STABILITY ANALYSIS, DISPLACEMENT MONITORING AND JUSTIFICATION OF THE CRITICAL SECTIONS OF THE KONAK TUNNEL

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ABSTRACT

STABILITY ANALYSIS, DISPLACEMENT MONITORING AND JUSTIFICATION OF THE CRITICAL SECTIONS OF THE KONAK TUNNEL

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The main focus of this research is numerical analysis and preliminary support design for the critical sections of the twin tube Konak Tunnel that was constructed in a highly populated area in Konak, İzmir. The displacements of the tunnel were monitored and justified by comparing with the results of the numerical analyses. The stability of the tunnel exit portal and associated slopes, which is one of the most challenging sections of the project, was analyzed as well.

In study area, volcanics, pyroclastics and some sedimentary deposits (sandstone, mudstone and conglomerate) often intertongue with each other especially in the exit portal area. The accurate determination of the shear strength and deformation parameters of these units is important for the assessment of portal slope stability and support design and displacement predictions in the tunnel design. Rock mass classification systems, namely, RMR, Q system and GSI, have been employed to obtain the rock mass shear strength and deformation parameters. Stress analysis around the tunnel openings has been done through employing 2D finite element analysis for inspecting the tunnel support design and the vertical displacement in the critical sections and five different measurement points. The results of the finite element analysis have been controlled and correlated with the results of monitored vertical displacements. Consequently, when the monitoring points on the critical sections are evaluated individually, 70 % of the points ensure the predicted displacement limits and only 12.5 % of the displacements mismatch ratio is higher than the 50 %. Moreover both the support system elements and the rock mass have not been yielded due to the redistribution of stress conditions.

KEYWORDS: İzmir region, Tunnel, Volcanics, Rock mass, Rock mass classification, Monitoring, Numerical modelling.

ÖZ

KONAK TÜNELİ KRİTİK KESİMLERİNİN DURAYLILIK ANALİZLERİ, DEFORMASYON İZLEMESİ VE DOĞRULANMASI

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Bu araştırmanın başlıca amacı, İzmir'in yoğun nüfuslu alanlarından biri olan Konak yerleşim bölgesinde çift tüplü olarak inşa edilen Konak Tüneli'nin kritik kesimlerinde sayısal analiz sonrası kazı ön destek tasarımı yapılmasıdır. Tünel açımı sırasında ölçülen deplasmanlar izlenmiş ve sayısal analiz sonuçları ile karşılaştırılarak doğrulanmıştır. Projenin en sorunlu bölümlerinden biri olan tünel çıkış portalı ve açık kazıları da bu çalışma kapsamında modellenmiş ve duraylılık analizleri yapılmıştır.

Çalışma alanında volkanikler, volkanik çökeller ve tortul kayaçlar (kumtaşı, çamurtaşı ve çakıltaşı) özellikle çıkış portal kesiminde birbirleriyle sık geçişlidirler. Tünel destek tasarımı ve deplasman tahminleri açısından bu karmaşıkların dayanım ve deformasyon parametrelerinin doğru olarak belirlenmesi tünel portal şev duraylılığı ve tünel destek tasarımı değerlendirmeleri için çok önemlidir. Bu doğrultuda RMR, Q Sistem ve GSI kaya sınıflamaları yapılmış, birbirleri ile deneştirilmiş ve kaya kütlesi dayanım ve deformasyonu bağlamında yorumlanmıştır. Bu yorumlar ışığında 2B sonlu eleman yöntemiyle tünel açıklığı çevresindeki gerilme çözümlemeleri yapılmış ve tünel destek tasarımı ile düşey deplasmanların denetlenmesi için belirlenen kritik kesimlerde beş farklı ölçüm noktasında veri olarak kullanılmıştır. Bu doğrultuda sonlu eleman çözümleri ile yapım aşamasında ölçülen deplasmanlar karşılaştırmalı olarak kontrol edilmiştir. Sonuç olarak kritik kesimleri ve ölçüm noktalarını teker teker değerlendirdiğimizde, % 70 oranda öngörülen düşey deplasmanların belirlenen limitler içerisinde olduğunu ve sadece %12,5'inin belirlenen limitlerin % 50'sinden fazla olduğu belirlenmiştir. Ek olarak hiçbir destek elamanının ve kaya kütlesinin değişen gerilme koşulları nedeniyle yenilmediği görülmüştür.

ANAHTAR SÖZCÜKLER: İzmir bölgesi, Tünel, Volkanik kayaçlar, Kaya kütlesi, Kaya kütlesi sınıflaması, Deplasman ölçümü, Sayısal modelleme.

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INTRODUCTION

1.1 Purpose and Scope

The increasing traffic load, air and noise pollution around the Konak district bring some problems for people who settle in this region. To get rid of the disturbance of casual life of people and decrease the traffic load, the Konak tunnel and access roads were planned by General Directorate of Highways. Along the Konak Tunnel, there exist many superstructures such as viaducts, open-cuts, jet grouts, anchors, piles, crossover roads, junctions and tunnels. However, the main purpose in this thesis is tunnel support design and analysis of critical sections including the exit portal of the tunnel. The aforementioned sections have been categorized as critical due to the high degree of weathering condition of the rock mass and related large vertical deformations measured along these sections. Hence, the tunnel support determination and the slope stability investigations of the exit portal with respect to rock mass classifications systems form the main purpose of the study. For these purposes, the following studies have been implemented:

- Prior studies about the geological conditions and geotectonic model of tunnel route and its vicinity have been elaborated,
- Literature survey for the tunnel and portal design have been performed,
- The rock mass characterization along the critical sections of the tunnel has been performed by the Geomechanical Classification (RMR, Rock Mass Rating) and NGI-Q System (NGI, Norwegian Geotechnical Institute),
- Empirical support design has been suggested,

- The verification of the empirical support design has been implemented by comparing the deformation measurements taken during tunnel construction and the results of the numerical model.

1.2 Methodology

In order to achieve the set goal, first of all, the geological settings and tectonics of the tunnel area have been evaluated.

The geotectonic model and the rock mass design parameters have been attempted to be connected in the next step. The engineering properties of the rocks have been used as design parameters. These parameters and rock mass classification systems, which will be given comparatively, have been used to specify tunnel support categories. The investigation methods to obtain the inputs of the rock mass classification systems have been presented in detail. Then, the latest developments about rock mass strength determination have been used in tunnel support design.

In addition, both kinematic and analytical slope stability analysis have been accomplished for the tunnel exit portal in order to verify open cut slope angles. Similarly, the slope support design, which is empirical, has been verified with the aid of finite element analyses.

In the end, the analysis presenting the efficiency of support design and displacement amounts have been discussed. In addition, the rock mass behavior surrounding the tunnel was attempted to be understood based on empirical rock mass classification systems along with drill work and the results of the rock mechanics laboratory test. Furthermore, an evaluation of the deformation during the tunnel construction with the numerical model was attempted to be performed.

1.3 Study Area

The study area is located in a highly populated area in Konak, İzmir (Figure 1). The Konak tunnel begins in the Ethnography Museum of Konak County and extends to Yeşildere Street. The 1650 m twin tube tunnels route passes through the Namık Kemal, Fatih, Duatepe and Kadiriye neighborhoods in south east direction and connect the Konak Square and Yeşildere Street to provide access to the İzmir-Urla Highway.

Figure 1: Location view of the project area (ITRF, 3°, Cent. Mer. 27 - Google Earth, 2015)

1.4 Project Characteristics

The total length of the highway is 2.5 km and the Konak Tunnel is located in between Km 0+550 to Km 2+200. The total length of the twin tube tunnel is 1650 meters and extends in the south east direction. The tunnel entrance base elevation is 4.0 m and the exit base level is 48.0 m; in this context, the inclination of the tunnel is 2.78 %. The diameter of the tunnel is 11.5 m and the distance between the outer walls of the tunnel is 23.0 m in the entrance and exit portals. A typical cross section of the horseshoe tunnel is given Figure 2.

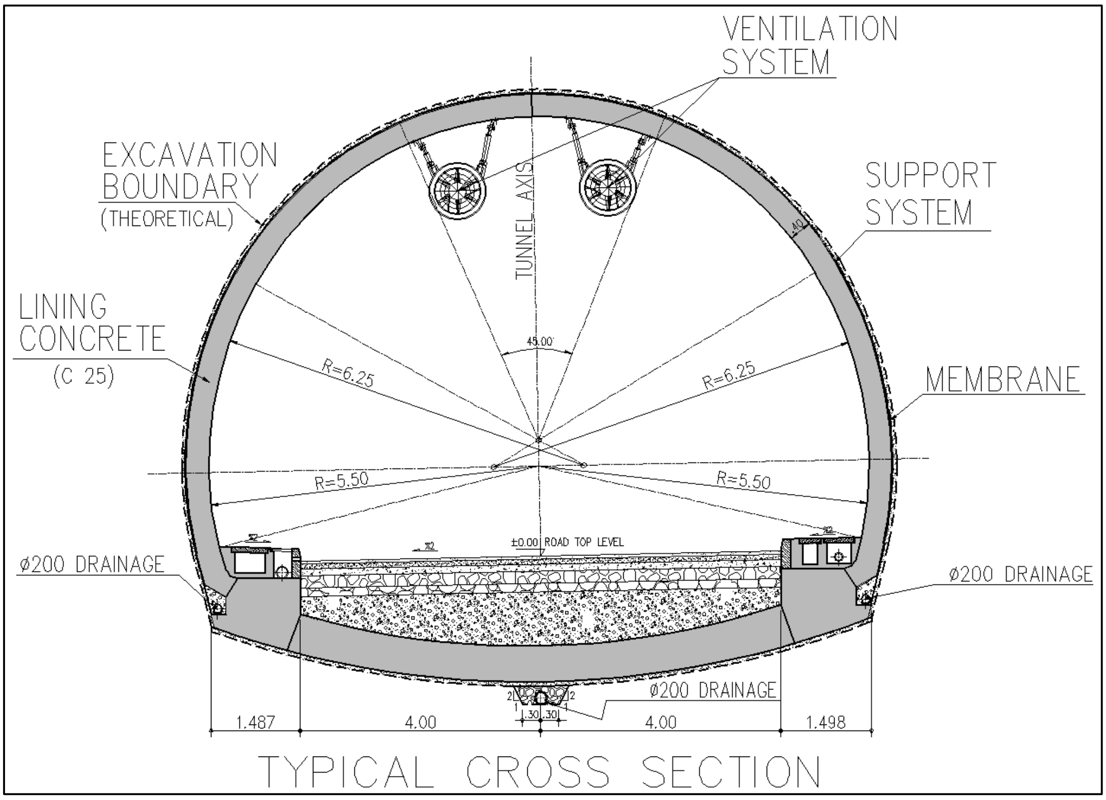


Figure 2: Typical cross section of the Konak tunnel

CHAPTER 2

GEOLOGY OF THE STUDY AREA

The study area and its neighborhood is in the Bornova Flysch Zone, which is in large scale interpreted as a part of the Anatolide-Tauride Block and exists in the northwest part of the Menderes Massif (Figure 3: Şengör (1984), Okay (1989a) Okay et al. (1994, 1996)). The Bornova Flysch Zone is in between the suture zone (İzmir-Ankara-Erzincan suture zone) of Neo-Tethys Ocean and the Menderes Massif that is in between Gondwana and Laurasia as per Paleozoic and Early Tertiary time interval. The suture zone along the İzmir-Ankara-Erzincan Ocean is formed by the rocks of past subduction zones and their products (APPENDIX-A).

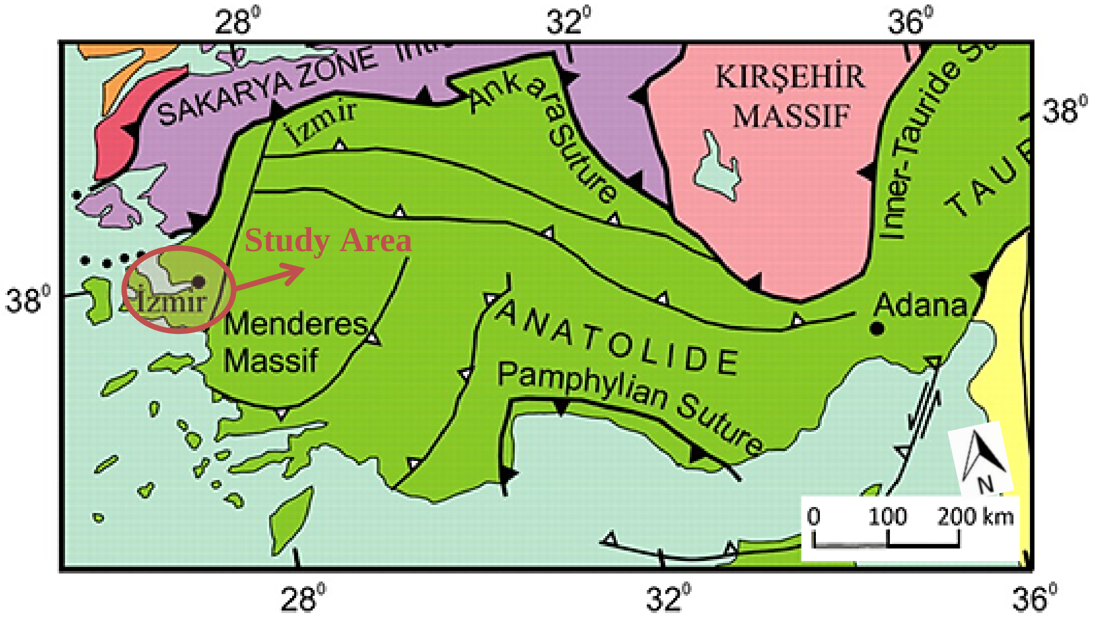


Figure 3: Tectonic map of Turkey showing the major sutures and continental blocks (as quoted by Okay and Tüysüz, 1999)

The study area is represented by the volcanic units and Neogene sedimentary rocks in the Bornova Flysch zone (Figure 4).

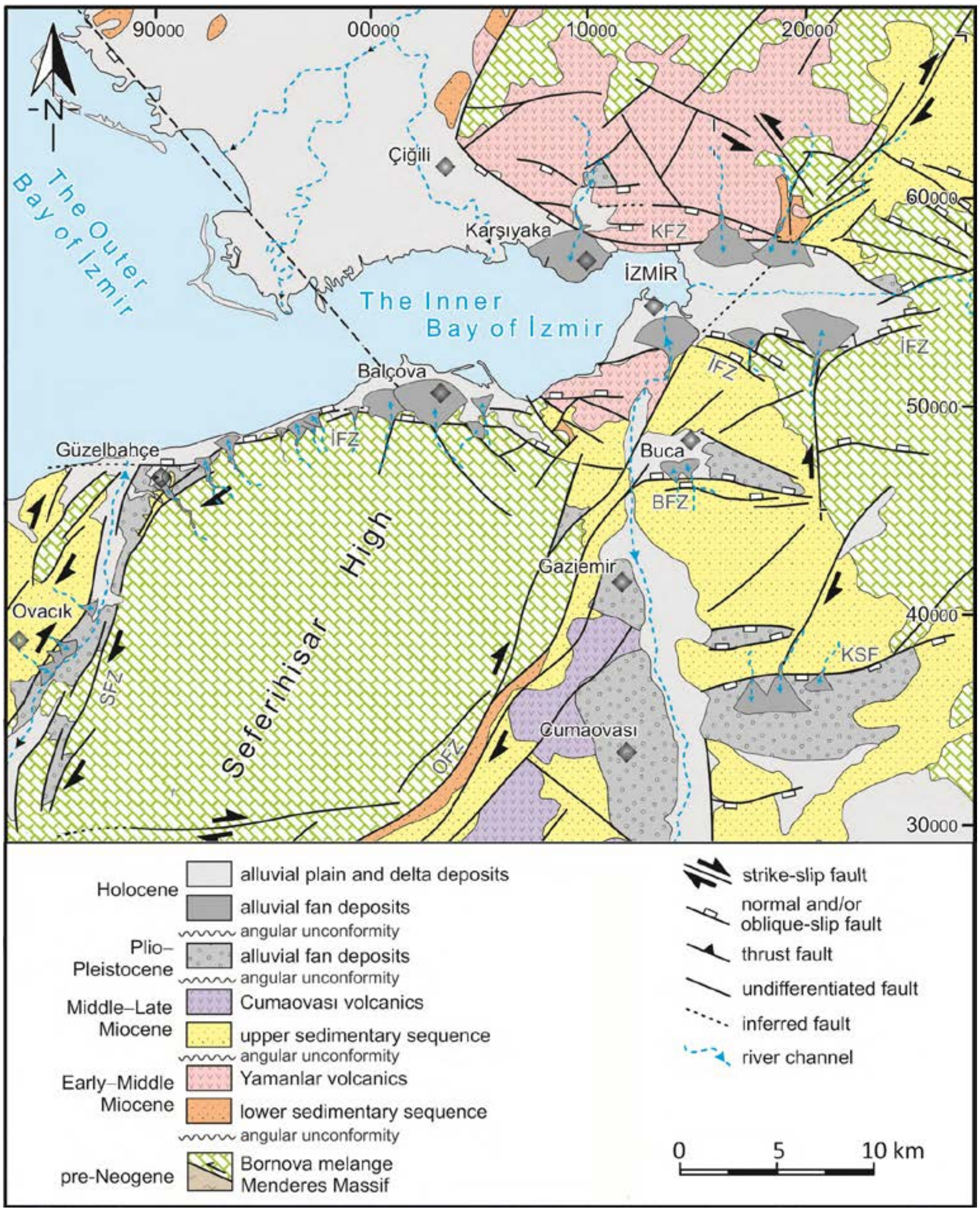


Figure 4: The larger scaled geological map of İzmir region (Uzel et al., 2012)

The tectonic evolution of the study area and the geological units along the tunnel route and its vicinity will be presented in detail in the following section.

2.1 Stratigraphy

The following formations, as sub-units of the Bornova Flysch zone, crop out in an order from older to younger in the study area and its neighborhood (Figure 5);

- Bornova Flysch (Mesozoic)
- Terrestrial and Marine Sedimentary Rocks (Early Miocene - Late Miocene)
- Volcanic Rocks (Miocene)
- Quaternary Sediments

In the next sections, the geological conditions related to tectonic and structural features of these units will be presented briefly.

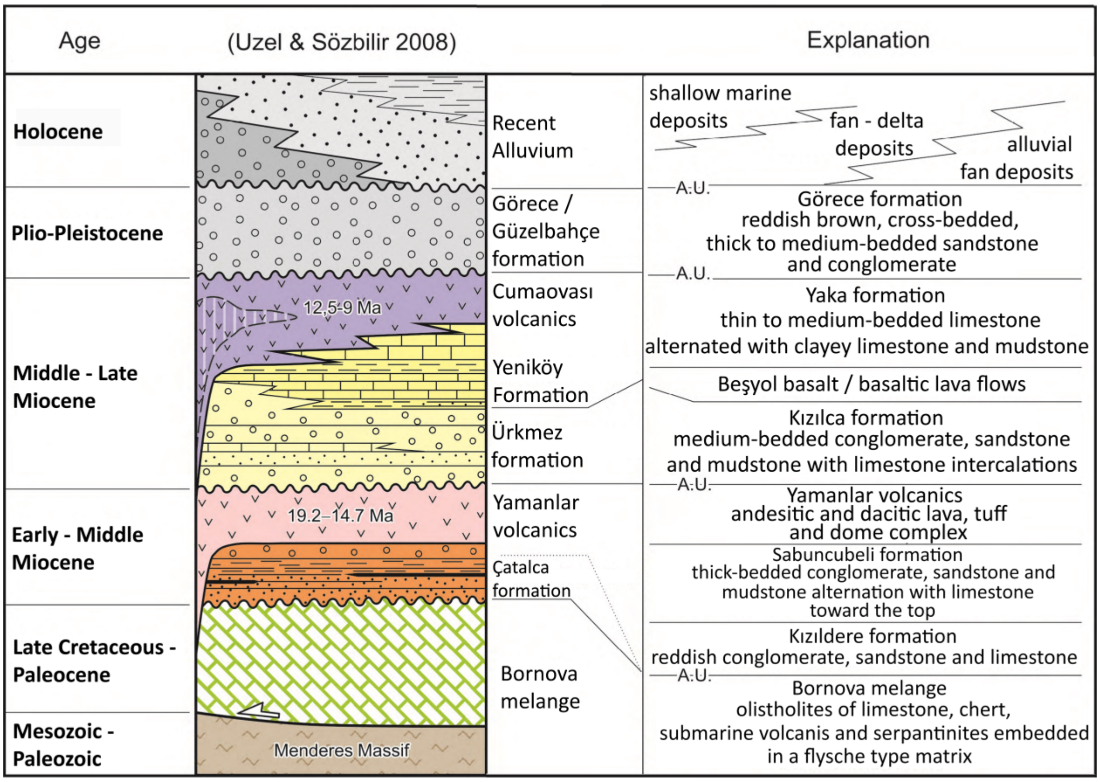


Figure 5: Stratigraphic section of the study area (Uzel et al., 2012)

2.1.1 Bornova Flysch

The Bornova Flysch is in the form of a mélange, which is generally dark colored and is being represented by numerous schist, micaceous sandstone, arkose, conglomerate, re-crystalline or dolomitic limestone, reddish pink to grayish limestone with schist and radiolarites. Various schists and highly re-crystallized limestones those are predominant within this flysch zone, show folding and metamorphism intensively. Serpentinites crop out in some parts of the flysch zone between İzmir Bay and Seferihisar and Doğanbey. Dark green, black or light green serpentines were formed as the result of the alteration of ultrabasic rocks and they show a fragile structure (Uzel et al., 2012).

2.1.2 Terrestrial and Marine Sedimentary Rocks

The terrestrial and shallow marine sedimentary rocks are formed by limestone, marl, sandstone and conglomerate that were deposited in the fore and back basins of island arc volcanism. Limestones containing locally plant roots are strong and gray-beige colored; marls are weak and thinly bedded. Carbonate cemented conglomerate and sandstone are stronger than marls. The grains are derived from basic units such as schist and ultrabasic rocks. There is a mottled appearance due to red-brown-beige-gray colors of the units. In the upper parts of the sequence, conglomerate content decreases, as the alternation of gray-beige colored sandstone-siltstone-marl-limestone become the dominant lithology. The thickness of the Miocene aged rock containing the coal veinlets is approximately 2500 m. Uzel et al., 2012 have described these units in two groups as “Lower Sedimentary Series” and “Upper Sedimentary Series”, which consists of Sabuncubeli and Çatalca Formations and of Kızılca Formation, respectively, based on the study carried out for the İzmir Bay (Figure 4).

2.1.3 Volcanic Rocks

In the study area and its vicinity, there was an active volcanism as both acidic and alkaline with calc-alkaline nature during the Mid-Miocene. Lavas are of alkaline basaltic, trachytic and rhyolitic origin. Rhyolitic rocks are locally perlites and form significant volcanic domes in the Cumaovası region. The chemical analyses made in various glassy rhyolite rocks and perlite in the region show that there are two phases in this type of volcanism. The alkaline and acidic lavas are located together in the region. As per the radiometric dating, the age was determined as Mid-Miocene (11.3, 11.9 and 12.5 million years ago).

The andesitic featured volcanics in the Kadifekale region are settled uncomfortably on the level of the terrestrial-marine deposits of clay and marl. The volcanic rocks in this region are generally observed in an order from top to bottom as tuff, agglomerate and andesite. Uzel et al., 2010 have described these volcanic units as “Yamanlar Volcanics”.

2.1.4 Quaternary Sediments

The Quaternary sediments deposited in the study area and its near plains are formed by various units ranging from clay to cobble size. These sediments which are the decomposed products of volcanic lavas, pyroclastics and sedimentary rocks are generally volcanic in origin. These deposits often exhibit characteristics of alluvium and colluvium or talus.

Alluvium; especially towards the exit of the tunnel area is loose, unconsolidated soil or sediments, which has been eroded and reshaped by the Yeşildere River, and redeposited in a non-marine setting.

Colluvium – Talus; slope debris is formed as a result of mechanical disintegration of the andesite rock mass whose particle size is ranging from block to sand or clay.

2.2 Tectonics

The units constituting the project area at a local scale and the Aegean and Mediterranean regions at a regional scale have been developed under the control of island arc volcanism, as associated with subduction zones.

Before Maastrichtian, the Intra Pontide Ocean was closed and the suture zone along the Sakarya Continent was united and collided with the Rodop-Pontide continent. During Paleocene, the İzmir-Ankara Ocean branch of Neo-Tethys began to close and by this closure, the Anatolide platform, with the northern branch, began to subduct below the Intra-Pontide continent (Şengör, A.M.C. and Yılmaz, Y., 1981 - Figure 3). This subduction resulted in the formation of Miocene units of island arc volcanism and lacustrine sedimentary rocks related with them, which is characteristic in the project area.

2.3 Structural Geology

İzmir and its vicinity are located in western Anatolia, which is dominated by Neo-Tectonic extensional tectonics. The city of İzmir is located towards the western end of the Gediz Graben and this graben occurred as a result of aforementioned tectonic compression. The most prominent feature that stands out as the structural geology of the region is the Horst-Graben structure. However, there is no enough information and findings available regarding the outside of the Gediz Graben, which can be a source of intense seismic activity in the presence of active faults. The linearity of Cumaovası, some faults in the western part of the Gediz Graben and Dumanlıdağ Fault zone in the Menemen region are indicated in the Active Fault Map of Turkey (Şaroğlu et al., 1992), where some active faults and other faults without any knowledge of their seismicity features have been mapped in some studies performed for Neo-Tectonical and regional purposes.

Thirteen active faults have been identified during active fault mapping studies made in an area with approximately 50 km radius, where İzmir City is the center (Table 1 & Figure 6). Information of the faults near to the project area is given in Section 2.5.

