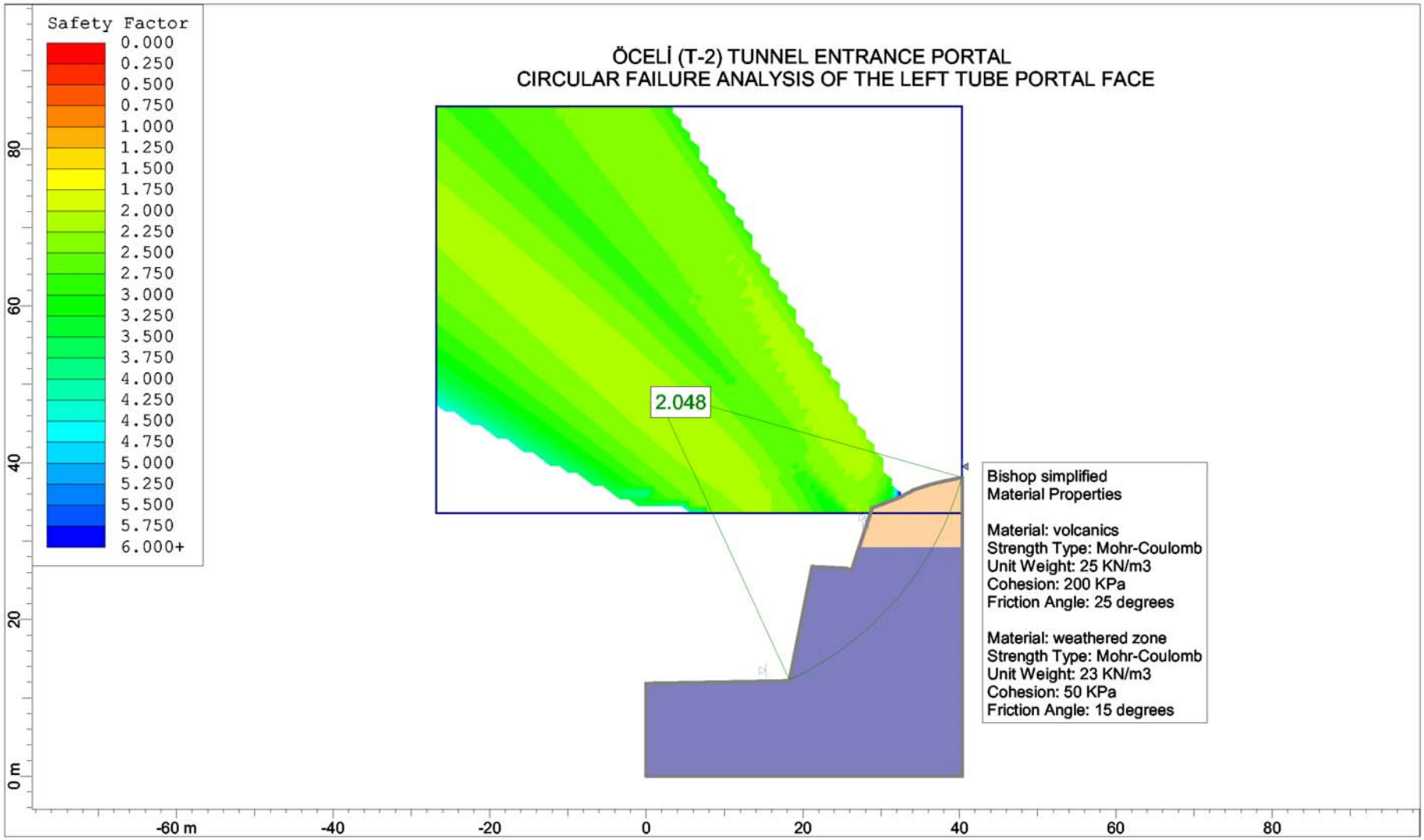

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
2.155
60
40
20
0 m
-40 m
-20
0
20
40
60

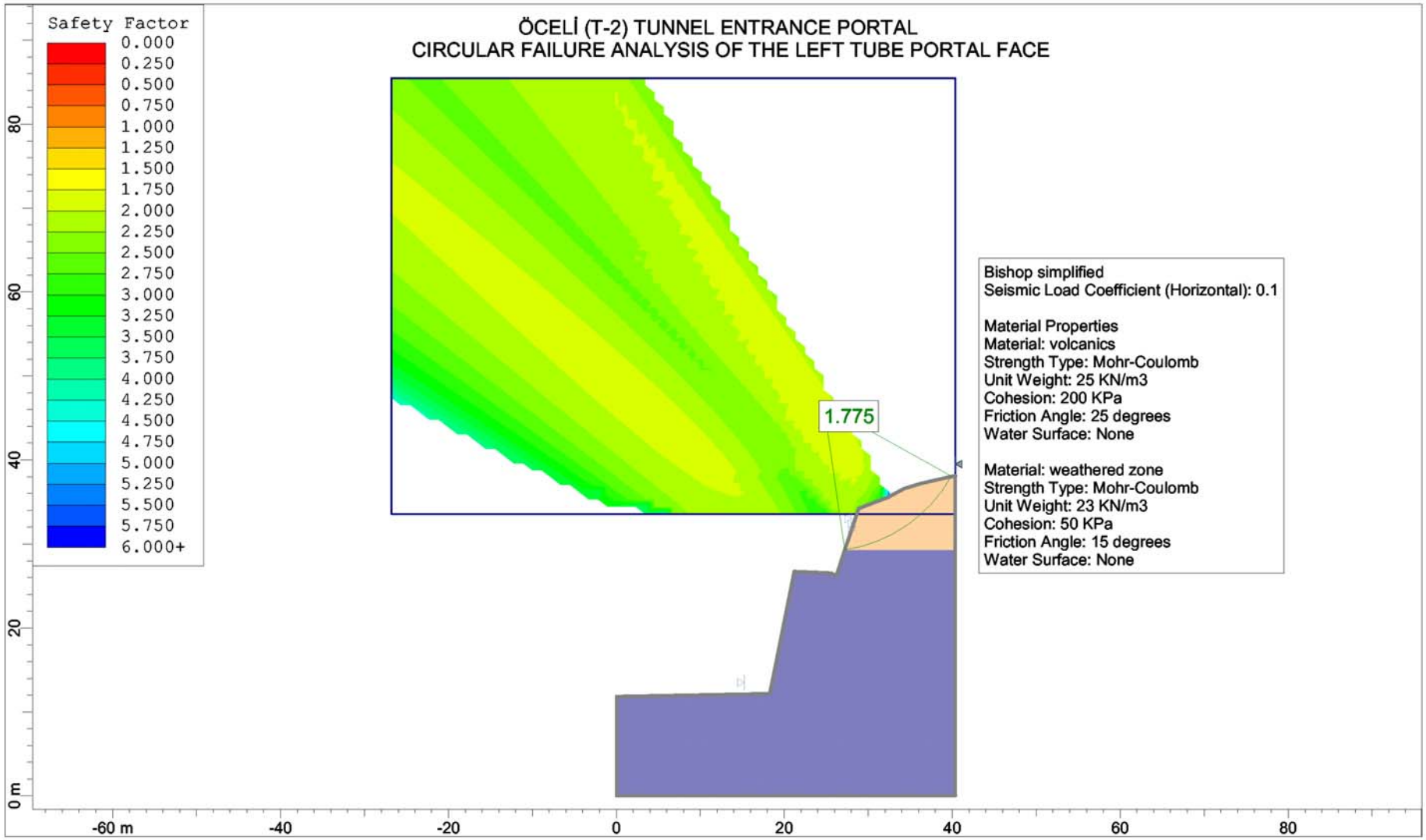

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.974
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
60
40
20
0 m
-40 m
-20
0
20
40
60
80

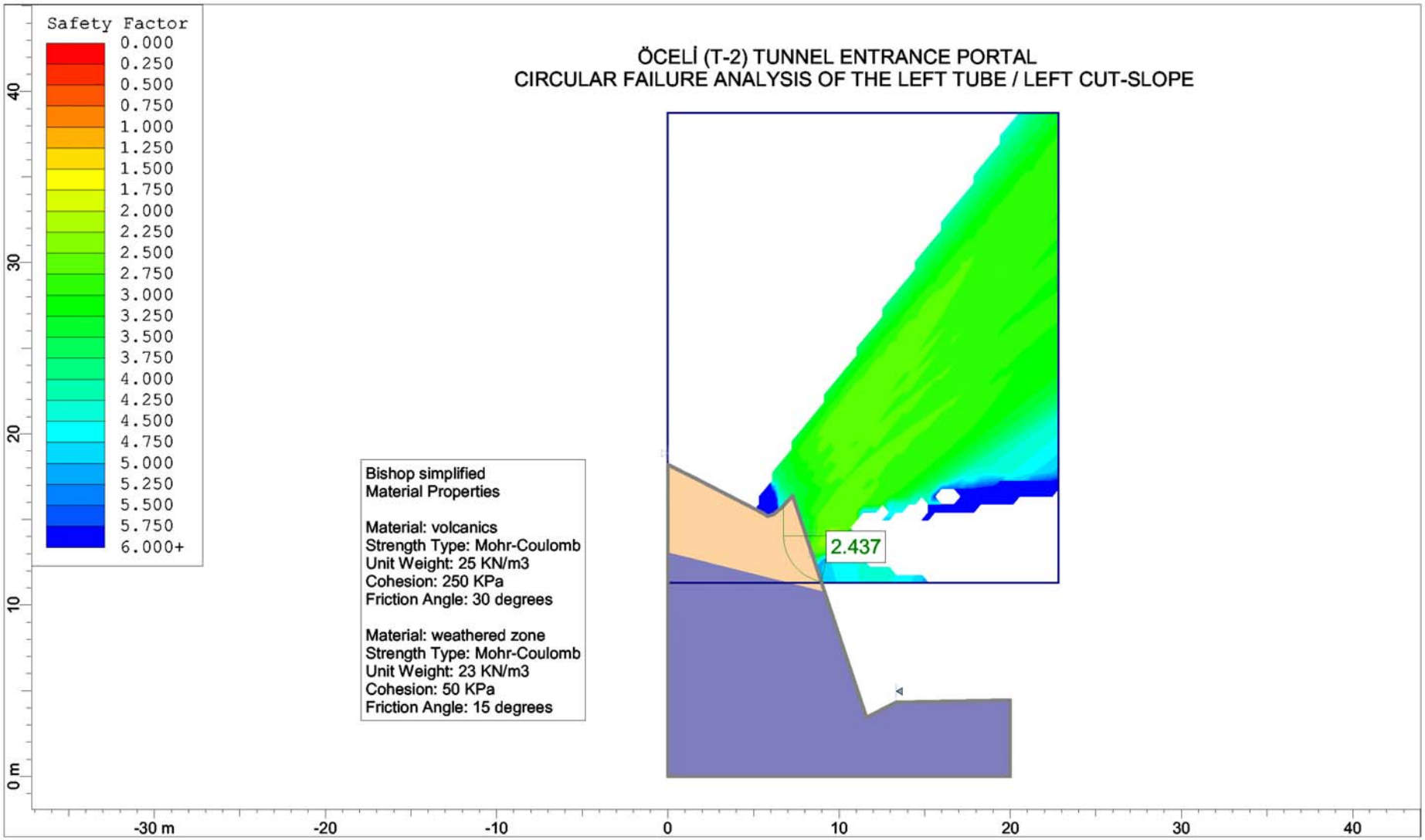

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.554
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
50
40
30
20
10
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50

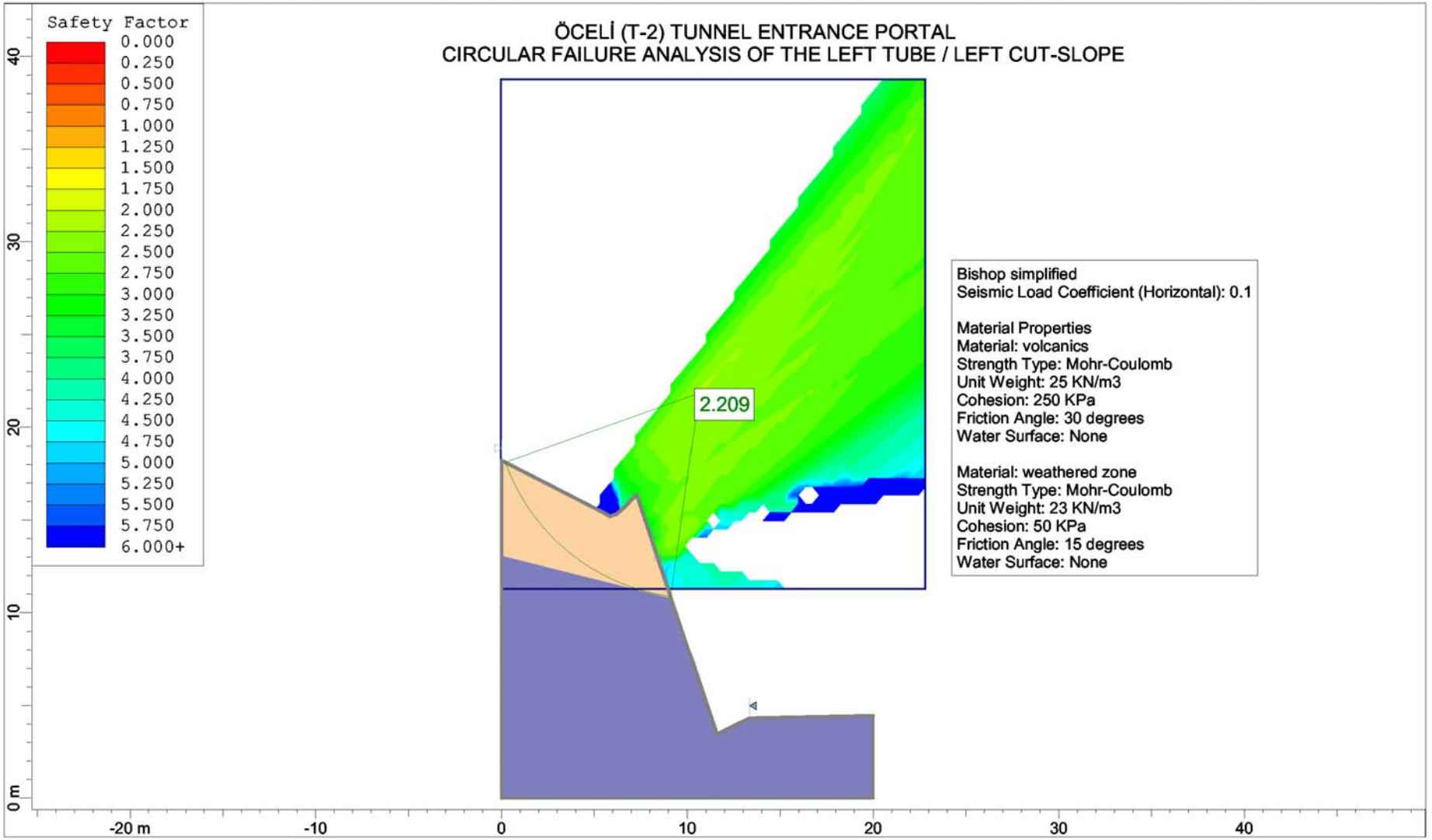

BOZTEPE (T-1) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.402
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 24 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 21 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
0 m
10
20
30
40
-30 m
-20
-10
0
10
20
30
40

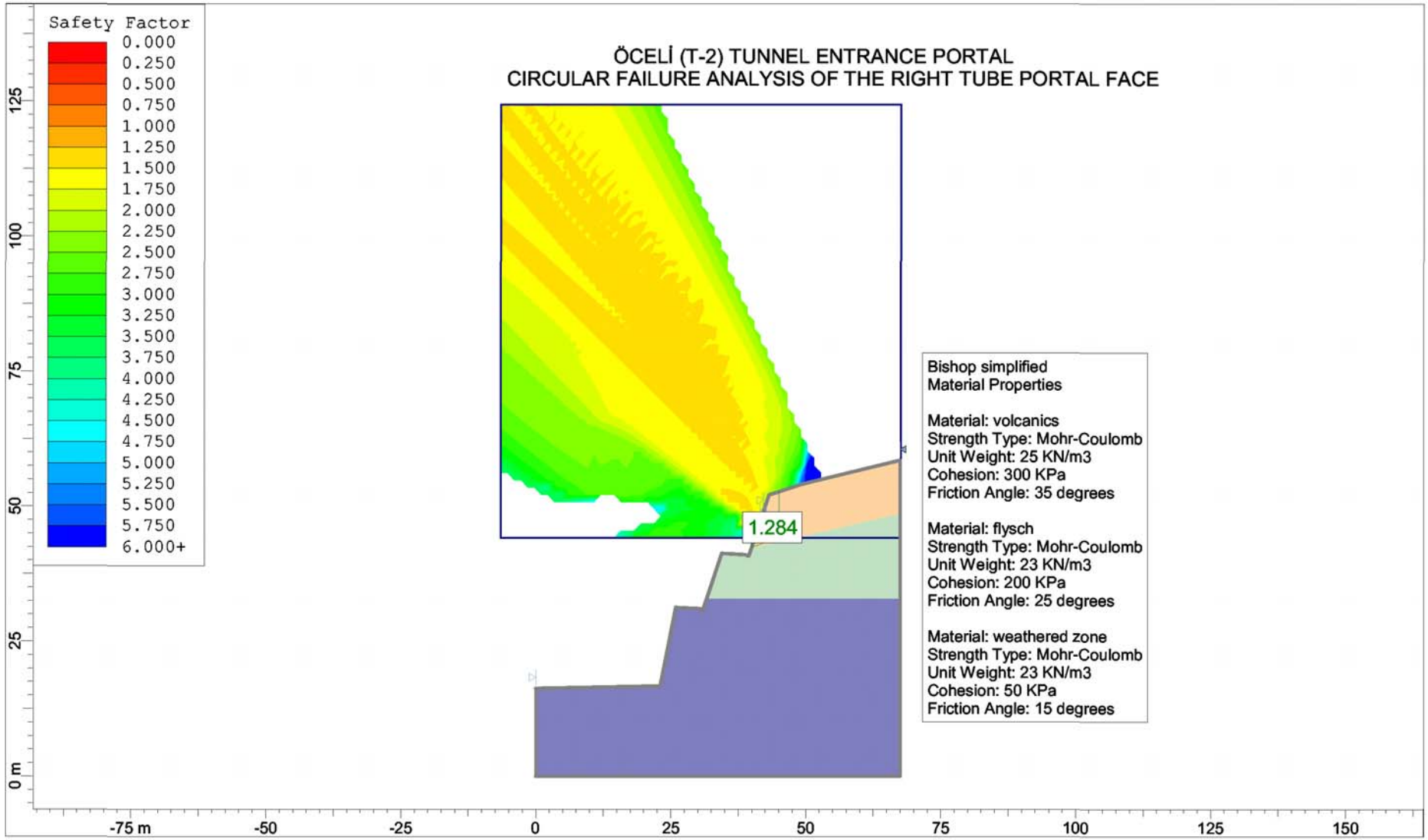
## THE ÖCELİ (T-2) TUNNEL

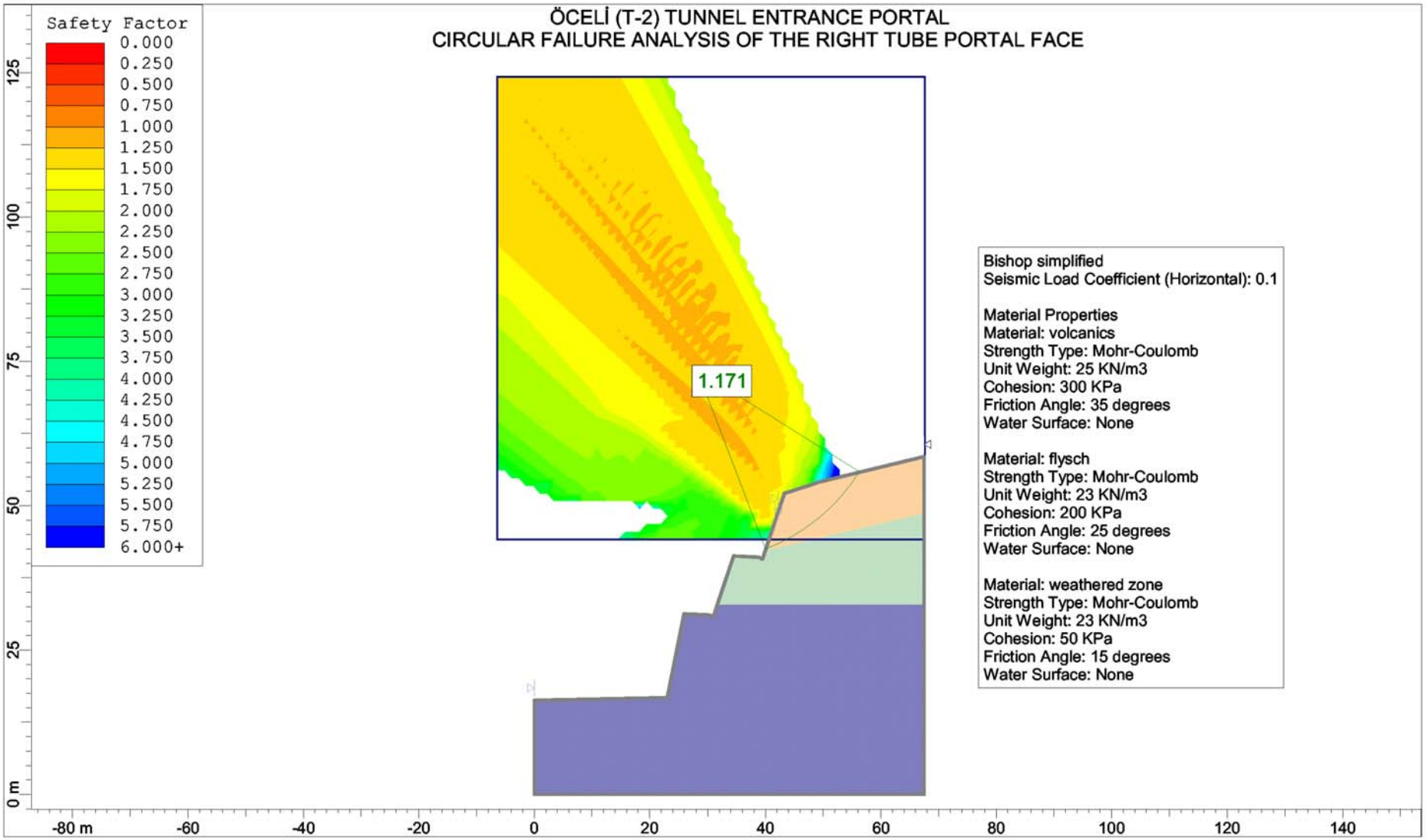

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.048
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
0 m
20
40
60
80
-60 m
-40
-20
0
20
40
60
80

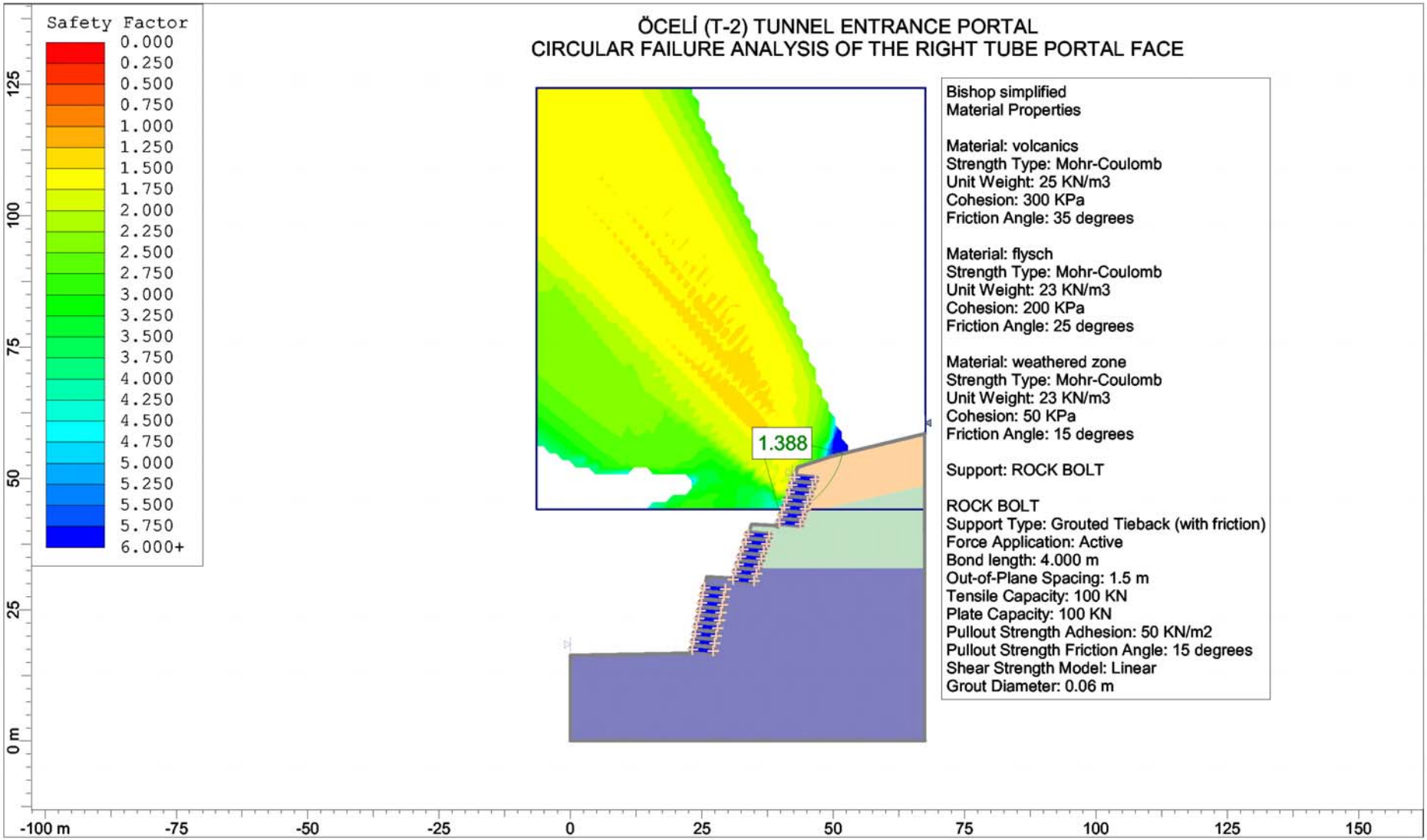

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.775
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
80
60
40
20
0 m
-60 m
-40
-20
0
20
40
60
80

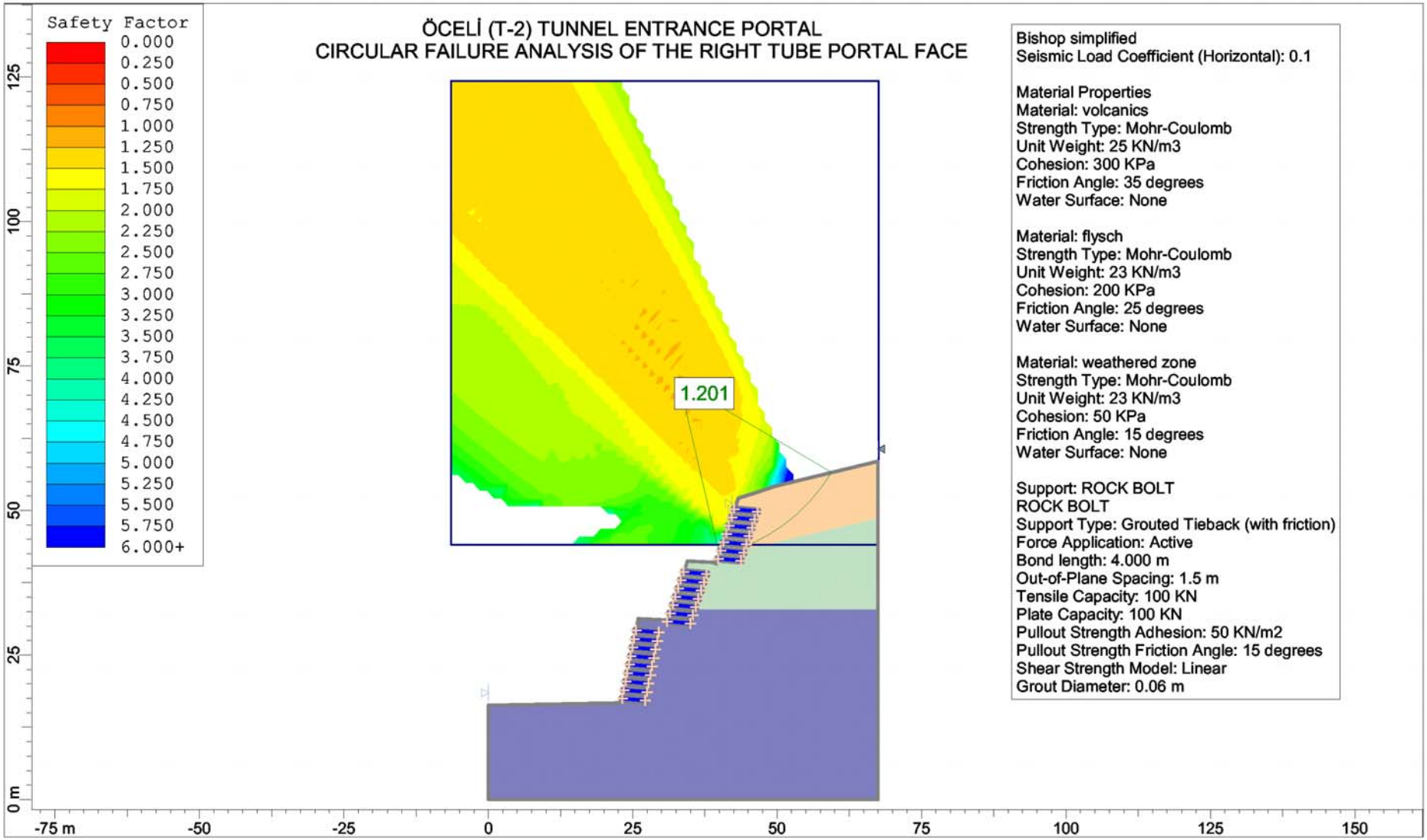

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
2.437
40
30
20
10
0 m
-30 m
-20
-10
0
10
20
30
40