Table 1: Some parameters related to the mapped active faults around İzmir (İzmir EIA, 2012)

No	Fault Name	Activity Class	Type	Total Length (km)	General Strikes	Dip Direction	Seismicity (Instrumental Eq.)
1	İzmir Fault	AF	N	35	D-B	60°N	1688 (Historical Eq.), 1977 (M:5.5)
2	Tuzla Fault	AF	RLSS	50	K30D	E	1992 (M:6.0)
3	Seferihisar Fault	AF	RLSS	30	K20D	E	2003 (M:5.6)
4	Gulbahce Fault	AF	V	70	K-G	E	1953 (M:5.0), 1979 (M:5.7), 1994 (M:5.0)
5	Main Detachment Fault of Gediz Graben (Western Part)	AF	N	27	K70D	18°N	-
6	Kemalpaşa Fault	AF	N	24	K75D	50°N	-
7	Manisa Fault	AF	N	40	K65B	55°N	1994 (M:5.2)
8	Dağkızılca Fault	AF	RLSS	27	K70D	E	1926 (M:6.5)
9	Güzelhisar Fault	PAF	RLSS	25	K70B	E	-
10	Menemen Fault Zone	PAF	RLSS	17	K45B	E	-
11	Yenifoça Fault	L		20	K-G	-	-
12	Gümüldür Fault	PAF	N	15	K55B	50° W	-
13	Bornova Fault	L	RLSS	19	K75B	E	-

AF: Active Fault, PAF: Possible Active Fault, L: Lineament, N: Normal, RLSS: Right Lateral Strike Slip, V: Vertical.

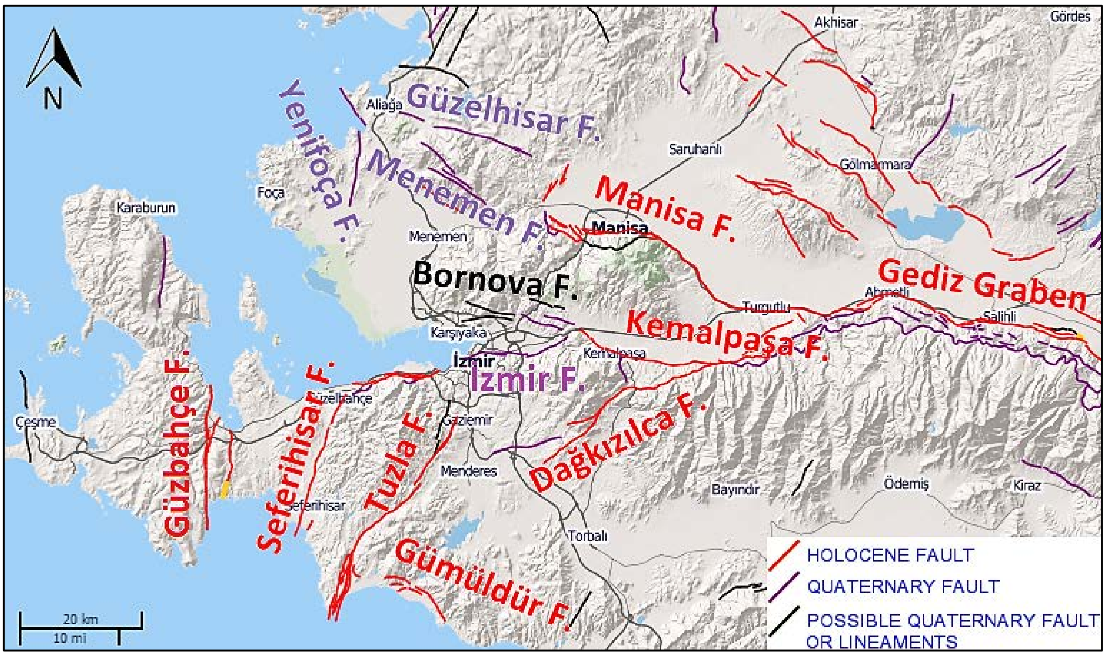


Figure 6: Fault map of İzmir region (MTA - Geoscience Map Viewer and Drawing Editor, 2015)

2.4 Geomorphology

The regional geomorphology was controlled first by Paleo-Tectonic [compression tectonics] and then Neo-Tectonic [extension tectonics] regimes. Accordingly, the continent-continent collision produced mountain and basin formation stage, which was followed by frequent volcanic activity. In the next stage, namely, active pulling tectonics, the geomorphology was controlled by young forms of erosion as typical for the region as horst and graben formation (Figure 7). Lithological characteristics of rocks, drainage system and geological structure have been active in the formation of current morphology. Additionally, related with geological formations those facts could be highlighted for the morphology of the project area and its close neighborhood (Bozkurt E., 2001).

The Miocene Yuntdağ volcano associated with the continent-continent collision and its volcanic products has taken place in the project area. The Yuntdağ volcanism which is a part of the volcanic Dumanlıdağ that rose up to an elevation of about 1000 m consisting of andesitic and rhyolitic pyroclastics, trachy-andesitic lava flows and domes is composed of dikes and lava flows. These levels are extremely resistant to external factors and therefore they are too rough and form a high topography. However, towards the foot of the volcano, accumulated screes developed by mechanical weathering of volcanic rocks provides recumbent morphology (Bozkurt E., 2001).

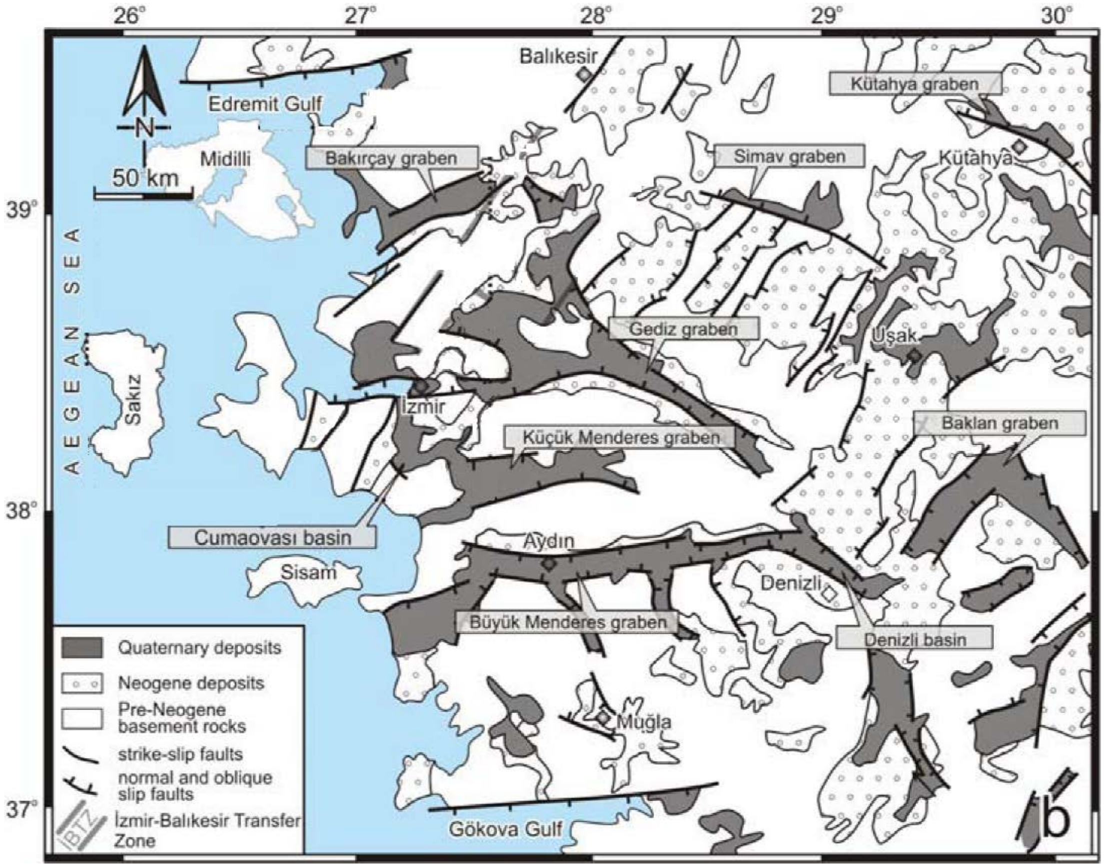


Figure 7: Simplified map of the western Anatolian grabens (Uzel et al., 2012)

2.5 Seismicity of the Study Area

The project area is located in a “1st Degree Earthquake Zone” according to the Department of Earthquake Research, Earthquake Zonation Map of Turkey of R. T. Ministry of Public Works and Settlement. For this region the peak ground acceleration is taken as 0.4g. (Figure 8).

In İzmir, from 1909 to present, there have been about 5 devastating earthquakes that resulted with deaths, injuries, property damage and losses (Table 2).

There are two alternatives to be used for the estimation of the magnitudes of earthquake, based on fault length. The first assumption is that the two separate geometrical segments of the fault can be broken individually. Both segments that comprise the fault is about 15 km long. In foresight of the two separate segments, the fault could break in one earthquake with a total fault length of 35 km.

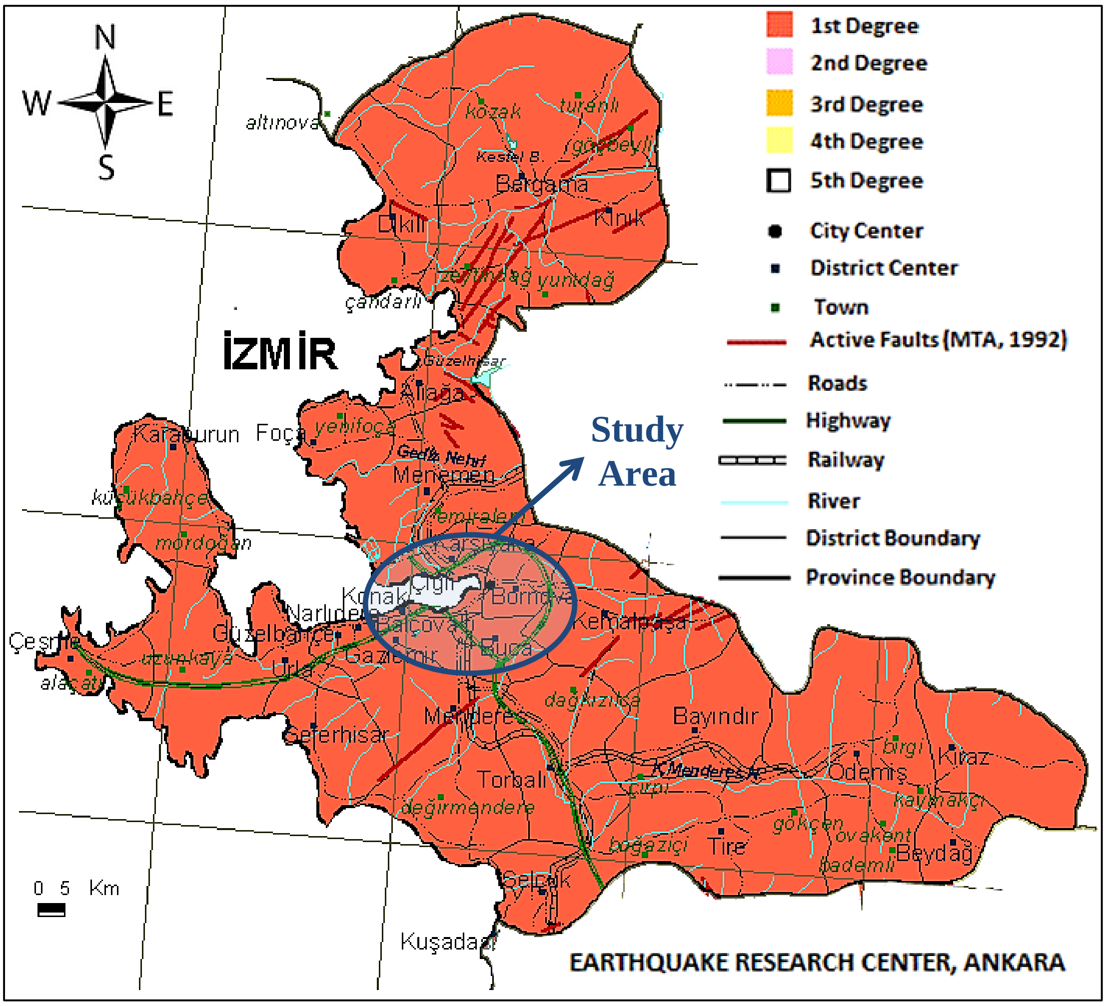


Figure 8: Location of the project area on the map of Turkey Earthquake Zones (Earthquake Research Center, Ankara)

Table 2 shows the location and magnitude of the earthquakes. As a result of the detailed investigations that are presented in the report of the General Directorate of Mineral Research and Exploration regarding İzmir (Ömer, E. et al. 2005), the İzmir fault has been defined as the closest fault zone to the project area and its vicinity. Detailed information related to the İzmir fault is presented below.

Table 2: Recent earthquakes that have occurred in the İzmir area (MTA, 2005)

Location	Date	Magnitude
Foça	19.01.1909	6.0
Soma	18.11. 1919	6.9
Dereköy-Torbalı	31.03.1928	
Dikili–Bergama	22.09.1939	6.6
Karaburun	22.07.1949	6.6
Karaburun-Çeşme	02.05.1963	6.6
Salihli	02.03.1965	5.6
Alaşehir	28.03.1969	6.5
Karaburun	06.04.1969	5.9
İzmir	01.02.1974	5.2
İzmir	16.12.1977	5.3
İzmir - Seferihisar - Menderes - Urla - Narlıbahçe - Buca - Karaburun - Bornova	06.11.1992	5.5
Seferihisar	10.04.2003	5.6

2.5.1 The İzmir Fault

In the eastern zone of the İzmir Bay, the E-W trending fault bounding this bay from the south is morphologically named as the İzmir Fault (Emre and Barka, 2000) (Figure 6). The İzmir fault, with a total length of 35 km between Güzelbahçe and Pınarbaşı is a normal dip-slip fault. Two faults are divaricated in the west end. The south branch terminated in accordance with the NE-SW trending dextral strike-slip of the Seferihisar faults. The northern branch towards NW in the İzmir Bay basin is most probably associated with a N - NW to S - SE trending fault zones that are located between Çiçekadaları and Uzunada. The fault crosses along the İzmir residential area in the E-W direction. Field studies show that the İzmir fault is a dip-slip normal fault caused by a massive earthquake that resulted in the surface rupture in Holocene. According to geological data, it can be said that the fault occurred after Miocene. No sediments older than Quaternary exist within the current basin of the İzmir rift, which has developed as a half graben on the hanging wall of the fault. The aforementioned fault, limits the Buca-Cumaovası rill that started to be formed in the erosional stage of Pliocene tectonically and this erosion remains unsettled along the fault. This information and data most probably indicates that the İzmir fault became active in the Late Pliocene - Early Quaternary.

Along the İzmir fault, periodically monitored micro-earthquakes have concentrated in the eastern zone of the fault (Akıncı et al, 2000). Instrumental epicenter locations of 1974 (M: 5.2) and 1977 (M: 5.3) earthquakes made territorial claims in the City of İzmir that were close to the İzmir fault. It is also worth noting that two earthquakes have damaged the buildings in the city center. The normal faulting mechanism was obtained from the 1977 earthquake fault plane solutions. However, according to the seismological data, it cannot be interpreted whether the source of those earthquakes is the İzmir fault or not.

CHAPTER 3

GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS

This section describes the investigations to determine the geotechnical parameters of the rock material and of the rock mass. In this sense, three groups of work, namely, surface, subsurface and laboratory investigations have been performed.

As well known, the rock mass behavior is commonly controlled by the discontinuity properties of the rock, which could be observed and studied during the surface investigations. Besides the weathering and groundwater conditions, aperture, roughness, persistence and spacing of these discontinuities are important for the determination of the rock mass strength.

During tunnel support design, the surface investigations are interpreted to resolve the rock mass behavior at the tunneling depth. Since the geotechnical conditions of the rock mass on the ground surface do not represent the conditions at tunneling depth, boreholes are drilled along the tunnel alignments at the tunneling depths.

The final stage of the investigations is the laboratory tests performed on rock samples which are taken from the boreholes. These core samples are preserved to provide the minimum disturbance and natural conditions for testing as these test results determine the rock material geotechnical parameters.

3.1 In-Situ Investigations

3.1.1 Surface Investigations

Before proceeding, there is a need to explain and to differentiate concepts classification and description related to the rock mass and rock material. Classification is a system or order list which is followed with information being recorded as foreseen. In description concept, all the intricate technical terms are written down; basically the personal intuition is important.

The rock material classification, which is a solid consisting of minerals used by geologists, needs a comprehensive study of mineralogy and petrography. This type of geological classification systems are not comprised of engineering properties of rocks. In a rock material description, the significant descriptive parameters required are; color, rock name, texture and structure, grain size, weathering conditions, strength and some other properties. Nonetheless, the rock mass description requires information related to discontinuities or weakness planes in addition to the description of the rock material. The illustrator indices of weakness planes, which are written below for the rock mass classification, can easily be gathered during field observations:

i) Location, orientation and number of discontinuities
ii) Type of discontinuities
iii) Spacing frequency between discontinuities
iv) Persistence and extent of discontinuities
v) Weathering and alteration state of discontinuities
vi) Aperture or separation of discontinuity surfaces
vii) Nature of discontinuity surfaces
viii) Infilling

The field descriptions of the rock masses were made on the basis of ISRM (2007) and BSI (1981). In addition, surface observations in the project area were made at outcrops that were observed rarely due to intense settlement and highly populated areas. Surface observations were limited with the outcrops especially at the exit portal and rarely at the entrance portal. Therefore, geological conditions along the tunnel route were evaluated according to the geological model, which is constituted for this study. As per these observations and research results, the tunnel route generally cuts the Miocene aged volcanic rock and volcano – sedimentary rocks with the same age. In general, volcanic rocks, which are formed in the study area, are represented by andesite, tuff and agglomerate. Besides, sedimentary rocks are represented by claystone, siltstone, sandstone and conglomerate. Among all lithologies in the project areas, only the andesite crops out to display its rock mass properties in natural slopes. Thus, these tangible data together with the geological model and borehole data have been used to determine the rock mass properties.

a) Surface investigation of the volcanic rocks

Andesitic lavas and pyroclastics (tuff and agglomerate) have especially been observed around the exit portal at Km 2+200. Miocene aged volcanic rocks, which are andesite, andesitic tuff and agglomerate, exhibit transition in both vertical and lateral directions. Additionally, according to observations made in this area, it was estimated that the sedimentary rocks and volcanic rocks may be in transition between each other. Volcanic rocks present similar mass strength parameters along both tubes of the tunnel alignment.

Andesitic lavas can easily be distinguished by their pinkish colored outcrops. Andesites are generally slightly weathered and weak to moderately strong (UCS in between 25.0 - 100.0 MPa – ISRM, 2007) around the exit portal of the Konak Tunnel. Andesite contains at least three (two systematic and one random) discontinuity sets in the exit portal area. In areas where weathering effects increase, many irregular discontinuity sets and a blocky appearance is possessed by andesite.

The discontinuities possessing orientation of 135/65º (dip direction/dip amount) and 075/90º are discontinuous, undulating and rough. The spacing of the discontinuities is between 60-600 mm with RQD (Rock Quality Designation) values between 25 - 75%. The aperture of the discontinuities is between 1.00 and 5.00 mm at the surface, and the discontinuities are slightly altered and not filled or rarely filled with non-softening and non-cohesive rock mineral.

Pyroclastic rocks (agglomerates and tuffs), which show lateral and vertical transition with andesitic lavas possess poorly sorted, angular to sub-angular block size materials within a matrix of ash and tuff. These rocks do not outcrop out in the exit portal area and are located under andesite as per the regional geological model. While the moderately weathered sections of the tuff and agglomerate are very weak (UCS in between 1.0 - 5.0 MPa – ISRM, 2007), the slightly weathered and fresh sections are weak (UCS in between 5.0 - 25.0 MPa – ISRM, 2007). Additionally, these sections are highly fractured where RQD value ranges in between 0% to 50% and the discontinuity spacing ranges between 60-200 mm on the average.

b) Surface Investigation of the sedimentary rocks

Exhibiting vertical and lateral transition with Miocene aged sedimentary rocks; sedimentary rocks generally show typical shallow marine and terrestrial characteristics. These rocks consist primarily of claystone, siltstone, sandstone and conglomerate. However, no sedimentary rock outcrops were encountered during field observations.

Lastly, except the rock units around the exit portal of the Konak Tunnel, fill material is observed and its thickness has been determined with the aid of the boreholes.

3.1.2. Boreholes

In order (1) to check the engineering geological model along the tunneling elevation, (2) to complete the lack information for interpretation, (3) to determine the lateral and vertical rock variations, (4) to allow in-situ tests and ground water measurements and (5) to obtain samples for laboratory tests, a total length of 1081 m of drilling has been performed. Twenty-one boreholes have been drilled where in this study the boreholes TSK-1-2-3-4-5 and EK-TSK-1 at the exit portal and TSK-6 and EK-TSK-2 at the most critical and deepest sections of the tunnel (Km 1+750 – 2+130) alignment deserve special attention. The brief information of all boreholes opened along the tunnel is presented in Table 3. The lithological changes, groundwater levels, average TCR's and average RQD's for the critical boreholes are presented Table 4. Detailed information about the borehole logs and core box photos are given in APPENDIX-B.

Table 3: List of boreholes drilled along the tunnel alignment

DRILLING NO	KM	**KOORDINATES** (Zone 35 & Cen. Mer. of Zone 27°)				GROUND ELEVATION (m)	DEPTH (m)
		ITRF		ED 50			
		X	Y	X	Y		
TSK-1*	2+200	512304.0	4252253.0	512355.7	4252432.5	85.00	40.00
TSK-2**	2+155	512299.0	4252313.0	512343.7	4252495.1	95.00	60.00
TSK-3*	2+180	512316.0	4252292.0	512373.6	4252467.6	94.00	50.00
TSK-4*	2+213	512363.0	4252296.0	512411.7	4252485.9	80.00	42.00
TSK-5*	2+207	512339.0	4252279.0	512389.6	4252453.3	79.00	34.00
TSK-6**	1+730	511999.0	4252610.0	512041.0	4252795.0	136.00	113.00
TSK-7(a)	1+245	511615.0	4252912.0	511657.0	4253097.0	120.00	110.00
TSK-8(a)	0+970	511441.0	4253123.0	511483.0	4253308.0	83.00	90.00
TSK-9(a)	0+815	511354.0	4253255.0	511395.0	4253441.0	61.00	61.00
TSK-10(a)	0+585	511255.0	4253461.0	511297.0	4253648.0	18.00	20.00
TSK-11(a)	0+560	511247.0	4253485.0	511289.0	4253672.0	15.00	16.00
TSK-12(a)	0+565	511223.0	4253467.0	511265.0	4253655.0	18.00	19.00
TSK-13(a)	0+575	511280.0	4253423.0	511321.0	4253661.0	15.00	16.00
TSK-14(a)	0+605	511245.0	4253433.0	511286.0	4253620.0	22.00	23.00
EK-TSK-1*	2+170	512335.0	4252325.0	512377.0	4252512.0	98.00	60.00
EK-TSK-2**	1+960	512166.0	4252454.0	512210.0	4252644.0	113.00	85.00
EK-TSK-3(a)	1+530	511837.0	4252752.0	511795.0	4252939.0	138.00	120.00
EK-TSK-4(a)	0+615	511273.0	4253435.0	511315.0	4253623.0	19.00	25.00
EK-TSK-5(a)	0+615	511287.0	4253442.0	511329.0	4253629.0	17.00	25.00
EK-TSK-6(a)	0+655	511269.0	4253390.0	511311.0	4253577.0	32.00	36.00
EK-TSK-7(a)	0+655	511297.0	4253401.0	511339.0	4253588.0	31.00	36.00
* Portal drillings reach to 5.00 m below the tunnel design elevation. ** Tunnel drillings reach to 10.00 m below the tunnel design elevation.						**TOTAL**	**1081.00**
(a) Grey colored boreholes out of the study area							

Table 4: The lithological changes, groundwater levels, average TCR's and average RQD's of the boreholes considered during this study

DRILLING NO	SECTION	LITHOLOGY	GROUNDWATER ELEVATION (m)	TCR (%)	RQD (%)
TSK-1	T-Px	0.00-4.00 m fill material	-	55	5
		4.00-9.00 m agglomerate			
		9.00-10.50 m tuff			
		10.50-12.00 m andesite			
		12.00-15.00 m agglomerate			
		15.00-15.80 m andesite			
		15.80-24.50 m tuff			
		24.50-30.00 m claystone-sandstone			
		30.00-31.50 m conglomerate			
		31.50-39.00 m sandstone			
		39.00-40.00 m claystone			
TSK-2	T-50x	0.00-6.00 m fill material	10.45	70	5
		6.00-14.00 m agglomerate			
		14.00-44.00 m andesite			
		44.00-46.00 m agglomerate			
		46.00-60.00 m tuff			
TSK-3	T-Px	0.00-12.00 m fill material	10.80	50	5
		12.00-15.70 m tuff			
		15.70-16.20 m agglomerate			
		16.20-30.50 m andesite			
		30.50-32.00 m tuff			
		32.00-39.00 m sandstone			
		39.00-43.00 m claystone			
		43.00-44.50 m siltstone			
		44.50-50.00 m claystone			
TSK-4	T-Px	0.00-0.60 m fill material	-	80	10
		0.60-30.50 m andesite			
		30.50-34.50 m weathered andesite			
		34.50-35.70 m tuff			
		35.70-36.50 m sandstone			
		36.50-36.80 m conglomerate			
		36.80-37.40 m siltstone			
		37.40-38.50 m conglomerate			
		38.50-41.00 m claystone			
		41.00-42.00 m tuff			
TSK-5	T-Px	0.00-5.00 m fill material	8.50	90	10
		5.00-12.00 m andesite			
		12.00-15.50 m tuff			
		15.50-16.80 m claystone			
		16.80-18.00 m claystone			
		18.00-21.65 m sandstone			
		21.65-23.35 m claystone			
		23.35-24.10 m conglomerate			
		24.10-30.90 m claystone			
		30.90-33.20 m sandstone			
		33.00-34.00 m siltstone			
TSK-6	T-100x	0.00-1.70 m fill material	23.00	100	25
		1.70-113.00 m andesite			
EK-TSK-1	T-Px	0.00-10.00 m fill material	13.17	100	30
		10.00-60.00 m andesite			
EK-TSK-2	T-75x	0.00-1.00 m fill material	7.60	95	38
		1.00-85.00 m andesite			
Note: P: Portal, T: Tunnel, e: Enterance, x: Exit					

The groundwater levels in the drillings have been interpreted as a perched aquifer rather than a static groundwater level. These groundwater levels are interpreted as the surface waters leaking via the discontinuity systems of rocks. In this context, these surface waters may have penetrated only the rocks which are close to the surface and more frequent and open discontinuous rock masses, in other words, the deeper parts of the rock masses could possibly not been affected by these surface waters. Within this framework, groundwater is not expected at the tunnel design elevation. Nevertheless, the groundwater can cause some construction difficulties at the tunnel portals due to the lower thickness of the overburden rock and open cuts.