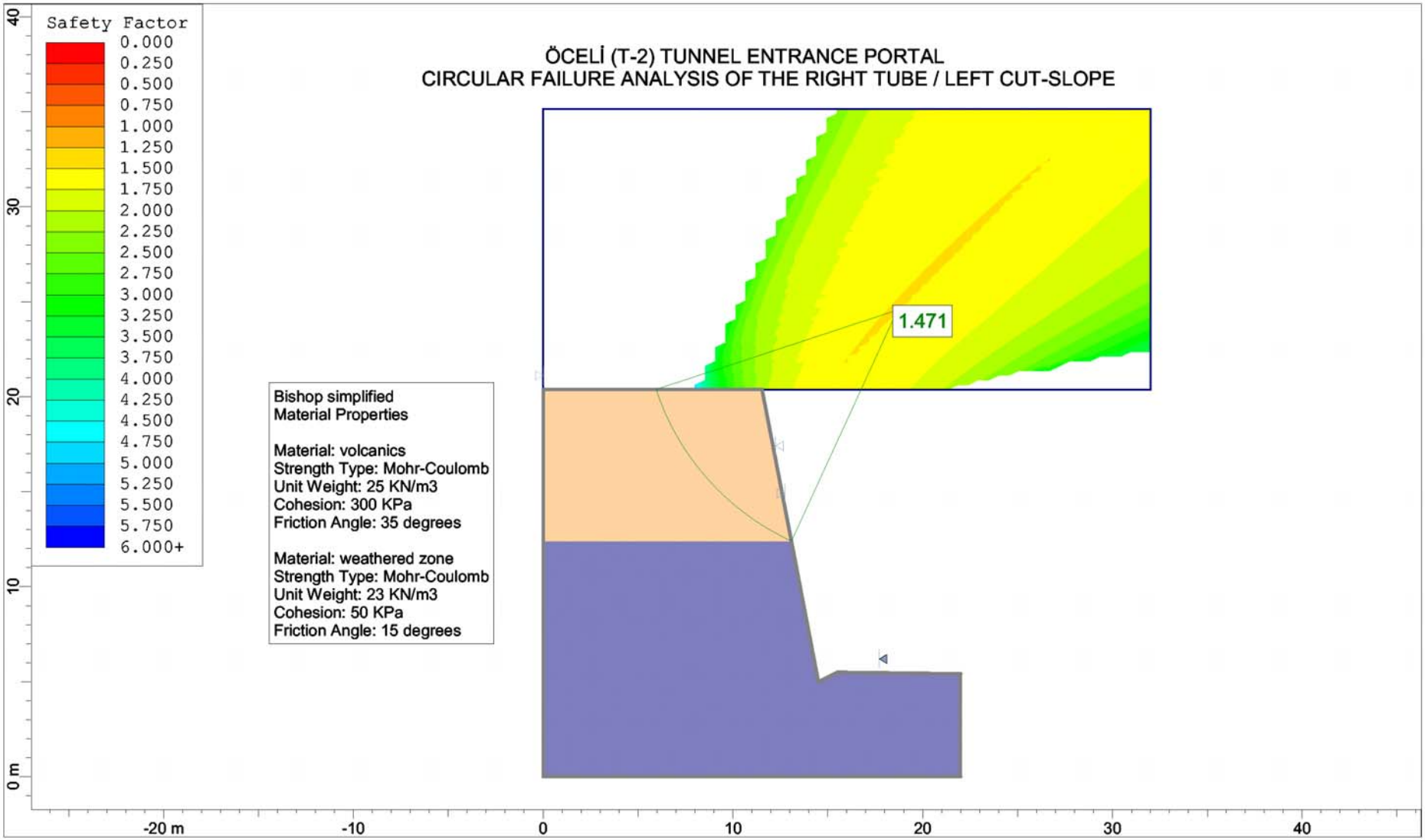

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.209
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
40
30
20
10
0 m
-20 m
-10
0
10
20
30
40

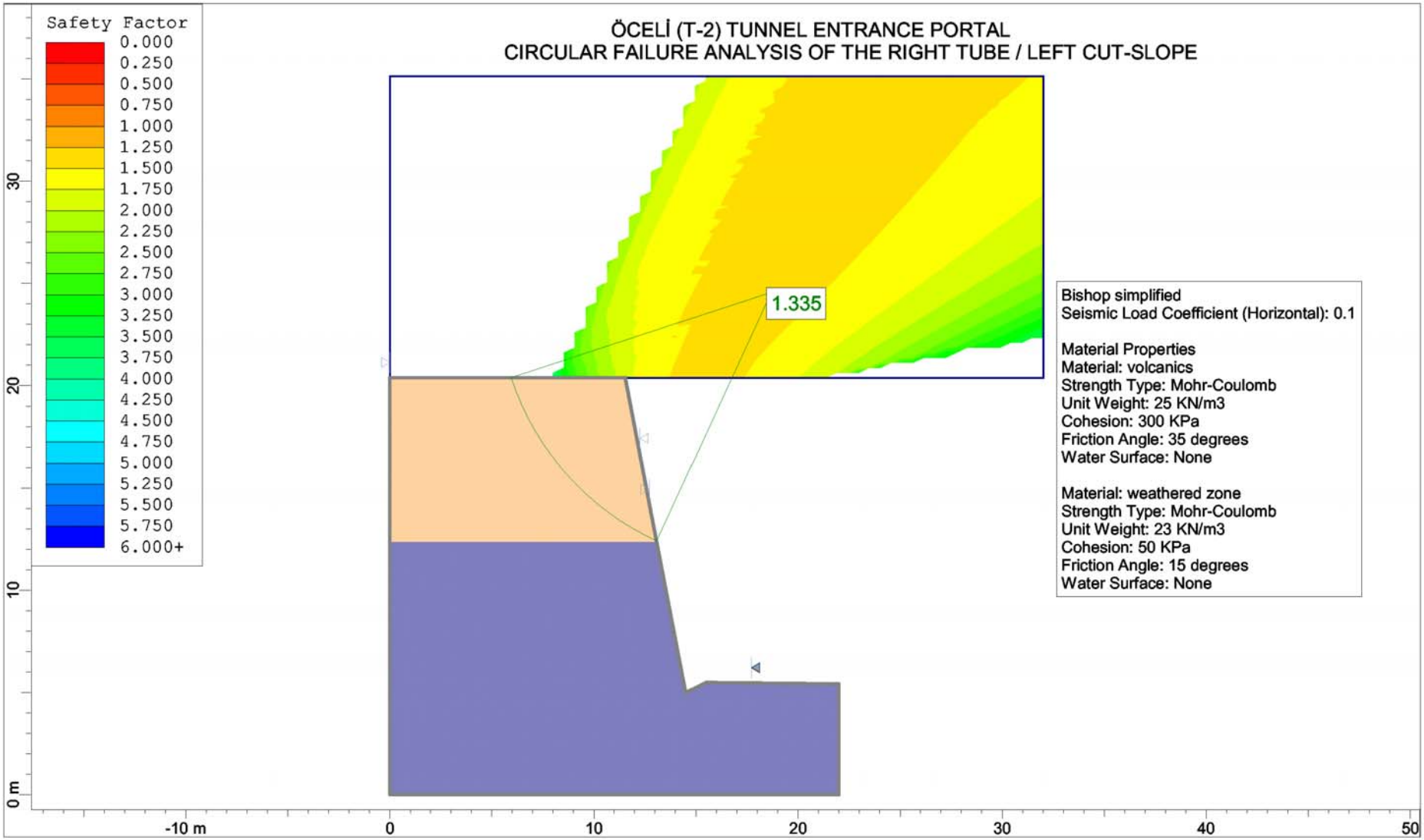

Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
1.284
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
125
100
75
50
25
0 m
-75 m
-50
-25
0
25
50
75
100
125
150

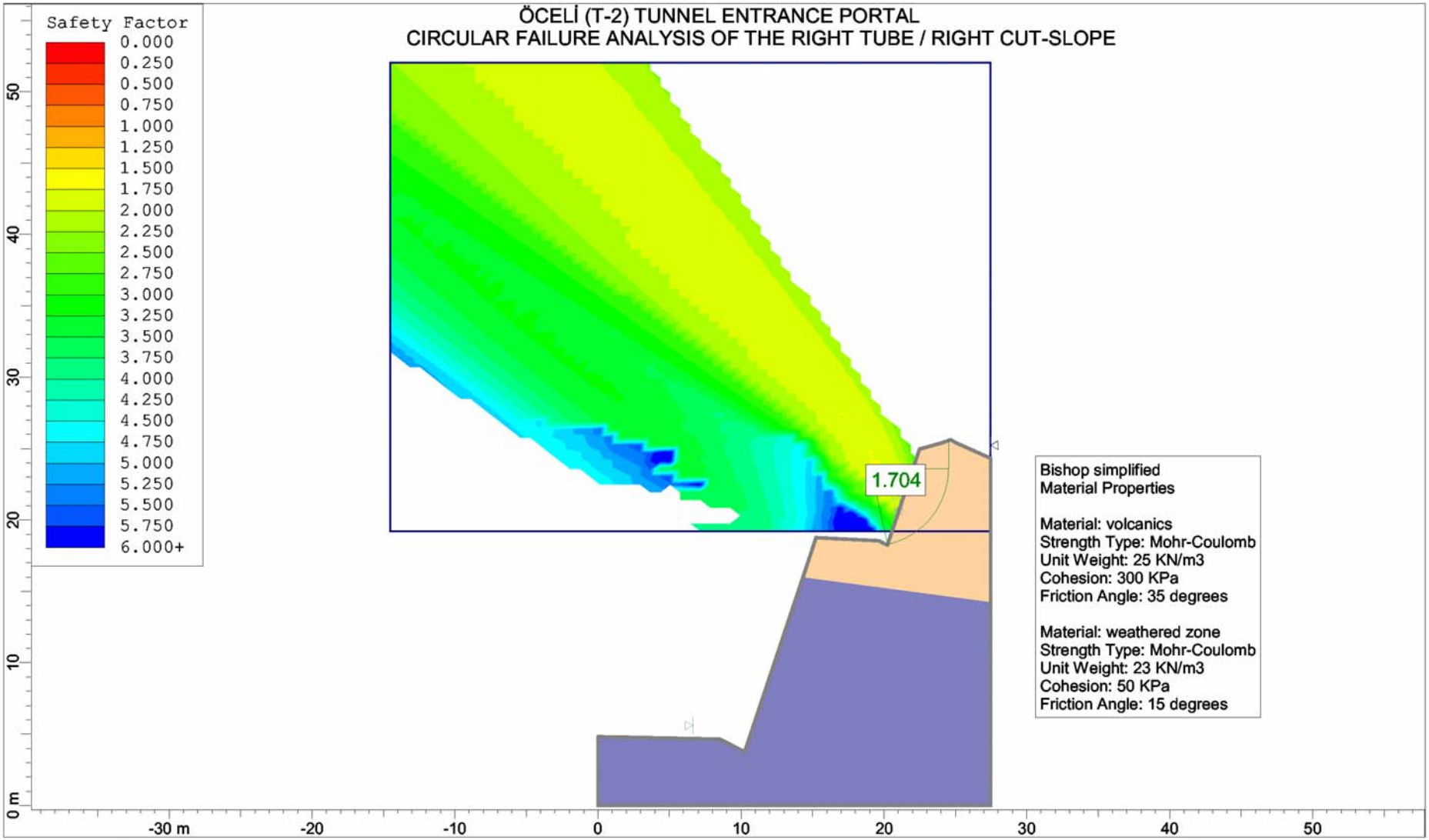

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.171
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Water Surface: None
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
125
100
75
50
25
0 m
-80 m
-60
-40
-20
0
20
40
60
80
100
120
140

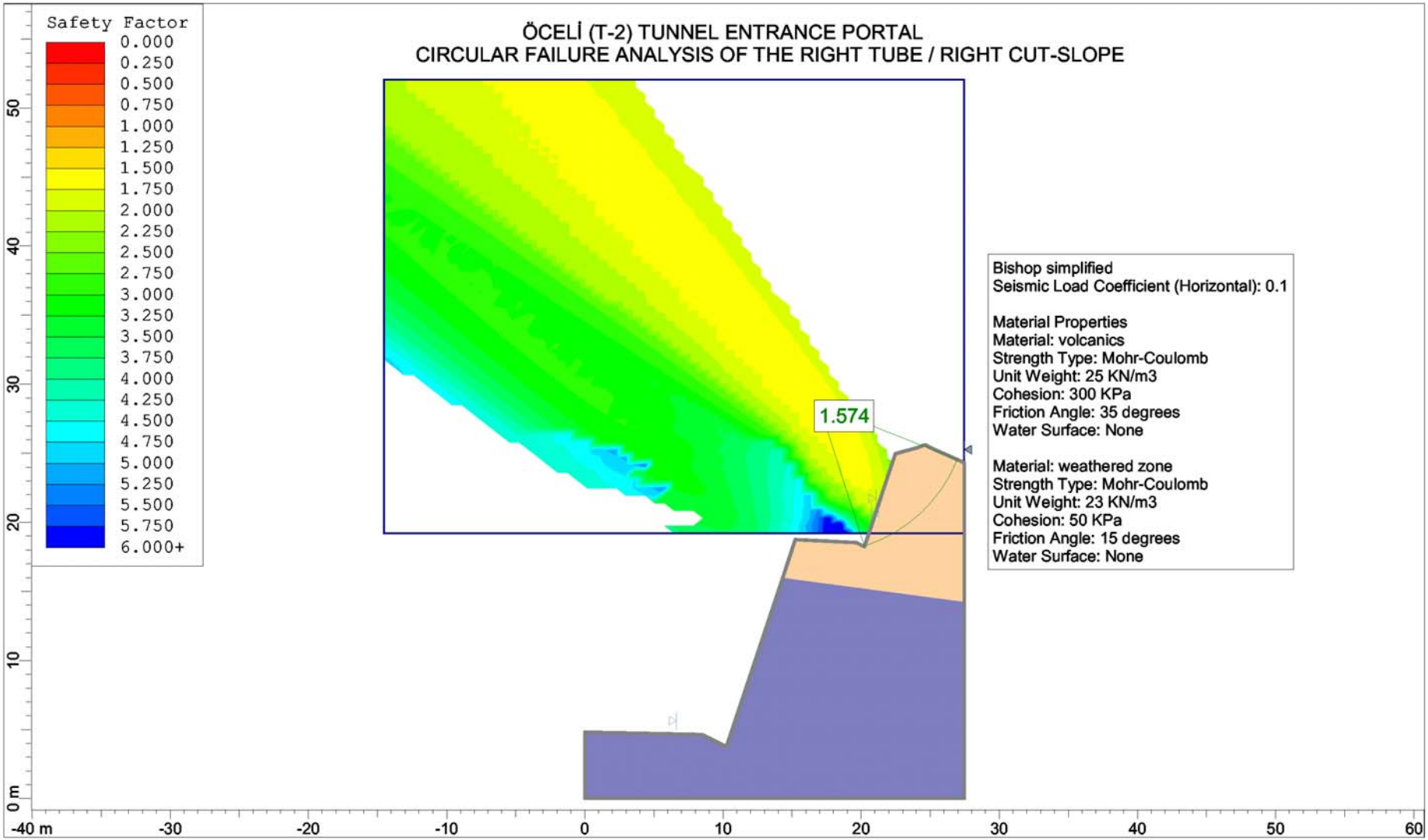

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.388
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Support: ROCK BOLT
ROCK BOLT
Support Type: Grouted Tieback (with friction)
Force Application: Active
Bond length: 4.000 m
Out-of-Plane Spacing: 1.5 m
Tensile Capacity: 100 KN
Plate Capacity: 100 KN
Pullout Strength Adhesion: 50 KN/m2
Pullout Strength Friction Angle: 15 degrees
Shear Strength Model: Linear
Grout Diameter: 0.06 m
125
100
75
50
25
0 m
-100 m
-75
-50
-25
0
25
50
75
100
125
150

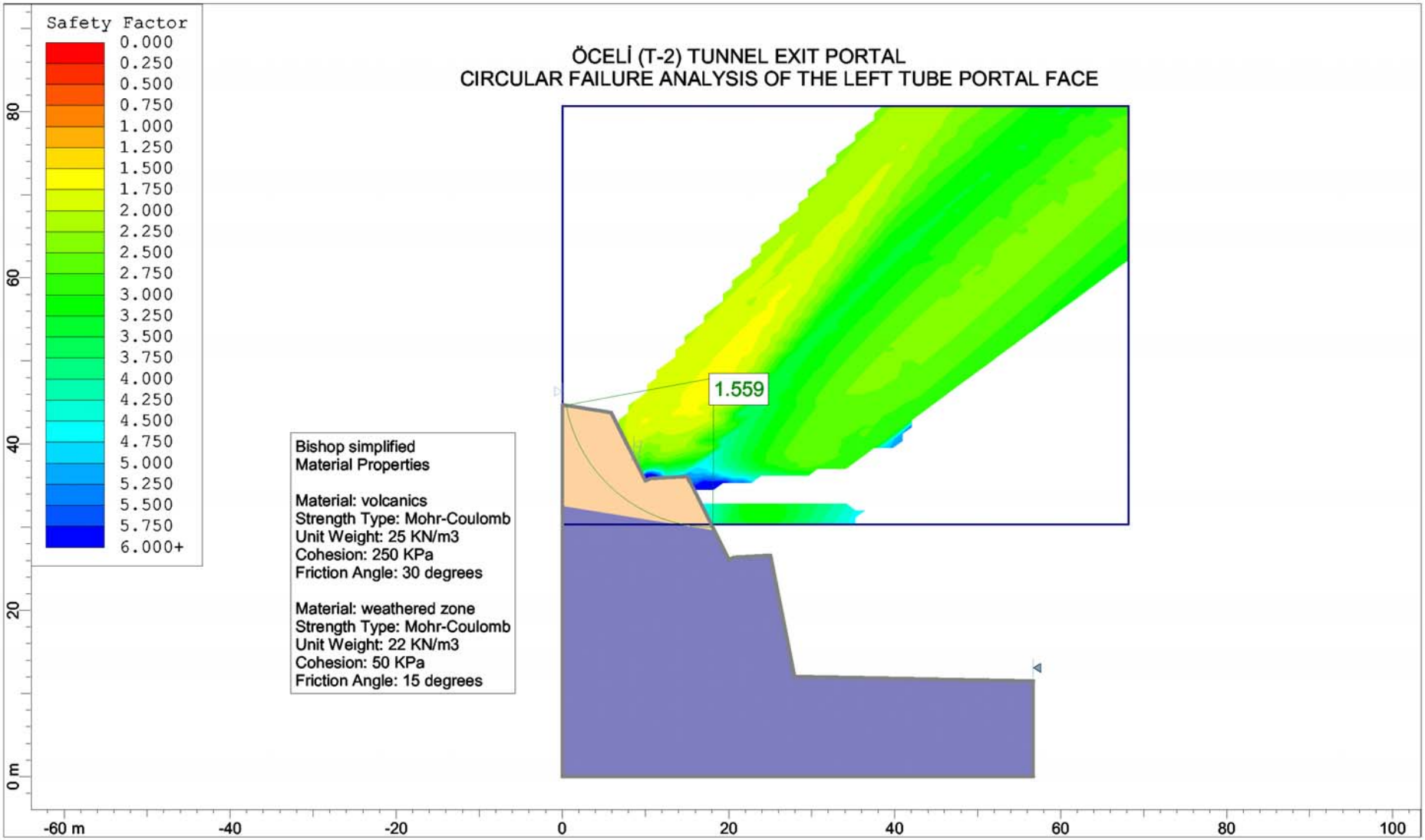

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.201
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Water Surface: None
Material: flysch
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 200 KPa
Friction Angle: 25 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
Support: ROCK BOLT
ROCK BOLT
Support Type: Grouted Tieback (with friction)
Force Application: Active
Bond length: 4.000 m
Out-of-Plane Spacing: 1.5 m
Tensile Capacity: 100 KN
Plate Capacity: 100 KN
Pullout Strength Adhesion: 50 KN/m2
Pullout Strength Friction Angle: 15 degrees
Shear Strength Model: Linear
Grout Diameter: 0.06 m
125
100
75
50
25
0 m
-75 m
-50
-25
0
25
50
75
100
125
150

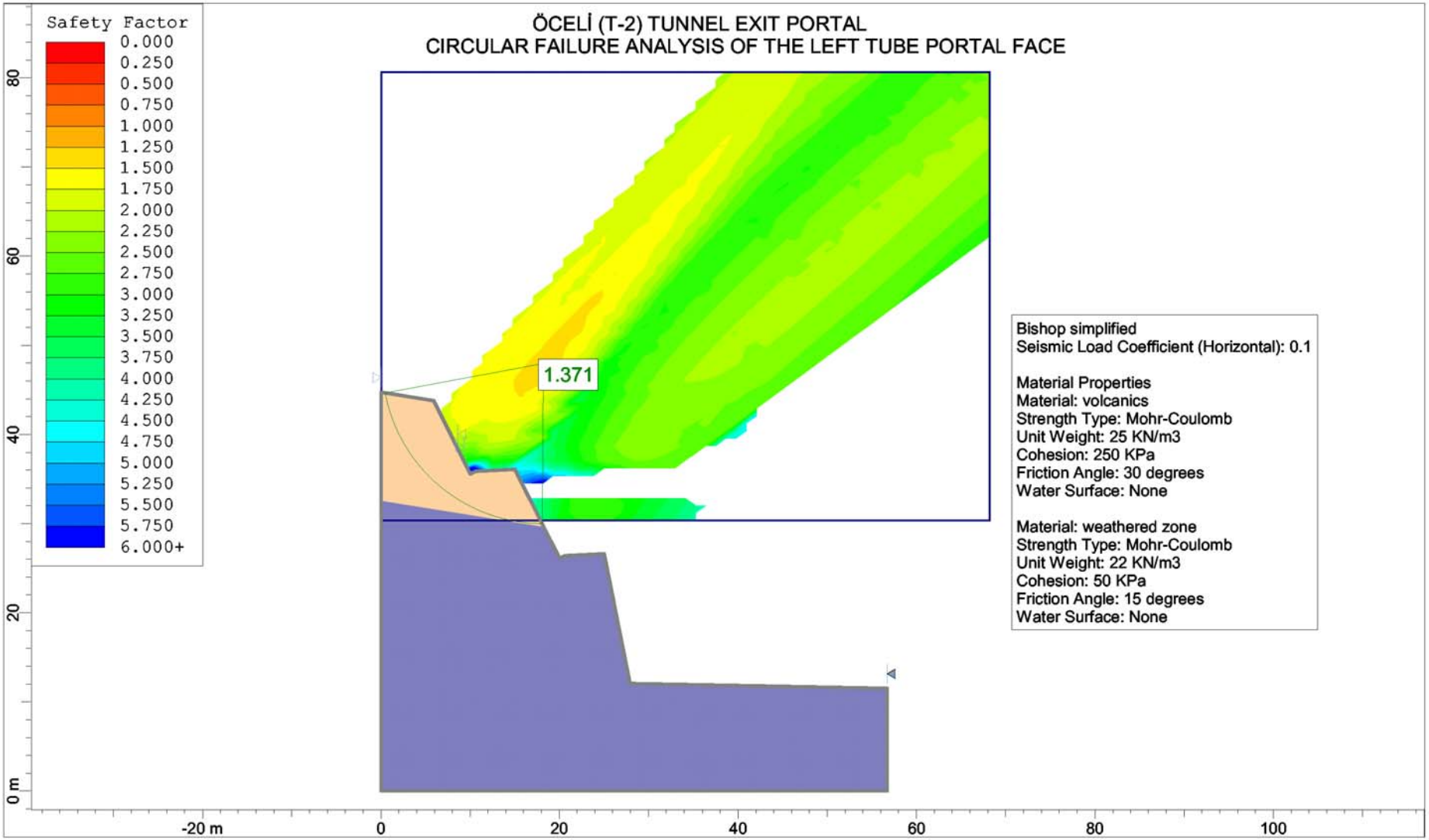

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.471
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
40
30
20
10
0 m
-20 m
-10
0
10
20
30
40

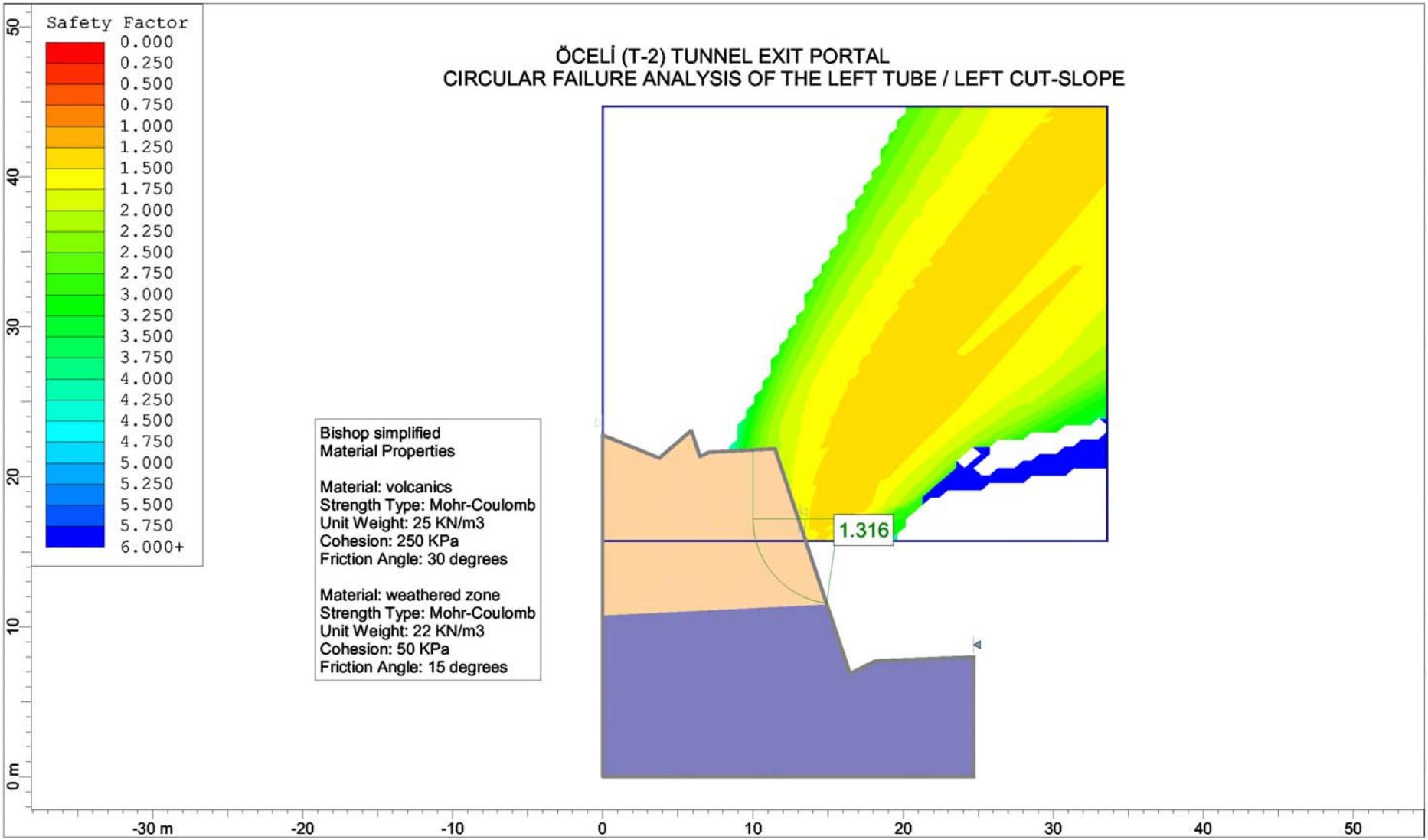

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.335
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
30
20
10
0 m
-10 m
0
10
20
30
40
50