In addition, the first 15 to 30 m of these drillings have crossed the sedimentary rock sequence. According to the observations of the core boxes, these parts are mostly composed of brown to yellowish brown claystone, sandstone and conglomerate. All are volcanic in origin because of their mode of occurrence. They are highly to moderately weathered thus their strengths are very weak to weak (UCS is between 1.00-5.00 MPa). Their RQD value ranges in between 0% to 50%. Consequently, in the slope stability analysis these sections will be treated as soil rather than rock at the exit portal.

3.2 Laboratory Tests

Laboratory rock mechanics tests were conducted on core samples taken from the drillings. A summary of these tests are presented in Table 5 and all related laboratory test results are given in APPENDIX-C.

Table 5: Summary of the laboratory tests results for the critical sections

Drilling No	Depth (m)	Sample Length (mm)	Sample Diameter (mm)	Sample Weight (g)	Δl (mm)	Δd (mm)	Axial Strain ε_a	Lateral Strain ε_d	Modulus of Elasticity ε (GPa)	Poisson's Ratio V	Natural Unit Weight (kN/m^3)	Failure Load P (kgf)	UCS q_u (MPa)	Point Load I_s (MPa)	Lithology
TSK-1	13.00-14.50	93	47	311.92							18.96	2926.54	16.87		andesite
TSK-1	33.00-33.30	91	46	309.18							20.06	591.43	3.56		tuff
TSK-2	22.00-23.00	95	47	421.38	1.212	0.201	0.01276	0.00428	6.44	0.328	25.08	7892.48	45.49		andesite
TSK-2	43.00-44.00	92	47	374.61	1.025	0.189	0.01114	0.00402	5.58	0.346	23.02	5802.09	33.44		andesite
TSK-2	49.50-50.00	47	47	173.55							20.88	127.00		0.575	tuff
TSK-2	59.00-59.20	86	43	267.52							21.01	805.56	5.55		tuff
TSK-3	26.00-26.60	92	47	388.20	1.065	0.189	0.01158	0.00402	5.88	0.325	23.86	6169.19	35.56		andesite
TSK-3	44.50-46.00	53	55	272.18							21.20	139.00		0.460	tuff
TSK-4	21.00-22.00	94	47	383.17							23.05	3517.97	20.28		andesite
TSK-4	36.00-37.00	92	46	300.02							19.25	693.00	4.17		alt. andesite
TSK-4	41.00-42.00	46	45	134.06							17.98	58.00		0.286	alt. andesite
TSK-5	17.00-18.00	96	48	400.97							22.64	479.26	2.65		tuff
TSK-6	93.00-94.00	95	47	413.82	0.851	0.135	0.00896	0.00287	4.06	0.359	24.63	5159.68	29.74		andesite
TSK-6	99.00-100.00	93	47	395.26	0.675	0.111	0.00726	0.00236	3.36	0.379	24.03	3630.13	20.92		andesite
TSK-6	101.00-103.00	95	47	404.50	0.991	0.168	0.01043	0.00357	4.83	0.354	24.08	5985.64	34.50		andesite
EK-TSK-2	56.00-56.35	96	47	403.23	1.040	0.213	0.01083	0.00453	7.58	0.321	23.75	8848.22	51.00		andesite
EK-TSK-2	67.17-67.35	97	47	439.40	1.020	0.172	0.01052	0.00366	9.60	0.310	25.61	10218.82	58.90		andesite
EK-TSK-2	74.00-74.78	95	47	438.91	1.140	0.207	0.01200	0.00440	10.44	0.297	26.12	11051.60	63.70		andesite

In order to investigate the ground conditions of the Konak Tunnel, eighteen samples for unit weight determination, fifteen samples for UCS (uniaxial compressive strength) determination and three samples for point load determination were tested. As known, the rock mechanics tests made on intact rock samples provide information about material properties of rocks. Therefore, these test results would not be directly incorporated into the tunnel support design calculations. The significance of the intact rock properties will be usually reduced by the discontinuity properties of the rock masses. If the intact rock is altered and weak or has widely spaced discontinuities, the intact rock properties may determine the behavior of the rock mass. Hence, the discontinuity properties have a greater significance than the intact rock properties.

As shown in Table 5 the average standard deviation of the uniaxial compressive strength of andesite was measured to be 39.35±15.97 MPa, the natural unit weight 23.84±1.03 kN/m^3, the modulus of elasticity 6.42±2.40 GPa and the Poisson’s ratio 0.33±0.03. For pyroclastics, on the other hand, the mean ± one standard deviation of the uniaxial compressive strength was measured to be 4.00±1.00 MPa and the natural unit weight 21.16±0.94 kN/m^3.

CHAPTER 4

ENGINEERING GEOLOGICAL PROPERTIES OF ROCKS AND ROCK MASS CLASSIFICATION

Rock material (intact rock) and rock mass are significant and basic concepts that need to be distinguished. Rock material is the smallest rock unit that does not involve any discontinuity. In other words, rock material is the part of the rock unit that does not include joint, bedding plane (layering), schistosity or weakness plane which can cause reduction in strength of the material. All weakness planes according to geological aspect such as bedding planes, joint, fault, shear zone, cleavage or schistosity that have zero tensile strength or very low tensile strength can be named as discontinuity. Although rock materials may include micro fractures, they cannot be considered as discontinuity or fracture (Ulusay et al., 2007).

Rock masses are formed by a combination of various geologic discontinuities (joints, bedding planes, schistosity, faults, shear zones, etc.) and solid rock blocks separated by discontinuities. The interval or frequency of discontinuities in the rock mass and the number of discontinuity sets play an important role to make a decision on the behavior of the examined rock. As an illustration, an illustration that indicates a transition from rock material (intact rock) to a jointed rock mass is shown in Figure 9. If discontinuities are widely spaced or the rock material between the discontinuities is weak or decomposed, the general behavior of the rock mass is highly affected by the behavior of the rock material which does not include discontinuities. Under these circumstances, the rock material can form a mimic structure of the rock mass at a small scale. However, if the number and frequency of the discontinuities increase, this creates an important effect on the discontinuous rock material parameters and on the behavior of the entire rock mass. In this case, the properties of the rock mass should be considered.

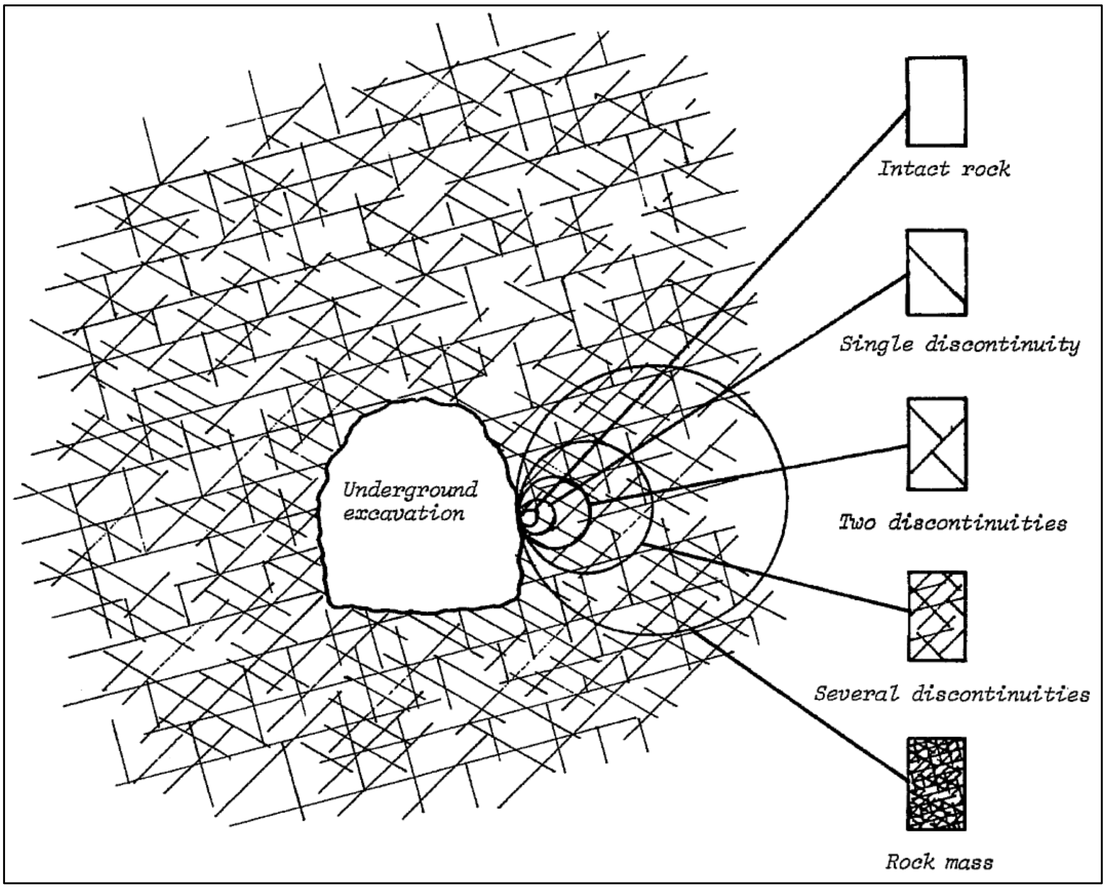


Figure 9: Sketch figure for transition from the rock material to the rock masses (Hoek, E., and Brown, E.T., 1980)

4.1 Rock Material and Rock Material Properties

Rock material, which has different sizes of rock fragments between the natural discontinuities such as joint in rock mass, stratification, schistosity, fault etc., does not include any fracture and weakness plane causing a decrease in the strength of the material. In other words, solid rock material is the smallest rock unit and it does not include any fracture. Although there are some micro fractures in rock material, they are not considered as discontinuity or fracture. These rock fragments can be in the range varying from mm to m and they are mostly considered with elastic and isotropic behavior. The major properties of the rock material are given below.

4.1.1 Unit Weight

The ratio of total mass of rock or soil sample to the total volume is called as unit weight and calculated by Eqn. (1). The total volume includes the voids of the material. If this value is small, it demonstrates that the material has porosity and includes void spaces.

$$\gamma = \mathrm{m}\ ({}^{g}/_{V}) \tag{1}$$

In this equation;

m: sample weight

g: acceleration of gravity

V: total volume of the sample

4.1.2 Uniaxial Compressive Strength (UCS)

Under uniaxial compression conditions, the applied load/force at the time of failure is defined as the uniaxial compressive strength for cylindrical (core) samples (ISRM, 2007) that have ratio of length to diameter ranges between 2.5 to 3. It is expressed as follows (Eqn. (2)):

$$\sigma_{\mathrm{ci}} = {}^{F}/_{A} \tag{2}$$

In this equation;

σ_{ci}: Uniaxial compressive strength

F: Applied force to the sample at failure

A: Area of sample surface where force is applied.

If the diameter of the sample increases, in other words the sample volume increases, the number of the micro-cracks in the rock materials can increase. In this case, the uniaxial compressive strength of rock material decreases as well. Definitely, this decrease is associated with the sample size or scale factor. Hoek and Brown (1980a) attempt to take into account the scale effect for the uniaxial compressive strength of the rock material with some empirical relationship. According to researchers suggestion, samples which have a 50 mm diameter and a length / diameter ratio of 2, are considered as reference samples and the uniaxial compressive strength measured during tests is corrected by the chosen reference diameter (50 mm). This correction is expressed by Eqn. (3):

$$\sigma_{\mathrm{ci}} = \frac{\sigma_{cd}}{(50/D)^{0.18}} \tag{3}$$

In this equation;

σ_{ci}: Uniaxial compressive strength of core sample with 50 mm diameter

D: Diameter of sample experimented in laboratory (mm)

σ_{cd}: Uniaxial compressive strength of sample with diameter D.

4.1.3 Point Load Strength Index (I_s)

The point load test is performed with the purpose for indirect measurement of uniaxial compressive strength of the core samples or irregularly shaped rock samples in the laboratory and/or in the field. Point load strength is an index related to the uniaxial compressive strength of the rock. Point load strength index (I_s) is calculated from Eqn. (4):

$$I_{s(50)} = P/D^2 \tag{4}$$

In this equation,

$I_{s(50)}$: Point load strength index

P: Load applied to sample in failure

D: Diameter of core or sample

Generally, this index is suggested for samples with a diameter of 50 mm. In the empirical relationship given below for the estimation of uniaxial compressive strength, coefficient C is known to vary between 13 and 50 depending on the type of rock and the degree of anisotropy (Norbury, 1986) (Eqn. (5)). Additionally, ISRM (2007) suggest that the C values can favorably be chosen between 20 and 25.

$$\sigma_{\mathrm{ci}} = \mathrm{C}\, I_{s(50)} \tag{5}$$

In this equation,

σ_{ci}: Uniaxial compressive strength

$I_{s(50)}$: Point load strength index

C: Correction factor

4.1.4 Elastic Modulus

Modulus of elasticity or Young's modulus is a measure of elastic deformation of the material under applied force. By definition, it is a value that measures a specimen or sub-surface’s resistance to be deformed elastically when a force applied to it. As a result of the relationship between strain in elastic deformation and normal stress (tensile or compressive stress), it is defined as strength per strain. Linear relationship between unit strain and normal stress can be defined as follows (Eqn. (6)):

$$E = {}^{\sigma}/_{\varepsilon} \tag{6}$$

In this equation,

E: Elastic modulus

σ: Normal stress (tensile or compressive stress)

ε: Strain in elastic deformation

4.1.5 Poisson’s Ratio

Poisson's ratio being involved in the deformation of the elastic material is a mechanical parameter used in rock engineering problems related to the deformation of rocks. Although there are many studies related with this parameter, the values of Poisson's ratio and determination of Poisson's ratio of rock types, especially for different rock types is still open for debate. The latest publication that highlights the importance of this parameter has been made by Gerçek (2006), who carried out an extensive literature survey. Constitutively, Poisson's ratio is defined as the ratio of the strain in the horizontal direction to the strain in the axial direction for a material that is subjected to uniaxial strain.

Poisson's ratio of the rock material can be determined indirectly by dynamic methods (ISRM, 1977; ASTM, 1998a) or directly by static tests (ISRM, 1978; ASTM, 1998b) in the laboratory. Gerçek (2006) states that porosity has a significant effect on Poisson’s ratio as well as geometry (size and shape), orientation, distribution and connections of pore spaces.

Regarding the determination of Poisson’s ratio for rock materials, although there is standardization for laboratory methods and there are many studies on it, it is still limited and open to debate for rock masses. Gerçek (2006) states in many of his studies that the Poisson’s ratio of the rock mass is greater than that of the rock material, sometimes unexpected values ($v>0.5$) can be encountered and this is related with discontinuities. Therefore, theoretically Poisson's ratio of the rock material of ($0 <v <0.5$) can be an acceptable limiting value for the jointed rock masses (Gerçek, 2006).

4.2 Rock Mass and Rock Mass Classification

Rock mass or in situ rock is a mass or system, created by the network of discontinuities together with rock material. Behavior of the rock mass under a certain stress is usually controlled by the interaction between the blocks of rock material and discontinuities. Rock material blocks bounded by discontinuities in rock masses can show varying characteristics from fresh rock material to weathered rock. Rock mass classification systems, which have been developed in order to examine these changes regularly, should not be considered as tools that can provide a complete engineering design. These systems should be used with observation based analytic and numerical solution techniques by considering design targets and field geology in order to make a final design. When these systems are used properly, they can be a useful tool for the preliminary design phase. The main purposes of using the rock mass classification system are,

i) To determine the main characteristics affecting the behavior of the rock mass
ii) To determine different rock mass classes by separating the rock mass of similar characteristics among their territory,
iii) To create benchmarks in order to understand the characteristics of each rock mass class
iv) To establish a relationship between the gained experience from rock mass conditions on site and the conditions encountered in other field by comparison.
v) To obtain a guide and numeric data for engineering design
vi) To provide a scientific and technical communication between engineers based on a common background (Bieniawski, 1989).

Since 1946, different rock mass classification systems have either been developed or suggested by different researchers (Table 6). Some of these systems have been derived from the re-modification of previously proposed systems by considering some factors. Here, all of these systems are not given systems that are most widely used today in rock engineering and tunneling applications and / or demand are essentially presented.

Table 6: Major 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

4.2.1 Rock Mass Rating System (RMR)

RMR Classification System or Rock Mass Rating (RMR) has been developed in between 1972 - 1973 by Bieniawski (Bieniawski, 1973). The system has been modified from 1973 to 1989 and reached the final format after the support of updated data (Bieniawski, 1989). The statistical evaluation of tunnels, big underground galleries, mining facilities, slopes and foundations related to 351 different applications and observations is the most important tool for bringing the method to its current form.

According to the RMR classification of the rock mass, the following 6 parameters are taken into consideration (Figure 10).

i) Uniaxial compressive strength of rock material: This parameter is important for the determination of the upper limit of the strength of the rock mass. Moreover, when considering the importance of rock mechanical compressive stress fields, it is clear that uniaxial compressive strength is a required parameter for the classification.

ii) Rock Quality Designation (RQD): RQD is a quantitative index of rock quality that is the percentage ratio of the total length of the cylindrical shaped core recovery pieces which have 10 cm or larger length and separated by discontinuities in a natural progress interval to the length of the progress interval (Deere, 1964). RQD suggested by Deere (1964) is presented by Eqn. (7):

$$RQD(\%) = \frac{\sum Length\ of\ Core\ Pieces\ (I) > 100mm}{Total\ Core\ Run\ Length\ (L)} \tag{7}$$

The number of the core pieces at the borehole depth, “I” is the length of core parts that are taken into consideration for RQD and longer than 10 cm, “L” is length of progression.

iii) Spacing of discontinuity

iv) Status of discontinuities and surface conditions (continuity, roughness, fillings, weathering, space)

v) Groundwater conditions

vi) Orientation of discontinuities.

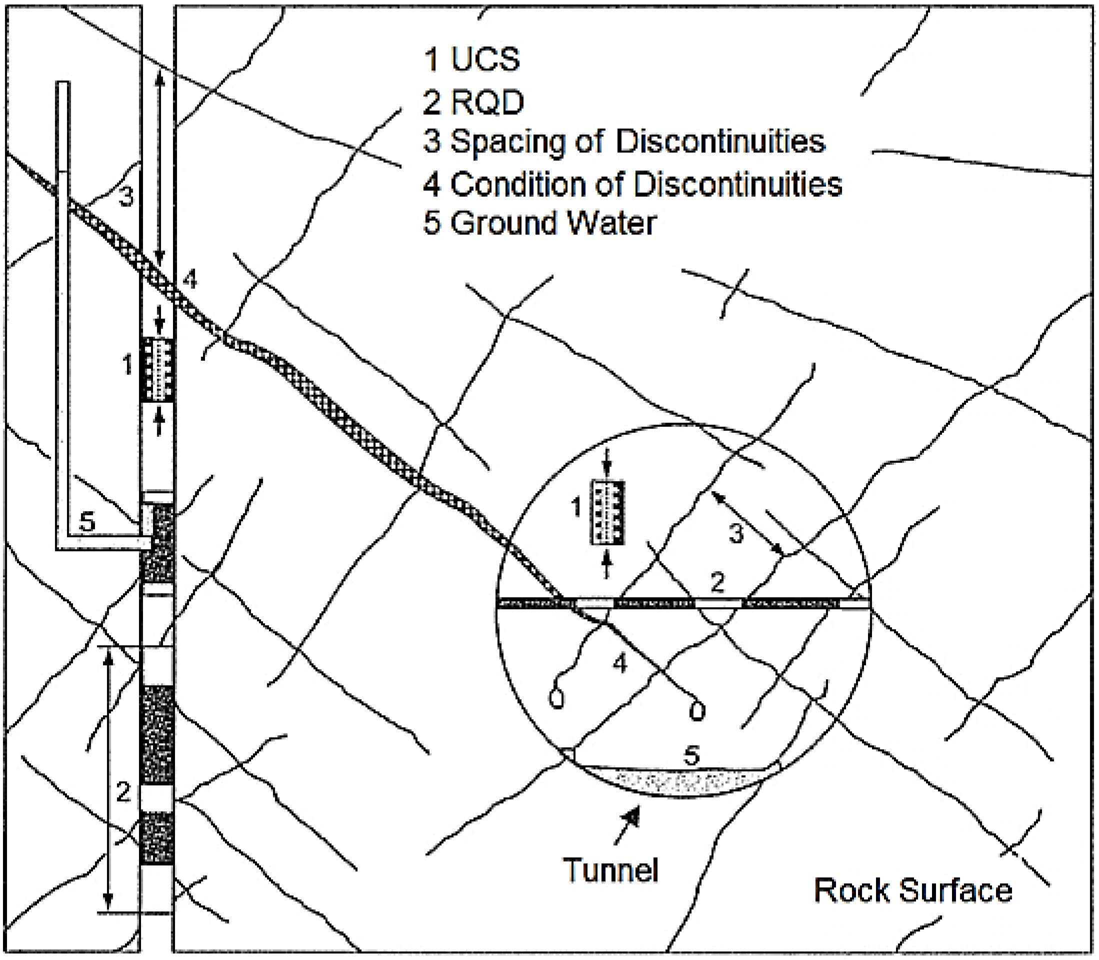


Figure 10: The parameters used in the RMR rock mass classification system (Hudson 1989)

For implementing the system, the rock mass is divided into structural regions which have similarity with respect to certain properties. It can be encountered in the structural areas that have a uniform distance between the discontinuities or rock types. In many cases, the boundaries of structural regions coincide with major discontinuities such as fault, dyke and shear zones. After structural zones are defined, classification required parameters are determined along excavation or every progression of the drilling work.

In 1973, when the system was proposed firstly, classification parameters were determined directly from a single chart. However, because the same score range is available for different parameter values, it involved shortages in terms of making a realistic scoring. These shortages have been fixed with the final update of the system in 1989.

While using the RMR Classification System, the criteria for each of the parameters in Table 7 and / or values are taken into account. Since the importance of different parameters in classification is not equal, the uniaxial compressive strength and ratings corresponding interval values related to RQD and discontinuity parameters are not determined by Table 7. They are determined by the help of the graphs given in Figure 11. The graph given in Table 7-D, in case of lack of RQD or discontinuity interval value, is suggested to determine the unknown parameter by using the known one.

In this system, discontinuity interval parameter is applied to a rock mass containing three discontinuity sets. Therefore, a consistent assessment could be made only for two discontinuity sets containing rock masses. Table 8 should be used for a better determination of ratings related with the condition of discontinuities.

The next step is to determine the effect of slope and direction of tunneling from Table 7-B. This step is made separately from previous evaluation. Because the effect of discontinuity orientation depends on the orientation of the excavation in engineering applications such as tunnels and underground mining operation, RMR rating correction related to this assessment is determined by using Table 7-C. However, due to this evaluation being qualitative, Table 7-B needs to be used in order to determine the appropriateness of the slope and the direction of the tunnel. The sum of the corrected value related to orientation and RMR value obtained from the sum of the first 5 parameters gives the final RMR value that represents rock mass. For civil engineering projects, generally, correction regarding discontinuity orientation need to be done. However, RMR classification system is used commonly for mining applications and for these applications, excavation processes contain dynamic periods and they may require underground openings that intersect each other from different directions. In this case, factors such as field strains, blasting etc., should be taken into account and, if necessary, the RMR values need to be calculated with the corrections of those factors. The coefficients obtained from the corrections must not be less than 0.5.

Table 7: RMR classification parameters (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 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 (I/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. 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	

C. 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	

D. 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

E. 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

Table 8: Guidelines for classification of discontinuity conditions (Bieniawski, 1989)

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

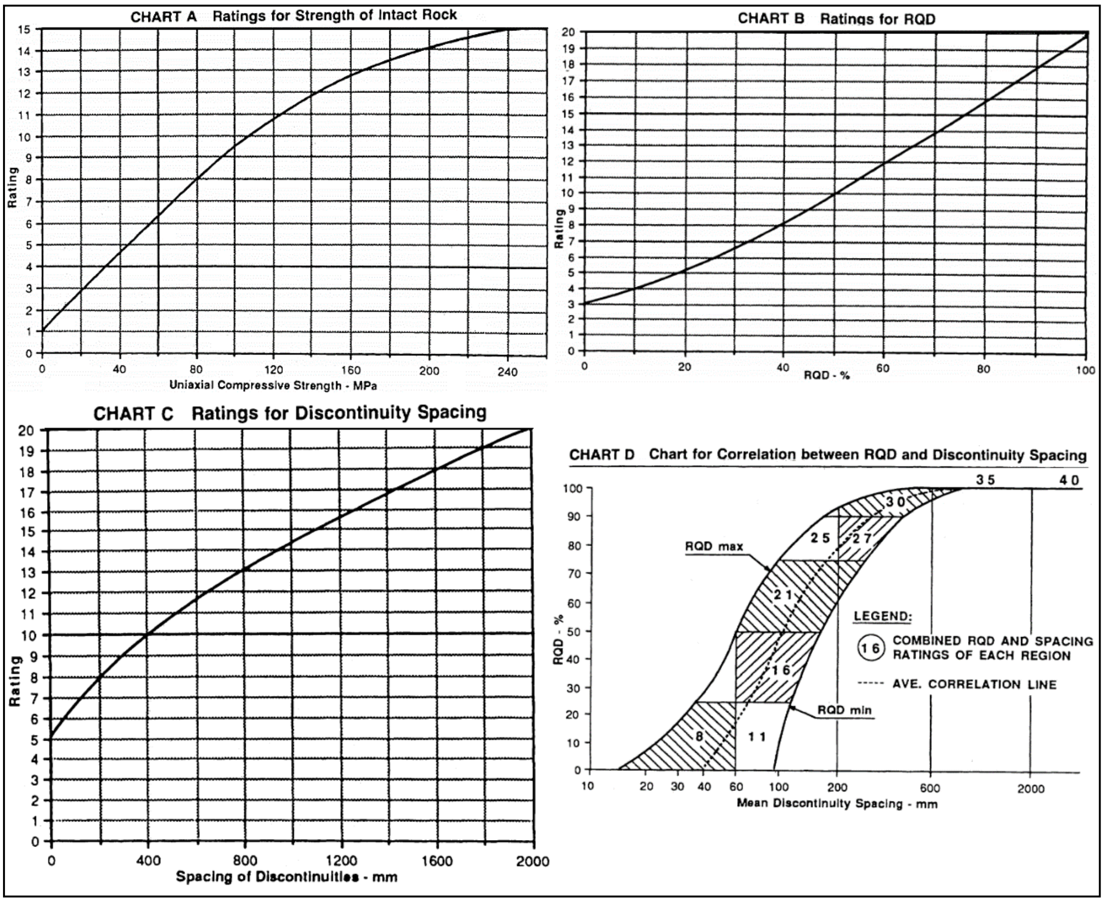


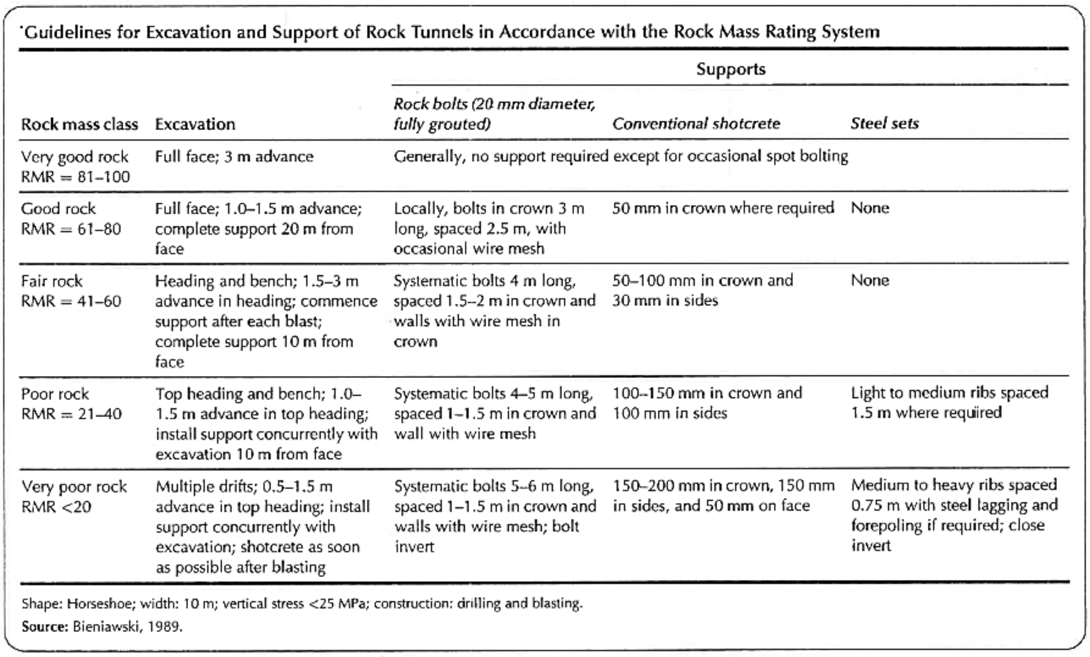
Figure 11: RMR parameters rating distribution (Bieniawski, 1989)

The resultant RMR rating obtained after making the necessary corrections can be used for the purposes as defined below.

i) Bieniawski (1989) suggested that the cohesion and internal friction angle of the rock mass can be roughly determined from Table 7, D and E sections.

ii) RMR value or rock class provides the opportunity to determine the support system by using the guide (Table 9) for the determination of the tunnel support system. Table 9 is used for the excavations carried out using conventional drilling and blasting methods.

Table 9: Tunnel excavation and support guide based on RMR System (Bieniawski, 1989)



'Guidelines for Excavation and Support of Rock Tunnels in Accordance with the Rock Mass Rating System

Rock mass class	Excavation	Supports: *Rock bolts (20 mm diameter, fully grouted)*	Supports: *Conventional shotcrete*	Supports: *Steel sets*
Very good rock RMR = 81–100	Full face; 3 m advance	Generally, no support required except for occasional spot bolting		
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 wire mesh	50 mm in crown where required	None
Fair rock RMR = 41–60	Heading and bench; 1.5–3 m advance in heading; commence 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 wire mesh in crown	50–100 mm in crown and 30 mm in sides	None
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 wall with wire mesh	100–150 mm in crown and 100 mm in sides	Light to medium ribs spaced 1.5 m where required
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 wire mesh; bolt invert	150–200 mm in crown, 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

Shape: Horseshoe; width: 10 m; vertical stress <25 MPa; construction: drilling and blasting.
Source: Bieniawski, 1989.

iii) For any specific dimension of the underground opening, the duration of standing of the unsupported tunnel section is determined from the graph in Figure 12.

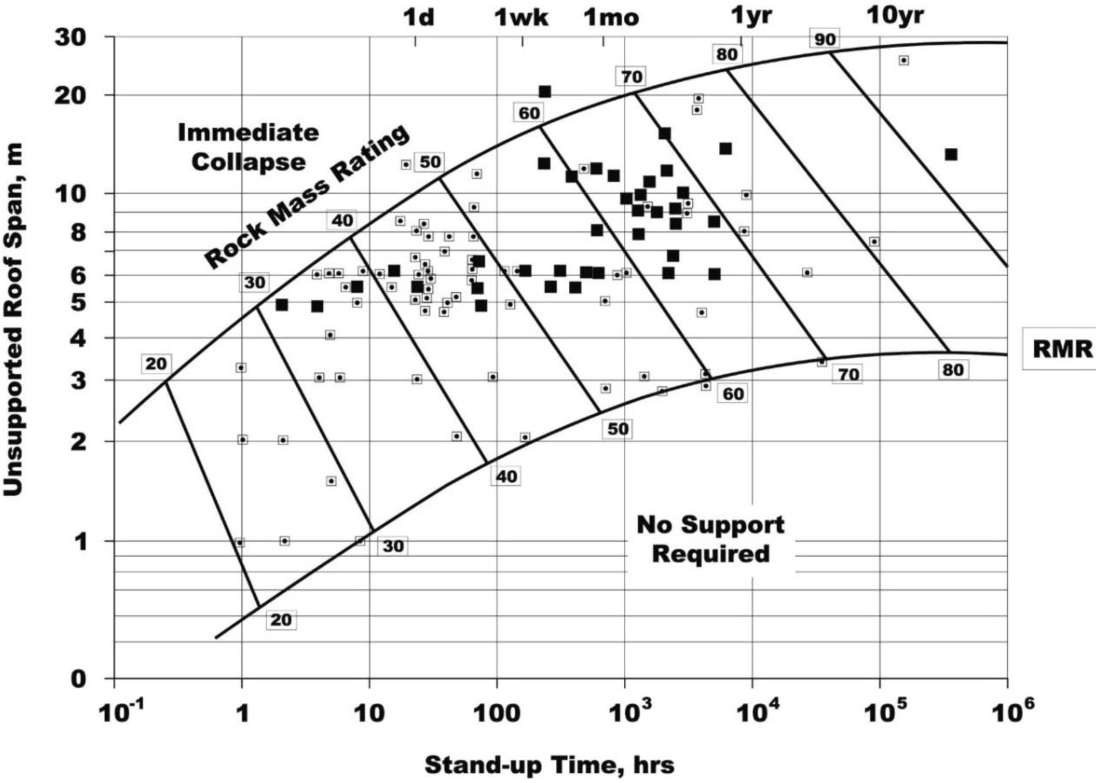


Figure 12: Duration of standing unsupported time (Bieniawski, 1989)

iv) Support load can be estimated using the RMR value by Eqn. (8).

$$P = \left[{}^{(100 - RMR)}\!/_{100}\right] B\gamma \tag{8}$$

In this equation,

P: Support load (kN)

B: width of the tunnel (m)

γ: unit weight of the rock (kN/m^3)

v) In the RMR classification system, Eqn. (9) can be used for the determination of in-situ deformation modulus of the rock masses (Bieniawski, 1978).

$$E_m = 2RMR - 100 \tag{9}$$

The unit of E_m is GPa, "Basic RMR" rating is used in Eqn. (9). In order to use Eqn. (9), the RMR value needs to be greater than 50. However, in the case the RMR value is lower than 50, Serafim and Pereira (1983) suggested using Eqn. (10):

$$E_m = 10^{(RMR-10)/40} \tag{10}$$

Additionally, caution is recommended when using Eqns. (9) or (10) since these equations, in some cases, can give higher values than the deformation modulus of the rock material (E_{intact}) that is determined from laboratory tests. Therefore, for the determination of the rock masses deformation modulus, more realistic values could be gained by applying a reduction factor (RF) defined by the RMR rating of Figure 13 on the determined deformation modulus of the rock material (Bieniawski and Nicholson, 1990) (Eqn. (11):

$$E_m = (RF)E_{intact} \tag{11}$$

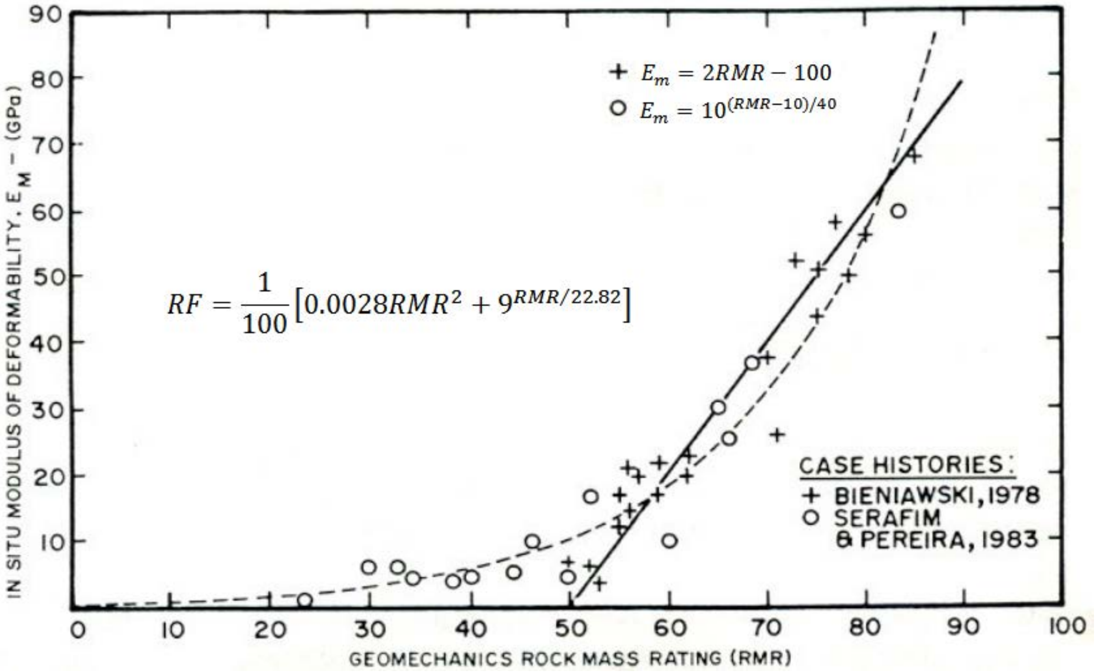


Figure 13: Reduction factor for the deformation modulus of the rock material determined from laboratory tests (Bieniawski and Nicholson, 1990)

4.2.2 NGI Tunneling Quality Index (Q-system)

Rock mass classification system named as Q or NGI (Norwegian Geotechnical Institute) has been developed by Barton (1974) specifically for tunnel design in the beginning of the 70's. Rock Tunneling Quality Q is calculated from 6 independent parameters by an equation which is given below (Eqn. (12)):

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF} \tag{12}$$

In this equation;

RQD: Rock quality designation

J_n: Joint set number

J_r: Joint roughness number

J_a: Joint alteration number

J_w: Joint water reduction factor

SRF: Stress reduction factor

In Eqn. (12), “RQD/Jn” refers to rock mass structure and block size, “Jr/Ja” refers to filled or unfilled discontinuity surface roughness and characteristics of discontinuity (the inter-block shear strength), and finally “Jw/SRF” refers to effective stress conditions. This system has been developed based on the experiences gained from more than 1000 cases in constructed tunnels. For the Q system, there is no significant change except a modification made by Grimstad and Barton (1993) and Barton and Grimstad (1994) related with the Stress Reduction Factor (SRF). Values of the 6 parameters, which can change according to different conditions used for the calculation of the Q value including the changes made to the SRF, are presented in Table 10.

Table 10: Q parameters for different conditions (Barton, 2002)

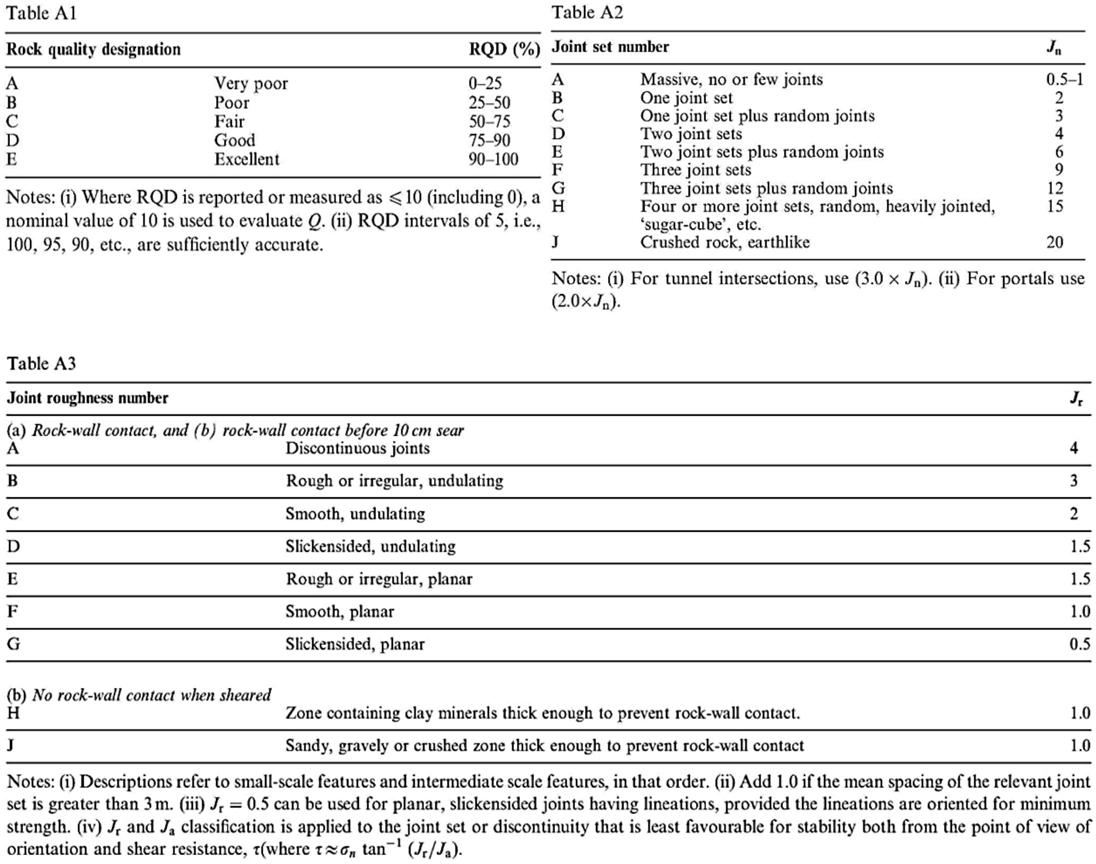


Table A1

Rock quality designation		**RQD (%)**
A	Very poor	0–25
B	Poor	25–50
C	Fair	50–75
D	Good	75–90
E	Excellent	90–100

Notes: (i) Where RQD is reported or measured as ⩽10 (including 0), a nominal value of 10 is used to evaluate Q. (ii) RQD intervals of 5, i.e., 100, 95, 90, etc., are sufficiently accurate.

Table A2

Joint set number		**J_n**
A	Massive, no or few joints	0.5–1
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints	12
H	Four or more joint sets, random, heavily jointed, ‘sugar-cube’, etc.	15
J	Crushed rock, earthlike	20

Notes: (i) For tunnel intersections, use ($3.0 \times J_n$). (ii) For portals use ($2.0 \times J_n$).

Table A3

Joint roughness number		**J_r**
(a) *Rock-wall contact, and (b) rock-wall contact before 10 cm sear*		
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
F	Smooth, planar	1.0
G	Slickensided, planar	0.5
(b) *No rock-wall contact when sheared*		
H	Zone containing clay minerals thick enough to prevent rock-wall contact.	1.0
J	Sandy, gravely or crushed zone thick enough to prevent rock-wall contact	1.0

Notes: (i) Descriptions refer to small-scale features and intermediate scale features, in that order. (ii) Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m. (iii) $J_r = 0.5$ can be used for planar, slickensided joints having lineations, provided the lineations are oriented for minimum strength. (iv) J_r and J_a classification is applied to the joint set or discontinuity that is least favourable for stability both from the point of view of orientation and shear resistance, τ(where $\tau \approx \sigma_n \tan^{-1} (J_r/J_a)$.

Table A4

Joint alteration number		ϕ_r approx. (deg)	J_a
(a) *Rock-wall contact (no mineral fillings, only coatings)*			
A	Tightly healed, hard, non-softening, impermeable filling, i.e., quartz or epidote	—	0.75
B	Unaltered joint walls, surface staining only	25–35	1.0
C	Slightly altered joint walls, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	25–30	2.0
D	Silty- or sandy-clay coatings, small clay fraction (non-softening)	20–25	3.0
E	Softening or low friction clay mineral coatings, i.e., kaolinite or mica. Also chlorite, talc, gypsum, graphite, etc., and small quantities of swelling clays	8–16	4.0
(b) *Rock-wall contact before 10 cm shear (thin mineral fillings)*			
F	Sandy particles, clay-free disintegrated rock, etc.	25–30	4.0
G	Strongly over-consolidated non-softening clay mineral fillings (continuous, but <5 mm thickness)	16–24	6.0
H	Medium or low over-consolidation, softening, clay mineral fillings (continuous, but <5 mm thickness)	12–16	8.0
J	Swelling-clay fillings, i.e., montmorillonite (continuous, but <5 mm thickness). Value of J_a depends on per cent of swelling clay-size particles, and access to water, etc.	6–12	8–12
(c) *No rock-wall contact when sheared (thick mineral fillings)*			
KLM	Zones or bands of disintegrated or crushed rock and clay (see G, H, J for description of clay condition)	6–24	6, 8, or 8–12
N	Zones or bands of silty- or sandy-clay, small clay fraction (non-softening)	—	5.0
OPR	Thick, continuous zones or bands of clay (see G, H, J for description of clay condition)	6–24	10, 13, or 13–20

Table A5

	Joint water reduction factor	Approx. water pres. (kg/cm^2)	J_w
A	Dry excavations or minor inflow, i.e., <5 l/min locally	<1	1.0
B	Medium inflow or pressure, occasional outwash of joint fillings	1–2.5	0.66
C	Large inflow or high pressure in competent rock with unfilled joints	2.5–10	0.5
D	Large inflow or high pressure, considerable outwash of joint fillings	2.5–10	0.33
E	Exceptionally high inflow or water pressure at blasting, decaying with time	>10	0.2–0.1
F	Exceptionally high inflow or water pressure continuing without noticeable decay	>10	0.1–0.05

Notes: (i) Factors C to F are crude estimates. Increase J_w if drainage measures are installed. (ii) Special problems caused by ice formation are not considered. (iii) For general characterisation of rock masses distant from excavation influences, the use of $J_w = 1.0, 0.66, 0.5, 0.33$, etc. as depth increases from say 0–5, 5–25, 25–250 to >250 m is recommended, assuming that RQD/J_n is low enough (e.g. 0.5–25) for good hydraulic connectivity. This will help to adjust Q for some of the effective stress and water softening effects, in combination with appropriate characterisation values of SRF. Correlations with depth-dependent static deformation modulus and seismic velocity will then follow the practice used when these were developed.

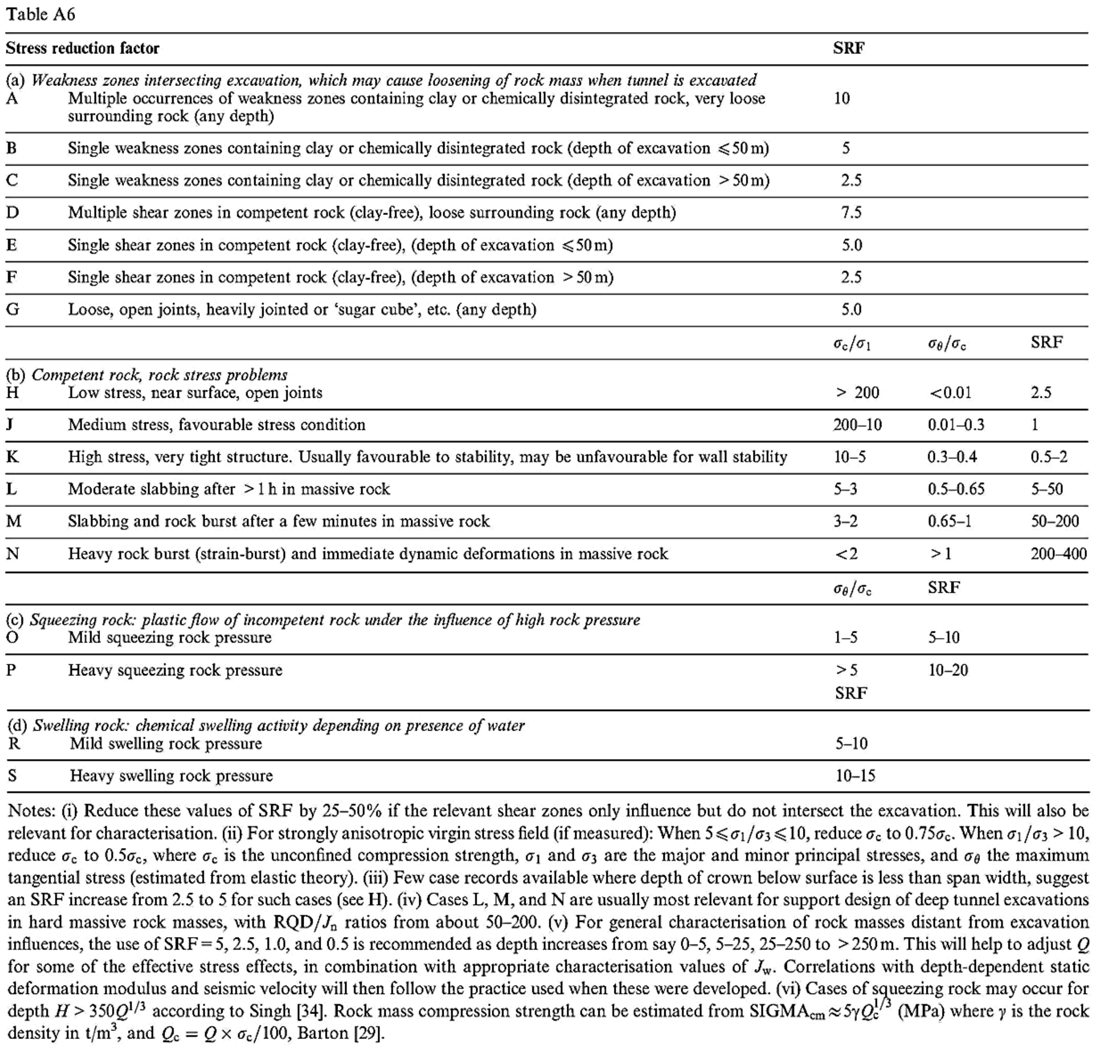


Table A6

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		
B	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation $\leqslant 50$ m)	5		
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)	7.5		
E	Single shear zones in competent rock (clay-free), (depth of excavation $\leqslant 50$ m)	5.0		
F	Single shear zones in competent rock (clay-free), (depth of excavation > 50 m)	2.5		
G	Loose, open joints, heavily jointed or 'sugar cube', etc. (any depth)	5.0		
		σ_c/σ_1	σ_θ/σ_c	SRF
(b) *Competent rock, rock stress problems*				
H	Low stress, near surface, open joints	> 200	<0.01	2.5
J	Medium stress, favourable stress condition	200–10	0.01–0.3	1
K	High stress, very tight structure. Usually favourable to stability, may be unfavourable for wall stability	10–5	0.3–0.4	0.5–2
L	Moderate slabbing after > 1 h 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
		σ_θ/σ_c	SRF	
(c) *Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure*				
O	Mild squeezing rock pressure	1–5	5–10	
P	Heavy squeezing rock pressure	>5	10–20	
		SRF		
(d) *Swelling rock: chemical swelling activity depending on presence of water*				
R	Mild swelling rock pressure	5–10		
S	Heavy swelling rock pressure	10–15		

Notes: (i) Reduce these values of SRF by 25–50% if the relevant shear zones only influence but do not intersect the excavation. This will also be relevant for characterisation. (ii) For strongly anisotropic virgin stress field (if measured): When $5 \leqslant \sigma_1/\sigma_3 \leqslant 10$, reduce σ_c to $0.75\sigma_c$. When $\sigma_1/\sigma_3 > 10$, reduce σ_c to $0.5\sigma_c$, where σ_c is the unconfined compression strength, σ_1 and σ_3 are the major and minor principal stresses, and σ_θ the maximum tangential stress (estimated from elastic theory). (iii) Few case records available where depth of crown below surface is less than span width, suggest an SRF increase from 2.5 to 5 for such cases (see H). (iv) Cases L, M, and N are usually most relevant for support design of deep tunnel excavations in hard massive rock masses, with RQD/J_n ratios from about 50–200. (v) For general characterisation of rock masses distant from excavation influences, the use of SRF = 5, 2.5, 1.0, and 0.5 is recommended as depth increases from say 0–5, 5–25, 25–250 to >250 m. This will help to adjust Q for some of the effective stress effects, in combination with appropriate characterisation values of J_w. Correlations with depth-dependent static deformation modulus and seismic velocity will then follow the practice used when these were developed. (vi) Cases of squeezing rock may occur for depth $H > 350Q^{1/3}$ according to Singh [34]. Rock mass compression strength can be estimated from $\mathrm{SIGMA}_{cm} \approx 5\gamma Q_c^{1/3}$ (MPa) where γ is the rock density in t/m^3, and $Q_c = Q \times \sigma_c/100$, Barton [29].