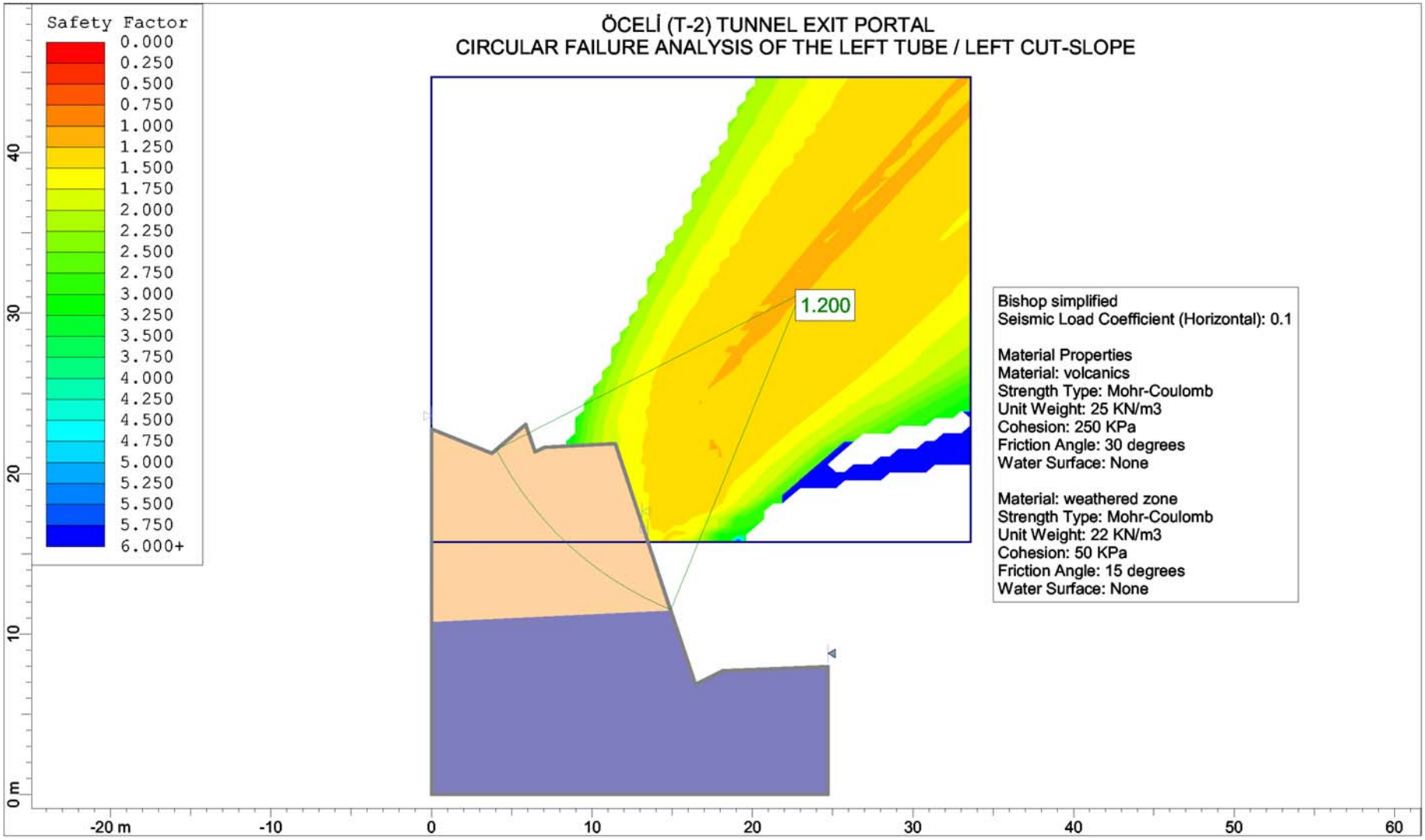

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.704
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
0 m
10
20
30
40
50
-30 m
-20
-10
0
10
20
30
40
50

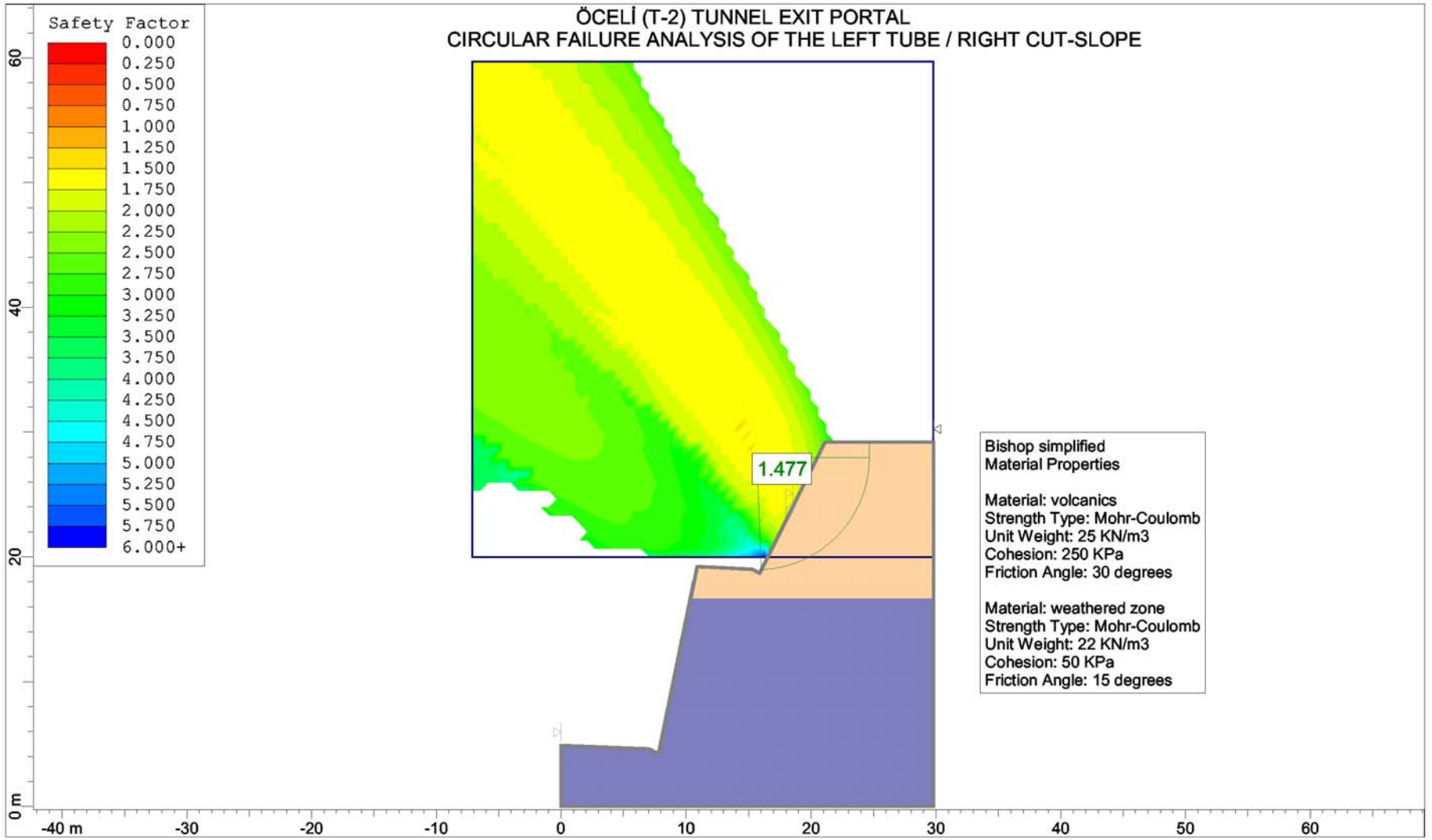

ÖCELİ (T-2) TUNNEL ENTRANCE PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.574
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 300 KPa
Friction Angle: 35 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 23 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
0 m
10
20
30
40
50
-40 m
-30
-20
-10
0
10
20
30
40
50
60

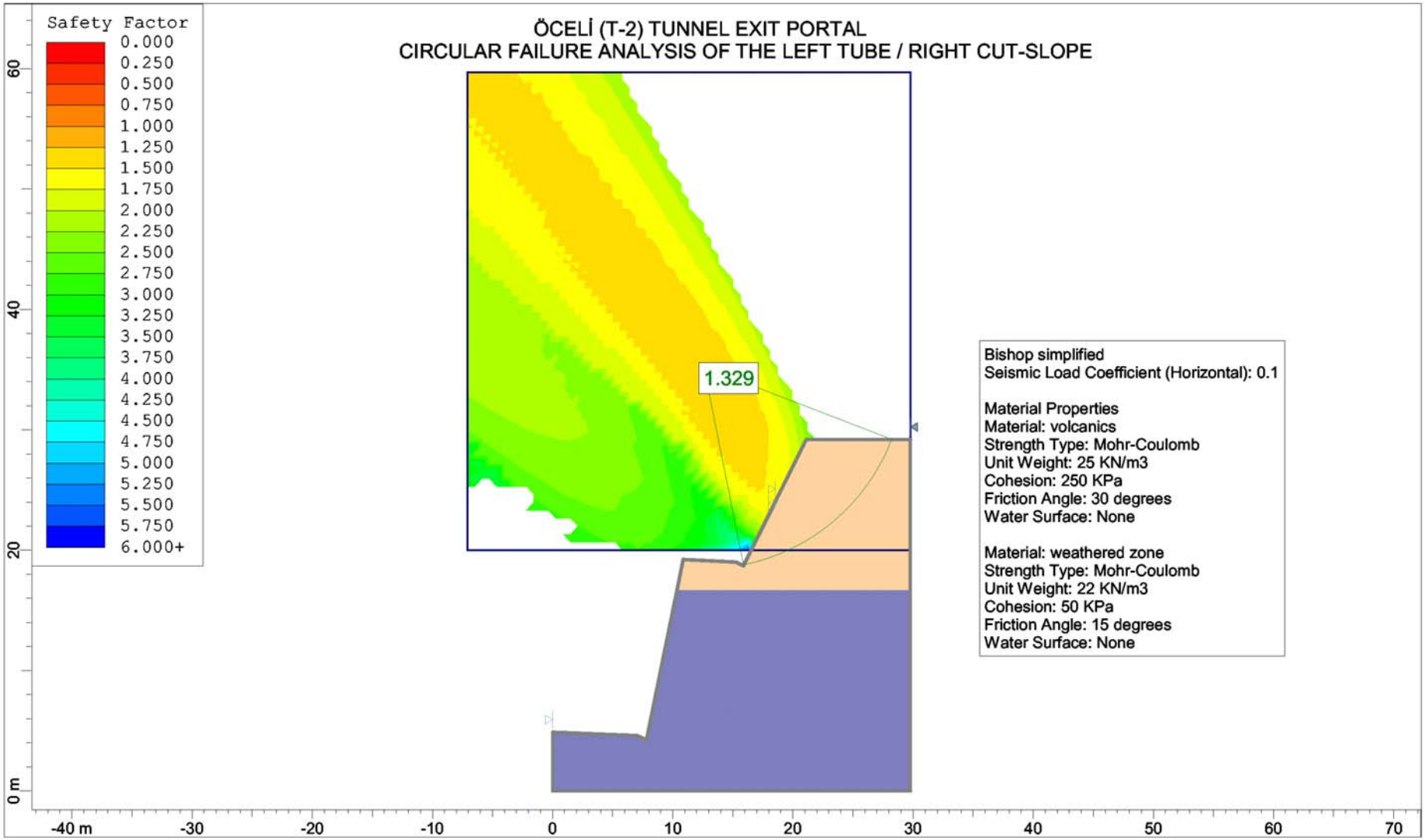

ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.559
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
80
60
40
20
0 m
-60 m
-40
-20
0
20
40
60
80
100

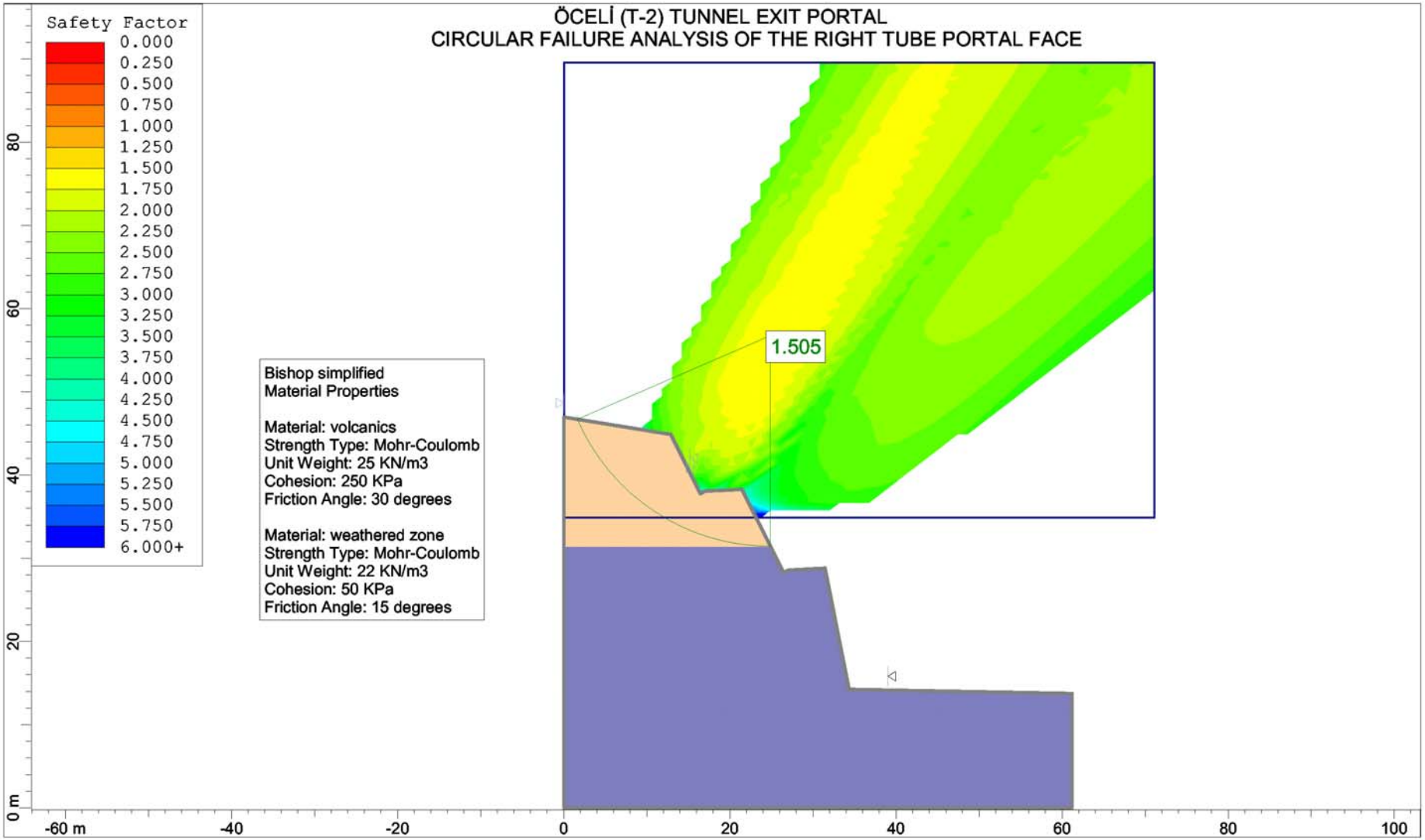

ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.371
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
80
60
40
20
0 m
-20 m
0
20
40
60
80
100

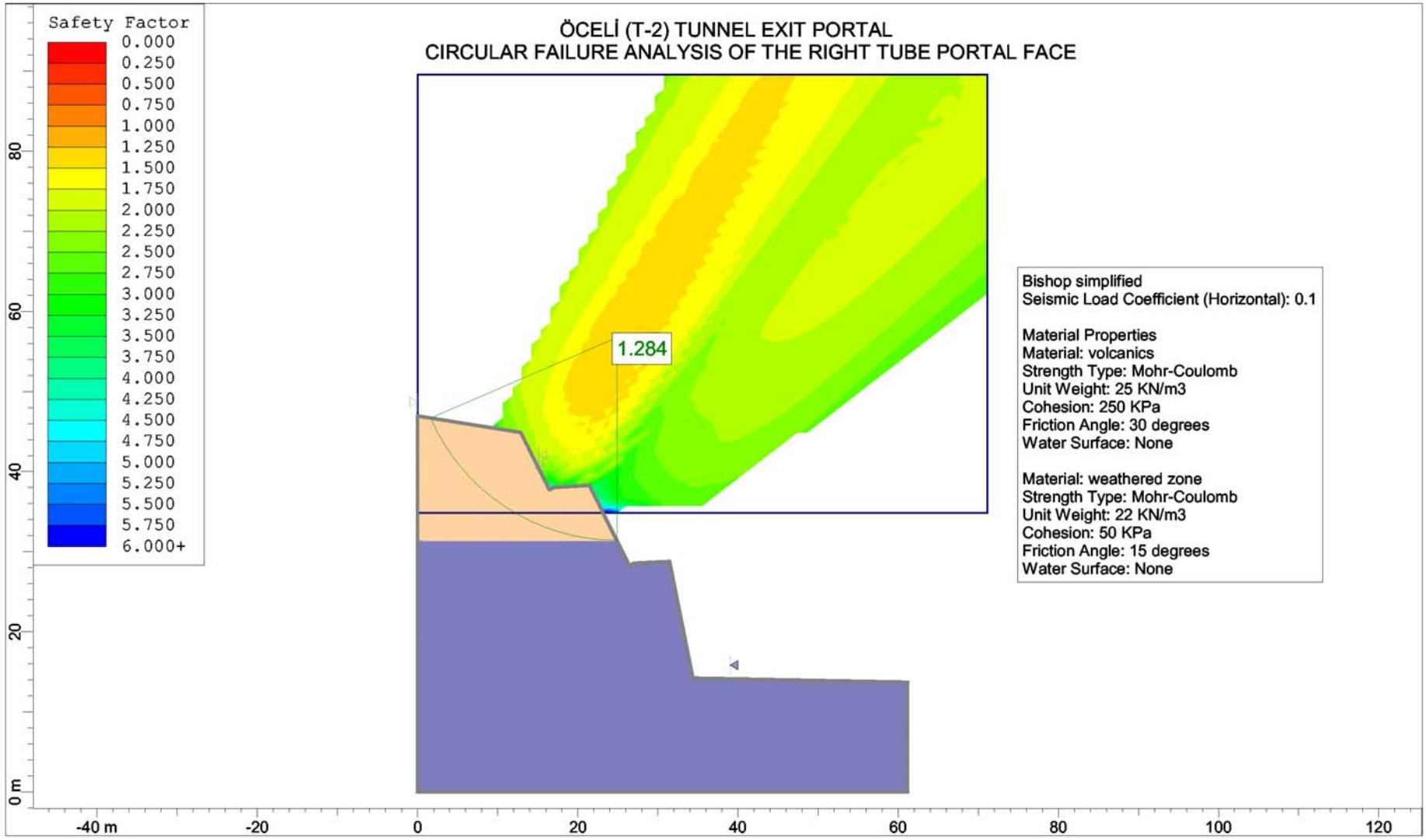

ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
1.316
50
40
30
20
10
0 m
-30 m
-20
-10
0
10
20
30
40
50

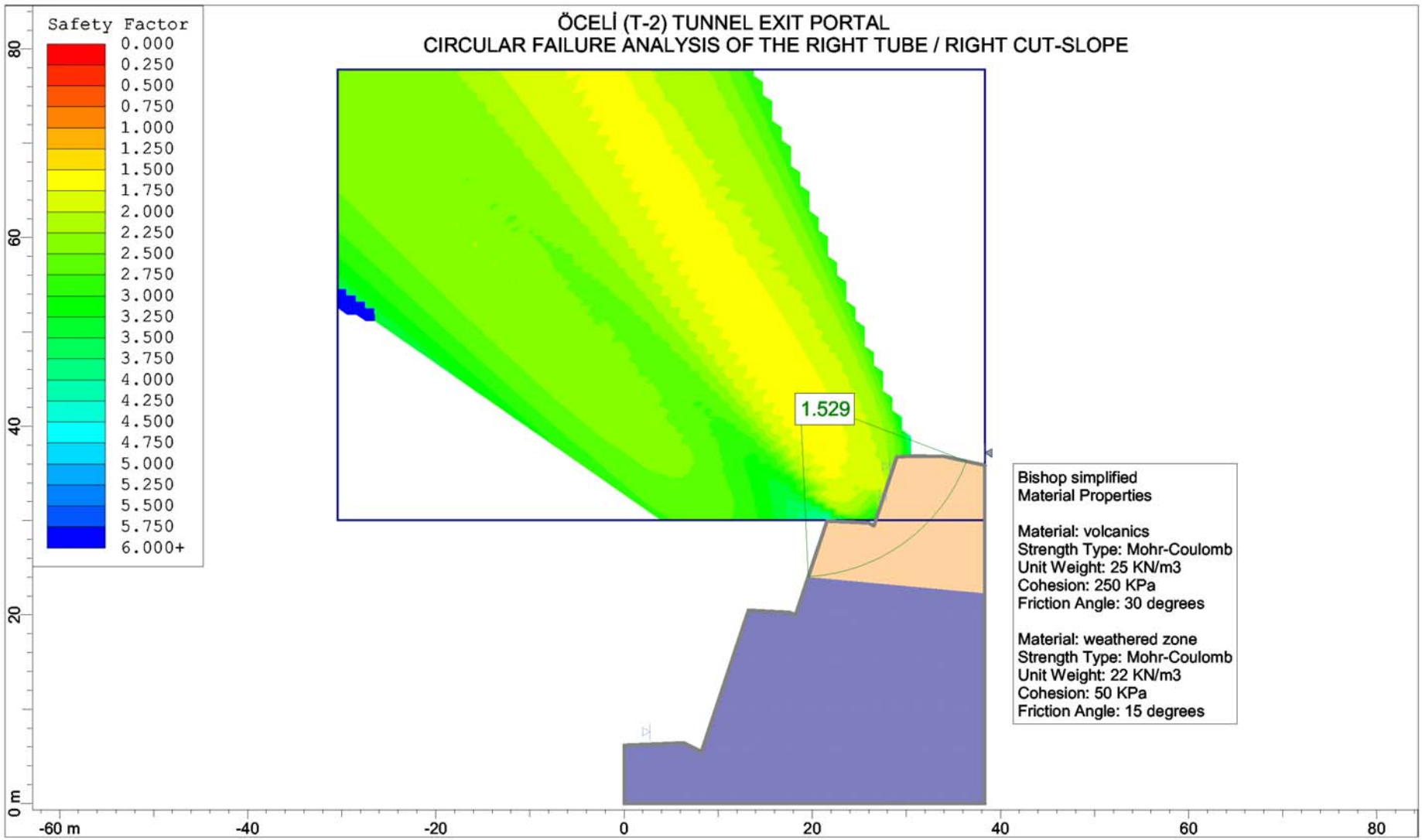

ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / LEFT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.200
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
40
30
20
10
0 m
-20 m
-10
0
10
20
30
40
50
60

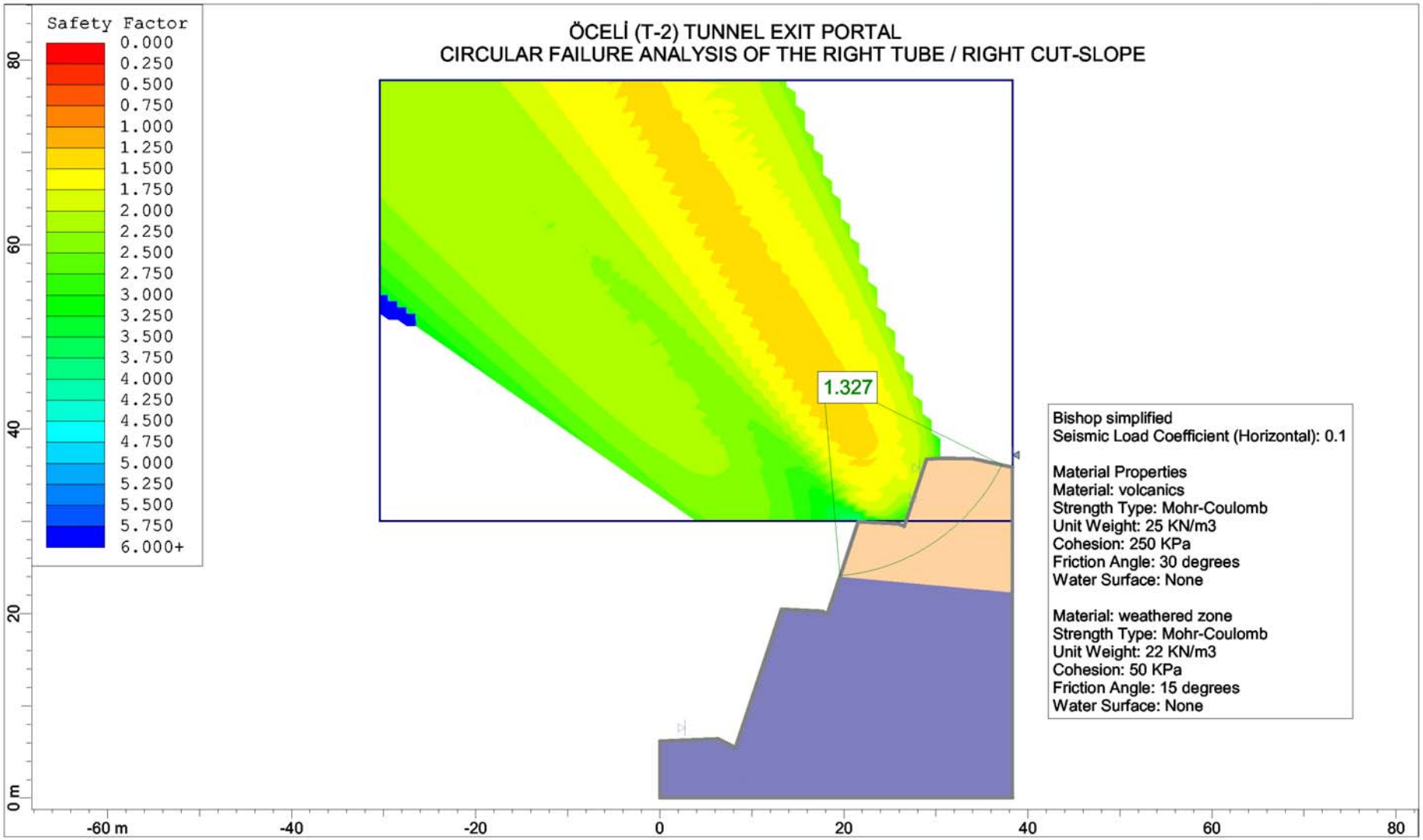

ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.477
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
60
40
20
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50
60


ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE LEFT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.329
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
60
40
20
0 m
-40 m
-30
-20
-10
0
10
20
30
40
50
60
70


ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
1.505
0 m
20
40
60
80
-60 m
-40
-20
0
20
40
60
80
100


ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE PORTAL FACE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.284
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
80
60
40
20
0 m
-40 m
-20
0
20
40
60
80
100
120


ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.529
Bishop simplified
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
80
60
40
20
0 m
-60 m
-40
-20
0
20
40
60
80


ÖCELİ (T-2) TUNNEL EXIT PORTAL
CIRCULAR FAILURE ANALYSIS OF THE RIGHT TUBE / RIGHT CUT-SLOPE
Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.327
Bishop simplified
Seismic Load Coefficient (Horizontal): 0.1
Material Properties
Material: volcanics
Strength Type: Mohr-Coulomb
Unit Weight: 25 KN/m3
Cohesion: 250 KPa
Friction Angle: 30 degrees
Water Surface: None
Material: weathered zone
Strength Type: Mohr-Coulomb
Unit Weight: 22 KN/m3
Cohesion: 50 KPa
Friction Angle: 15 degrees
Water Surface: None
80
60
40
20
0 m
-60 m
-40
-20
0
20
40
60
80

# APPENDIX – I
# FINITE ELEMENT ANALYSES RESULTS

# THE BOZTEPE (T-1) TUNNEL

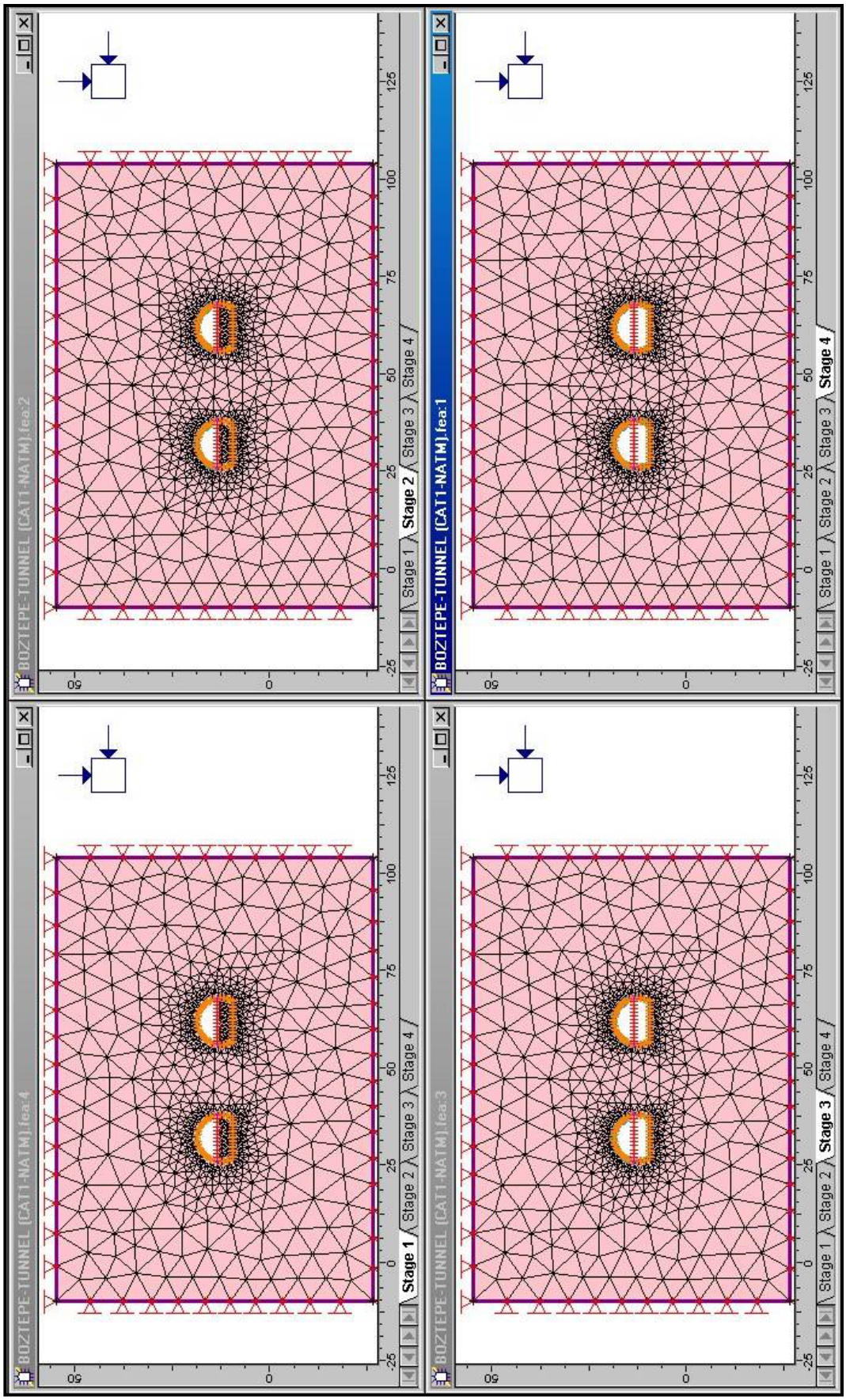



Figure I.1. Excavation stages of ground category (I) of Boztepe (T-1) tunnel.

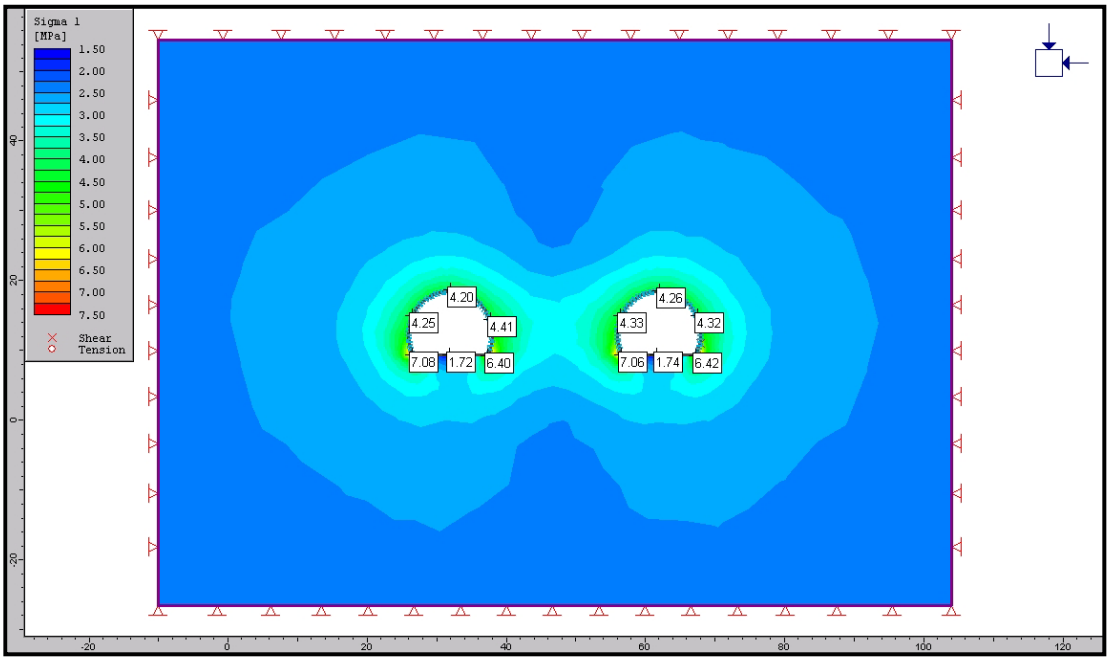



Figure I.2. General view of model for ground category (I) of Boztepe (T-1) tunnel.

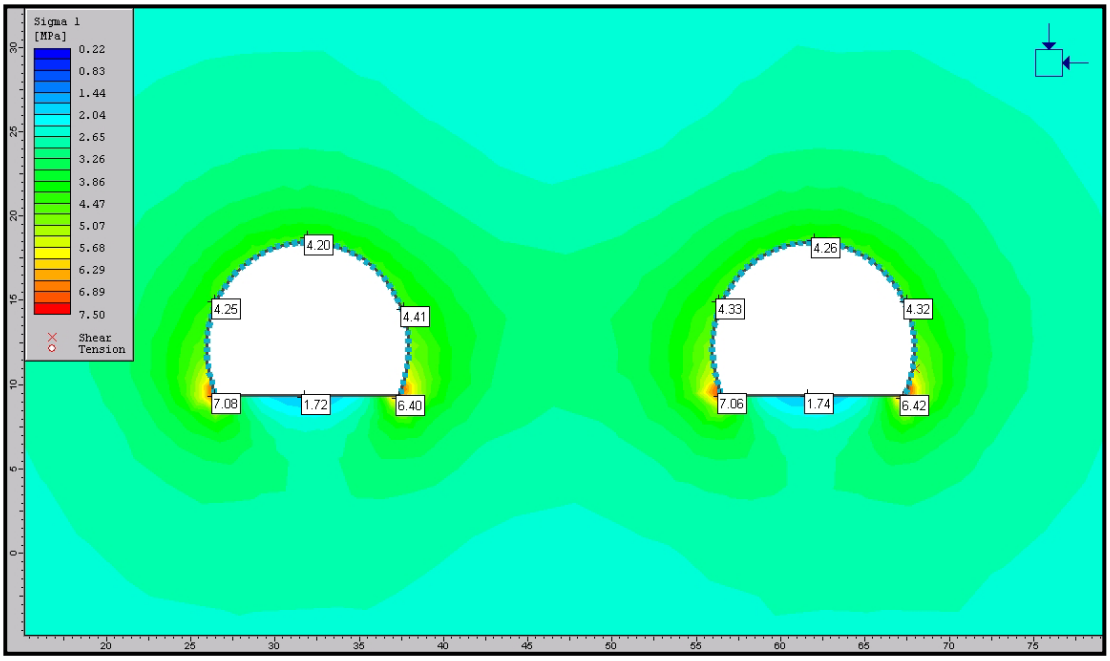



Figure I.3. Major principal stress ($\sigma_1$) concentration of ground category (I) of Boztepe (T-1) tunnel.

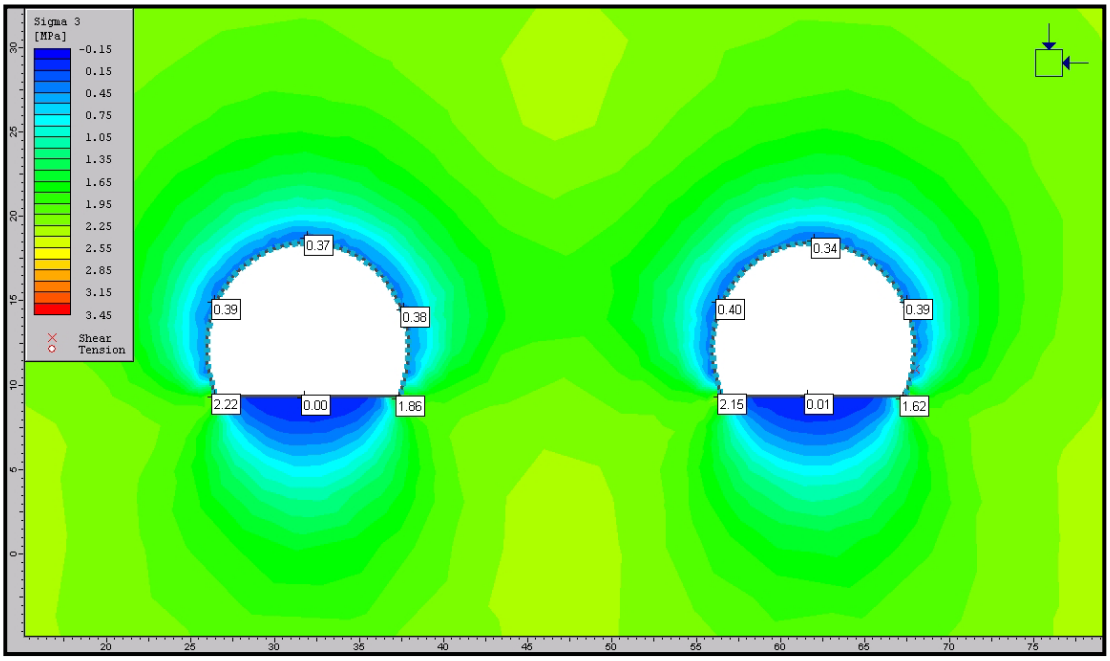



Figure I.4. Minor principal stress ($\sigma_3$) concentration of ground category (I) of Boztepe (T-1) tunnel.

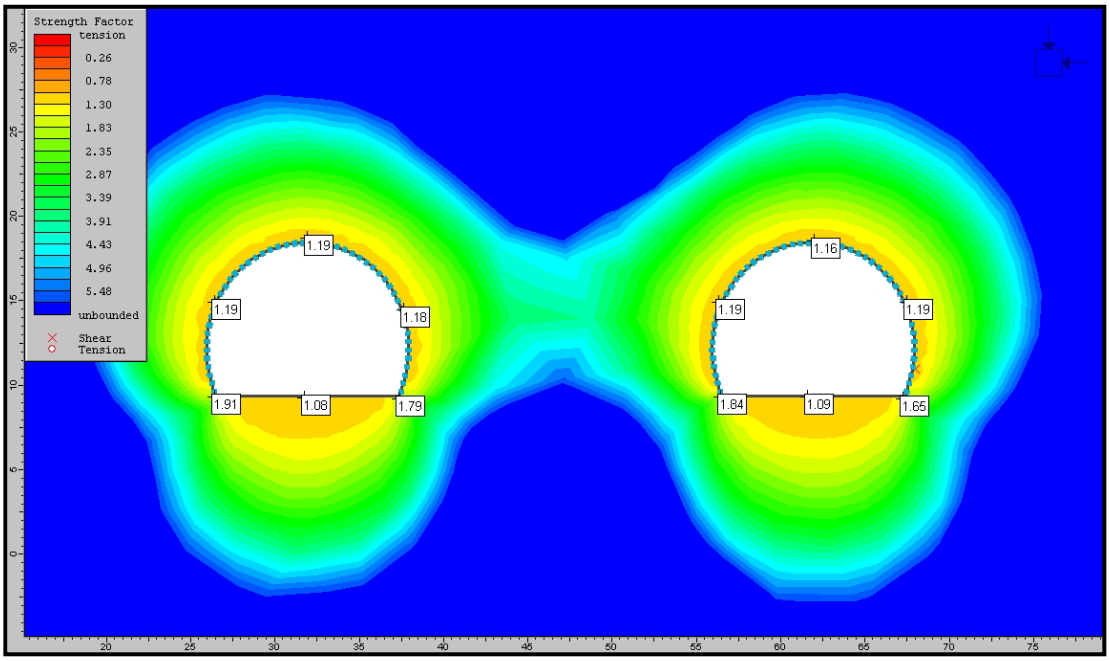



Figure I.5. Strength factor concentration of ground category (I) of Boztepe (T-1) tunnel.

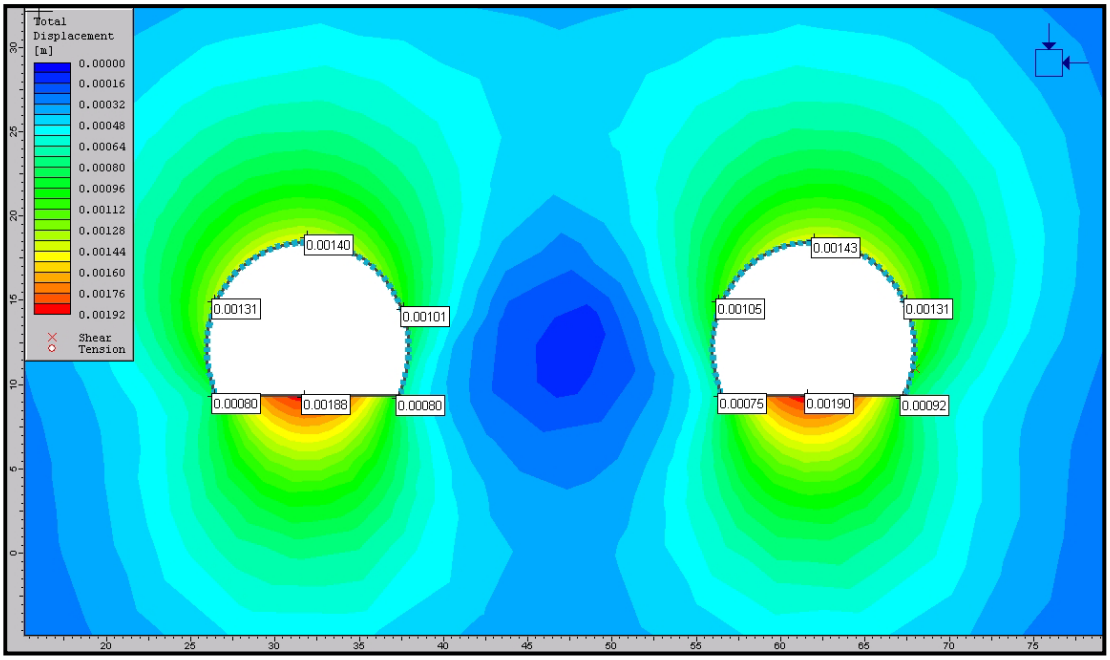



Figure I.6. Total displacement concentration of ground category (I) of Boztepe (T-1) tunnel.

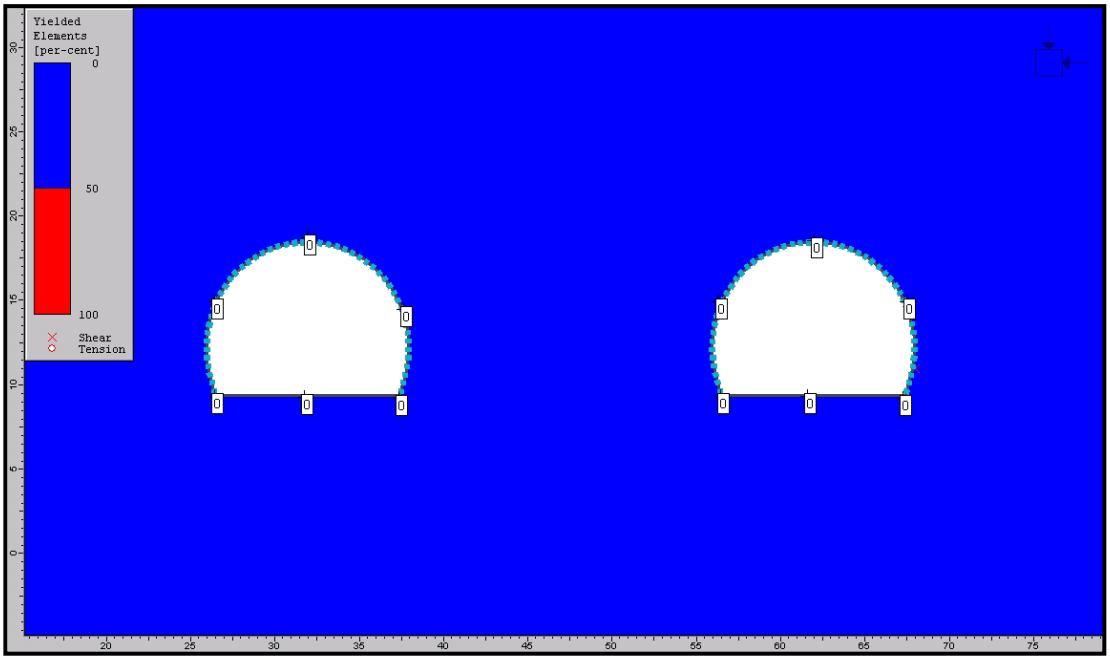



Figure I.7. Illustration of percentage of yielded elements of ground category (I) of Boztepe (T-1) tunnel.

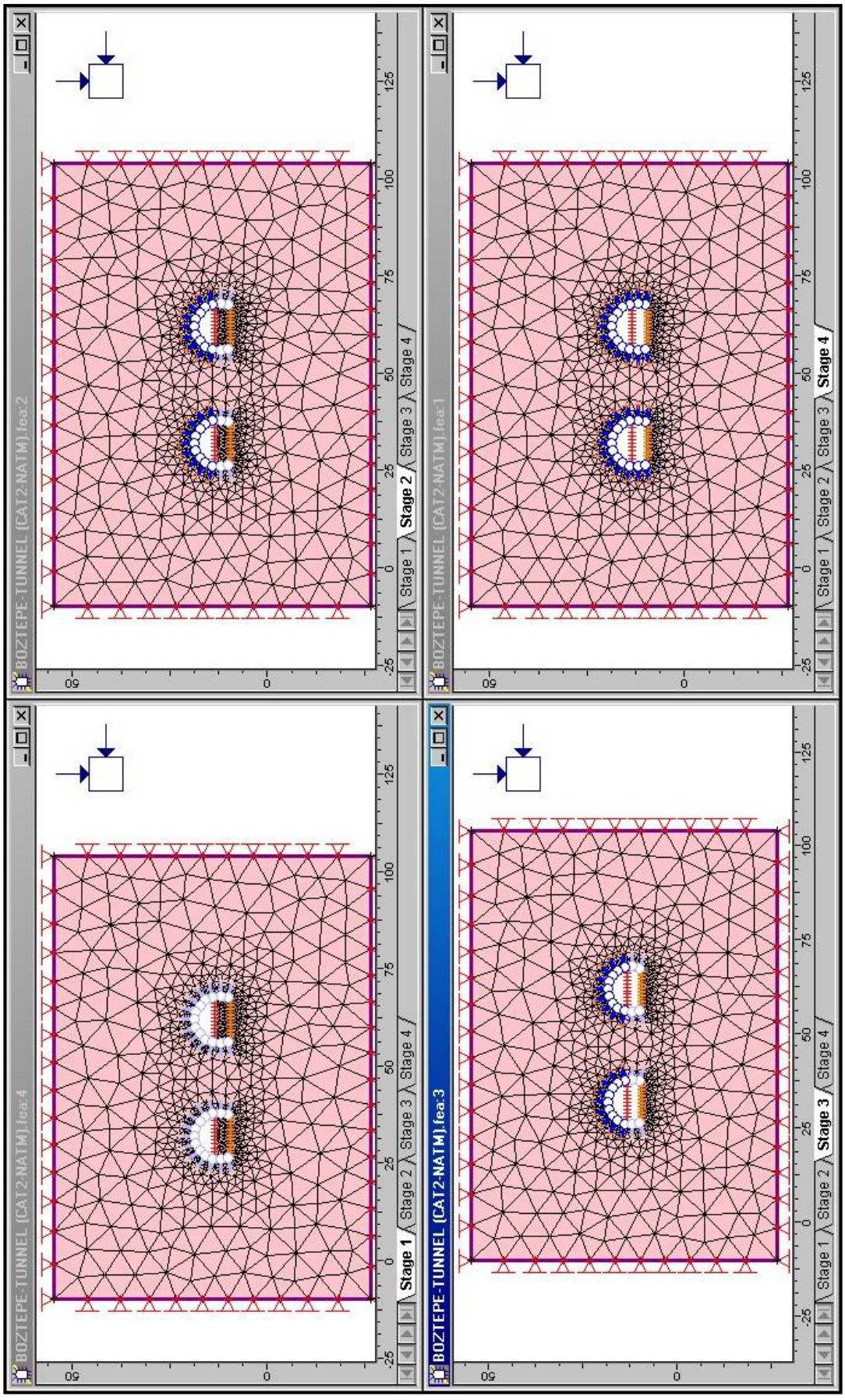



Figure II.1. Excavation stages of ground category (II) of Boztepe (T-1) tunnel.

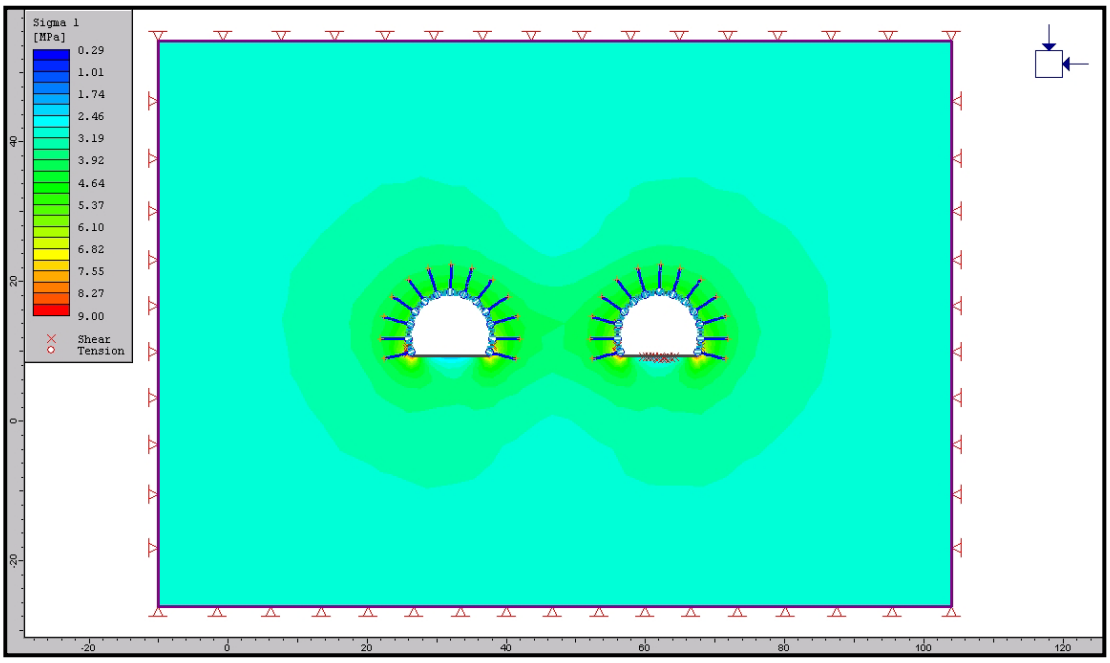



Figure II.2. General view of model for ground category (II) of Boztepe (T-1) tunnel.

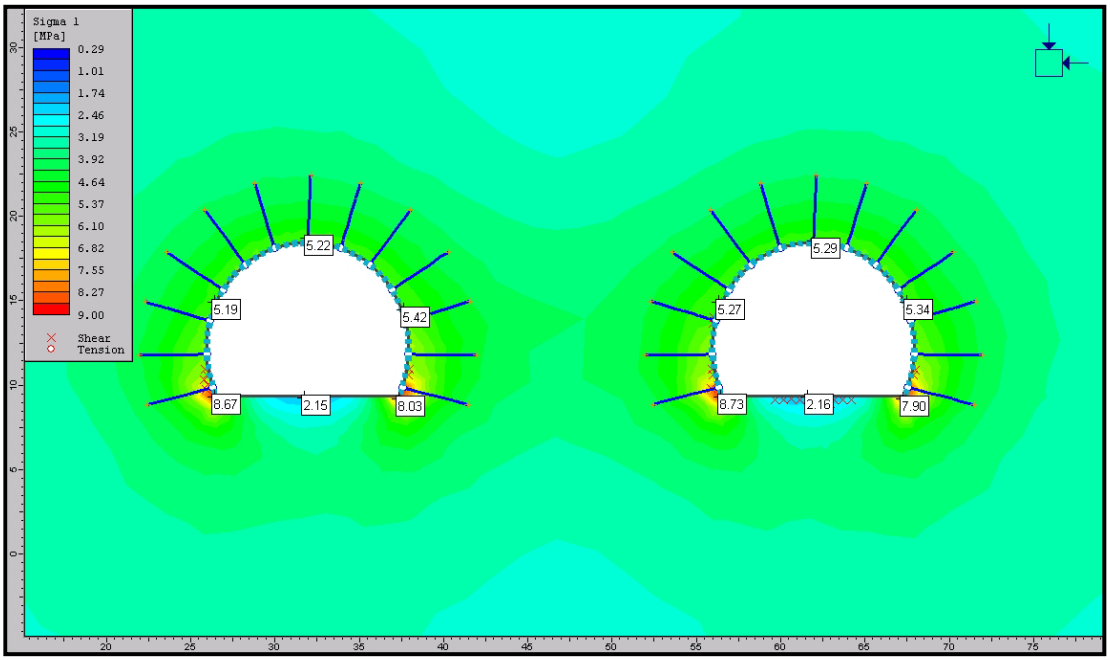



Figure II.3. Major principal stress ($\sigma_1$) concentration of ground category (II) of Boztepe (T-1) tunnel.

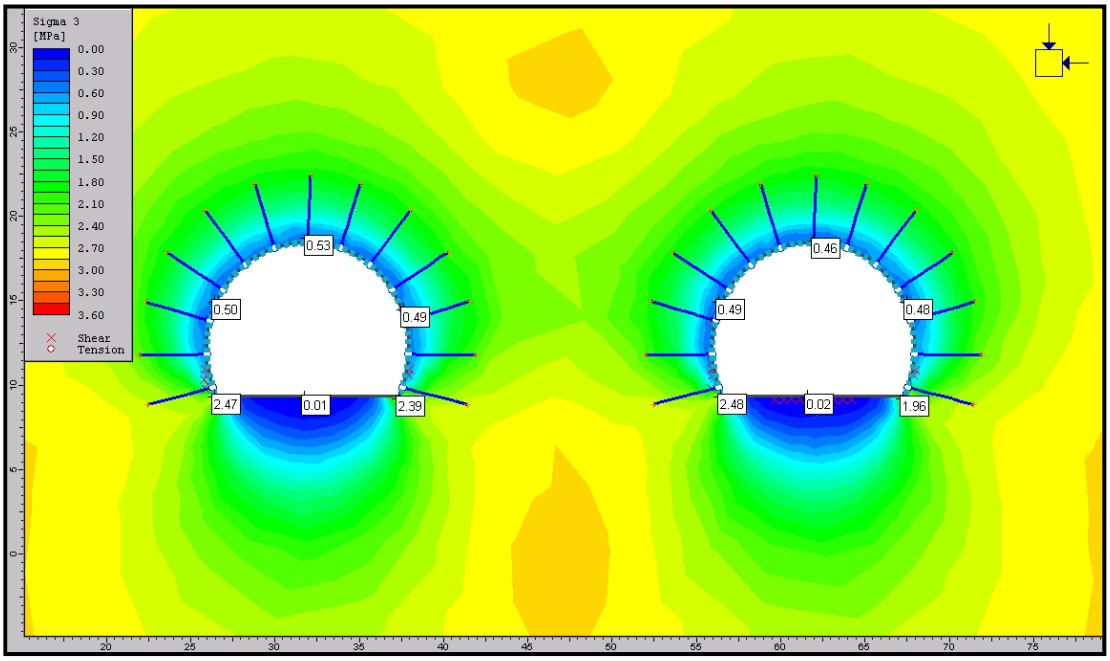



Figure II.4. Minor principal stress ($\sigma_3$) concentration of ground category (II) of Boztepe (T-1) tunnel.