Related with the Q value, in terms of sensitivity and support requirements of underground openings, Barton and others (1974) defined a parameter named as "equivalent size, D_e". This parameter is calculated from Eqn. (13):

$$D_e = \frac{Excavation\ span,diameter\ or\ height\ (m)}{Excavation\ Suppoert\ Ratio\ (ESR)} \tag{13}$$

The ESR value in the above equation is a kind of safety factor and this value has an impact on the support system placed in order to provide the stability of the underground openings. According to the type and purpose of the underground excavation, the original ESR values had been proposed by Barton et al. (1974). However; Barton and Grimstad (1994) made some modifications and updated the

ESR values after 1994. The original and updated ESR values are given in Table 11 comparatively.

Table 11: Original and updated ESR values by Barton et al. (1974) and 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 Rectangular / square section	2.5 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 Q values which are calculated from Eqn. (12) by using the values determined from Table 10 for the Q system parameters, change between 0.001 and 1000. The Q system, depending on these values, has nine different rock mass classifications that vary from exceptionally good to exceptionally poor category. Rock mass classifications related to the Q system and the graph showing the relationship between Q and De are given in Figure 14.

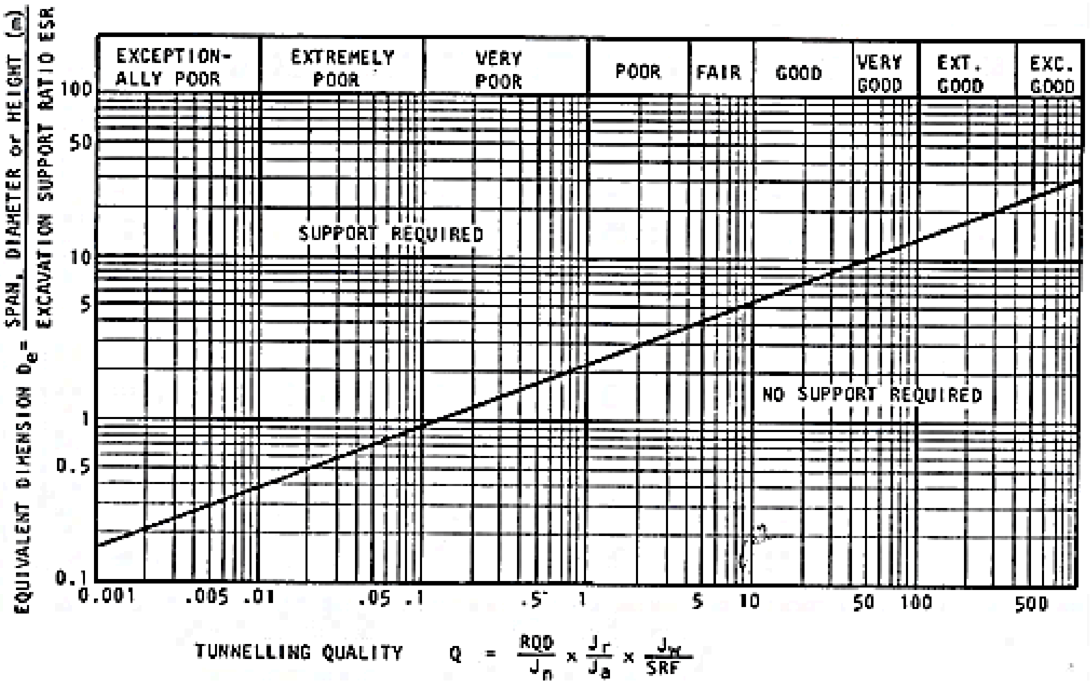


Figure 14: Rock mass quality of Q System (Barton et. al 1974)

The Q classification system is used for underground openings such as tunnels, galleries and big underground chambers. In this manner, the main application areas for the use of selected parameters and Q values determined are given below.

i) Support System Selection

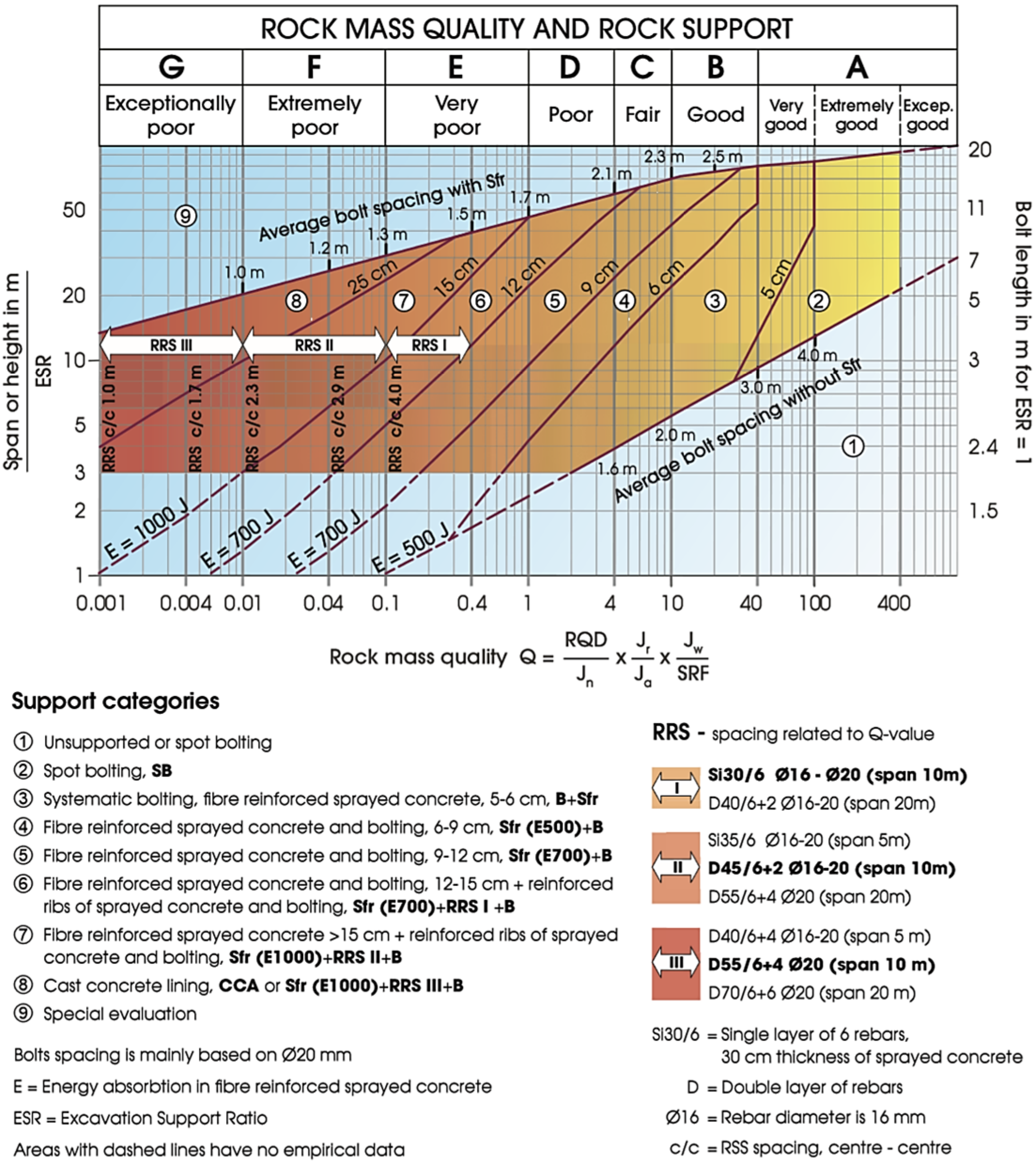
This system has been updated to the final version by Barton (2002) by considering improved support system technology and observations made in underground openings since 1974.

Therefore, in this study the updated support system chart is presented in Figure 15. Q values and supports (permanent and temporary) given in Figure 15 are related to the roof of the opening. Support system for side walls can be determined by considering the height of the wall and corrections to be made to the Q values as indicated below (Barton, 2002).

$$Q>10 \quad \rightarrow \quad Q_{wall} = 5.0Q \qquad (14)$$

$$0.1<Q<10 \quad \rightarrow \quad Q_{wall} = 2.5Q \qquad (15)$$

$$Q<0.1 \quad \rightarrow \quad Q_{wall} = Q \qquad (16)$$



Support categories

① Unsupported or spot bolting
② Spot bolting, **SB**
③ Systematic bolting, fibre reinforced sprayed concrete, 5-6 cm, **B+Sfr**
④ Fibre reinforced sprayed concrete and bolting, 6-9 cm, **Sfr (E500)+B**
⑤ Fibre reinforced sprayed concrete and bolting, 9-12 cm, **Sfr (E700)+B**
⑥ Fibre reinforced sprayed concrete and bolting, 12-15 cm + reinforced ribs of sprayed concrete and bolting, **Sfr (E700)+RRS I +B**
⑦ Fibre reinforced sprayed concrete >15 cm + reinforced ribs of sprayed concrete and bolting, **Sfr (E1000)+RRS II+B**
⑧ Cast concrete lining, **CCA** or **Sfr (E1000)+RRS III+B**
⑨ Special evaluation

Bolts spacing is mainly based on Ø20 mm

E = Energy absorbtion in fibre reinforced sprayed concrete

ESR = Excavation Support Ratio

Areas with dashed lines have no empirical data

RRS - spacing related to Q-value

I: **Si30/6 Ø16 - Ø20 (span 10m)**
D40/6+2 Ø16-20 (span 20m)

II: Si35/6 Ø16-20 (span 5m)
D45/6+2 Ø16-20 (span 10m)
D55/6+4 Ø20 (span 20m)

III: D40/6+4 Ø16-20 (span 5 m)
D55/6+4 Ø20 (span 10 m)
D70/6+6 Ø20 (span 20 m)

Si30/6 = Single layer of 6 rebars, 30 cm thickness of sprayed concrete
D = Double layer of rebars
Ø16 = Rebar diameter is 16 mm
c/c = RSS spacing, centre - centre

Figure 15: Q values and supports (permanent and temporary) (Grimstad 2002 - Barton, 2002)

ii) Determination of the largest unsupported span and roof support pressure (P_{roof})

$$\text{Maximum (Unsupported) Span} = 2\,(\text{ESR})Q^{0.4} \qquad (17)$$

$$P_{roof} = \frac{2}{J_r} Q^{-1/3} \tag{18}$$

If the number of the joint sets is less than three, the roof support pressure is calculated from Eqn. (19):

$$P_{roof} = \frac{2}{3} J_n^{1/2} J_r^{-1} Q^{-1/3} \tag{19}$$

iii) Determination of rock bolt and anchor size

Both supports lengths depend on the excavation dimensions. The lengths of the bolts used in the roof generally depend on the width of the excavation, the ones used in side walls depend on the length of excavation. Accordingly, equations that can be modified according to construction condition are proposed below by Barton et al, 1974.

$$\text{Roof Bolt Length (L)} = 2 + ((0.15\text{B})/\text{ESR}) \tag{20}$$

$$\text{Roof Anchor Length (L)} = 0.4\text{B}/\text{ESR} \tag{21}$$

$$\text{Side Wall Bolt Length (L)} = 2 + ((0.15\text{H})/\text{ESR}) \tag{22}$$

$$\text{Side Wall Anchor Length (L)} = 0.35\text{H}/\text{ESR} \tag{23}$$

In these equations;

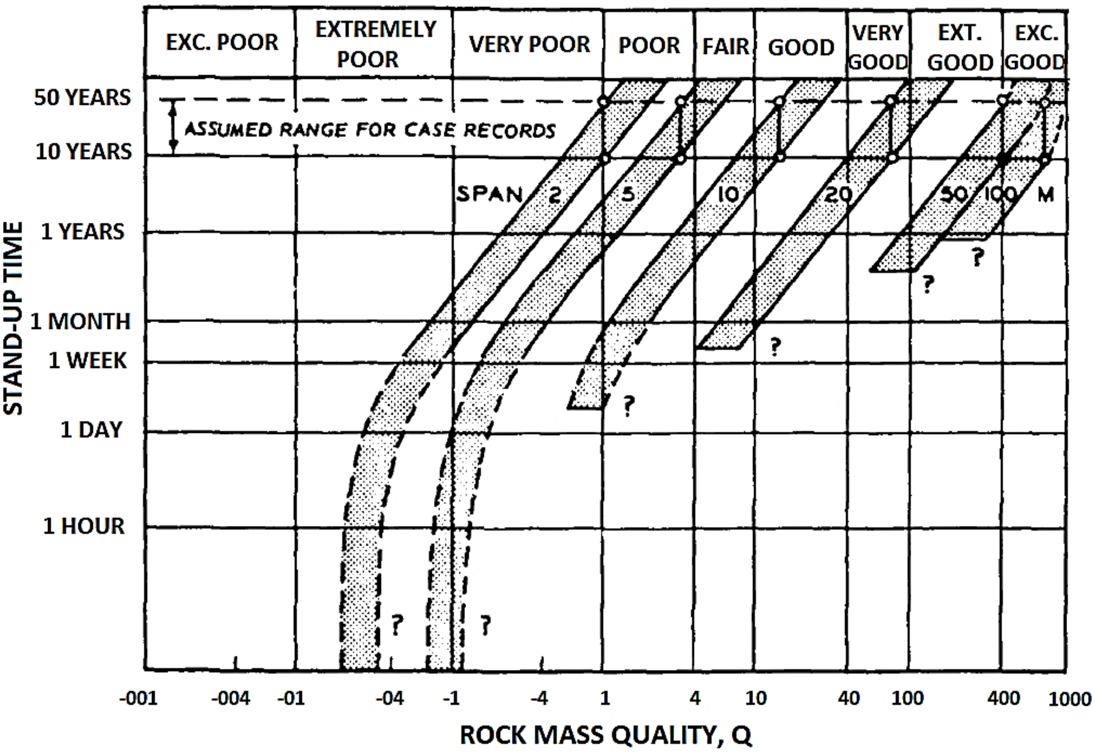
B: Excavation width (m)

H: Excavation length (m)

L: Bolt or anchor length (m)

iv) Unsupported span time

The chart given in Figure 16 shows the relationship between Q and unsupported stand-up time. The shaded sections represent the first evaluation which is proposed to predict the decreasing amount of the unsupported standing duration, if the unsupported opening width exceeds the planned widest opening in design.



Note: Theenvelopes represent a preliminary attempt at predicting how much the stand-up time reduces when the span of an unsupported excavation is increased beyond the maximum design span

Figure 16: Q system stand up time vs rock mass quality (Barton, 1976)

v) Estimation of the rock mass deformation modulus

As in the RMR system, the rock mass deformation modulus E_m can be predicted from the Q values from empirical relations given below (Eqn. (24) (Grimstad and Barton, 1993) and Eqn. (25) (Barton, 2002)).

$$E_m(GPa) = 25\ Log_{10}Q \qquad (for\ Q > 1) \tag{24}$$

$$E_m = 10Q_c^{1/3} \qquad where\ Q_c = Q\,\frac{\sigma_c}{100} \tag{25}$$

In this equation;

σ_c = Uniaxial compressive strength of rock material

vi) Estimation of the shear strength parameters

The shear strength parameters, namely, the friction angle and cohesion can be predicted from Q values from empirical relations given below (Eqns. (26) and (27); Barton and Pandey, 2011).

$$\Phi = tan^{-1}[(J_r/J_a)J_w] \tag{26}$$

$$c = \left({}^{RQD}/_{J_n}\right)\left({}^{1}/_{SRF}\right)\left({}^{\sigma_c}/_{100}\right) \tag{27}$$

In this equation;

σ_c = Uniaxial compressive strength of rock material (MPa)

Φ = Friction angle (°)

c = Cohesion (MPa)

<u>Comparison of the RMR and Q System</u>

Both the RMR and Q classification systems are based on the rating of the three main features of rock masses. These are the strength of rock material, frictional properties of discontinuities and the geometry of the rock block defined by the discontinuities. The strength of the rock material in the Q system is considered as a factor of the rock stress described with SRF. In order to understand the effect of these parameters, the total change range of these features in RMR and Q can be used for comparison. It is observed that there are similarities between the two methods related to three main rock properties that are taken into consideration. However, there is no evidence showing the direct relation between these two systems. Evaluations made for the stress and strength of rock material are extremely different for both systems.

Despite the differences between the RMR and Q system, prediction of the system rating from the other by using Eqn. (28) as proposed by Bieniaewski (1976) is known to be the most popular relation for conversion from RMR to Q.

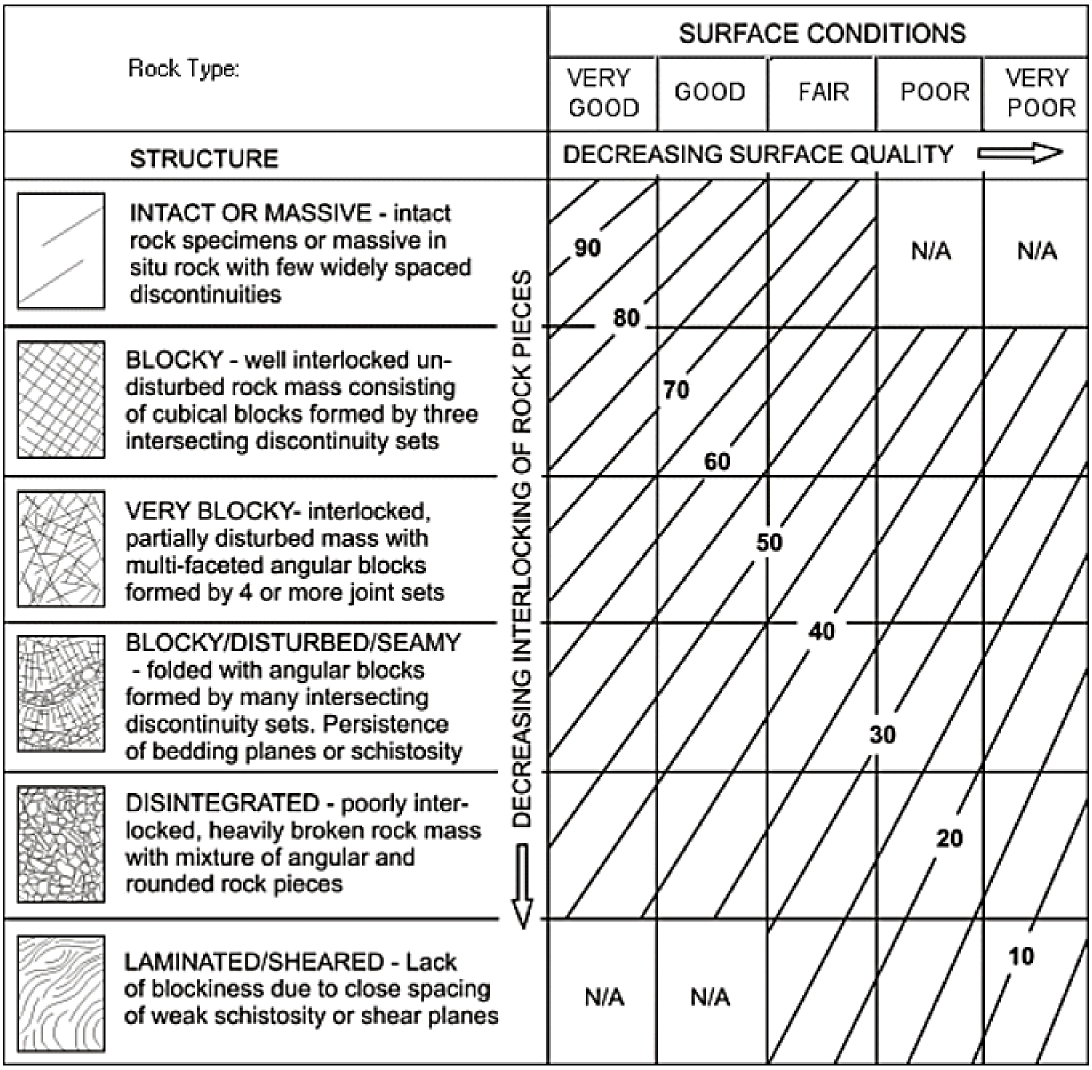
$$RMR = 9\ lnQ + 44 \tag{28}$$

In addition to Eqn. (28) above, different equations are proposed in the following years for the same purpose.

Another difference between the RMR and Q is related to the evaluation of the discontinuity spacing parameter. If there are three or more joint sets and these joints are widely spaced, it is hard to expect that the Q system reflects the rock material properties. It should be considered that the situation of jointing with large spacing will reduce the J_n parameter extremely in the Q system. Therefore, considering the numerical relationship between these two systems, Eqn. (26) should be used with caution.

4.2.3 Geological Strength Index (GSI)

The Geological Strength Index (GSI) has been presented by Hock and Brown in 1997 for both hard and weak rock masses. Experienced geological engineers generally show an affinity for a fast, simple but not completely reliable rock mass classification which is based on visual inspection of geological conditions. In this classification, at the first stage five main qualitative classifications of rock mass structures were suggested which were intact-massive, blocky, very blocky, blocky-disturbed and disintegrated. Additionally, five different surface conditions which are similar to the RMR discontinuity condition descriptions for rock masses were recommended. During 1997 to 2013 the classification chart has been modified and laminated-sheared section and special chart for flysch type of rock masses have been added in GSI classification system (Figure 17). After the 2013, some quantification related to jointed rock mass has been added for in GSI chart by Hoek, E., et al. (Figure 18) due to the lack of measurable parameters for describing the discontinuity surfaces and the rock mass structures. According to Hoek and Brown (1997), estimation of a range of GSI values for the rock masses should be more reliable than estimation of a single value.



Rock Type:

SURFACE CONDITIONS

VERY GOOD | GOOD | FAIR | POOR | VERY POOR

STRUCTURE

DECREASING SURFACE QUALITY

INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities

BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets

VERY BLOCKY- interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets

BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity

DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces

LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes

DECREASING INTERLOCKING OF ROCK PIECES

Figure 17: Rock mass characterization on the basis of interlocking and joint alteration by GSI (Hoek, 1999a)

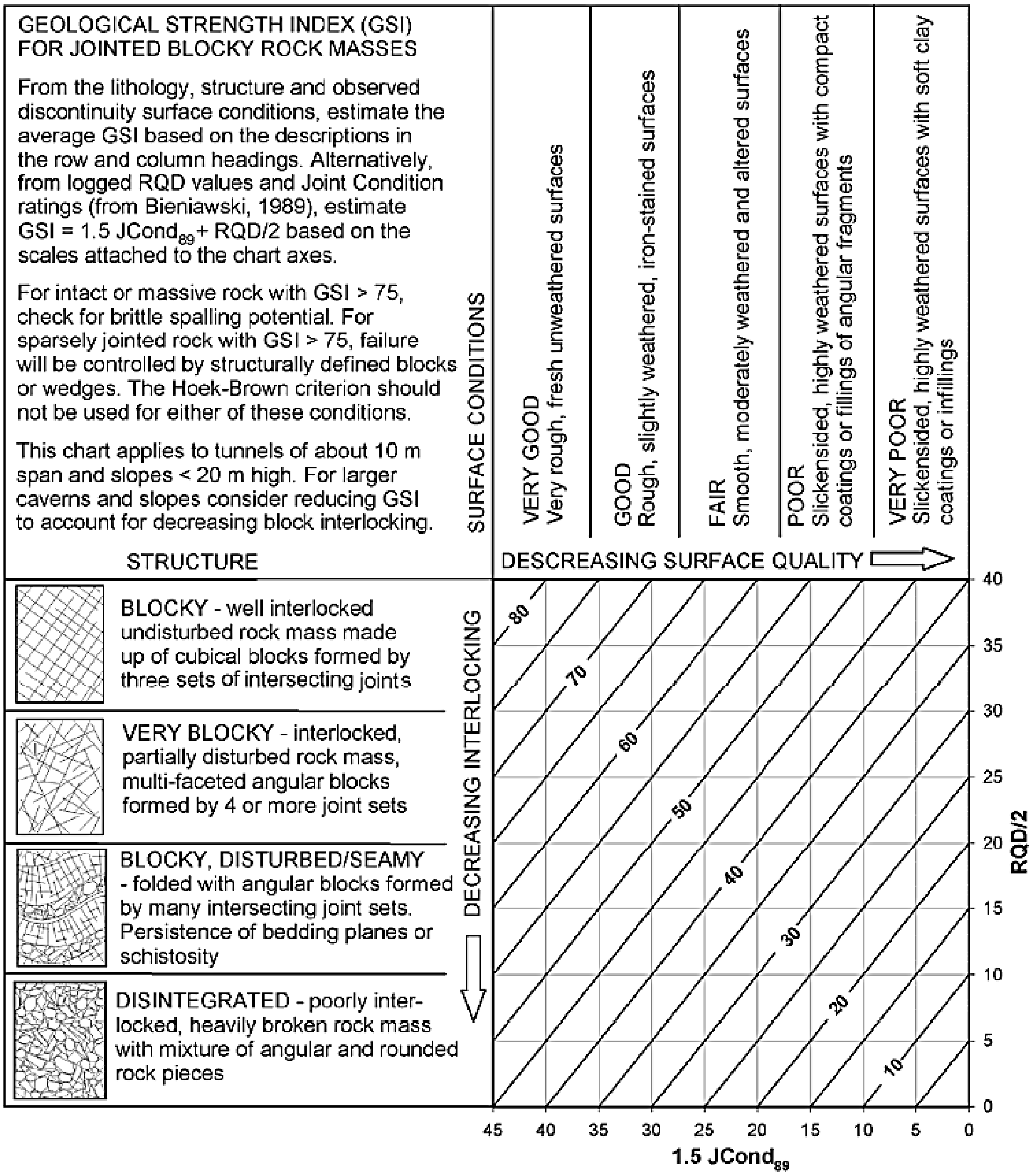


Figure 18: Quantification of GSI classification system by joint conditions and RQD (JCond89 values taken from RMR) (Hoek et al. 2013)

Hoek and Brown (1980) proposed a method for obtaining estimates of the strength of jointed rock masses and they modified their estimation at the end of 2006. The most significant part of the Hoek-Brown system is the process of reducing the material constants σ_{ci} and m_i from their laboratory test values to compatible in situ values. This is accomplished through the GSI classification systems (Hoek and Diederichs, 2006). Summary tables and details of this classification system are provided in the next chapter.

For the better quality (GSI value higher that 20) rock masses, the GSI value could be estimated directly from the latest version of RMR with using the GSI = RMR-5 equation. However, estimation of very poor quality rock mass GSI value from RMR is very difficult due to the missing balance between the ratings of classification systems.

4.2.4 The New Austrian Tunneling Method (NATM)

The main reason of using NATM for the tunnels is the suitability of the method in allowing the rock mass to withstand itself against deformations as much as possible. By the help of this method, the deformation of the rock mass is controlled and loads on the support systems decrease at the time of the excavation. Therefore, rock mass supports itself as much as possible as a consequence of this acceptable deformation.

The support systems do not carry the entire rock load; however, they are used to form a load carrying arch by controlling plastic deformation and prevent weakening which can be defined as loosening of the rock strength. Hence, the flexibility of the support systems is an important parameter for this system. When the strength of the rock is not enough to bear its load, the support pressure applied near to the bearing capacity of the rock stabilizes the excavation.

Whereas 22 principles mentioned by Mueller (1978) were almost explained with the aid of NATM, the number of these principles can be gathered under the title of 7 manners by the most of authorities dealing with tunnel and support design.

a) Exploitation of the strength of rock mass:

According to this principle, the strength of the rock mass which is the fundamental element of tunnel support can be mobilized by reducing the rock deformations and preclusion of rock mass loosening.

b) Shotcrete Protection:

Application of the early temporary support is essential to preserve the rock mass strength by reducing rock mass deformations to a minimum. Steel sets, rock bolts and shotcrete can be described as temporary support measures of NATM. The application of shotcrete and NATM are almost universally associated each other. Shotcrete is appropriate as a temporary support with its natural and high early strength and rigidity. However, other support types such as steel sets should often be supplemented by shotcrete.

During tunneling, after the excavation phase, a thin layer of shotcrete, which has supplementary support or not, is applied immediately to limit the deformations of the rock mass. This support method is successful because, the shotcrete generates full strata-support contact eliminating the nature of irregularities along the tunnel profile.

c) Deformation, Measurement and Monitoring:

An important purpose of NATM is to use experience and to update the support system continuously by the help of the monitoring the rock mass during excavation.

A tunneling practice has too many support opportunities in the consequence of the increasing support equipment knowledge and the support variety is thought to be important due to the differences in the geological conditions faced along the tunnel.

d) Flexible Support:

The concept of NATM relies on the use of a flexible support system which is compatible with different ground conditions easily. The emphasis is emplaced on limiting rock mass deformations from the earliest appropriate occasion by using shotcrete supplemented by rock bolts, wire mesh or steel sets. These temporary support measures are an important component of the load-carrying arch of NATM with the concrete lining which is constructed after the stabilization of the deformations in the tunnel. Generating the required opening shape and final extents of the tunnel are the major roles of this lining.

e) Closing of the Invert:

In NATM, the support system is a thick walled cylinder which includes the rock and the lining. According to the slit amount, the cylinder shows different characteristics. For example, it can be closed or not according the laying type. The timing of the invert closing which is identified in NATM as a crucial support parameter has an important bearing on the total attitude of the lining and the surrounding ground. Although the invert is closed very quickly to control ground movements in the soft ground, it will be closed at a certain distance behind the face in the rock tunnels to permit ground distressing which is ensured by controlled deformation.

f) Tunneling Contract Agreement:

Because of the flexibility of NATM for the tunnel support and estimation of the need to adapt to varying ground conditions, a contract, which includes an equal degree of flexibility with regard to changes during construction, will be needed. NATM, which could not have been governed by a system, need both completed design at the tender stage and the full construction responsibility at the same time.

g) Rock Mass Classification:

The ground can be classified into different classes during tunnel construction (Table 12). This is performed as per the ground characteristics and other geological and hydrogeological conditions, with each class being defined by a particular type, amount of permanent support, besides specific excavation steps. As a tunnel support concept, NATM uses the strength of the surrounding ground as the principal supporting constituent related to operating a two-step lining technique which is temporary and primary support. The temporary support is the fundamental load-bearing constituent.

In NATM, installation the support system at the right time just before the loss of the stability of the rock mass is a significant matter in terms of pace and economy. Elastic and plastic deformation of rock, which is allowed to hold the undesirable loads by itself lets one avoid the excessive loads on the tunnel support system. Hence, instrumentation made and commented at the excavation stage accompanies the success of the method. Figure 19 shows the time selection for the installation of the support system. According to this approach, the most suitable time for the support system installation can be chosen by positioning equilibrium point as close to the minimum value of the Load-Deformation curve as possible. To this end, high sensitivity monitoring should be performed during excavation.

Table 12: Rock classification system (Rabcewicz, 1965)

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		

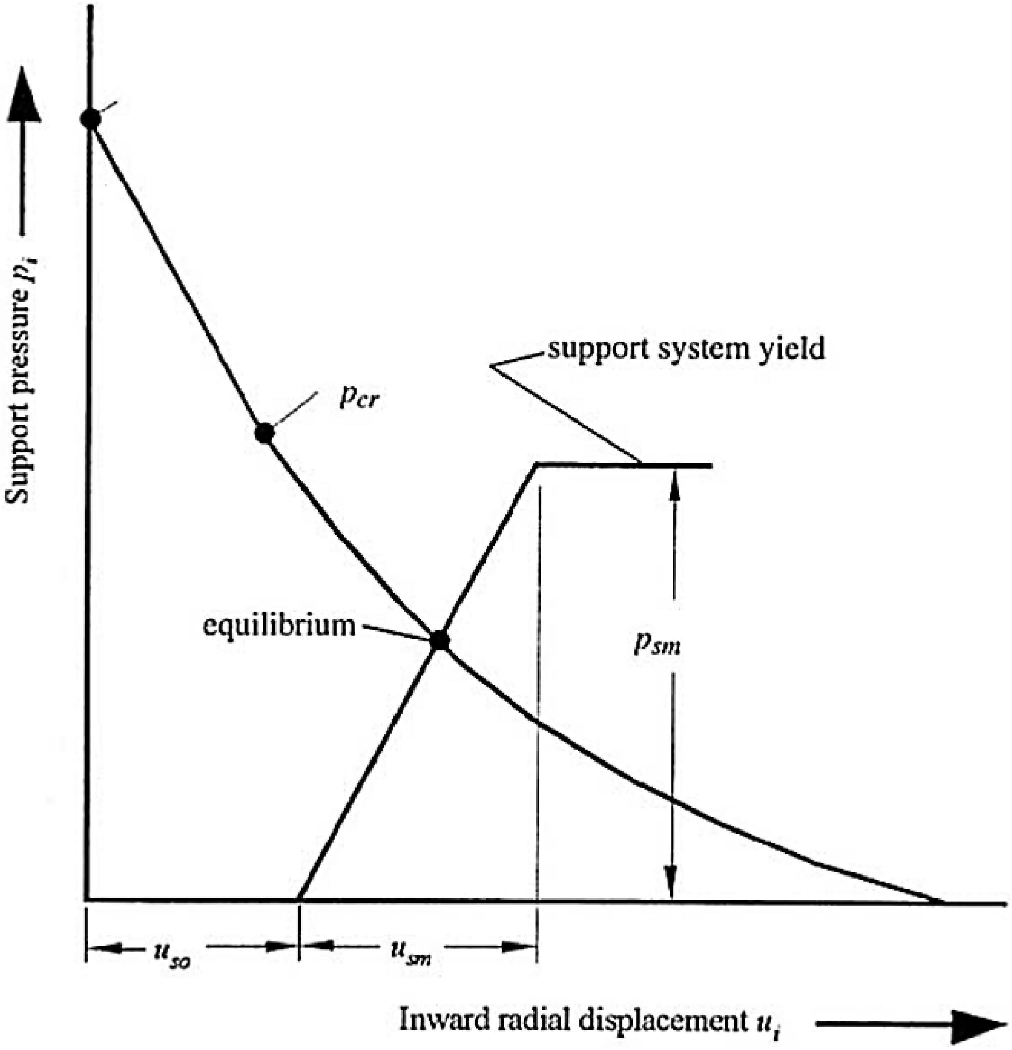


Figure 19: The relationship between support pressure and radial deformation in tunnels (Daemen, 1977 as quoted by Hoek, Kaiser and Bawden, 1995)

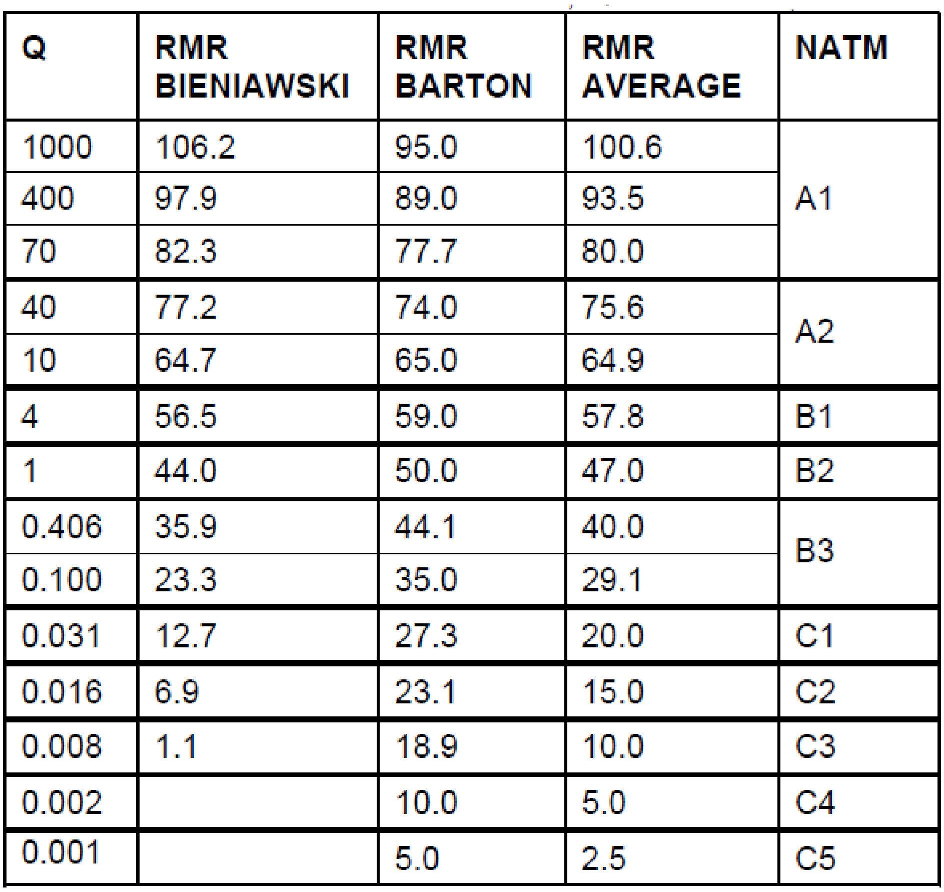
NATM rock mass classification is presented Table 13.

Table 13: NATM temporary support amounts

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 rock bolts; 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, fore-poling; 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, fore-poling, 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, fore-poling, 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, fore-polling or lagging, ribs; top heading (1.5 m), bench (3.0 m), invert arch (100-150 m); tunnel excavator.
C5:	Shotcrete, fore-polling or lagging, ribs; top heading (1.5 m), bench (2.0 m), invert arch (24-50 m); tunnel excavator.

NATM rock mass classification is descriptive and far away from being quantitative. The correlation, suggested by Bieniawski (1996) among the classifications of RMR, Q system and NATM is presented below (Table 14 and Figure 20).

Table 14: Correlations of RMR, Q and NATM (Bieniawski, 1996)



Q	RMR BIENIAWSKI	RMR BARTON	RMR AVERAGE	NATM
1000	106.2	95.0	100.6	A1
400	97.9	89.0	93.5	
70	82.3	77.7	80.0	
40	77.2	74.0	75.6	A2
10	64.7	65.0	64.9	
4	56.5	59.0	57.8	B1
1	44.0	50.0	47.0	B2
0.406	35.9	44.1	40.0	B3
0.100	23.3	35.0	29.1	
0.031	12.7	27.3	20.0	C1
0.016	6.9	23.1	15.0	C2
0.008	1.1	18.9	10.0	C3
0.002		10.0	5.0	C4
0.001		5.0	2.5	C5

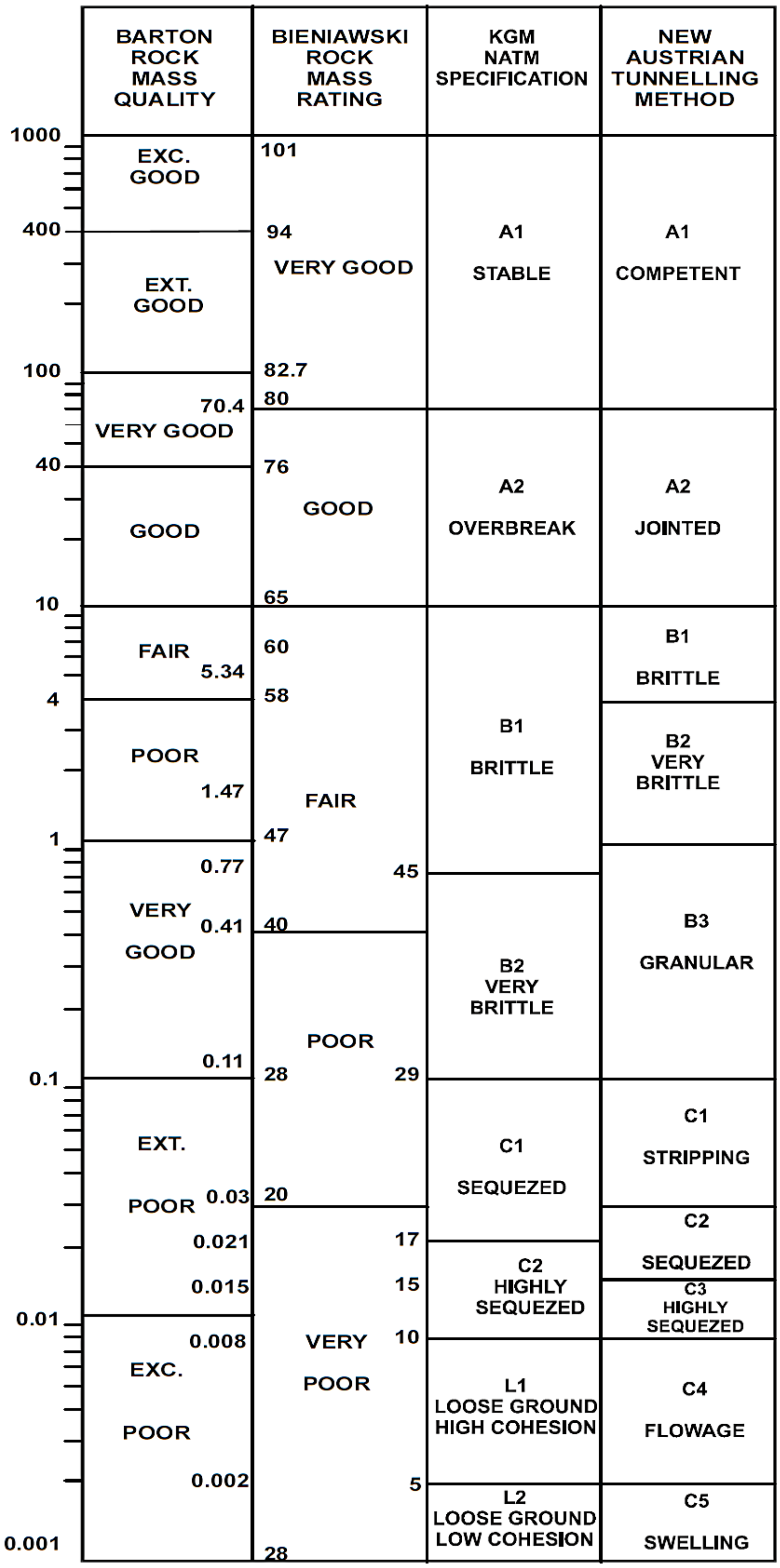


Figure 20: Correlations of RMR, Q and NATM (based on Bieniawski 1996 - Sopacı, 2003)

CHAPTER 5

TUNNEL SUPPORT THROUGH EMPRICAL ROCK MASS CLASSIFICATIONS

In the international tunnel practices, different empirical rock mass classifications systems are used for the tunnel support design. The most commonly used rock mass classification systems are the Q-System (NGI Tunneling Quality Index – Barton and Grimstad, 1993 & Grimstad, 2002) and the Rock Mass Rating System (RMR - Bieniawski, 1989), which are quantitative systems. The New Austrian Tunnel Method (NATM - Whittaker and Frith, 1990), which provides a descriptive or qualitative classification, is also generally used in the European countries.

All classification systems have their advantages and disadvantages. For example, although the support design members are proposed for any size of a tunnel, the Q classification system could not offer tangible stand up time for excavations. Similarly, the RMR classification was developed especially for underground excavations for mining purposes and its support suggestions are limited to 10 m openings only. In this context, combination of the strengths of both classifications is used together in the tunnel support design for obtaining more reliable and accurate data. NATM classification, which is controlled by observations and deformation measurements during the tunnel excavation, is based on more subjective geotechnical data in comparison with the Q and RMR classifications (Sopacı & Akgün, 2008).

For this study, evaluations are based on data obtained from limited surface observations, borehole drillings reaching to a depth of 10 m below the tunnel elevation and rock mechanics laboratory tests.

5.1 Q-System and Generalized Support Types

Q classification parameters were interpreted by the mass and material characteristics of rocks. These parameters are presented separately for the portal and tunnel sections in the following parts of the chapter. Undoubtedly, numerous and different Q values can be encountered along the tunnel route. Therefore, Q values have been defined for certain intervals of both rock and support characteristics as seen in laboratory test results and boreholes.

Along the Konak Tunnel 21 boreholes were drilled which are around 1081 m long in total. However, in this study, the tunnel critical sections, having a length of 484 m have been explored by 8 boreholes. Starting from KM 0+550 and ending at KM 2+200, the Konak Tunnel has two tubes running parallel to each other. The tunnel has a modified horseshoe shape with 11.5 m span diameter and 10.3 m height. The tunnel starts to be driven at an elevation of 4.0 m and reaches up to the surface at an elevation of 48.0 m. The drillings at the portals were executed on the axis of each tube and head of portal slope excavation, whereas the others were drilled on the project axis (Figure 21). Each tube starts and daylights at the same chainage. The studied part of the Konak Tunnel is starting at KM 1+750, where the overburden on the tunnel elevation reaches to 100 m.

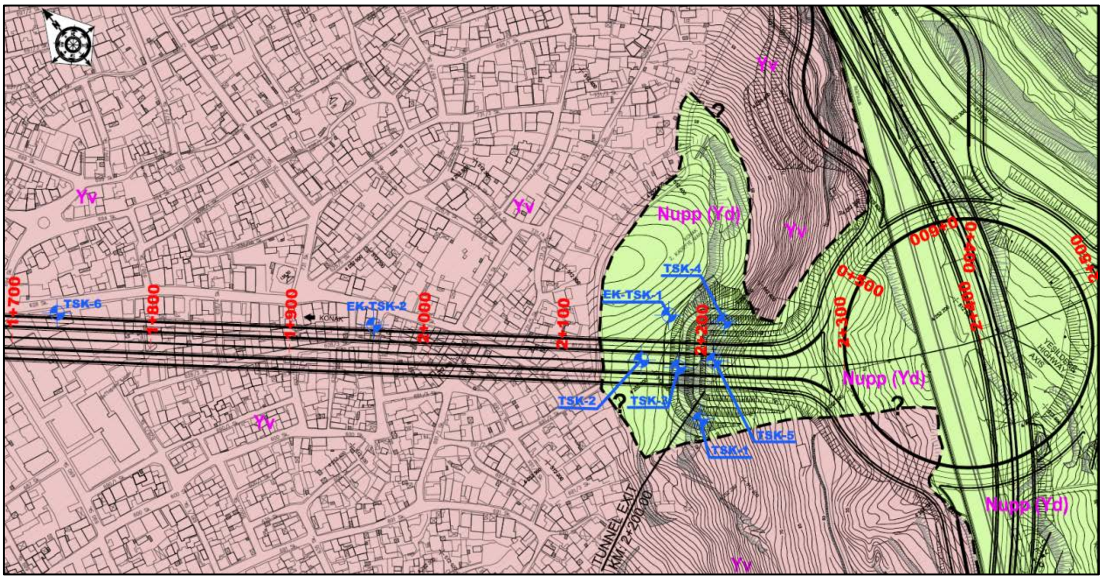


Figure 21: Borehole lay-out of the critical sections and the exit portal of Konak Tunnel (Yv: Yamanlı Volcanics, Nupp: Upper Sedimentary Sequence, Yd: Fill Material)

According to the drillings, at the exit portal of tunnel, it has been determined that mostly andesite masses being in transition with pyroclastics will be cut at tunnel elevation (Table 15). Critical sections which are studied and analyzed in this study are located at this part of the tunnel. The exit portal of tunnel is mostly formed by tuff, andesite and sandstone, claystone and conglomerate of the Upper Sedimentary Sequence that are in transition with each other (Figure 22).

Table 15: Expected rock masses at the tunnel elevation

Geotechnical Section$^{(1)}$	T-100x	T-75x	T-50x	T-Px
KM Chainage	1+770	1+950	2+130	2+165
	1+950	2+130	2+165	2+200
Drilling Included	TSK-6 (RQD=40%)	EK-TSK-2 (RQD=40%)	TSK-2 (RQD=10%)	TSK-1 (RQD=12%)
				TSK-3 (RQD=5%)
				TSK-4 (RQD=15%)
				TSK-5 (RQD=10%)
				EK-TSK-1 (RQD=10%)
Lithology in Tunnel	Andesite	Andesite	Tuff Agglomerate Wth. Andesite	Tuff Agglomerate Wth. Andesite Sed. Seq.

(1) P: Portal, T: Tunnel, e: Enterance, x: Exit

* RQD values are determined from 10 m above and below the tunneling elevation.

** Wth.: Weathered, Sed. Seq.: Sedimentary Sequence

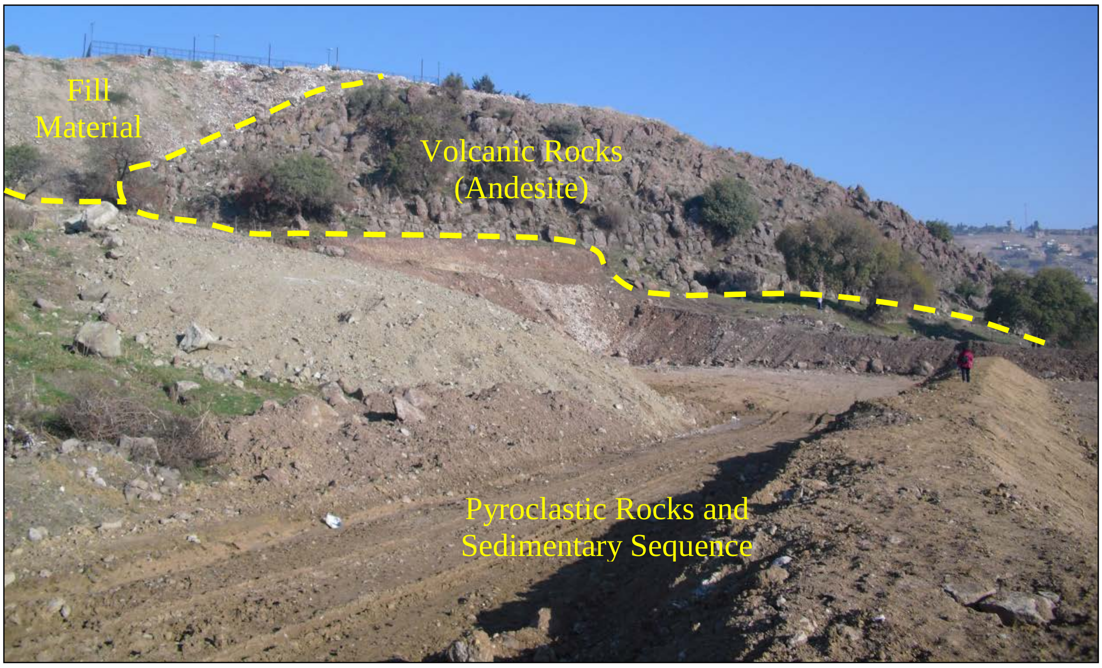


Figure 22: General view of tuff, andesite and Upper Sedimentary Sequence (sandstone, claystone and conglomerate)

The tunnel alignment is divided into discrete parts depending on the overburden above the tunnel elevation and formation variation for the purpose of support design. Therefore, each drilling has been analyzed at the tunneling elevation and summed up in Table 4. Consequently, the studied parts of the Konak Tunnel were interpreted in 4 discrete parts mainly related to the tunnel excavation depth including the exit portal (T-Px). All the related parameters for the Q-Classification system for these parts are summarized in Table 16 and these parameters are provided under the section 4.2.2 from Table 10.