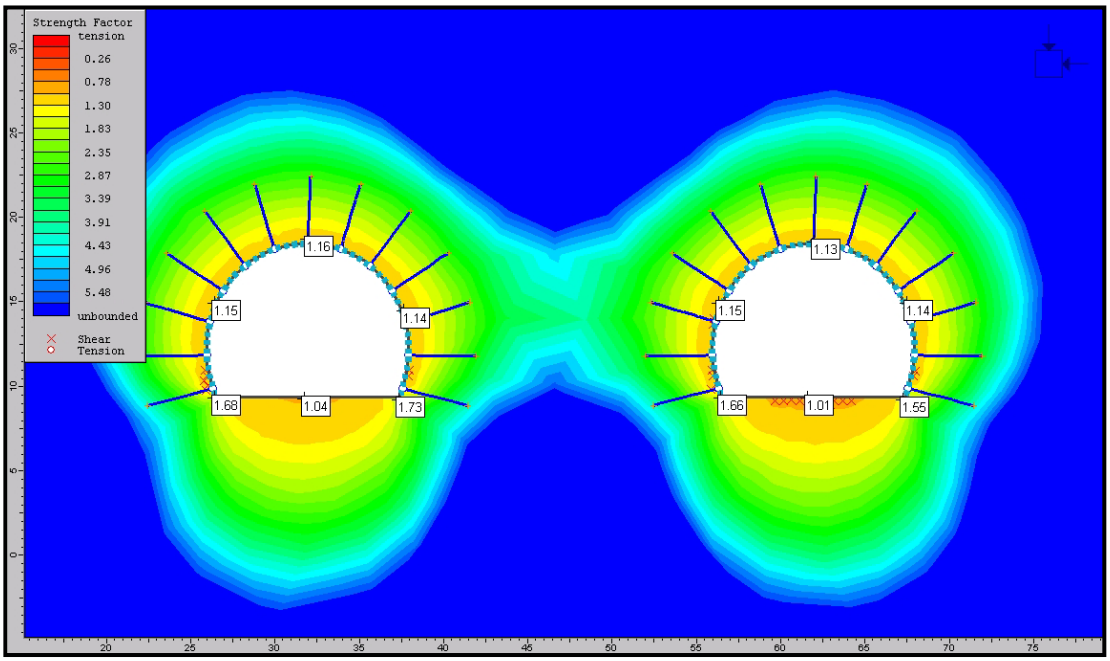



Figure II.5. Strength factor concentration of ground category (II) of Boztepe (T-1) tunnel.

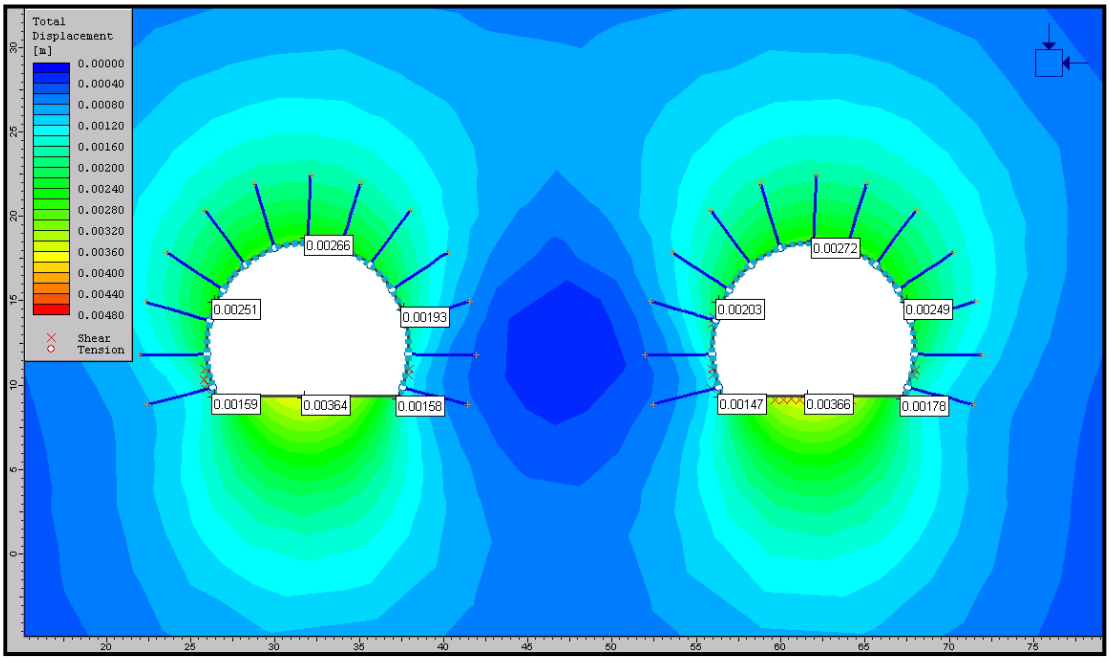



Figure II.6. Total displacement concentration of ground category (II) of Boztepe (T-1) tunnel.

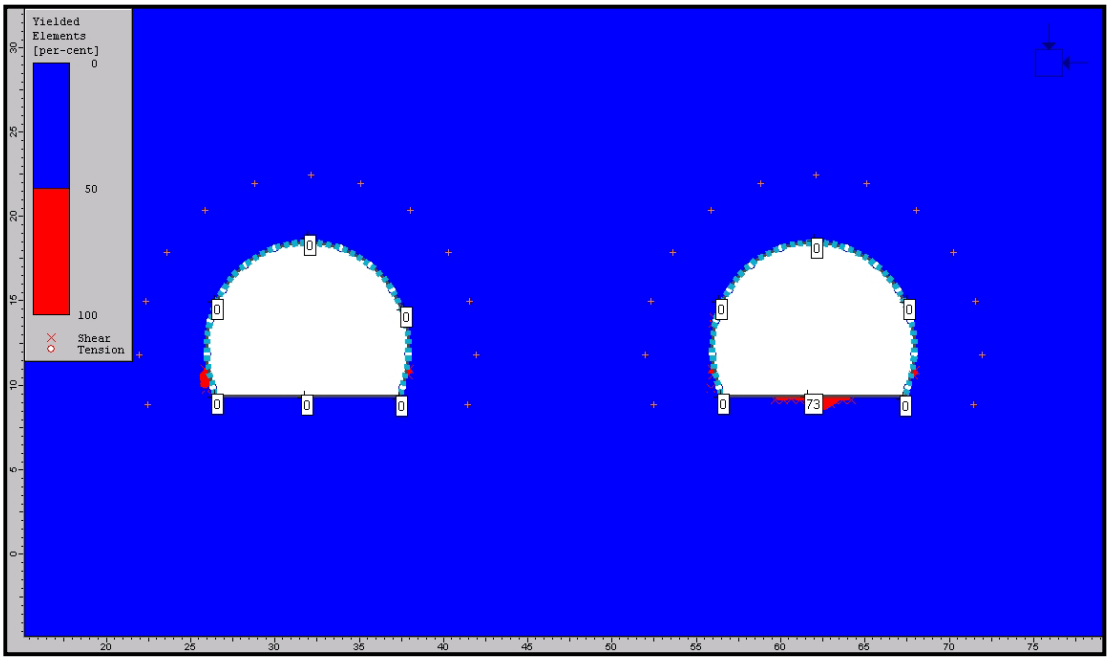



Figure II.7. Illustration of percentage of yielded elements of ground category (II) of Boztepe (T-1) tunnel.

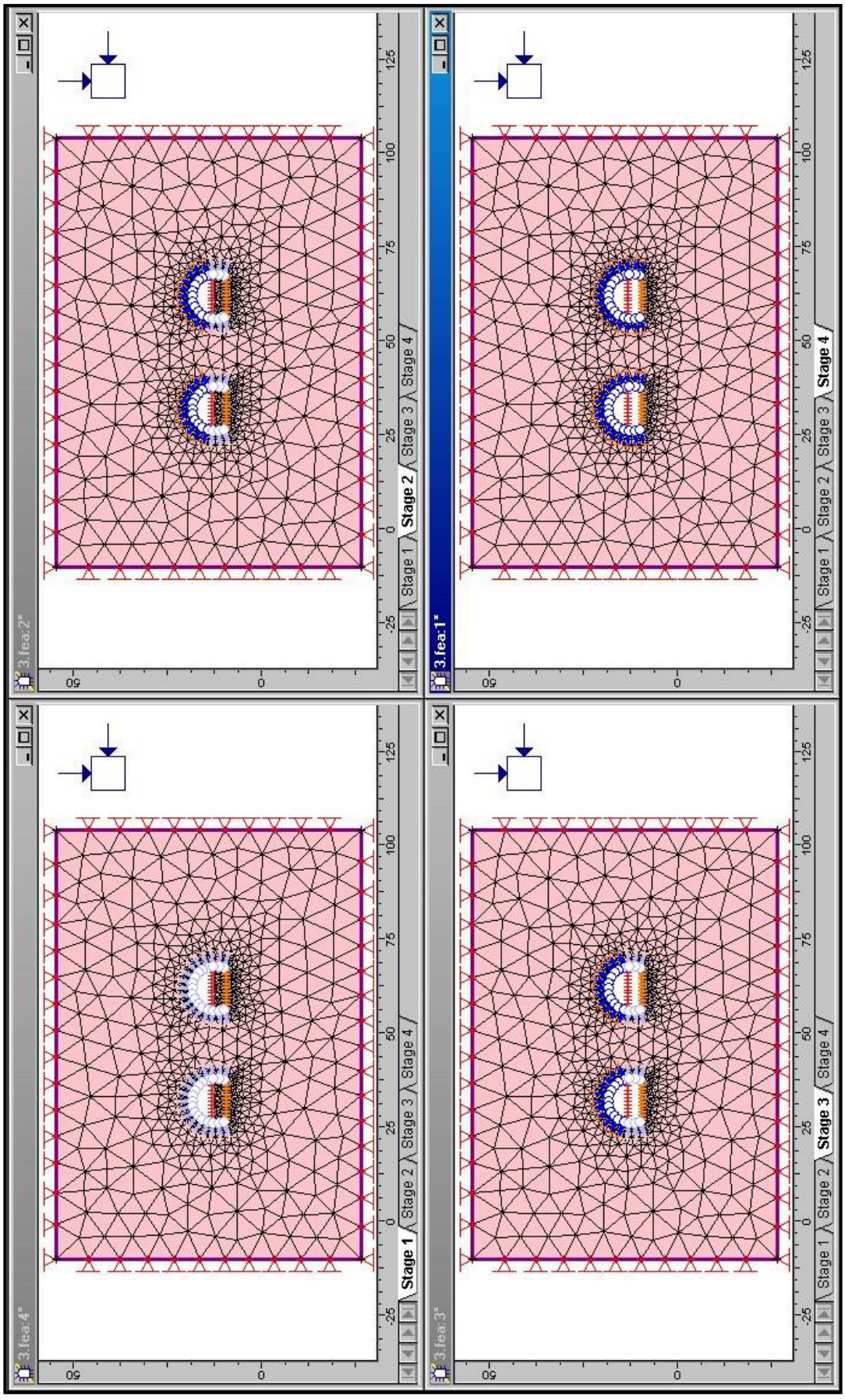



Figure III.1. Excavation stages of ground category (III) of Boztepe (T-1) tunnel.

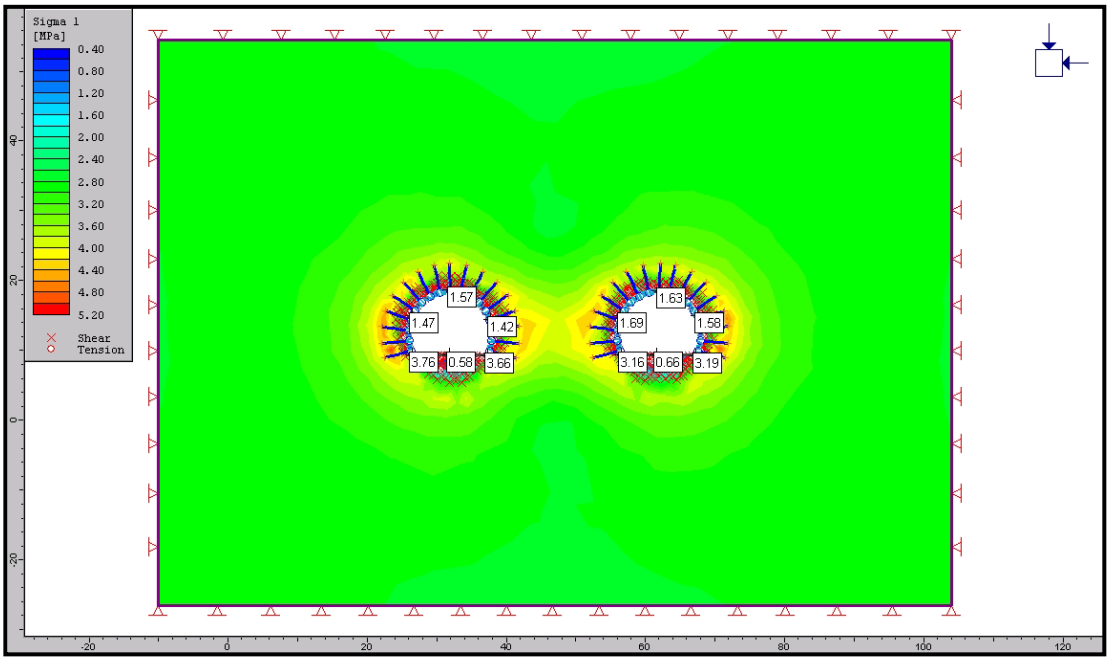



Figure III.2. General view of model for ground category (III) of Boztepe (T-1) tunnel.

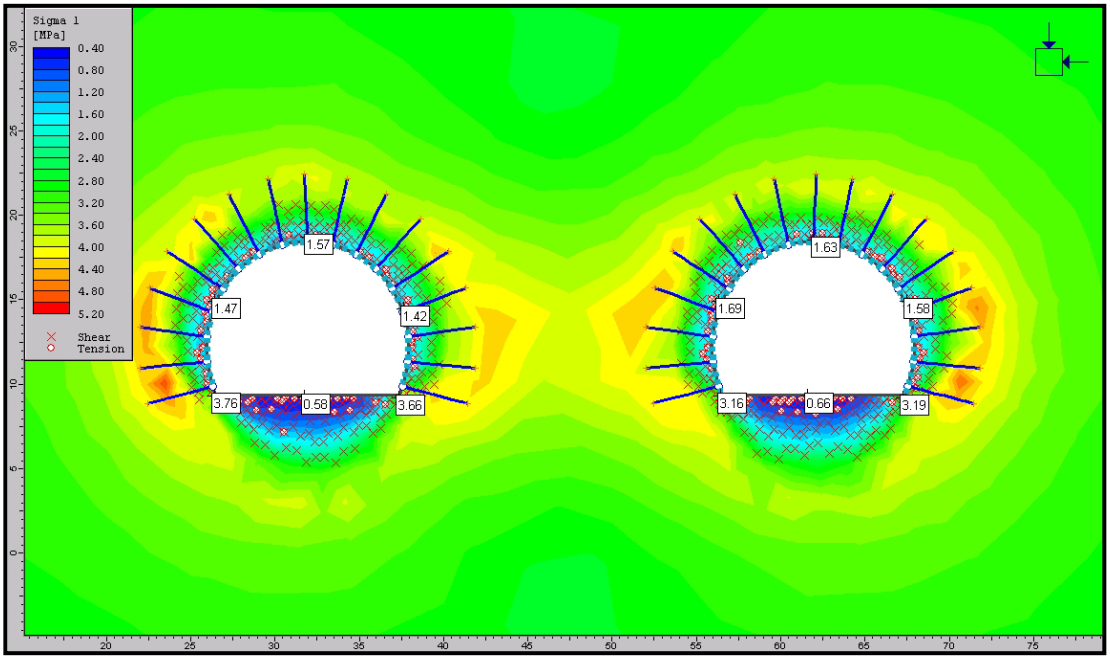



Figure III.3. Major principal stress ($\sigma_1$) concentration of ground category (III) of Boztepe (T-1) tunnel.

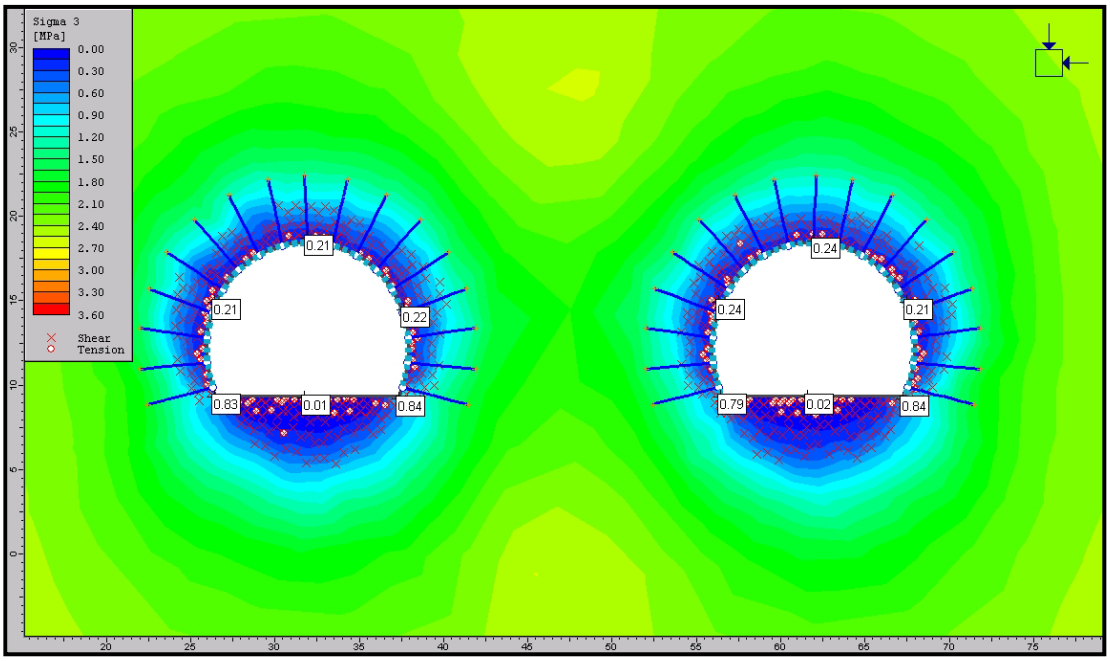



Figure III.4. Minor principal stress ($\sigma_3$) concentration of ground category (III) of Boztepe (T-1) tunnel.

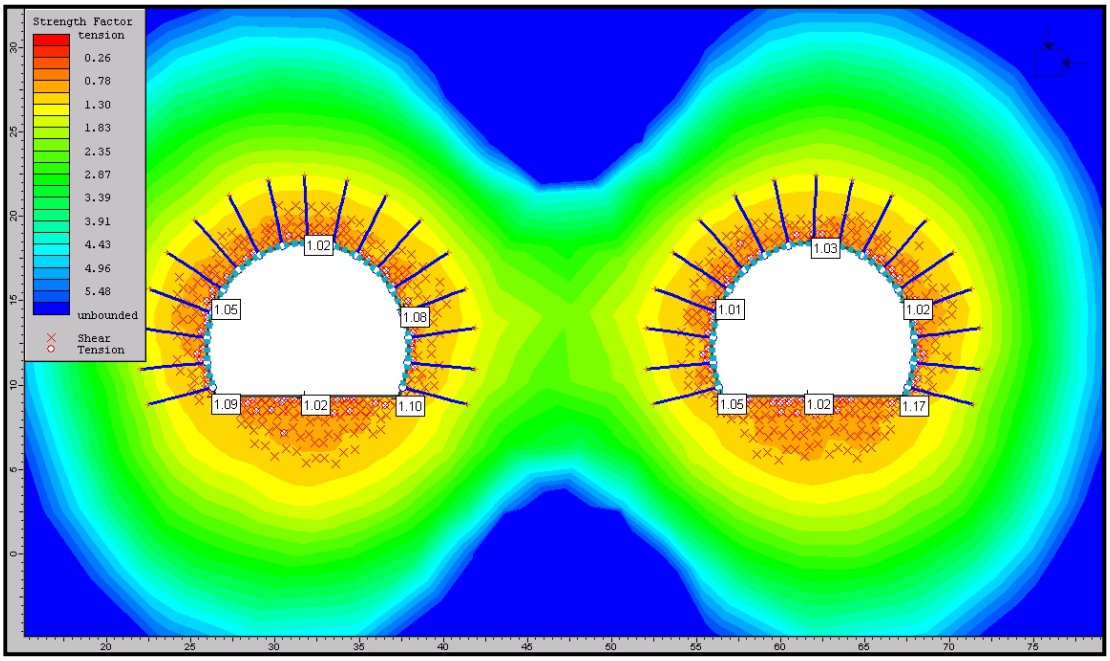



Figure III.5. Strength factor concentration of ground category (III) of Boztepe (T-1) tunnel.

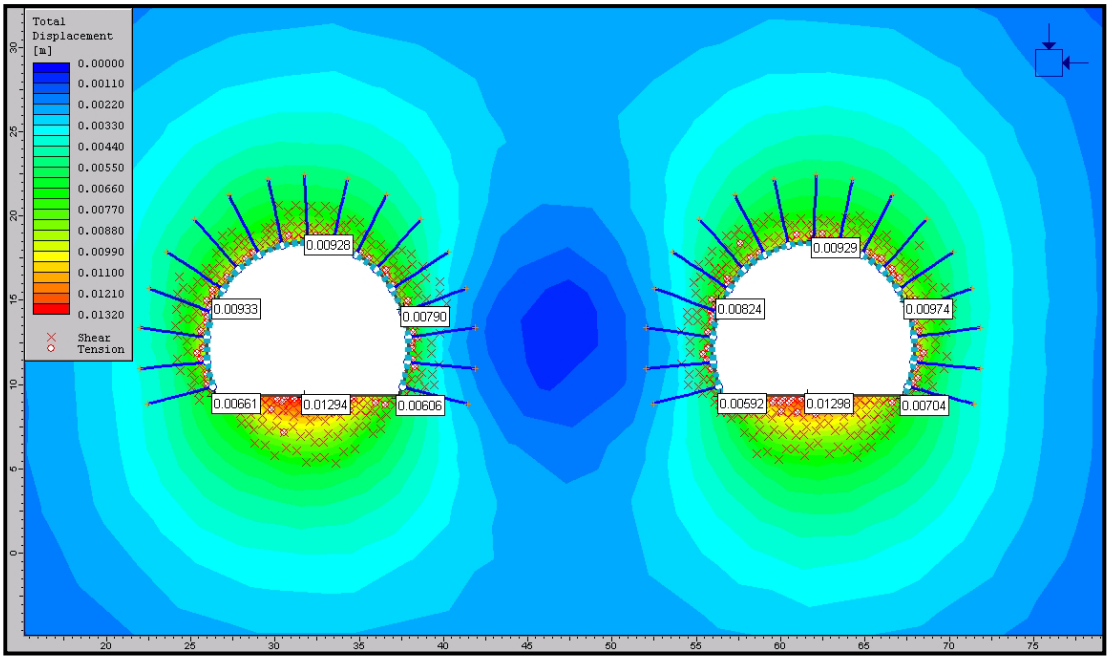



Figure III.6. Total displacement concentration of ground category (III) of Boztepe (T-1) tunnel.

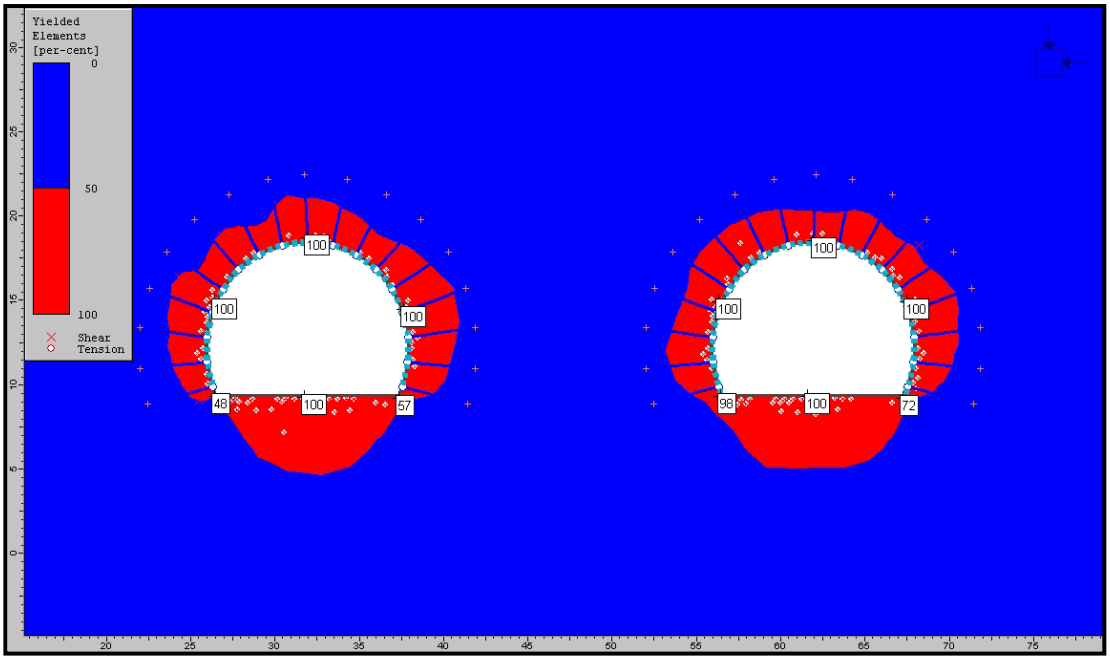



Figure III.7. Illustration of percentage of yielded elements of ground category (III) of Boztepe (T-1) tunnel.

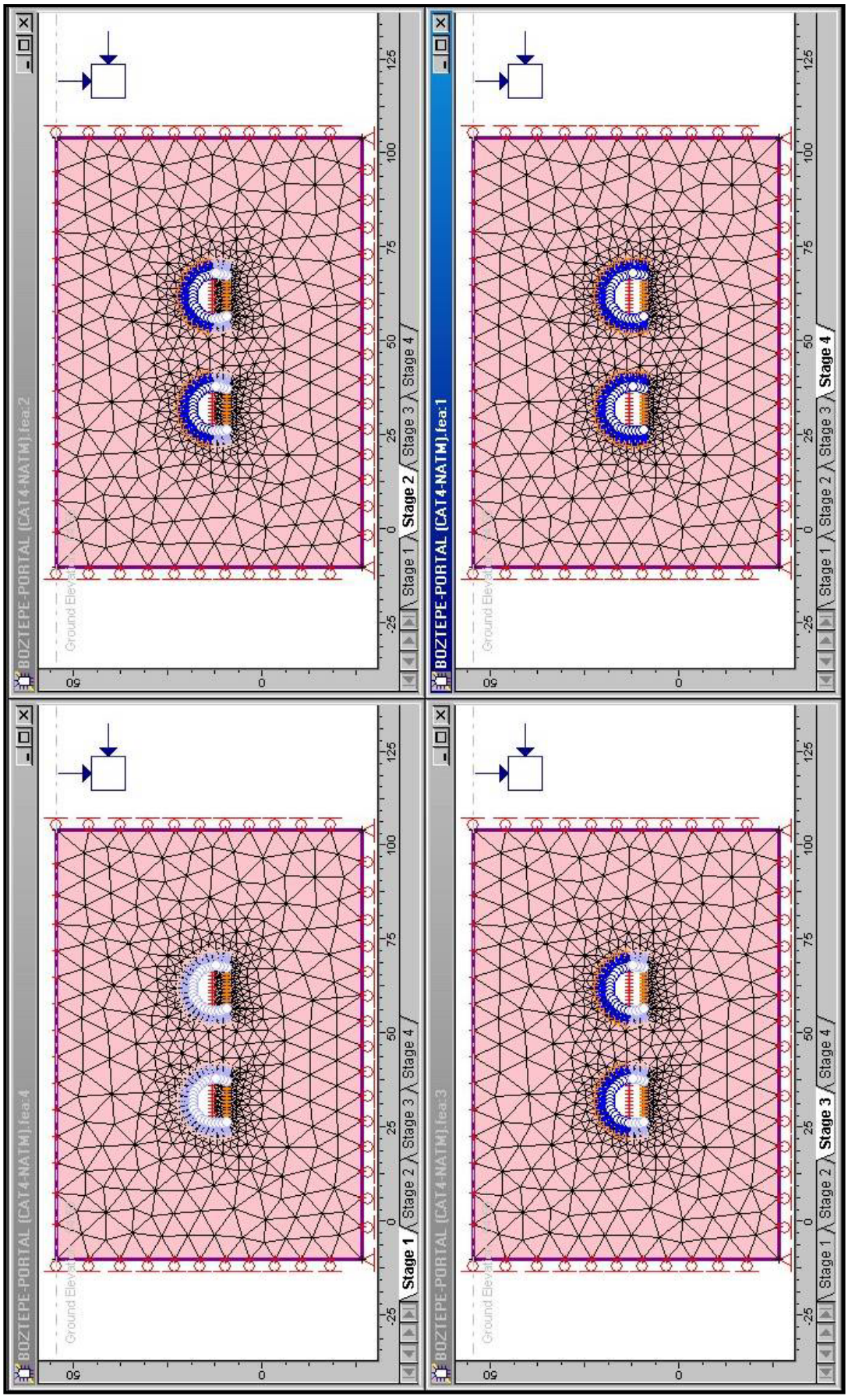



Figure IV.1. Excavation stages of ground category (IV) of Boztepe (T-1) tunnel.

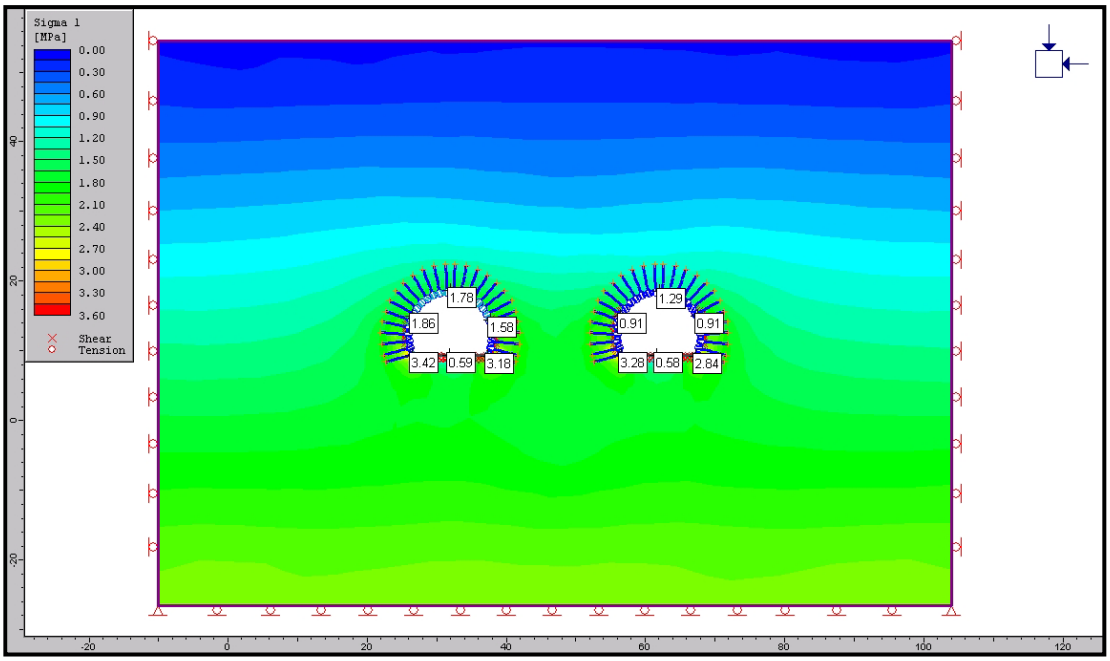



Figure IV.2. General view of model for ground category (IV) of Boztepe (T-1) tunnel.

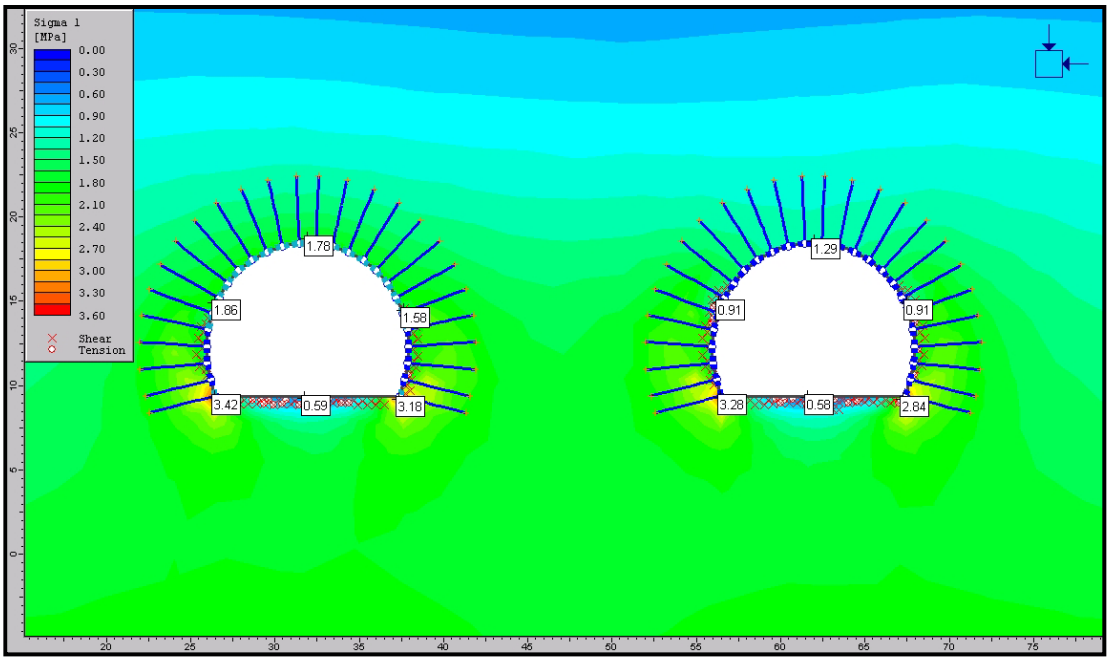



Figure IV.3. Major principal stress ($\sigma_1$) concentration of ground category (IV) of Boztepe (T-1) tunnel.

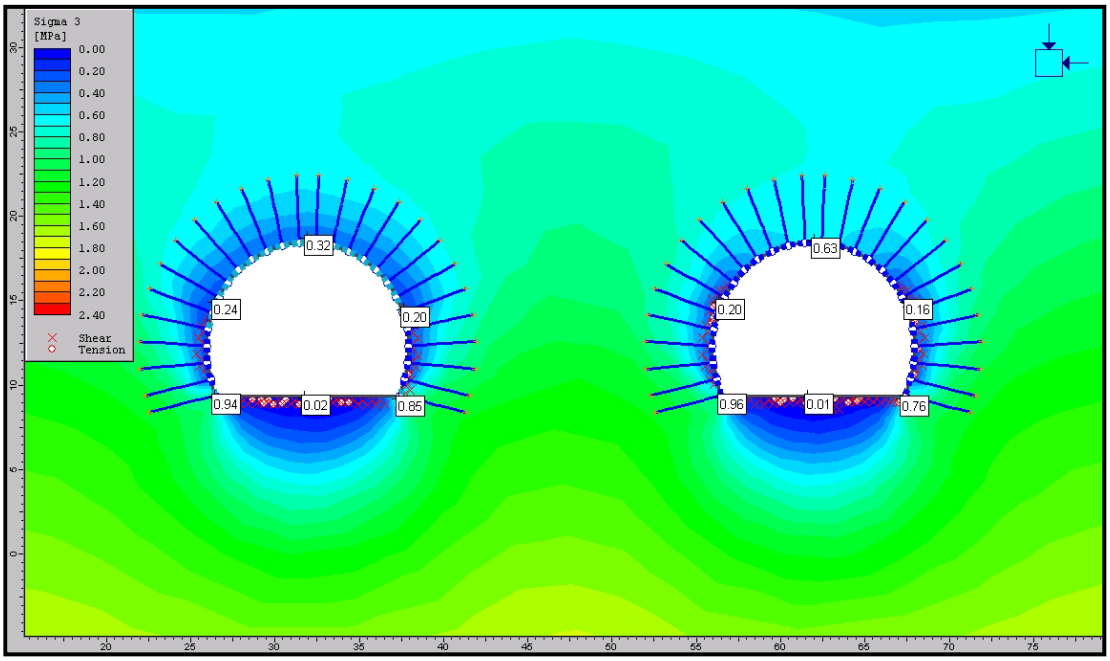



Figure IV.4. Minor principal stress ($\sigma_3$) concentration of ground category (IV) of Boztepe (T-1) tunnel.

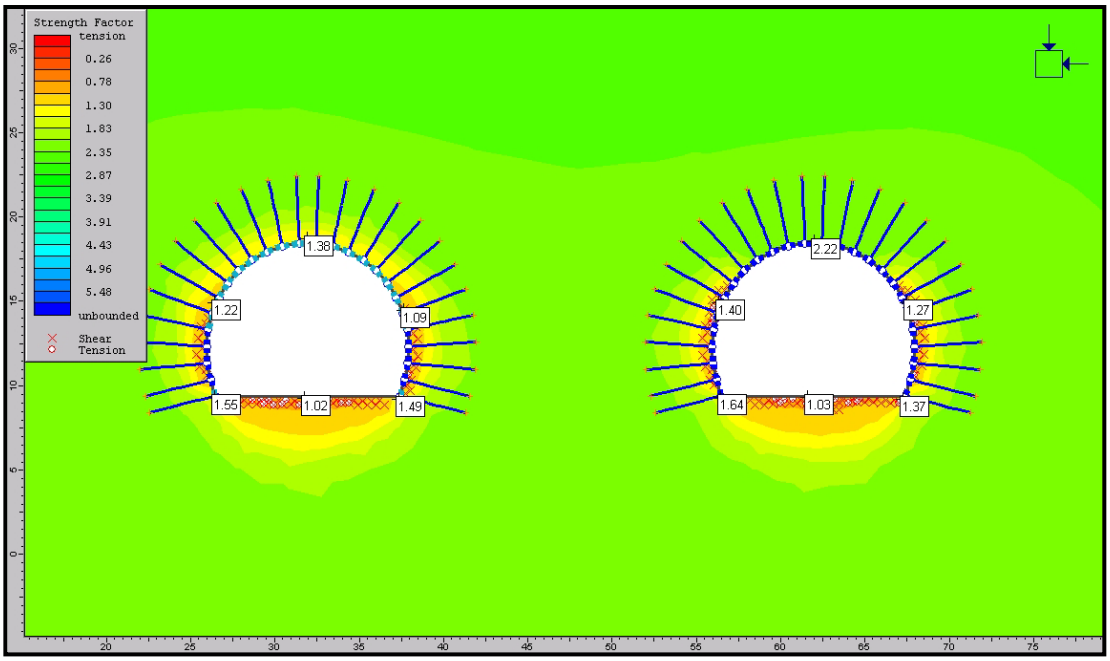



Figure IV.5. Strength factor concentration of ground category (IV) of Boztepe (T-1) tunnel.

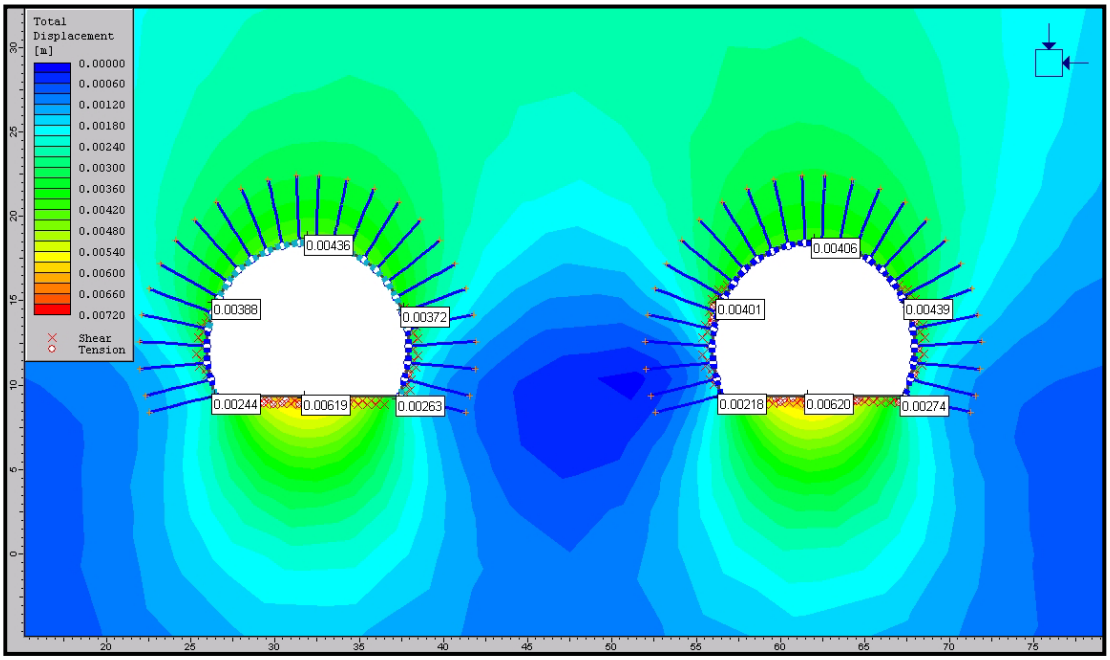



Figure IV.6. Total displacement concentration of ground category (IV) of Boztepe (T-1) tunnel.

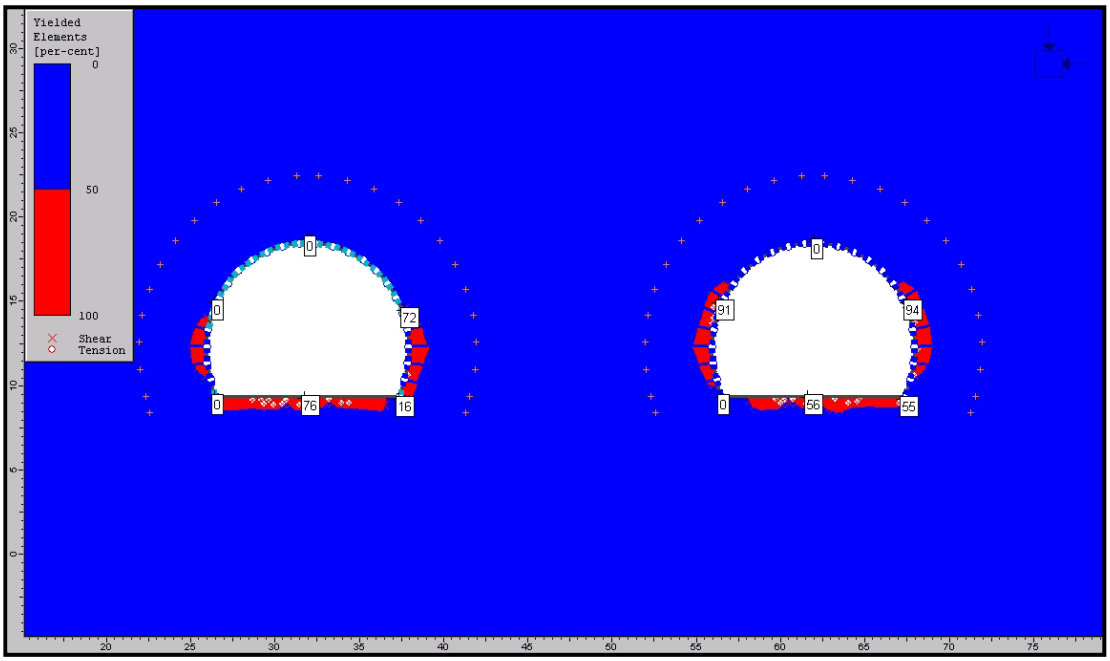



Figure IV.7. Illustration of percentage of yielded elements of ground category (IV) of Boztepe (T-1) tunnel.

## THE ÖCELİ (T-2) TUNNEL

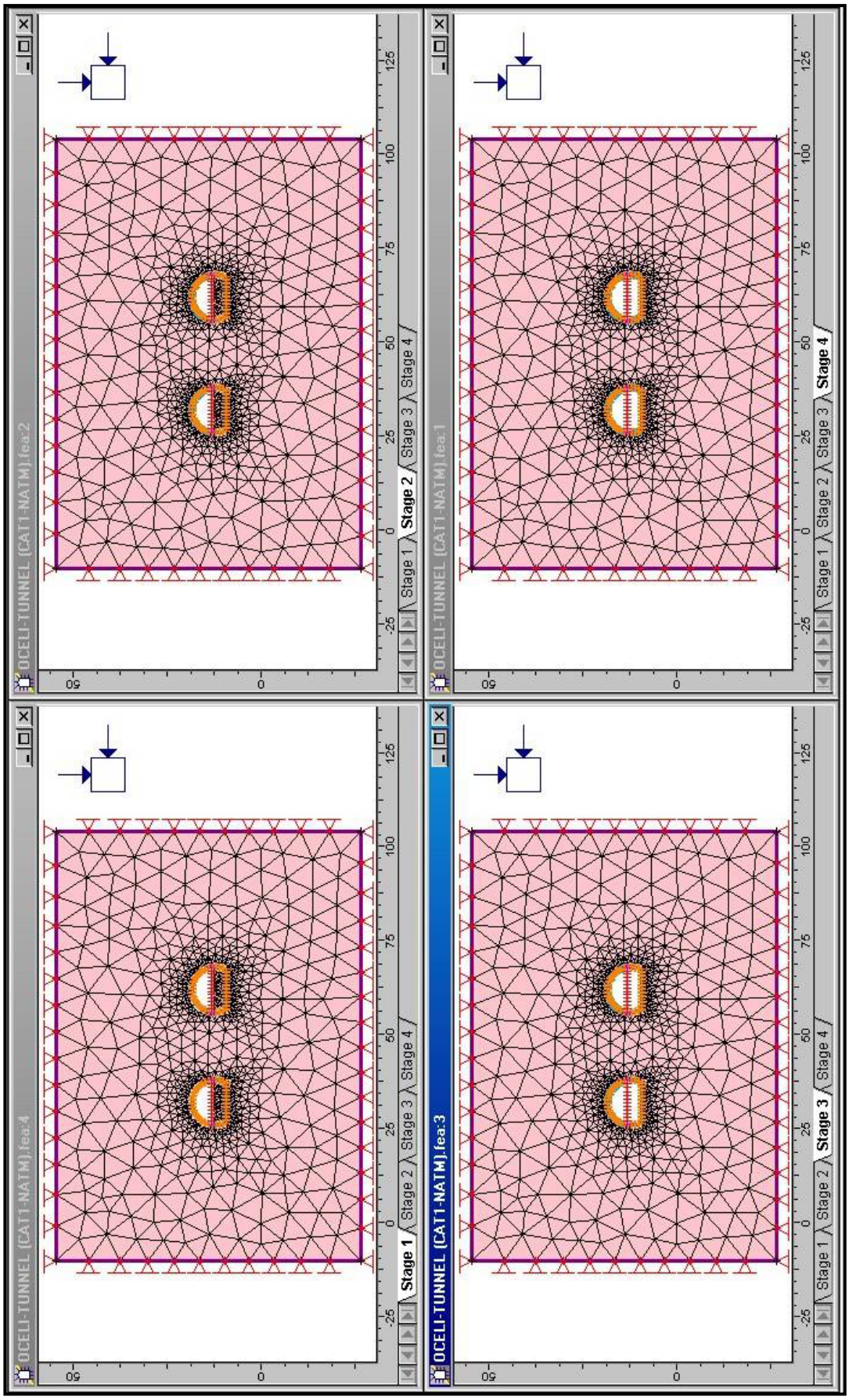



Figure I.1. Excavation stages of ground category (I) of Öceli (T-2) tunnel.

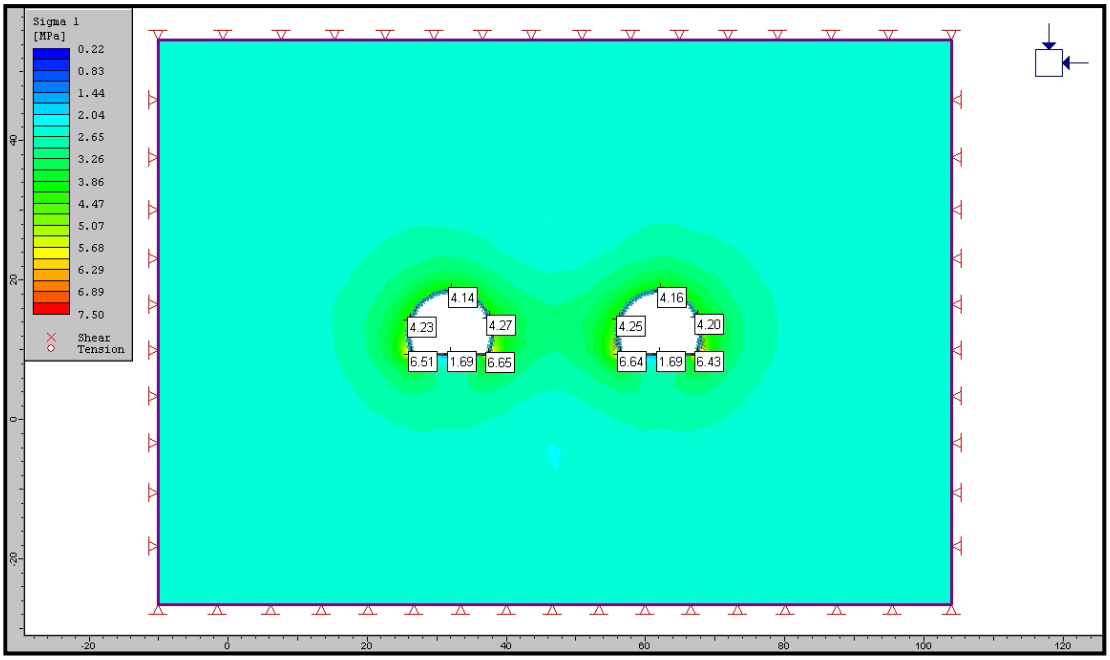



Figure I.2. General view of model for ground category (I) of Öceli (T-2) tunnel.

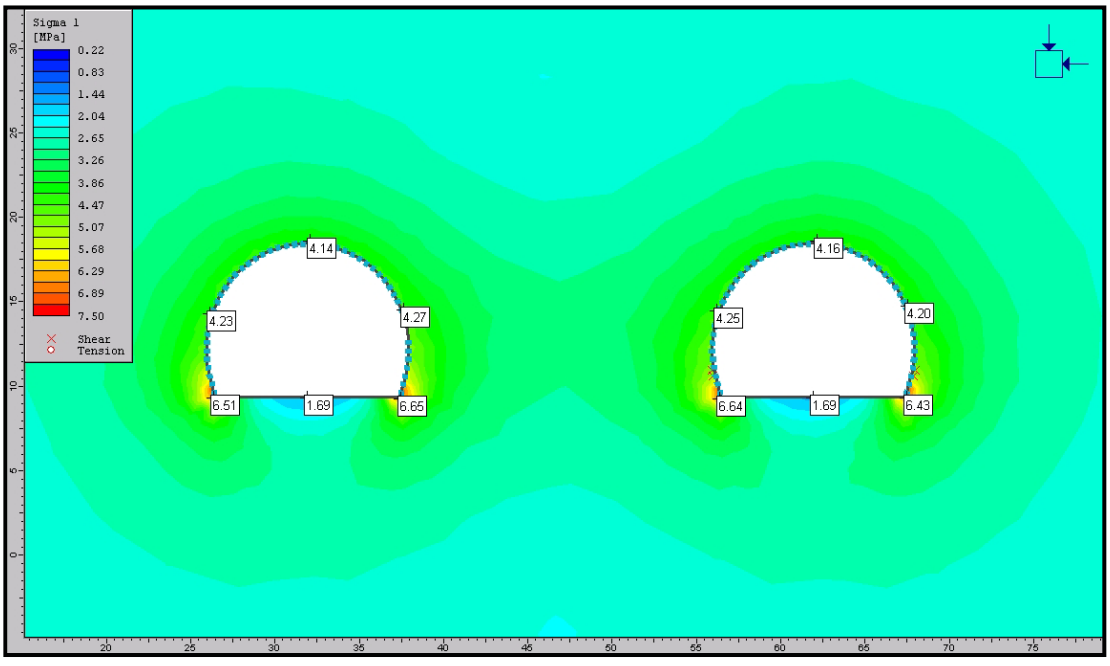



Figure I.3. Major principal stress ($\sigma_1$) concentration of ground category (I) of Öceli (T-2) tunnel.

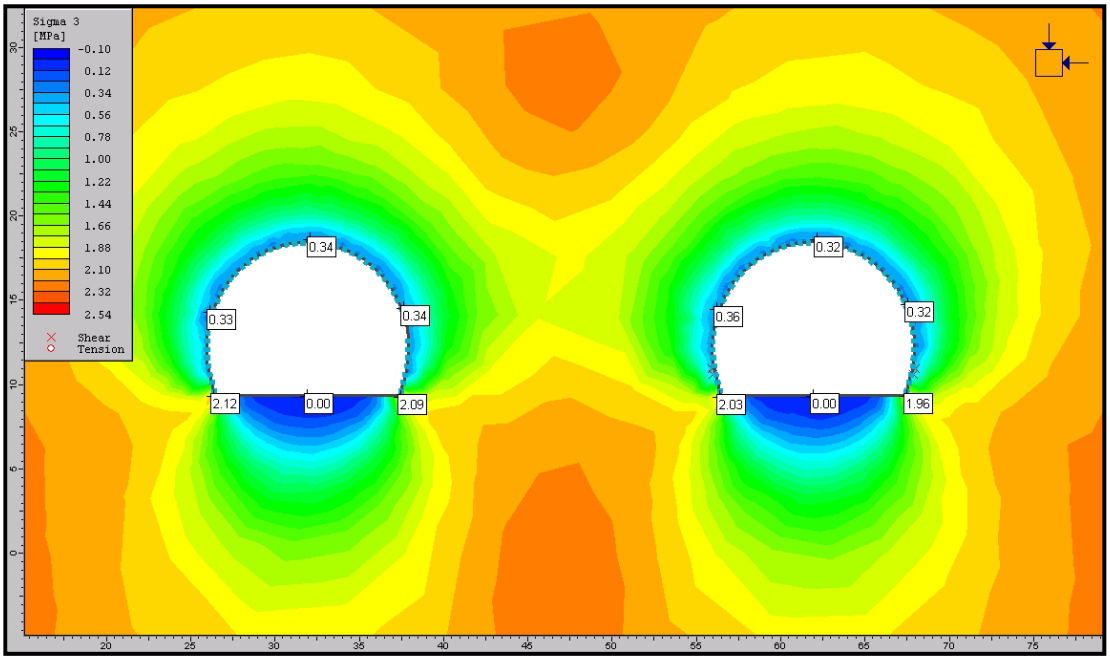



Figure I.4. Minor principal stress ($\sigma_3$) concentration of ground category (I) of Öceli (T-2) tunnel.

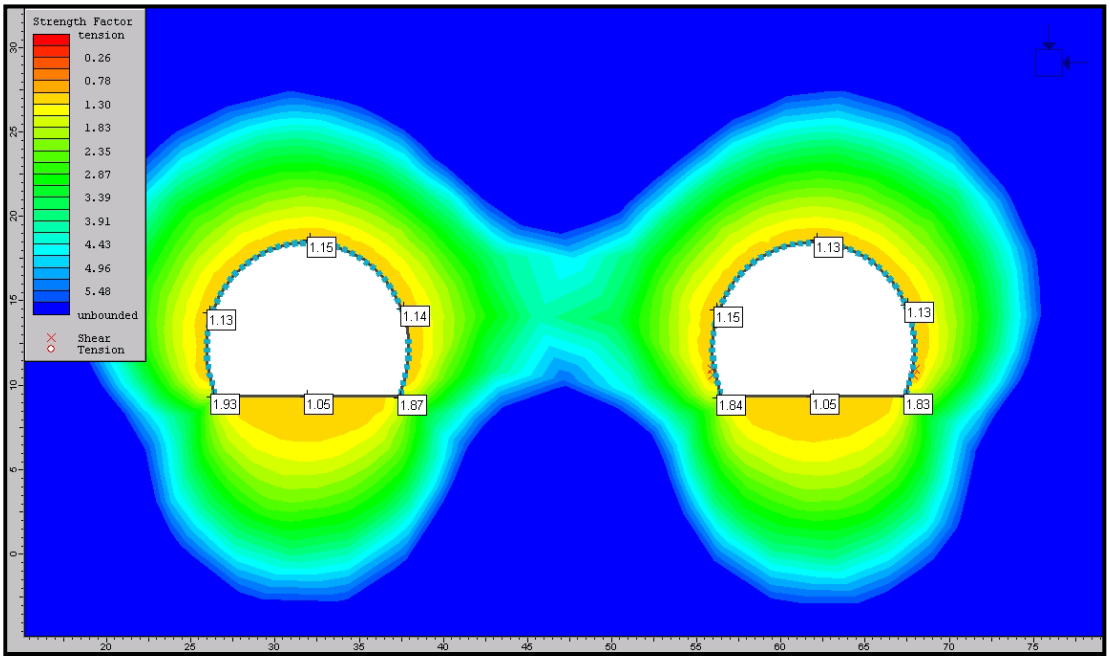



Figure I.5. Strength factor concentration of ground category (I) of Öceli (T-2) tunnel.

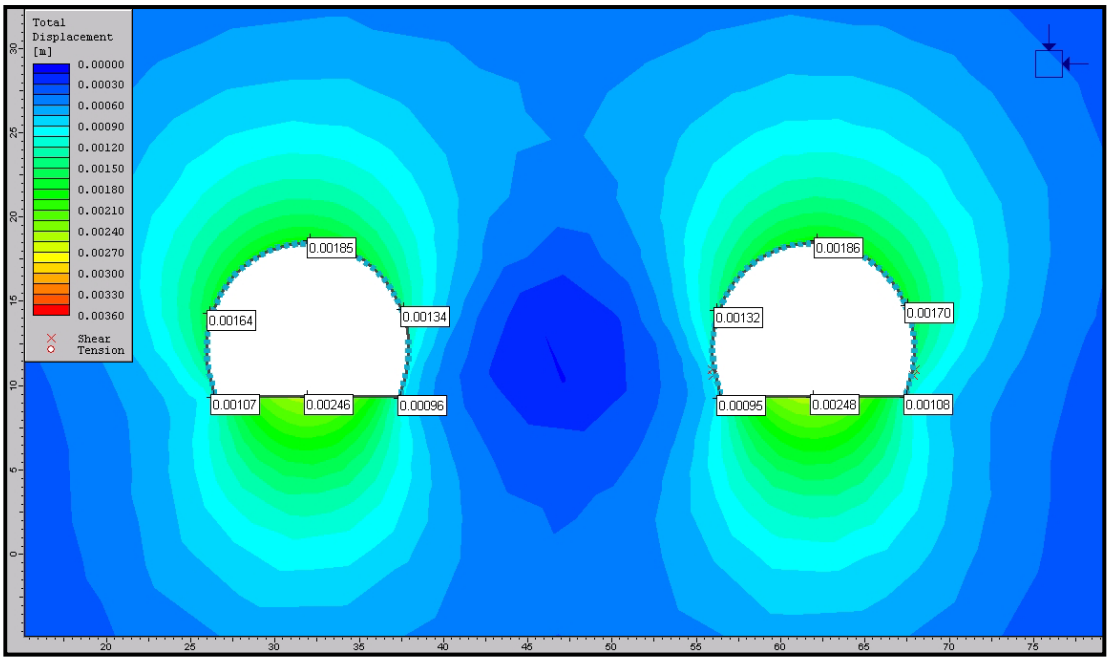



Figure I.6. Total displacement concentration of ground category (I) of Öceli (T-2) tunnel.