Table 16: Q System classification of the critical sections of the Konak Tunnel

Geotechnical Section(1)	**RQD(2) (%)**	**Jn***	**Jr***	**Ja***	**Jw***	**SRF**	**H (m) (Burden)**	**UCS(3) (Mpa)**	**Q**
T-Px	10	12 (2.E)	2 (3.a.C)	4 (4.a.E)	0.66 (5.B)	5.0	35	10	**0.06**
T-50x	10	6 (2.E)	2 (3.a.C)	4 (4.a.E)	0.66 (5.B)	5.0	50	15	**0.11**
T-75x	50	9 (2.F)	3 (3.a.B)	2 (4.a.C)	1 (5.A)	2.5	75	40	**3.33**
T-100x	50	9 (2.F)	3 (3.a.B)	2 (4.a.C)	1 (5.A)	1.0	100	45	**8.33**

(1) P: Portal, T: Tunnel, e: Enterance, x: Exit
(2) RQD values are determined from 10 m above and below the tunneling elevation.
(3) UCS values are determinde from the laboratory test resuls. For the sedimentary rock mean values of test results are used but for the volcanic rocks test results are used directly.
* Section numbers and related parts of Q flow chart are given in parentheses.

After the determination of the Q values for discrete sections, an average ESR value of 1.0 for “major highway or railroad tunnels” has been selected (Table 17). On account of determining the support category, the equivalent dimension (D_e) values have been entered in support chart with respect to Q values. Hence, D_e values of tunnel excavation have been determined by Barton’s (Barton et al., 1974) rock mass quality versus the equivalent dimension chart from Figure 14 (Figure 23 & Table 17).

Table 17: ESR, D_e and maximum unsupported wall height for the critical sections of the Konak Tunnel

Geotechnical Section[(1)]	Q	Rock Class	D_e (m)	ESR	Wall Height (D_e x ESR) (m)
T-Px	0.06	Extremely Poor	0.77	1.00	0.77
T-50x	0.11	Very Poor	0.97	1.00	0.97
T-75x	3.33	Poor	3.58	1.00	3.58
T-100x	8.33	Fair	5.07	1.00	5.07
(1) P: Portal, T: Tunnel, e: Enterance, x: Exit					

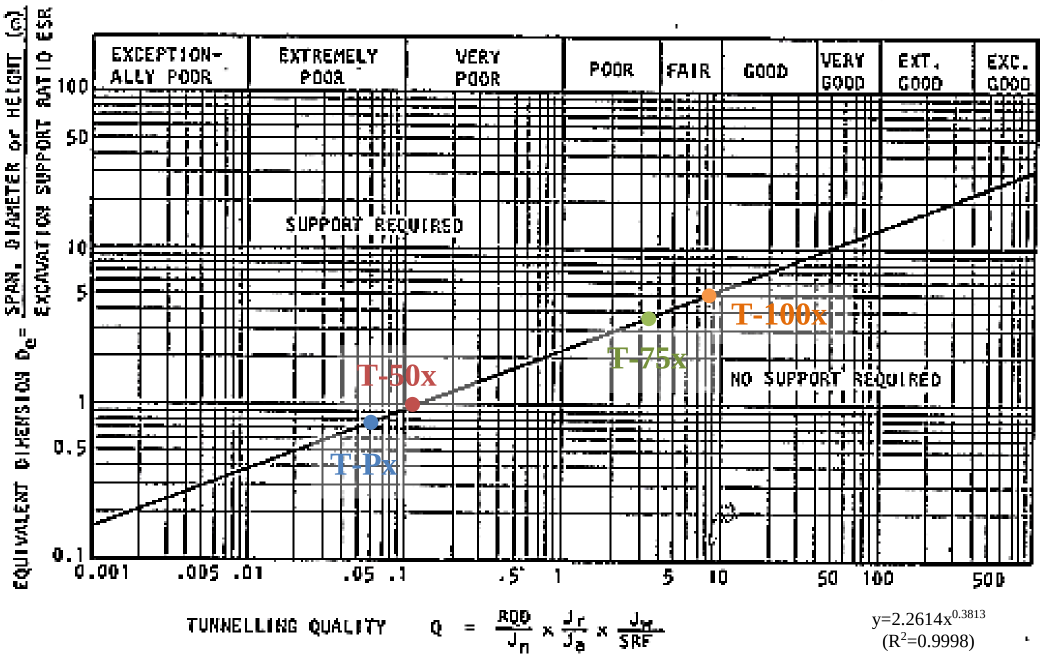
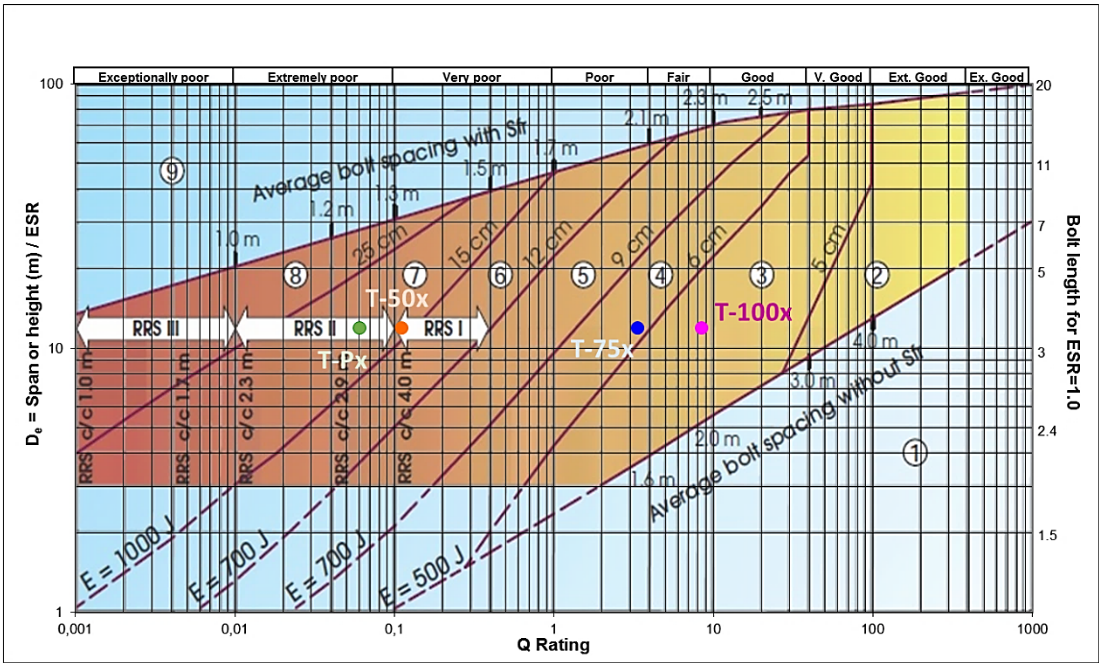


Figure 23: Correlation chart between Q and D_e values for determining the maximum unsupported height of the tunnel wall

Consequently, the support categories and support members have been obtained and presented in Figure 24 and summarized in Table 18. According to the calculated Q values, three rock mass classes have been determined and support elements for the roof and wall have been presented separately (Table 18). Additionally, the maximum unsupported spans which are related to the selected Q values have been calculated from Eqn. (17) and shown in Table 17.



Support categories

① Unsupported or spot bolting
② Spot bolting, **SB**
③ Systematic bolting, fibre reinforced sprayed concrete, 5-6 cm, **B+Sfr**
④ Fibre reinforced sprayed concrete and bolting, 6-9 cm, **Sfr (E500)+B**
⑤ Fibre reinforced sprayed concrete and bolting, 9-12 cm, **Sfr (E700)+B**
⑥ Fibre reinforced sprayed concrete and bolting, 12-15 cm + reinforced ribs of sprayed concrete and bolting, **Sfr (E700)+RRS I +B**
⑦ Fibre reinforced sprayed concrete >15 cm + reinforced ribs of sprayed concrete and bolting, **Sfr (E1000)+RRS II+B**
⑧ Cast concrete lining, **CCA** or **Sfr (E1000)+RRS III+B**
⑨ Special evaluation

Bolts spacing is mainly based on Ø20 mm

E = Energy absorbtion in fibre reinforced sprayed concrete

ESR = Excavation Support Ratio

Areas with dashed lines have no empirical data

RRS - spacing related to Q-value

I	**Si30/6 Ø16 - Ø20 (span 10m)** D40/6+2 Ø16-20 (span 20m)
II	Si35/6 Ø16-20 (span 5m) **D45/6+2 Ø16-20 (span 10m)** D55/6+4 Ø20 (span 20m)
III	D40/6+4 Ø16-20 (span 5 m) **D55/6+4 Ø20 (span 10 m)** D70/6+6 Ø20 (span 20 m)

Si30/6 = Single layer of 6 rebars, 30 cm thickness of sprayed concrete
D = Double layer of rebars
Ø16 = Rebar diameter is 16 mm
c/c = RSS spacing, centre - centre

Figure 24: The Q system support categories for Konak Tunnel

Table 18: Summary of the Q values and suggested support for the Konak Tunnel

Q Range		10.0 ≤ Q < 40.0	4.0 ≤ Q < 10.0	1.0 ≤ Q < 4.0	0.1 ≤ Q <1.0	0.01 ≤ Q <0.1
Q (Calculated)		-	8.33	3.33	0.11	0.06
Uniaxial Compressive Strength (MPa)		-	40	40	15	10
Max. Unsupported Roof Span (m)		-	5.07	3.58	0.97	0.77
Max. Unsupported Wall Height (m)		-	4.67	3.24	0.83	0.65
Suggested Support Categories by Q-system	Roof	7.5 cm shotcrete	15.0 cm shotcrete with single weldmesh layer	20.0 cm shotcrete with double weldmesh layers	20.0 cm shotcrete with double weldmesh layers	22.5 cm shotcrete with double weldmesh layers
		+ Tensioned rockbolts (Ø28mm, spacing 1.5m, L=4.0m)	+ Tensioned rockbolts (Ø28mm, spacing 1.5m, L=4.0m)	+ Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)	+ Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)	+ Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)
					+ Steel ribs (I160, spacing 1.0m)	+ Steel ribs (I160, spacing 1.0m)
					+ Invert concrete	+ Invert concrete
	Wall	7.5 cm shotcrete	7.5 cm shotcrete	Same with roof	Same with roof	Same with roof
		when needed untenisoned rockbolts (Ø28mm, spot, L=4.00m)	when needed untenisoned rockbolts (Ø28mm, spot, L=4.00m)			

As a result, with respect to the Q system, the rock masses of the critical sections vary from “Extremely Poor Rock” to “Fair Rock” along the Konak Tunnel. As can be seen in Table 18, three support categories have been suggested by the Q intervals. Additionally, Q_{wall} values were calculated from Eqns. 14-16 and the bolt lengths were calculated from Eqn. (20) and (21). Finally, the elastic modulus of the rock masses along the tunnel section has been calculated by Eqns. (24) and (25) and summarized in Table 19.

Table 19: Elastic modulus of the rock masses on the tunnel section

Geotechnical Section	Q	UCS (MPa)	Em (GPa)
T-Px	0.06	10	1.82
T-50x	0.11	15	2.55
T-75x	3.33	40	11.00
T-100x	8.33	45	15.53

5.2 RMR Classification and Largest Span Recommendation

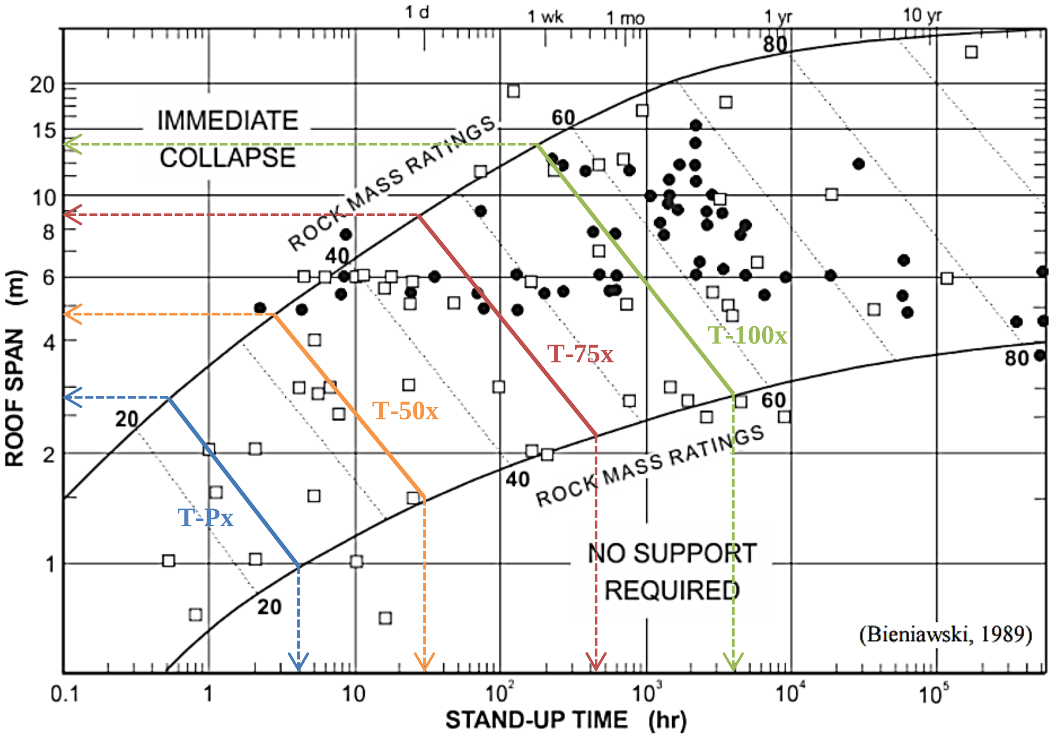
The Q classification system is competent and useful for the generalized support types and the application of support elements for a given span or height. However, it gives no detailed information about the “Unsupported Span”. Even though Bieniawski made some studies as per Q values and dimensions of the tunnel excavations for unsupported span, the results of those studies have been interpreted in international scientific environments. Therefore, benefiting from the unsupported span determination through the RMR classification is mandatory for tunnel analysis. Moreover, physical parameters which are used in tunnel analysis are determined and improved from the RMR related formulations. In this sense, during tunnel support design, the Q and RMR empirical rock classifications are used together in a manner in which they complement each other.

The RMR classification system consists of the five main parameters, namely the rock material strength (UCS), discontinuity spacing, RQD, groundwater and discontinuity conditions. Especially, the rock material strength (UCS), discontinuity spacing and RQD are more quantitative than the other two. Therefore, choosing a range of parameters is more realistic instead of giving only one number for the wide range of rock masses. On the other hand, groundwater and discontinuity conditions are more descriptive and defined more clearly in the form of RMR.

In order to determine the rock mass shear strength parameters, stand up times and rock mass classes, the rock mass rating system is used and the basic RMR values are obtained. Additionally, as related to the structural geology of the tunneling area, major joint orientation is important for the direction of tunnel excavation. Because of the incompatibility of the orientations of the joint sets and the tunnel, the rock mass is punished with correction factors from 0 to (-12). This punishment is not related to the five major rock mass parameters and RMR classification. However, in highly tectonic regions like the project area, the joint orientations change so often in very small intervals. Hence, it is not easy to determine the discontinuity orientations and punishing the rock mass strength parameters and changing the rock mass classes is not fair. As a result, discontinuity orientations and correction factors will be disregarded in the RMR calculations.

The RMR assessment of the tunnel portal faces was another attempt. In the Q system, Barton (2002) suggests that the joint number (J_n) values are assigned twice the number in the portal regions. Hence, Q values of the portal region are decreased by half of its original value (Q_{portal}=Q/2). The empirical expression RMR=9LnQ+44 will be used in these classifications and RMR values will be calculated. These RMR values will be used for the determining the shear strength parameters in the finite element analyses.

In order to calculate the RMR values, the beforehand specified geological and geotechnical data of the rock mass for the Q classification system were reconsidered. RMR calculation details are presented in APPENDIX-D for all discrete sections which are included with in this thesis. A summary of the RMR classification results has been presented in Table 20. Moreover, the maximum unsupported spans and stand up times as per the RMR results have been interpreted from Figure 25.



(Bieniawski, 1989)

Figure 25: RMR results with maximum unsupported spans and stand up time

Table 20: Determined geotechnical parameters and support categories with the RMR classification

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
RMR	23.0	33.5	46.5	57.0
Rock Class	IV	IV	III	III
Description	Poor Rock	Poor Rock	Fair Rock	Fair Rock
Cohesion (kPa)	100-200	100-200	200-300	200-300
Friction Angle (°)	15-25	15-25	25-35	25-35
Max. Unsupported Span (m)	3.5	4.8	8.8	13.3
Stand-up Time for Unsupported Span	4.0 hr.	30.0 hr.	17.5 days	5.6 months
Modulus of Elasticity (GPa)	2.11	3.87	8.18	14.00
RMR Support Sugestions (Roof & Wall)				
Excavation	Top heading and bench 1-1.5m advance in top heading. Install support concurrently with excavation 10m from face.		Heading and bench 1.5-3m advance in top heading. Commence support after each blast. Complete support 10m from face.	
Rock Bolts	Systematic bolts 4-5m long, spaced 1-1.5m in roof and walls with wire mesh (ϕ28, fully bonded).		Systematic bolts 4m long, spaced 1.5-2m in roof and walls with wire mesh in roof (ϕ28, fully bonded).	
Shotcrete	100-150mm in roof and 100mm in sides.		50-100mm in roof and 30mm in sides.	
Steel Sets	Light to medium ribs spaced 1.5m where required.		None	
Note: Support categories are suggested for horseshoe shape tunnel with 10m span and excavated by drilling and blasting.				

The results of the RMR classification showed that the rock quality varied from “Poor Rock” to “Fair Rock” along the critical sections of the Konak Tunnel. Besides rock quality, engineering parameters of the rock masses and support suggestions with the maximum unsupported span and stand-up time have been illustrated above. Moreover, the RMR values have been used for elastic modulus calculations of the rock masses by Eqns. (9) and (10).

The RMR and Q classifications have several empirical correlations. The most commonly used one is proposed by Bieniawski (1976) and given in Eqn. (28) in section 4.2.2. By this equation, the RMR and Q values of discrete sections of the tunnel have been controlled and correlated (Figure 26). The correlation line between the RMR and Q values of the discrete sections is similar to Bieniawski's correlation.

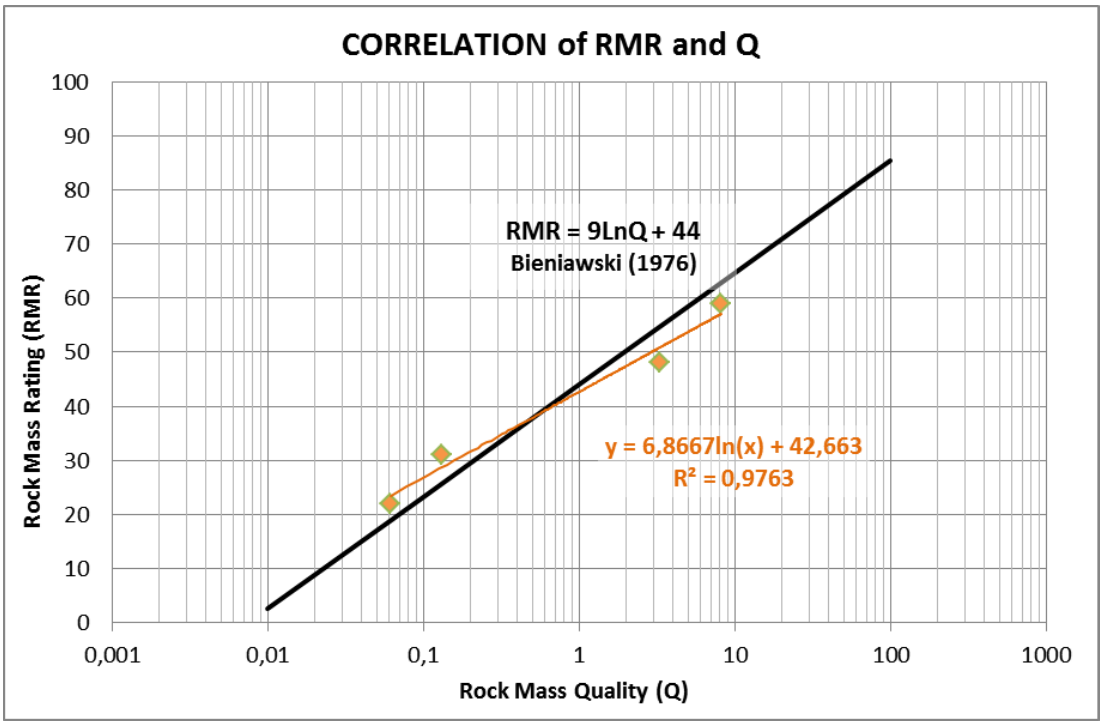


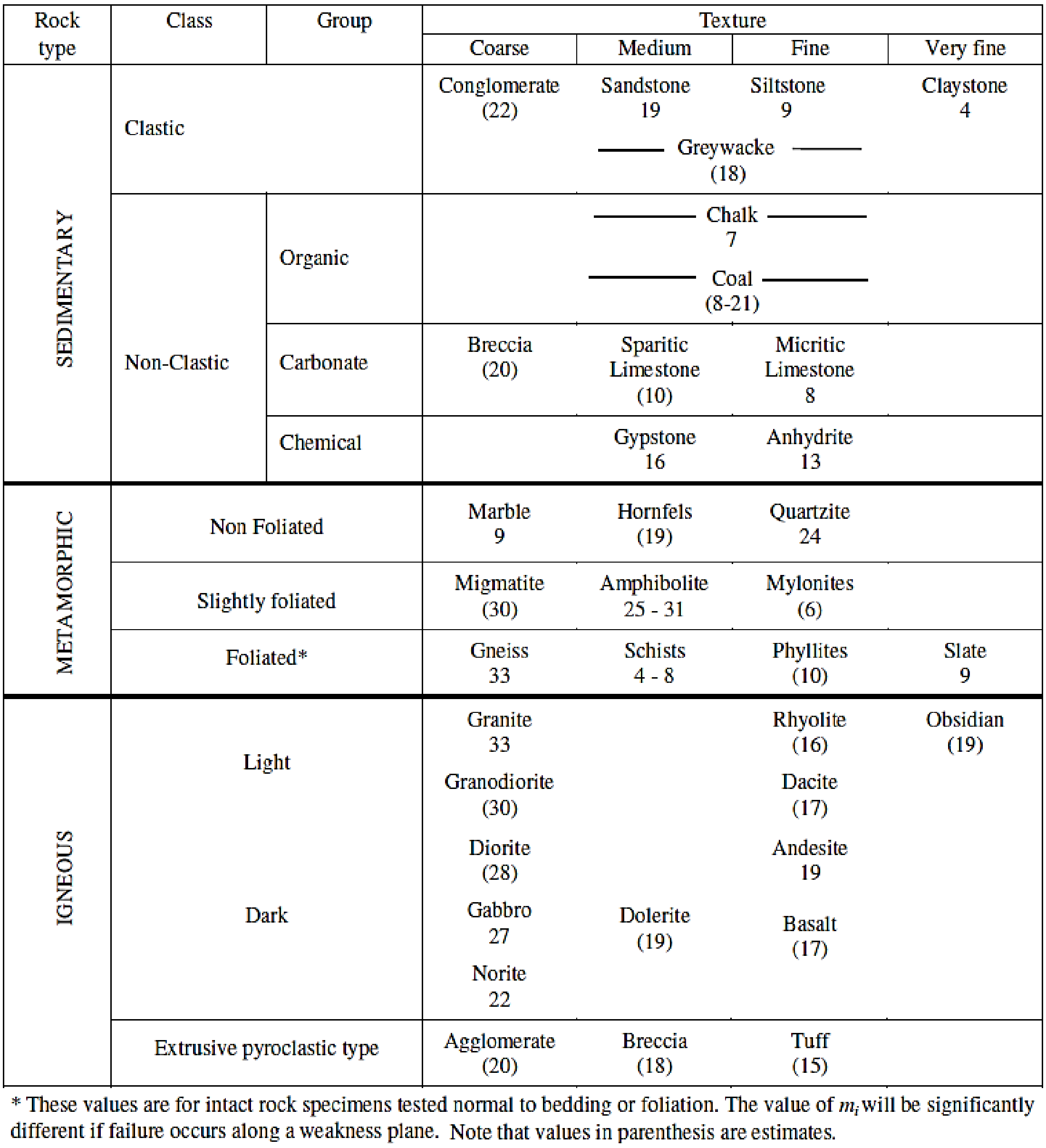
Figure 26: Correlation between RMR and Q values of the Konak Tunnel

5.3 GSI Classification and Strength Parameters

The GSI classification is based on the visual impressions on the rock mass structure and provides a system for estimating the strength reduction of rock mass for different geological conditions. This system is describing and presenting the constant parameters for the rock masses strength estimations which are σ_{ci} and mi parameters. Meaning of the σ_{ci} is uniaxial compressive strength of the rock material and m_i, on the other hand, is material constant which is defined by Hoek (2002) and with respect to the laboratory test results of the rock material. These m_i values for different rock units are given in Table 21.