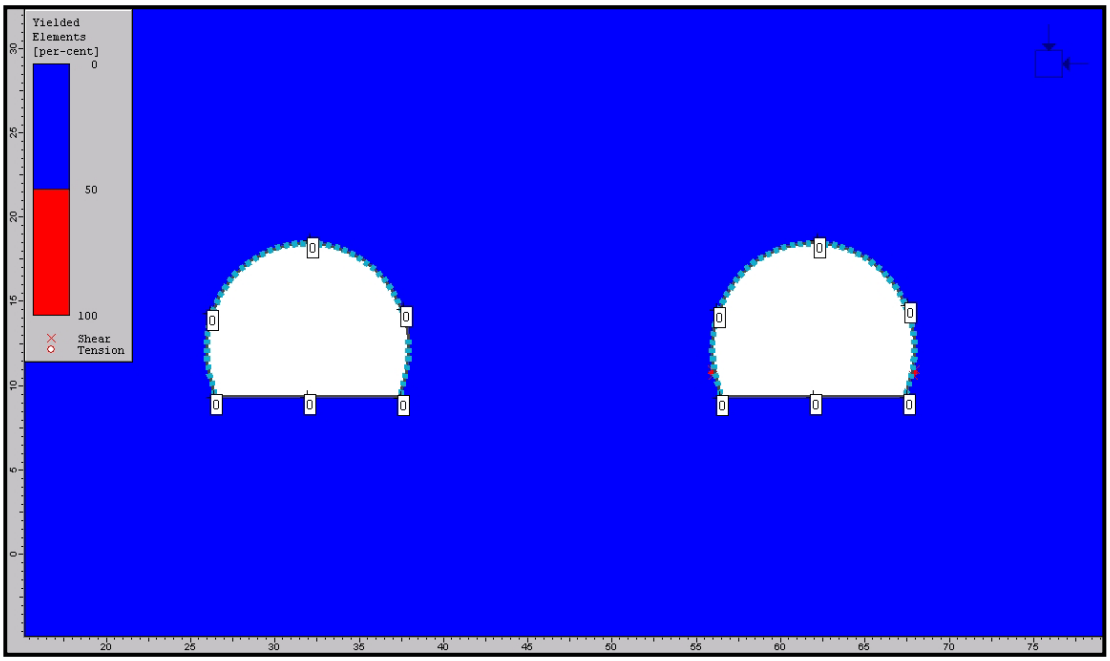



Figure I.7. Illustration of percentage of yielded elements of ground category (I) of Öceli (T-2) tunnel.

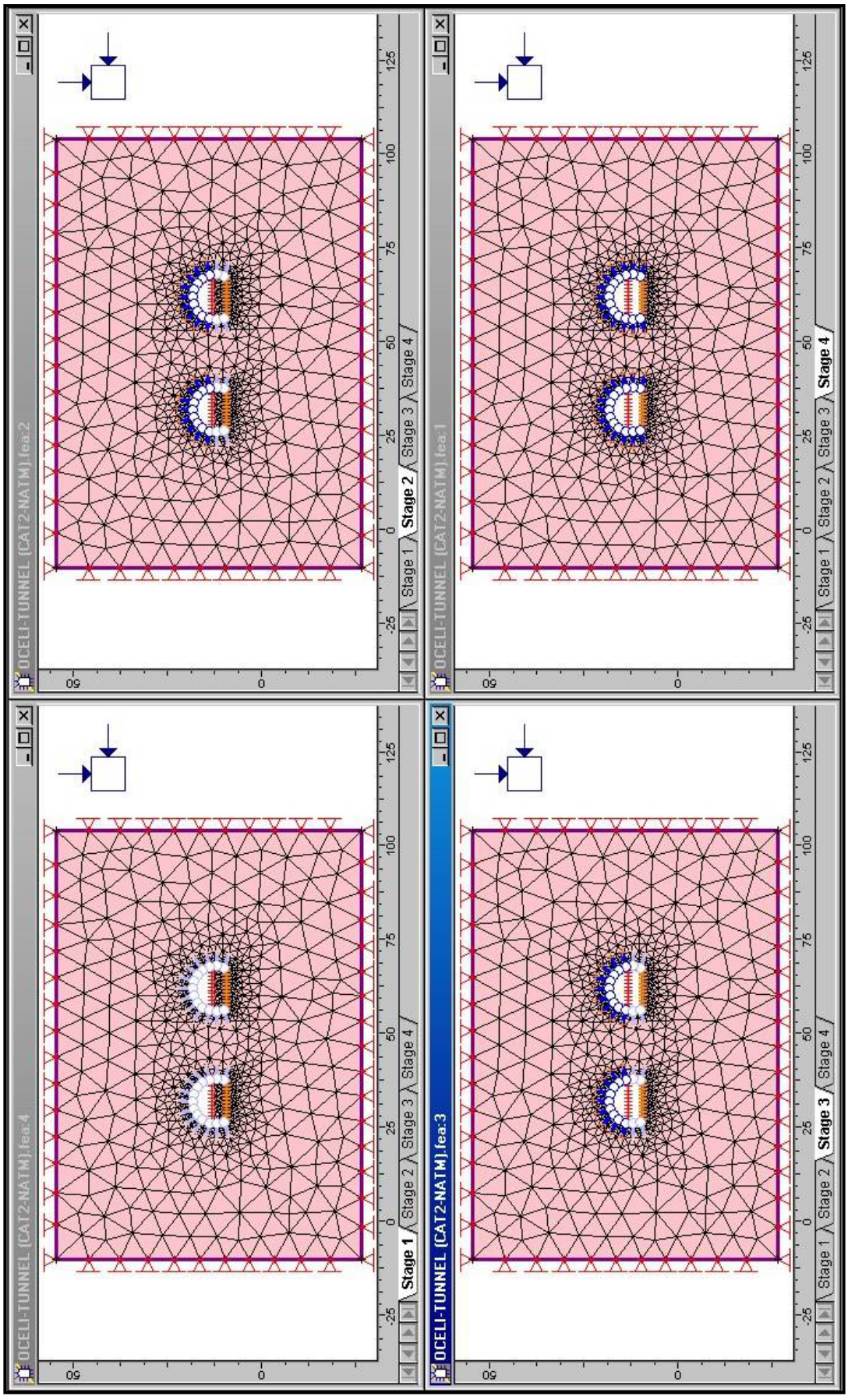



Figure II.1. Excavation stages of ground category (II) of Öceli (T-2) tunnel.

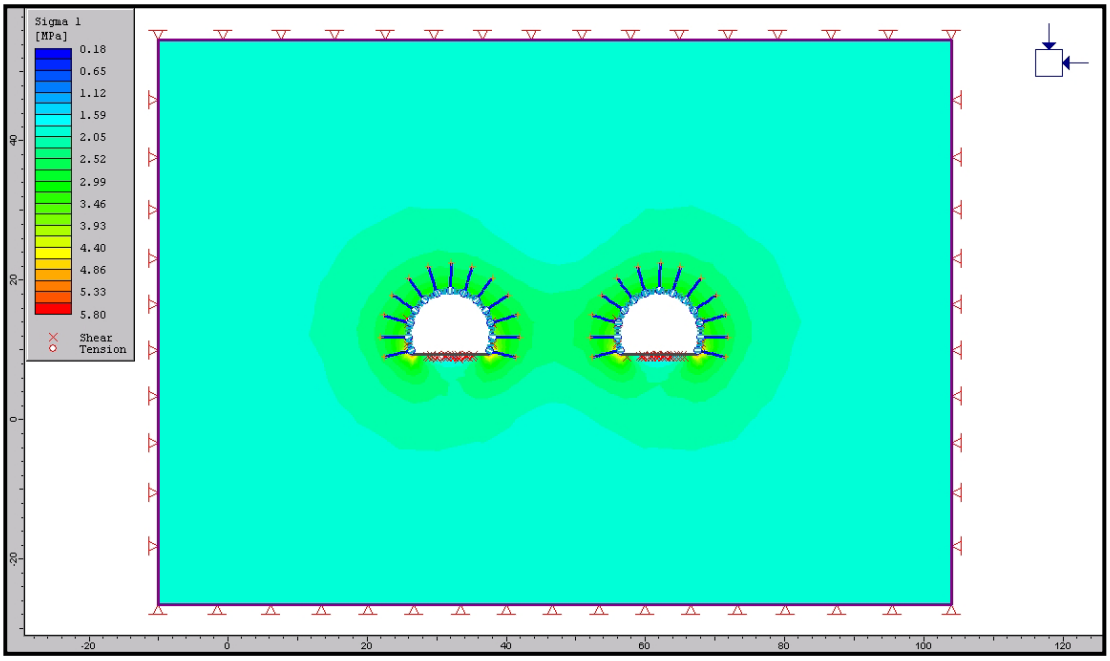



Figure II.2. General view of model for ground category (II) of Öceli (T-2) tunnel.

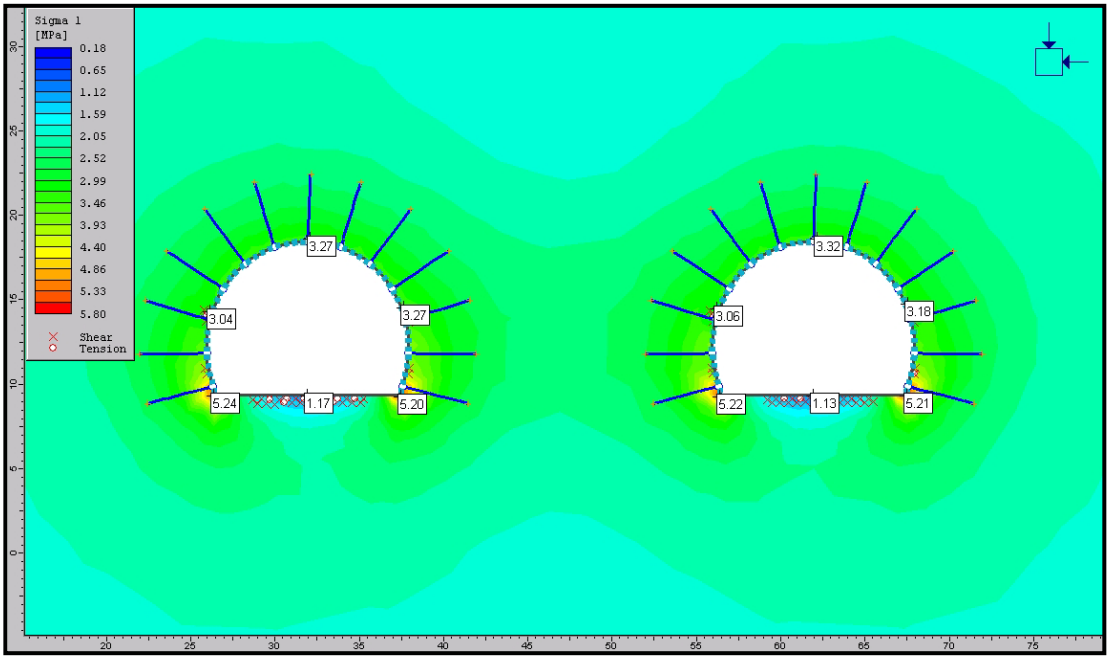



Figure II.3. Major principal stress ($\sigma_1$) concentration of ground category (II) of Öceli (T-2) tunnel.

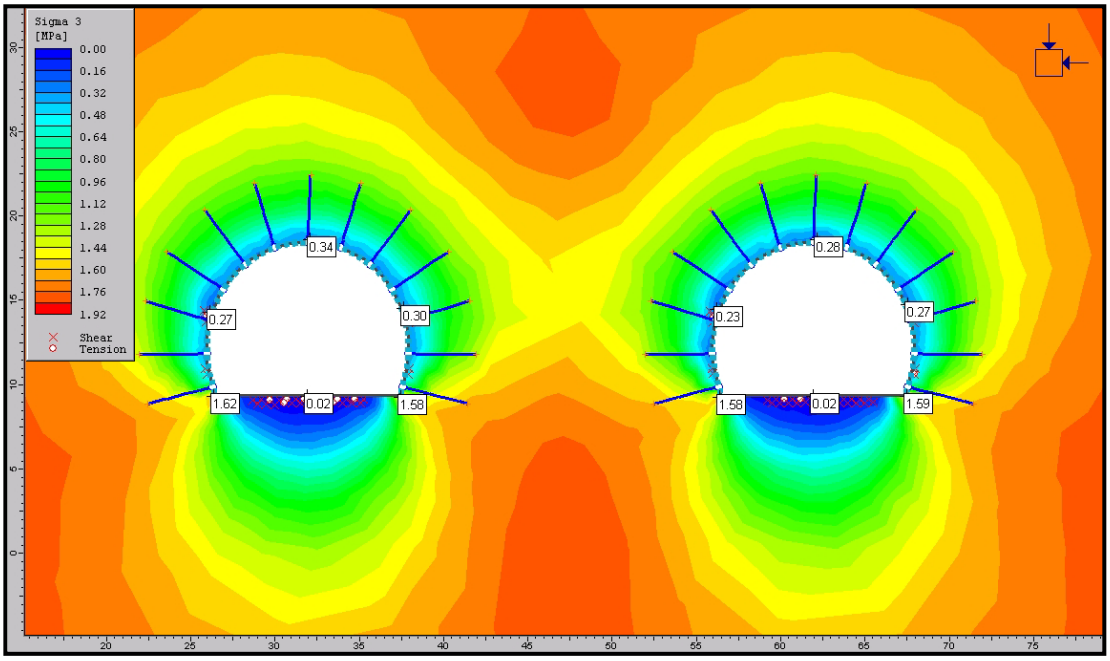



Figure II.4. Minor principal stress ($\sigma_3$) concentration of ground category (II) of Öceli (T-2) tunnel.

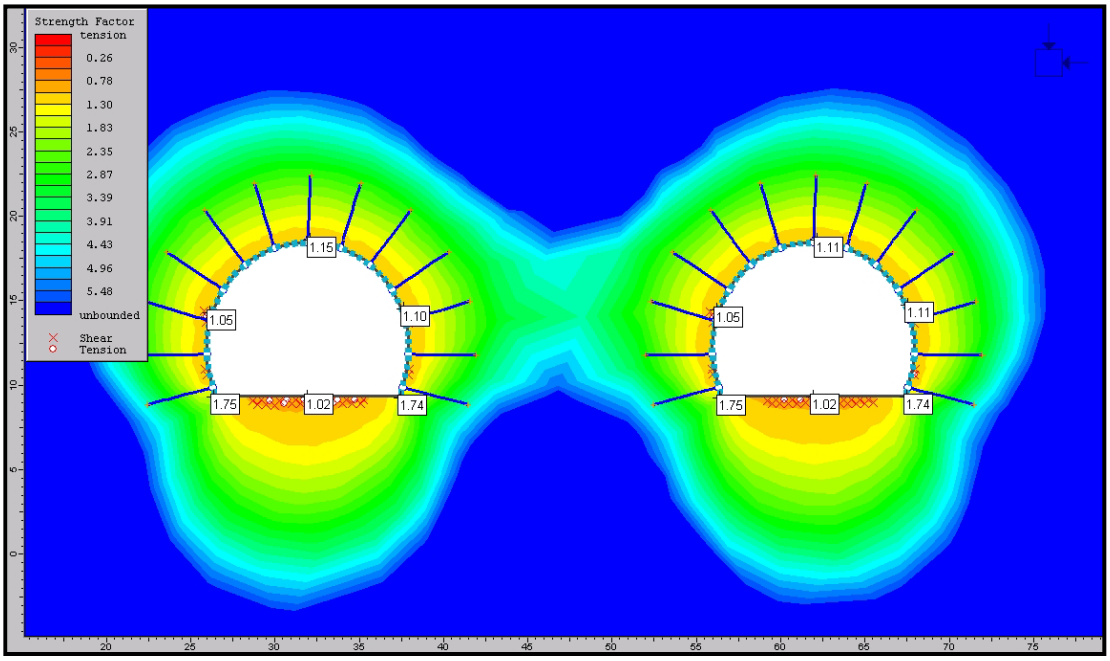



Figure II.5. Strength factor concentration of ground category (II) of Öceli (T-2) tunnel.

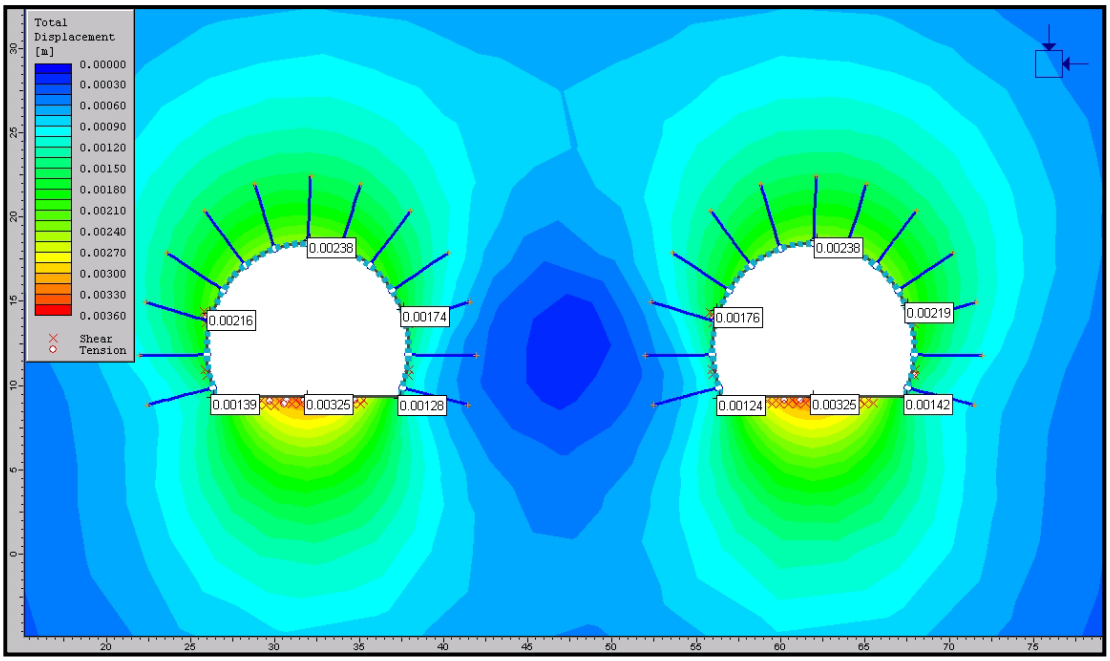



Figure II.6. Total displacement concentration of ground category (II) of Öceli (T-2) tunnel.

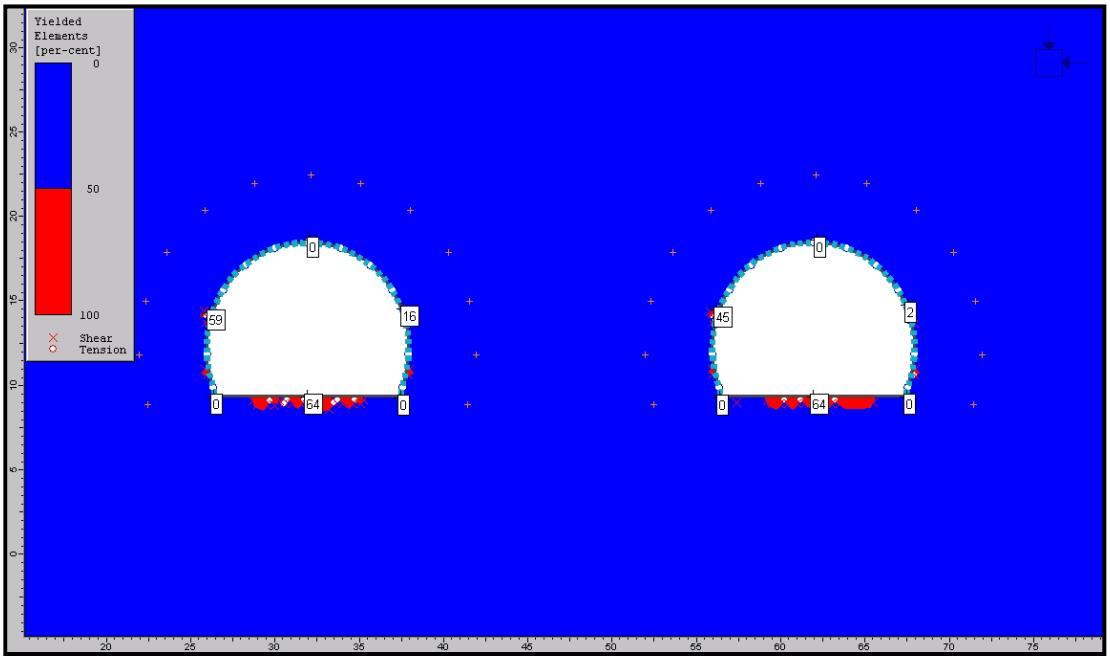



Figure II.7. Illustration of percentage of yielded elements of ground category (II) of Öceli (T-2) tunnel.

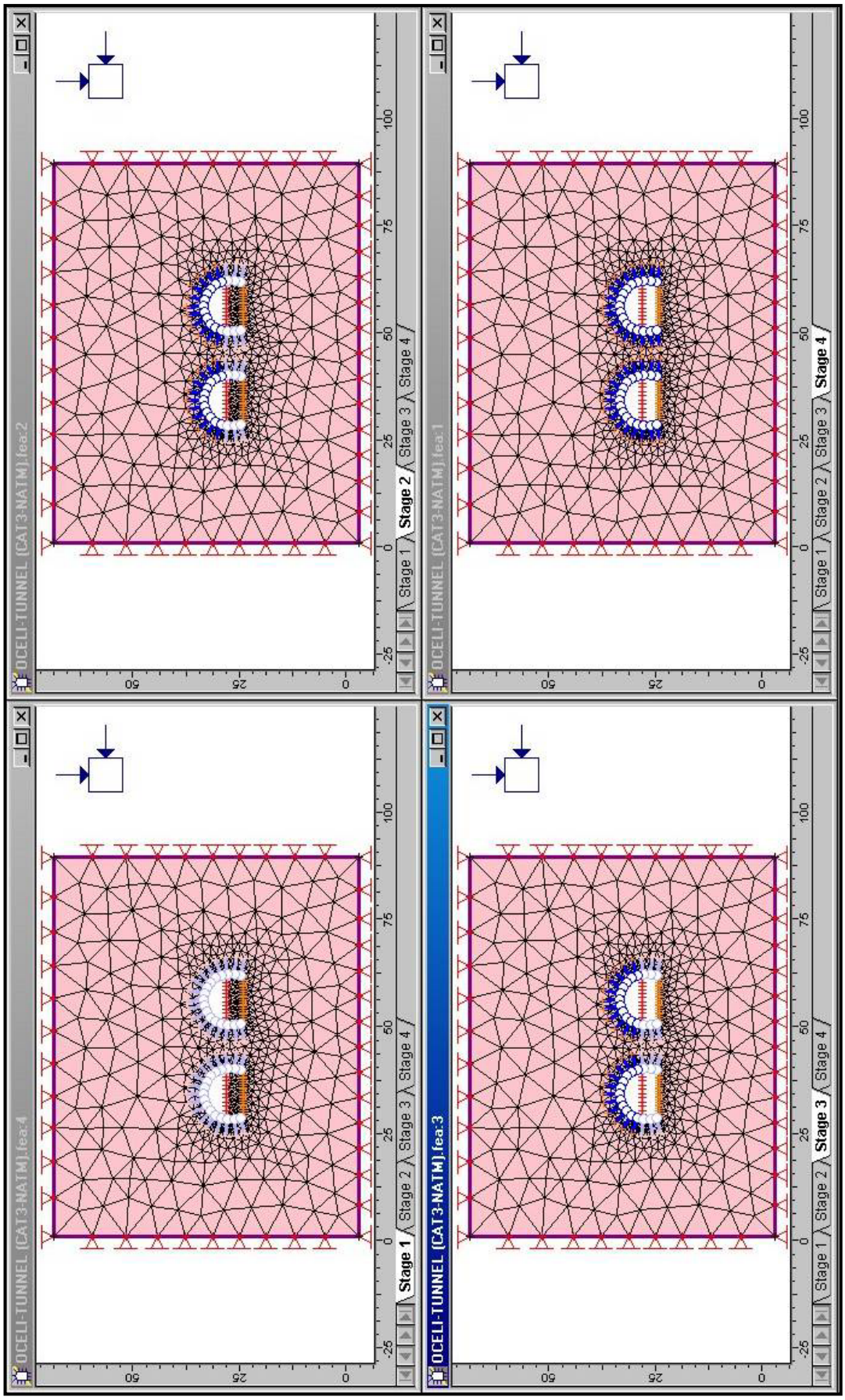



Figure III.1. Excavation stages of ground category (III) of Öceli (T-2) tunnel.

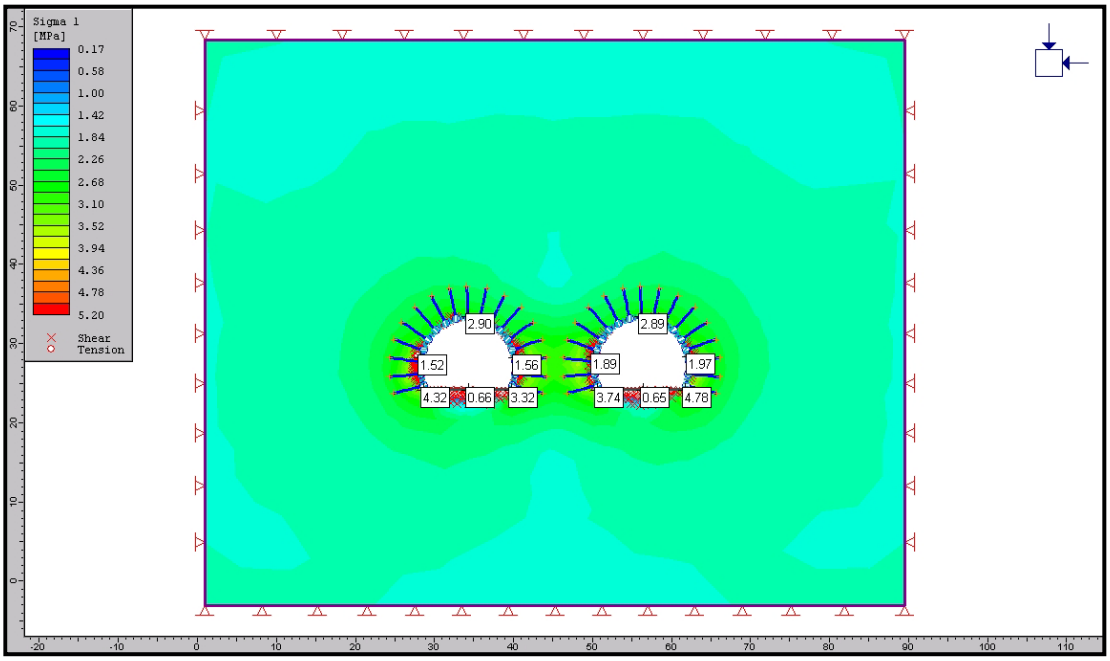



Figure III.2. General view of model for ground category (III) of Öceli (T-2) tunnel.

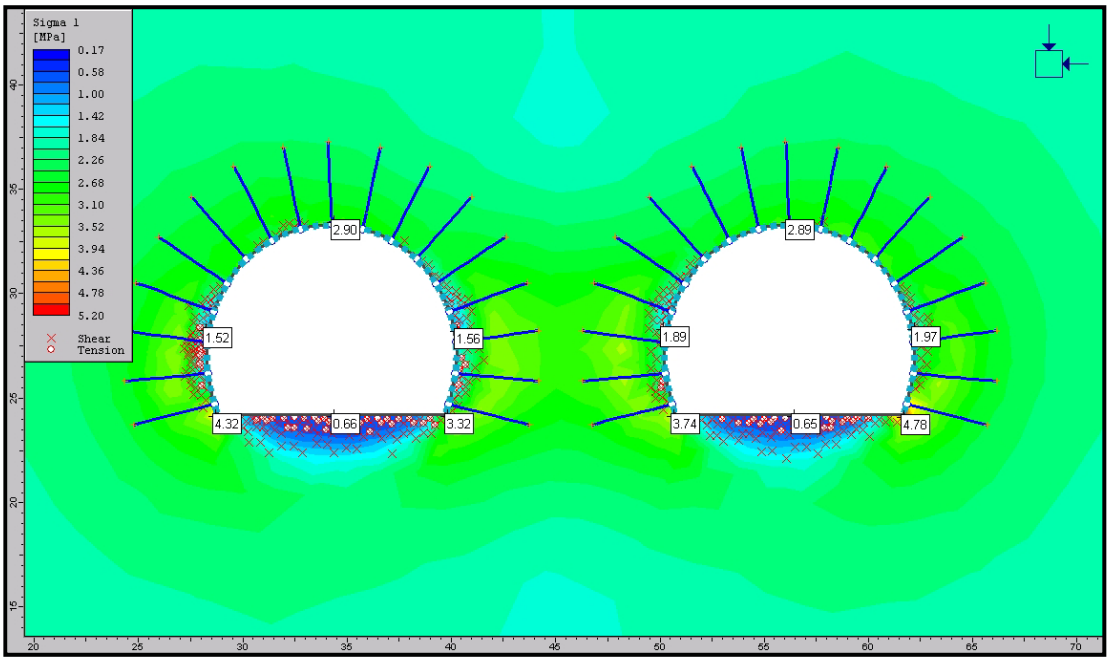



Figure III.3. Major principal stress ($\sigma_1$) concentration of ground category (III) of Öceli (T-2) tunnel.

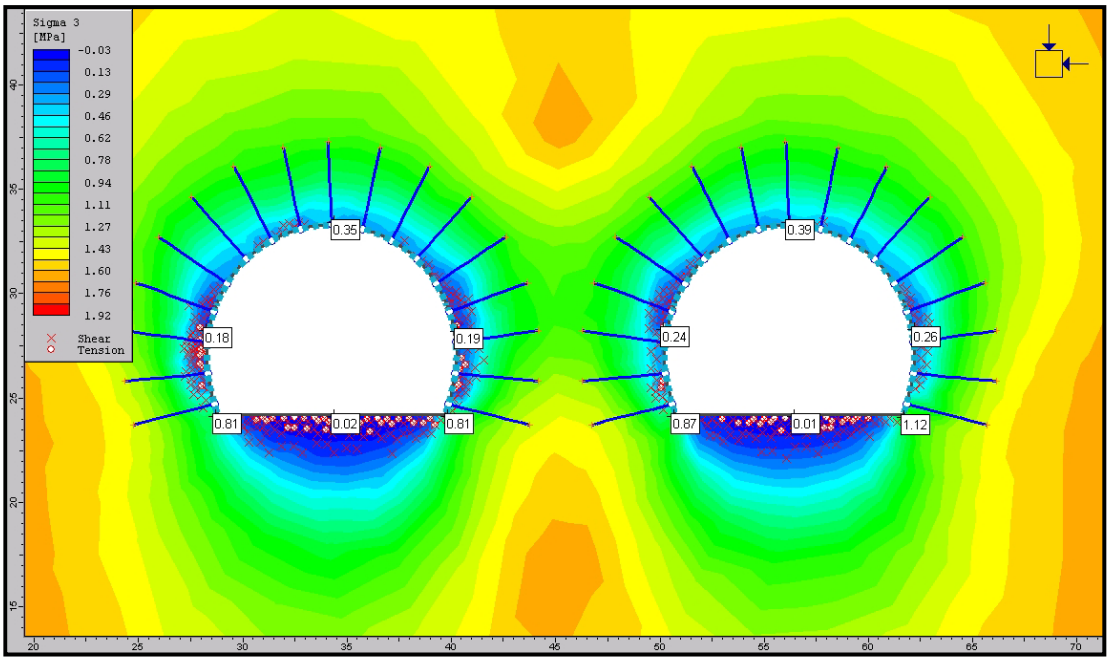



Figure III.4. Minor principal stress ($\sigma_3$) concentration of ground category (III) of Öceli (T-2) tunnel.

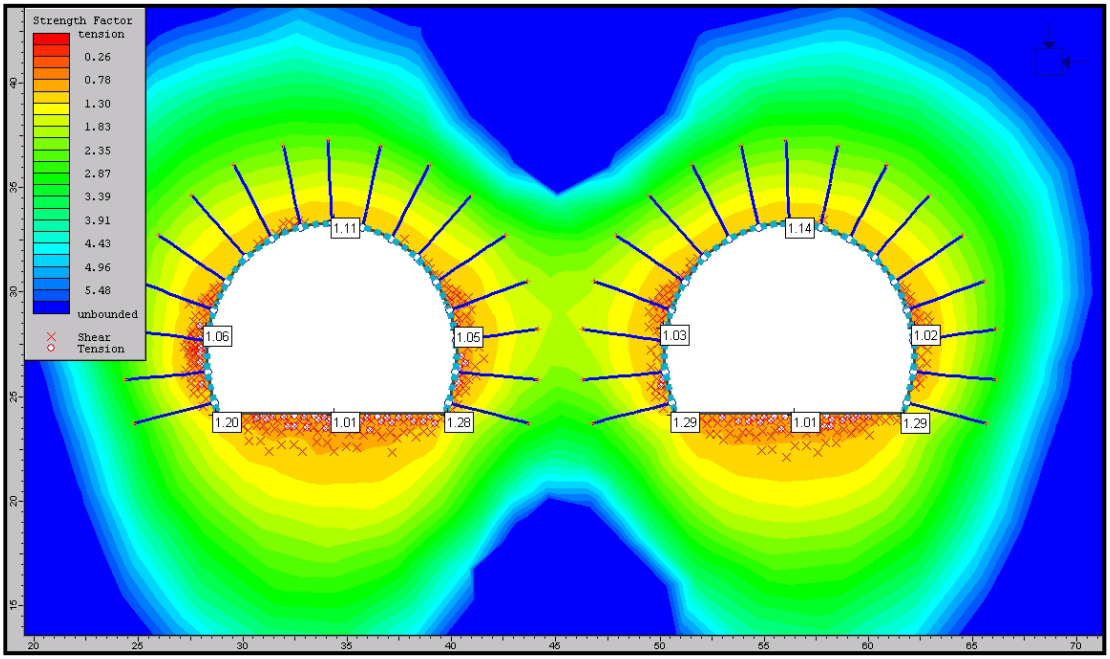



Figure III.5. Strength factor concentration of ground category (III) of Öceli (T-2) tunnel.

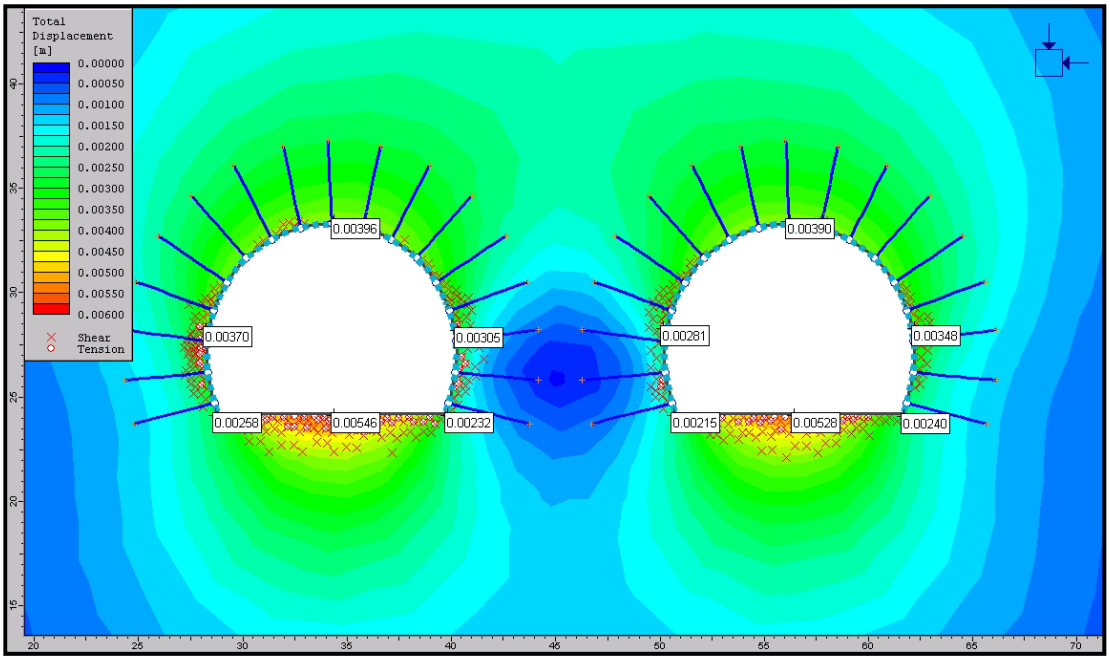



Figure III.6. Total displacement concentration of ground category (III) of Öceli (T-2) tunnel.

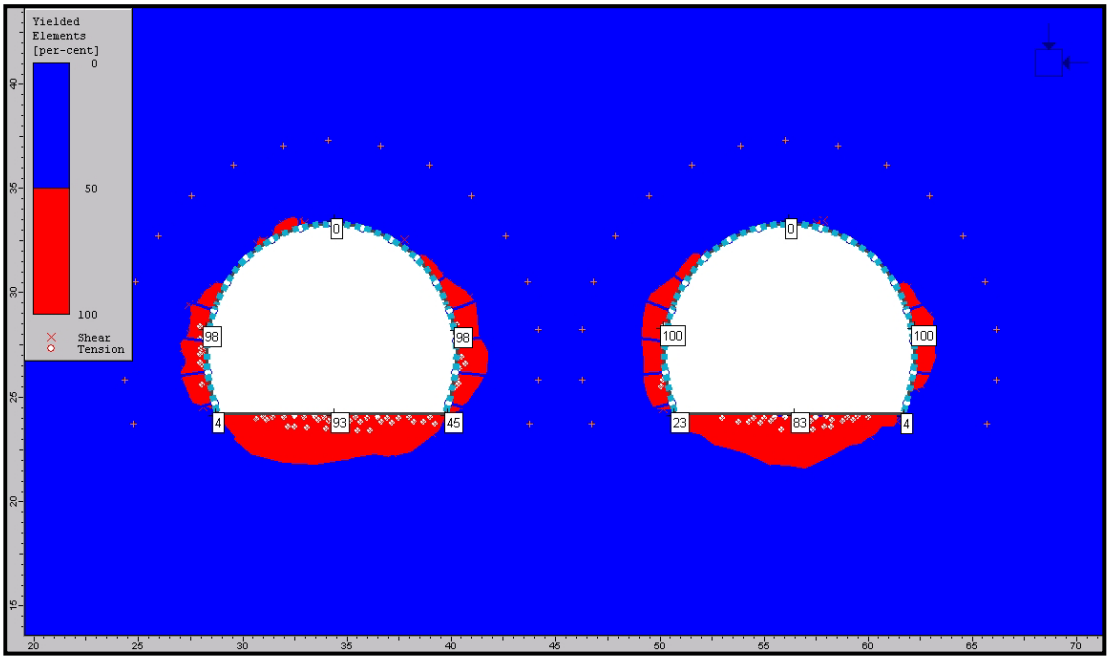



Figure III.7. Illustration of percentage of yielded elements of ground category (III) of Öceli (T-2) tunnel.

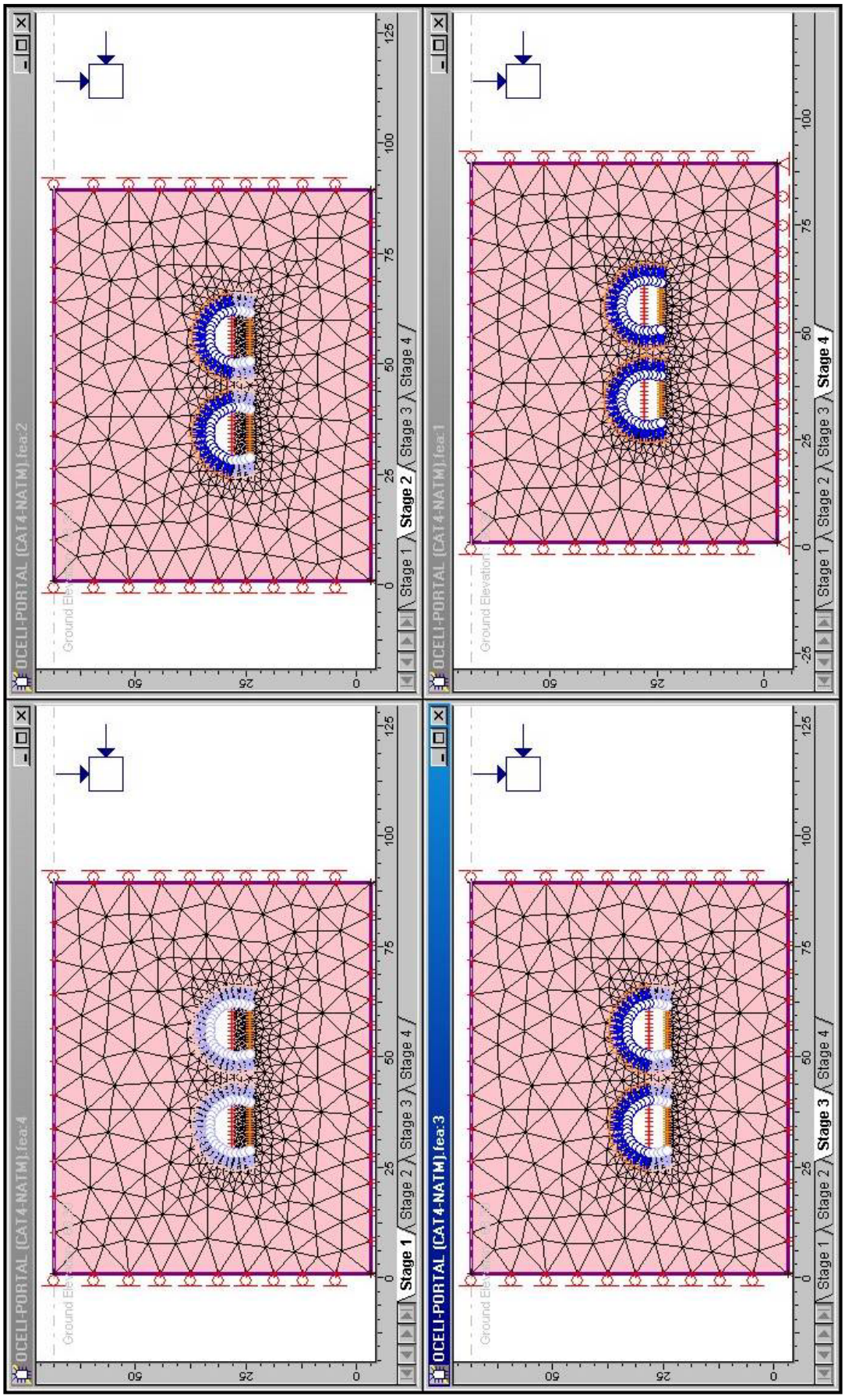



Figure IV.1. Excavation stages of ground category (IV) of Öceli (T-2) tunnel.

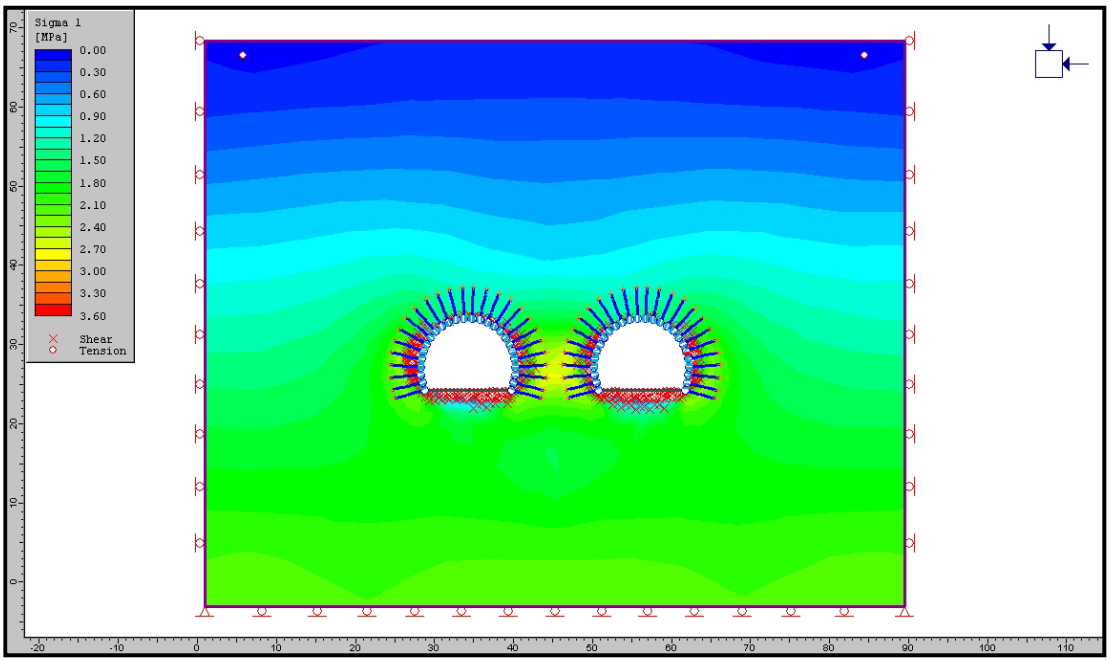



Figure IV.2. General view of model for ground category (IV) of Öceli (T-2) tunnel.

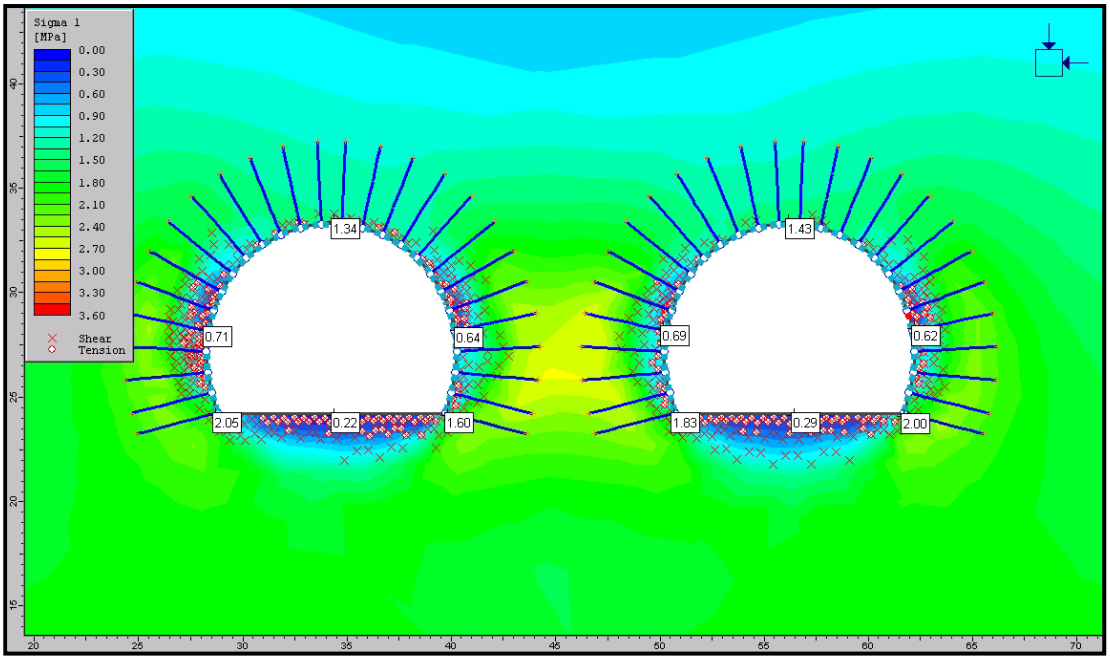



Figure IV.3. Major principal stress ($\sigma_1$) concentration of ground category (IV) of Öceli (T-2) tunnel.

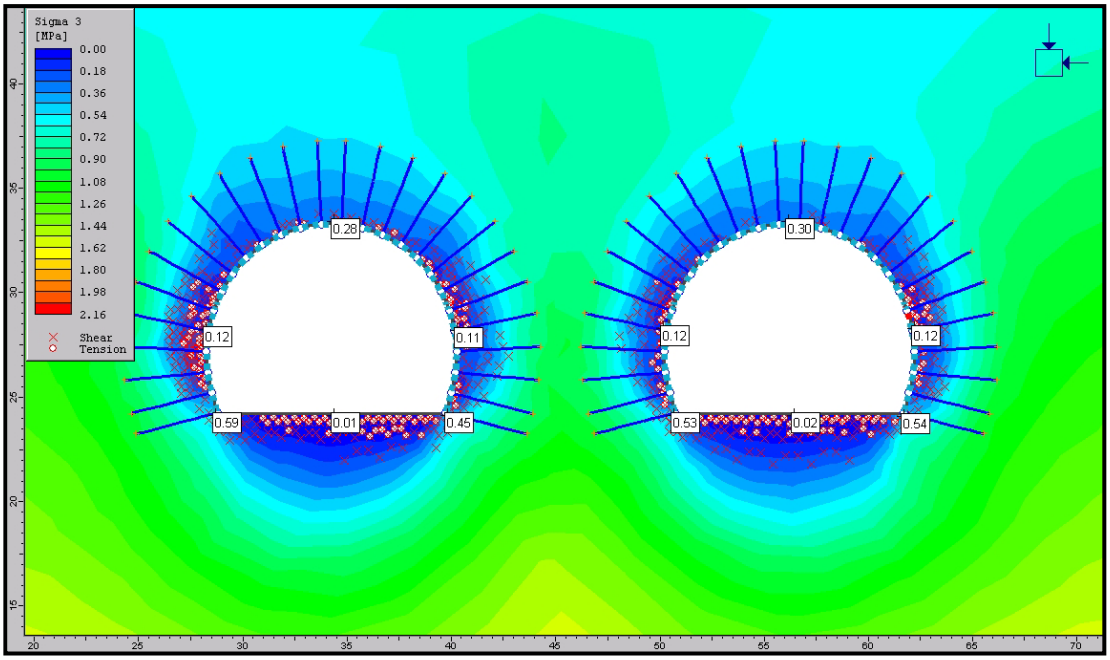



Figure IV.4. Minor principal stress ($\sigma_3$) concentration of ground category (IV) of Öceli (T-2) tunnel.

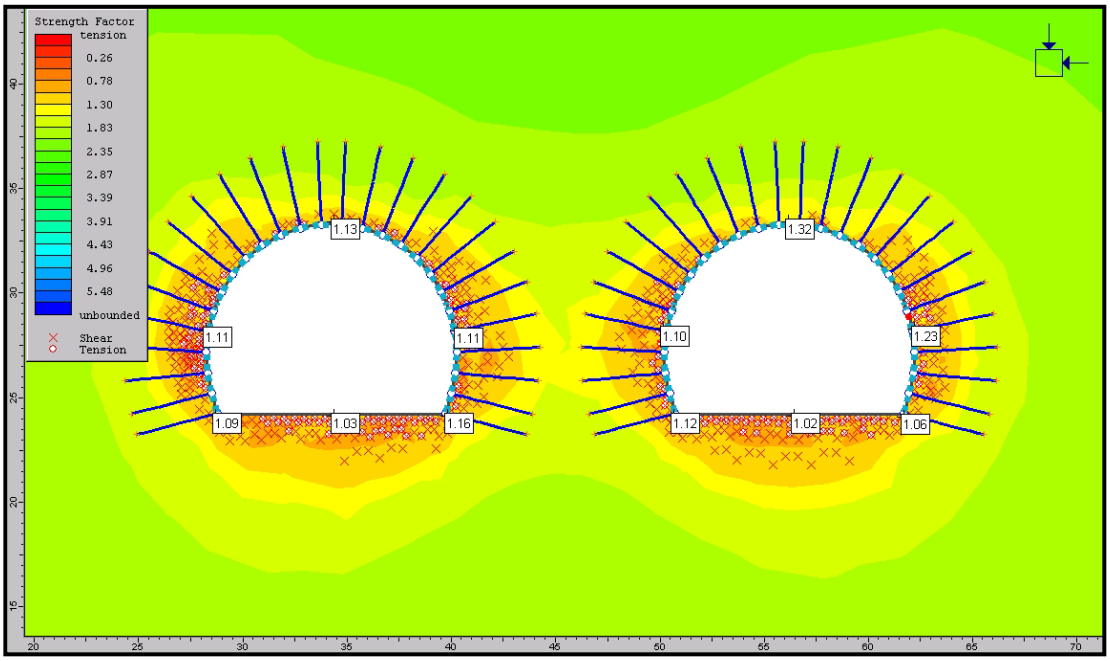



Figure IV.5. Strength factor concentration of ground category (IV) of Öceli (T-2) tunnel.

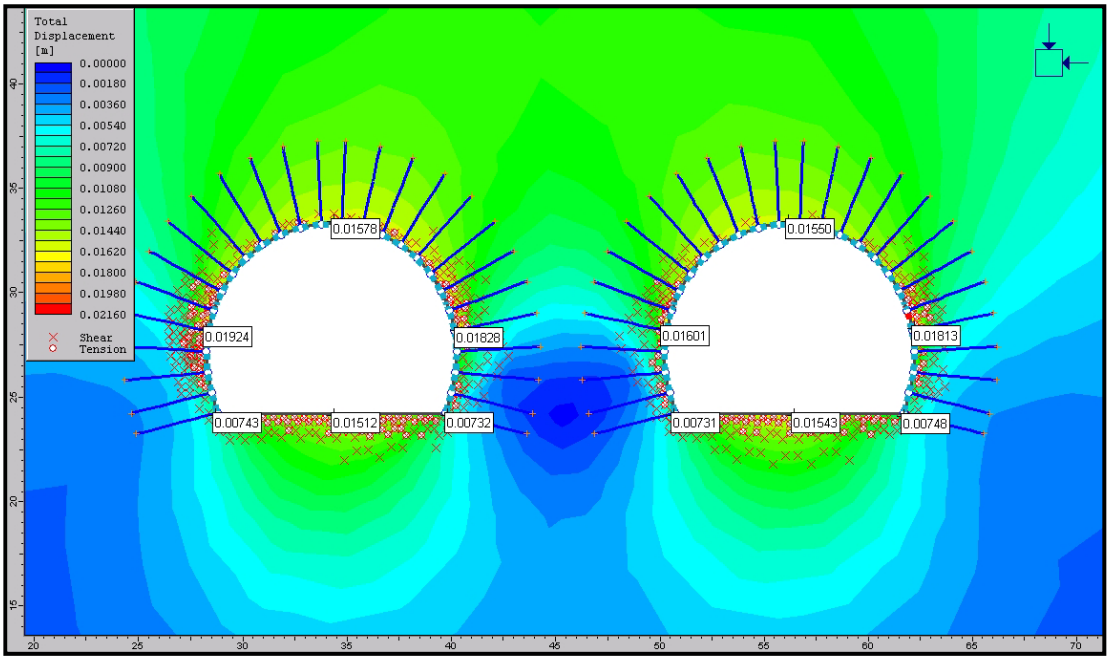



Figure IV.6. Total displacement concentration of ground category (IV) of Öceli (T-2) tunnel

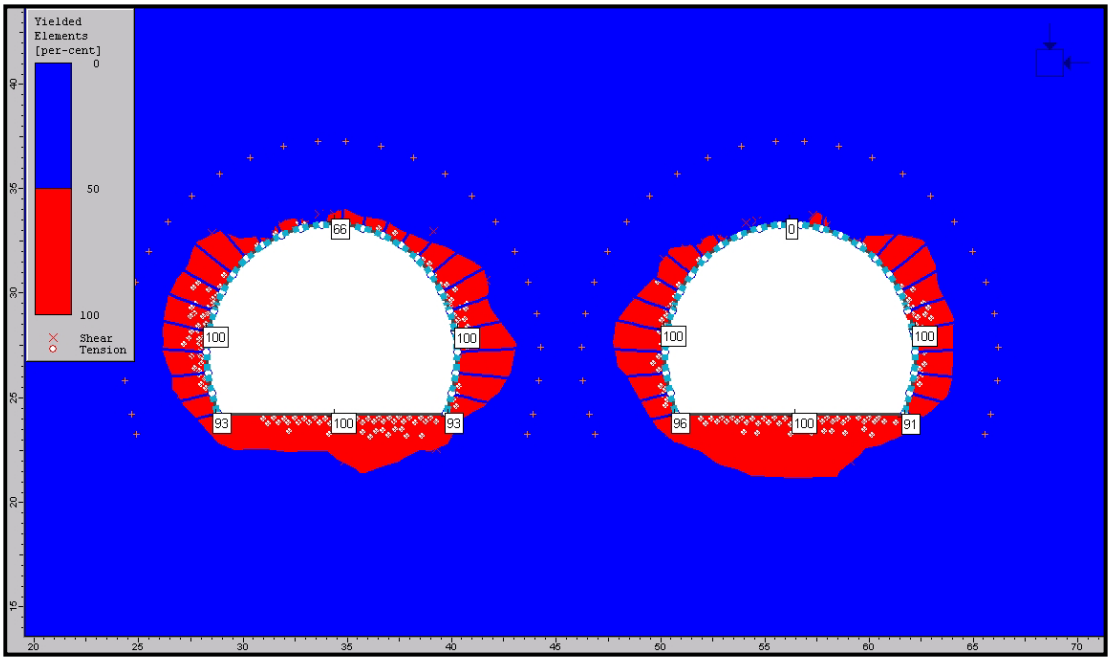



Figure IV.7. Illustration of percentage of yielded elements of ground category (IV) of Öceli (T-2) tunnel.