Careful consideration has been given to calculation of the strength reduction amounts of rock masses. GSI values for all geotechnical sections have been calculated from the RMR-5 equation which was suggested by Hoek (1997). Additionally, shear strength parameters, deformation modulus and other rock material constants have been calculated and taken from RocLab (Rocscience v1.033 – 2013) software. The results of this classification system are illustrated in Table 22 and detailed RocLab software outputs are given in APPENDIX-I.

Table 21: Values of m_i for different rock materials (Hoek et al. 1997)



Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerate (22)	Sandstone 19	Siltstone 9	Claystone 4
				Greywacke (18)		
	Non-Clastic	Organic		Chalk 7 Coal (8-21)		
		Carbonate	Breccia (20)	Sparitic Limestone (10)	Micritic Limestone 8	
		Chemical		Gypstone 16	Anhydrite 13	
METAMORPHIC	Non Foliated		Marble 9	Hornfels (19)	Quartzite 24	
	Slightly foliated		Migmatite (30)	Amphibolite 25 - 31	Mylonites (6)	
	Foliated*		Gneiss 33	Schists 4 - 8	Phyllites (10)	Slate 9
IGNEOUS	Light		Granite 33 Granodiorite (30) Diorite (28)		Rhyolite (16) Dacite (17) Andesite 19	Obsidian (19)
	Dark		Gabbro 27 Norite 22	Dolerite (19)	Basalt (17)	
	Extrusive pyroclastic type		Agglomerate (20)	Breccia (18)	Tuff (15)	

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

Table 22: Determined geotechnical parameters with the GSI classification

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
Average E_i* (GPa)	6.42			
Average γ* (kN/m^3)	23.84			
Average Poissons Ratio*	0.335			
GSI**	20 (18.0)	30 (28.5)	40 (41.5)	50 (52.0)
UCS (MPa)	10	15	40	45
Averge m_i***	11	19	19	19
E_d (GPa)	0.293	0.552	1.025	1.972
Max. Overburden (m)	35	50	75	100
c (MPa)	0.081	0.183	0.418	0.646
Φ (°)	35.85	45.05	52.37	53.86

* Laboratory test result

** Values in parenthesis calculated from directly GSI = RMR - 5 equation.

*** m_i values calculated from the average of all units in section.

5.4 New Austrian Tunneling Method (NATM) Classification

The NATM is more descriptive and needs more interpretation than the RMR and Q rock mass classification systems. In other words, the purpose of NATM is not classifying the rock masses; it provides suggestions about excavation stages and excavation methods. Henceforth, NATM has been based on the two other classifications made before. This study for the critical sections of the Konak Tunnel provides the correlation opportunity for NATM and the other two rock mass classification systems which are RMR and Q (Table 23). Consequently, NATM descriptions, support recommendations and excavation methods have been displayed in Table 24 for the all the critical sections of the Konak Tunnel.

Table 23: Correlated NATM descriptions with RMR and Q system for the critical sections of the Konak Tunnel

Geotechnical Section	Tunneling Depth (m)	Lithology	Q	Rock Class for Q	RMR	Rock Class for RMR	NATM
T-Px	35	Andesite, agglomerate, tuff and lower sedimentery sequence (sandstone - claystone - conglomerate)	0.06	Extremely Poor	23.0	Poor	**C1**
T-50x	50	Andesite, tuff and agglomerate	0.11	Very Poor	33.5	Poor	**B3**
T-75x	75	Andesite	3.33	Poor	46.5	Fair	**B2**
T-100x	100	Andesite	8.33	Fair	57.0	Fair	**B1**
* Descriptions are direcly taken from the correlation chart given in Figure 18.							

Table 24: NATM Support and excavation recommendations for the Konak Tunnel

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
Q - System	0.04 ≤ Q < 0.1	0.1 ≤ Q < 1	1 ≤ Q < 4	4 ≤ Q < 10
NATM	C1	B3	B2	B1
Excavation Stage	Three Stages (top heading, bench and invert arch)	Two stages (top heading and bench)	Two stages (top heading and bench)	Two stages (top heading and bench)
Excavation Method	Smooth blasting and roadheader or excavator	Smooth blasting and roadheader or excavator(if needed)	Smooth blasting and roadheader or excavator(if needed)	Smooth blasting
Round	1.0-1.5 m top heading, 2.0 m bench, 100-150 m invert arch	1.5-2.0 m top heading, 3.0 m bench	2.0-2.5 m top heading, 3.5 m bench	2.0-3.0 m top heading, 4.0 m bench
NATM Support Suggestion	Shotcrete, systenatic bolting, steel ribs, forepolling	Shotcrete, systenatic bolting, steel ribs, forepolling (if needed)	Shotcrete, systenatic bolting, forepolling	Shotcrete, systenatic bolting

5.5 Rock Mass Characterization and Tunnel Support Design

Three different classification systems have been used for the rock mass characterization and support design recommendations. Stand up times and maximum unsupported spans have been proposed by the RMR classification system. Excavation stages, excavation methods or round lengths have been determined by

NATM descriptions. And lastly, support recommendations have been taken from the Q system. The description of tunnel excavation requirements has been illustrated in Table 25.

Table 25: Excavation and Support recommendations for the critical sections of the Konak Tunnel

<table>
<tr><th colspan="2">Geotechnical Section</th><th>T-Px</th><th>T-50x</th><th>T-75x</th><th>T-100x</th></tr>
<tr><th colspan="2">Q - Range</th><td>0.04 ≤ Q < 0.1</td><td>0.1 ≤ Q < 1</td><td>1 ≤ Q < 4</td><td>4 ≤ Q < 10</td></tr>
<tr><th colspan="2">Q</th><td>0.06</td><td>0.11</td><td>3.33</td><td>8.33</td></tr>
<tr><th colspan="2">RMR</th><td>23.0</td><td>33.5</td><td>46.5</td><td>57</td></tr>
<tr><th colspan="2">NATM</th><td>C1</td><td>B3</td><td>B2</td><td>B1</td></tr>
<tr><th colspan="2">Max. Unsupported Span (m)</th><td>3.5</td><td>4.8</td><td>8.8</td><td>13.3</td></tr>
<tr><th colspan="2">Stand-up Time for Unsupported Span</th><td>4.0 hr.</td><td>30.0 hr.</td><td>17.5 days</td><td>5.6 months</td></tr>
<tr><th colspan="2">Excavation Stage</th><td>Three Stages (top heading, bench and invert arch)</td><td>Two stages (top heading and bench)</td><td>Two stages (top heading and bench)</td><td>Two stages (top heading and bench)</td></tr>
<tr><th colspan="2">Excavation Method</th><td>Smooth blasting and roadheader or excavator</td><td>Smooth blasting and roadheader or excavator(if needed)</td><td>Smooth blasting and roadheader or excavator(if needed)</td><td>Smooth blasting</td></tr>
<tr><th colspan="2">Round</th><td>1.0-1.5 m top heading, 2.0 m bench, 100-150 m invert arch</td><td>1.5-2.0 m top heading, 3.0 m bench</td><td>2.0-2.5 m top heading, 3.5 m bench</td><td>2.0-3.0 m top heading, 4.0 m bench</td></tr>
<tr><th rowspan="6">Suggested Support Categories by Q-system</th><th rowspan="4">Roof</th><td>22.5 cm shotcrete with double weldmesh layers</td><td>20.0 cm shotcrete with double weldmesh layers</td><td>20.0 cm shotcrete with double weldmesh layers</td><td>15.0 cm shotcrete with single weldmesh layer</td></tr>
<tr><td>Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)</td><td>Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)</td><td>Tensioned rockbolts (Ø28mm, spacing 1.0m, L=4.0m)</td><td>Tensioned rockbolts (Ø28mm, spacing 1.5m, L=4.0m)</td></tr>
<tr><td>Steel ribs (I150 -I160, spacing 1.0m)</td><td>Steel ribs (I150 -I160, spacing 1.0m)</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Invert concrete</td><td>Invert concrete</td></tr>
<tr><th rowspan="2">Wall</th><td rowspan="2">Same with roof</td><td rowspan="2">Same with roof</td><td rowspan="2">Same with roof</td><td>7.5 cm shotcrete</td></tr>
<tr><td>when needed untenisoned rockbolts (Ø28mm, spot, L=4.00m)</td></tr>
</table>

The rock masses control the stability of the tunnel excavation with their intact rock properties and discontinuities. Hence, the strength parameters and deformation properties of the rock mass around the tunnel excavation is critical and the determination of these parameters create concern for engineers (Sopacı et al., 2005). Many researchers have been initiated different empirical approaches for reaching the rock mass deformation modulus and shear strength parameters. Some of these approaches are given in sections 4.2.1 and 4.2.2 above (Eqn. (9)-(10)-(11)-(25)-(26)-

(27)). Furthermore, it was also benefited from some other studies and their empirical relations are given in Eqn. (29; Gökçeoğlu et al. 2003), Eqn. (30; Zhang and Einstein, 2004) and Eqn. (31; Hoek and Diederichs, 2006). All these empirical approaches are based on the intact rock strength (uniaxial strength); rock mass classifications and jointing index (RQD). The calculation results for this study have been displayed in Table 26. As seen in this table, only the mean value of the elastic modulus for the volcanic rocks (andesite - altered andesite) is presented because of the limited laboratory test results (insufficient number of specimens for testing). However, this was not a drawback since the volcanic rocks, especially andesite, is most commonly encountered unit along the tunneling area. Only around the exit portal of the tunnel, upper sedimentary sequence rock, which is the alternation of sandstone, claystone and conglomerate, has been determined to be present. Besides, all these rock masses present similar engineering properties due to their weathering degree.

The Mohr - Coulomb failure criterion will be used in both the finite element analyses for tunnel excavation and limit equilibrium solutions for slope stability analyses.

$$E_m = 0.0736e^{0.0755RMR} \tag{29}$$

In this equation;

E_m = Deformation modulus of the rock mass (GPa)

$$E_m/E_r = 10^{0.0186RQD-1.91}\ (mean) \tag{30}$$

In this equation;

E_m = Deformation modulus of the rock mass (GPa)

E_r = Elastic modulus of the intact rock (GPa)

$$E_{rm} = E_i\left(0.02 + \frac{1-D/2}{1+e^{((60+15D-GSI)/11)}}\right) \tag{31}$$

In this equation;

E_{rm} = Deformation modulus of the rock mass (GPa)

E_r = Elastic modulus of the intact rock (GPa)

D = Disturbance factor

Table 26: Summary of the shear strength parameters and the deformation modulus for the geotechnical sections

Geotechnical Section		**T-Px**	**T-50x**	**T-75x**	**T-100x**
UCS (MPa)		10	15	40	45
RQD (%)		10	10	50	50
Q		0.06	0.11	3.33	8.33
RMR		23.0	33.5	46.5	57
GSI		20	30	40	50
Average Ei* (GPa)		6.42			
Deformaton Modulus of Rock Mass					
Bieniawski - 1978(1) (GPa)		-	-	-	14.00
Serafim & Pereira - 1983(2) (GPa)		2.11	3.87	8.18	-
Barton - 2002(3) (GPa)		1.82	2.55	11.00	15.53
Nicholson & Bieniawski - 1990(4) (GPa)		0.253	0.453	0.832	1.286
Gökçeoğlu et al. - 2003(5) (GPa)		0.418	0.923	2.464	5.443
Zhang & Einstein - 2004(6) (GPa)		0.218	0.218	1.210	1.210
Hoek & Diederichs, 2006(8) (GPa)		0.293	0.552	1.025	1.972
Shear Strength Parameters of Rock Mass					
RMR	**Cohesion (kPa)**	100-200	100-200	200-300	200-300
	Friction Angle (°)	15-25	15-25	25-35	25-35
GSI	**Cohesion (kPa)**	81	183	418	646
	Friction Angle (°)	35.85	45.05	52.37	53.86
Barton & Pandey - 2011(7)	**Cohesion (kPa)**	16.7	50.0	888.9	2500.0
	Friction Angle (°)	18.26	18.26	56.31	56.31

* Average intact rock elastic modulus are recommended for volcanic rocks which are andesite, agglomerate and tuff.

(1) Equation 9; **(2)** Equation 10; **(3)** Equation 25; **(4)** Equation 11; **(5)** Equation 29; **(6)** Equation 30; **(7)** Equation 26&27; **(8)** Equation 31

CHAPTER 6

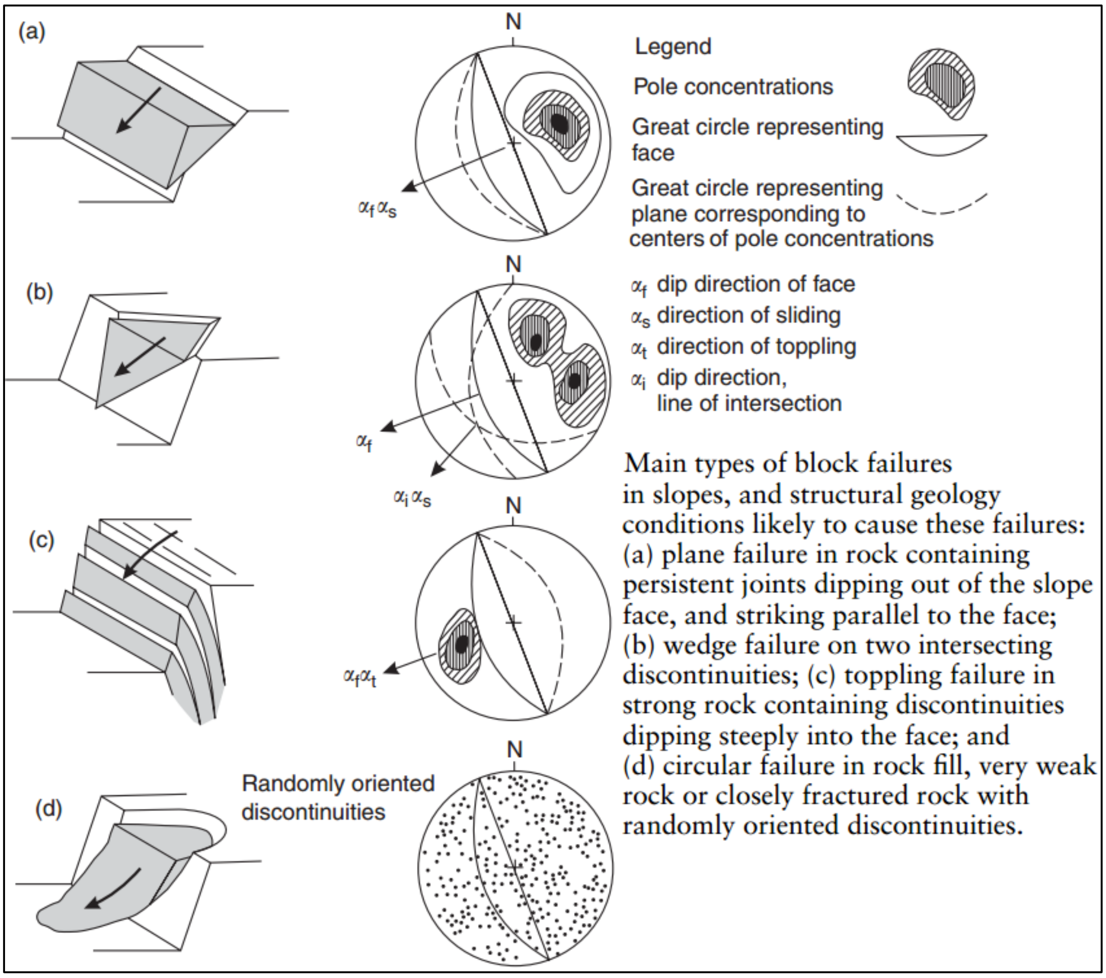
TUNNEL PORTAL SLOPE DESIGN

The major object of rock slope studies is determining the rock slope stability and safety conditions to stabilize the unstable natural and excavated slopes by procuring optimum conditions in terms of reliability and economy. Disparate geological conditions can cause different type of failures on slope and it is crucial that slope specialists should be capable to recognize the potential instabilities at the beginning of a project.

All the microscopic and macroscopic features that affect the strength and deformation characteristics of rocks can be called upon as defects. Consequently, rock slope stability depends on the strength characteristics of rock, the geometrical and strength characteristics of discontinuities and effects of weathering on rock and rock defects.

The first phase of a slope design is composed of studying geological maps, air photographs, outcrops and core samples taken through drilling. Discontinuities particularly have a dominant effect on rock slopes. Although there are many stable slopes that are at steep angles and considerable height, gentle slopes having inconsiderable heights may fail. This distinction is a result of discontinuities such as faults, joints and bedding planes having different inclinations that are present within the rock mass (Hoek and Bray, 1981).

There are four types of failure which are planar, wedge, toppling (rock fall) and circular failures, commonly seen in rock slopes (Figure 27). The first three are more predominant in the rock slope and the failure system is controlled by the discontinuity planes with their orientations, spacings and surface conditions. Discontinuity controlled failures can be comprised of a single discontinuity or multiple discontinuities that intersect or combine each other. On the other hand, circular (rotational) failures occur in heavily jointed or fractured rock masses, showing very weak or heavily weathered rock and soil like behavior. The circular type of failure in rock slopes is controlled by material properties, water condition and foundation strength.



Main types of block failures in slopes, and structural geology conditions likely to cause these failures: (a) plane failure in rock containing persistent joints dipping out of the slope face, and striking parallel to the face; (b) wedge failure on two intersecting discontinuities; (c) toppling failure in strong rock containing discontinuities dipping steeply into the face; and (d) circular failure in rock fill, very weak rock or closely fractured rock with randomly oriented discontinuities.

Figure 27: The types of rock slope failure (Hoek and Bray, 1981)

6.1 Geotechnical Field Evaluation of the Exit Portal

Two different meanings of the “portal” term are mentioned in this thesis. One of them is the tunnel portal which is the portion of the tunnel starting from its entrance to a location that is determined by using a height of the overburden that is equal to three times of the tunnel span. The other is the open cut slopes of the tunnel entrance and exit. The slopes considered are the side cut slopes which are located at the right and left sides and the face slope through the tunneling. The portals are the regions where the engineer first meets with the rock mass. Geological conditions present clues for recognition of the rock mass at the portals. Tunnel portals have special significance in tunnel construction and these are the most crucial parts of tunnel; thus, slopes of the portals will be examined in this section.

The first step of portal design is to determine safe slope angles. For this purpose, a discontinuity survey (site investigation) can be done and samples can be collected from the field and the shear strength parameters can be determined from these samples by laboratory tests. After the determination of the discontinuity characteristics and the shear strength parameters, these parameters are put into the empirical relations and into the limit equilibrium analyses to determine the safe slope angles. Specific conditions and necessities such as urbanization occasionally affect the slope angle.

Unfortunately, the collected samples do not represent the in-situ characteristics of the rock mass. Therefore, in addition to the first step mentioned above, determination of the rock mass shear strength parameters comes into consideration. In order to determine the rock mass shear strength parameters, the rock mass rating system (RMR) has been used and the basic RMR values have been provided.

The rock slopes of the Konak Tunnel exit portal are heterogeneous or contain several rocks having different geological origins and different lithological units, namely, volcanic rocks and upper sedimentary sequence. According to the surface investigations in the exit portal area, only andesite contains random joint systems.

These irregular joint systems display a blocky appearance and they have larger apertures and soft infillings. Apart from that, upper sedimentary and pyroclastic units are highly weathered in composition and are expected to show soil-like behavior. Therefore, all of the rock units which are located at the exit portal area have been evaluated as one type of a rock mass with a soil-like behavior, whose strength, deformation, and competence characteristics are expected to be similar. An RMR value of 21 has been specified for this rock mass at the exit portal of the Konak Tunnel and its rock category has been determined as “Poor Rock” (APPENDIX-D).

All of these studies showed that geometrical solutions (kinematic analyses) are not proper for the rock mass which is located at the exit portal of the Konak Tunnel; because the failure mechanism is not controlled by the discontinuity surfaces (Figure 28). Hence, the mass failure (circular failure) has been examined in following sections of thesis.

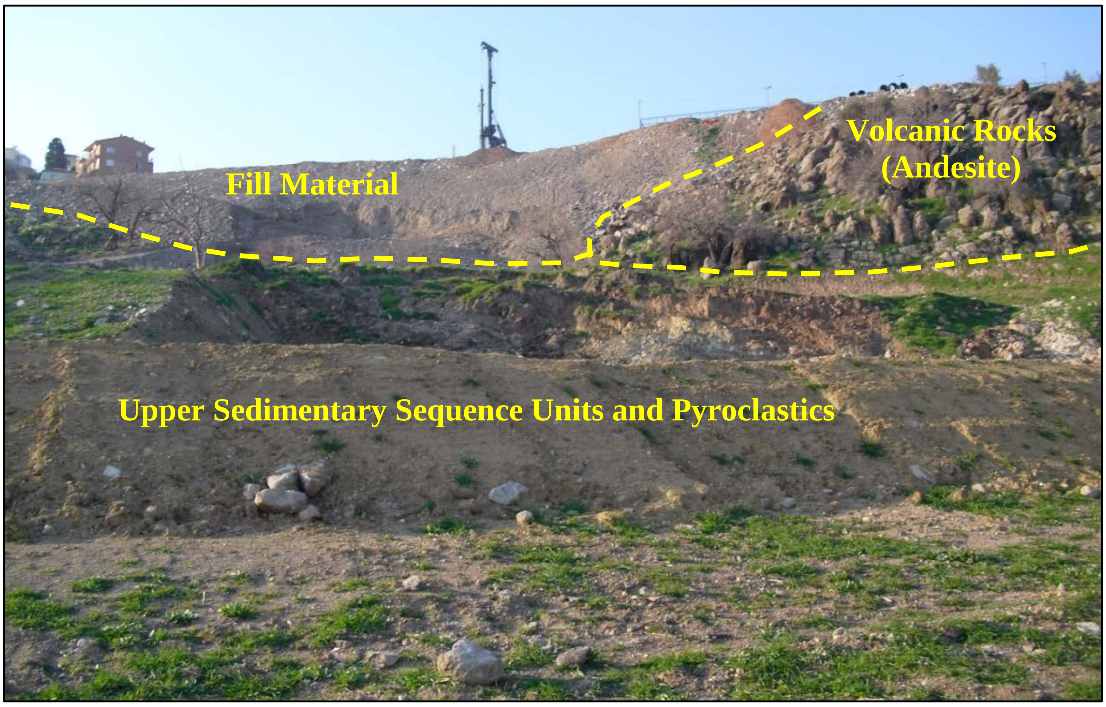


Figure 28: General view of the Konak Tunnel exit portal

Also, except from field studies, laboratory tests and rock mass rating study, there was one another important limitation for the selection of open cut slopes ratio. Consultant's specifications have played an important role in selecting the angle of slope. Because of the limitations of urbanization, open cut excavation boundaries or excavation orientations could not be changed. In the light of this information, slope angles have been selected as 1h:4v (h: horizontal & v: vertical) at the portal face and 1h:2v at the side slopes and the upper part of the portal face.

6.2 Limit Equilibrium Analyses

The safety factor is a unitless indicator of the stability and it is used by the classical methods of slope stability analysis which is based on the concept of limit equilibrium. The purpose of the method is to examine the stability of any mass assuming incipient or developing failure along a potential surface for sliding. Limit equilibrium methods are based on analytical solutions and consider the weight of the sliding block, shear strength parameters (c and ϕ), water conditions and pore water pressure (u), geometry of the slope, seismic acceleration, tension cracks position and external loads. Pockoski and Duncan (2000) summarized these components of equilibrium in 2000 for comparing the methods sufficiency and the summary table is given in APPENDIX-J. Hence limit equilibrium analyses are different from the kinematical analyses (Hoek and Bray, 1981):

Since 1950s the Simplified Bishop method has been widely used for stability analysis. Solution of any limit equilibrium formulation cannot be compared with a closed form correct solution as it is statistically uncertain. Even though there is no direct comparison between different methods it can be said that factor of safety determined using Bishop's simplified method for circular surfaces differ by less than 5 percent with respect to the more attentive Spencer or Morgenstern-Price solutions (Sopacı & Akgün, 2009). Consequently, Simplified Bishop, Spencer and Morgenstern-Price methods of limit equilibrium solution results will be given together in this study.

The stability of cut slopes at the exit portal of the Konak Tunnel is determined by the Upper Miocene sedimentary units which are sandstone, claystone and conglomerate and Miocene aged volcanic rocks which are andesite, agglomerate and tuff (APPENDIX-A). All these rock units are highly weathered and especially the sedimentary units and tuff show soil-like behavior. Therefore, a circular type of failure has been foreseen and the related limit equilibrium analyses have been performed at the weathered zone of the portal area. This recommendation is supported by the borehole logs and core photos (Figure 29 and APPENDIX-B). At the tunneling elevation or at the highest cut slope excavation, weathering effects have been high and the rock mass is expected to behave like a soil in-situ.

Konak Tunnel / TSK-3 (30.50 m to 44.00 m) Tunneling Level

Konak Tunnel / TSK-4 (34.00 m to 40.00 m) Tunneling Level

Konak Tunnel / TSK-5 (30.00 m to 34.00 m) Tunneling Level

Figure 29: Core box photos from the exit portal boreholes at the maximum excavation height

Consistent with the specifications of the contractor, the maximum height of the cut slope excavations were designed to be about 17.50 m on which 5.0 m wide benches were planned. The cut slopes on the left and right were planned to have 1h:4v inclination at the lower slopes which were similar to the portal face. The Upper slopes were designed at 1h:2v for the left cut slopes and portal face and 1h:2v to 1h:1v at the right cut slopes (Table 27 and Figure 30).

Table 27: Cut slopes and portal face inclination angles

Location	Section	Inclination (h:v)	Max. Height (m)	Bench Width (m)
Portal Face	Lower Slope	1:4	17.50	5.00
	Second Slope	1:2	11.50	
	Third Slope	1:2	11.50	
	Upper Slope	Perpendicular	9.90	-
Left Cut Slope	Lower Slope	1:4	17.50	5.00
	Second Slope	1:2	11.50	
	Upper Slope	1:2	9.20	-
Right Cut Slope	Lower Slope	1:4	17.50	5.00
	Second Slope	1:2	11.50	
	Upper Slope	1:1	18.30	-

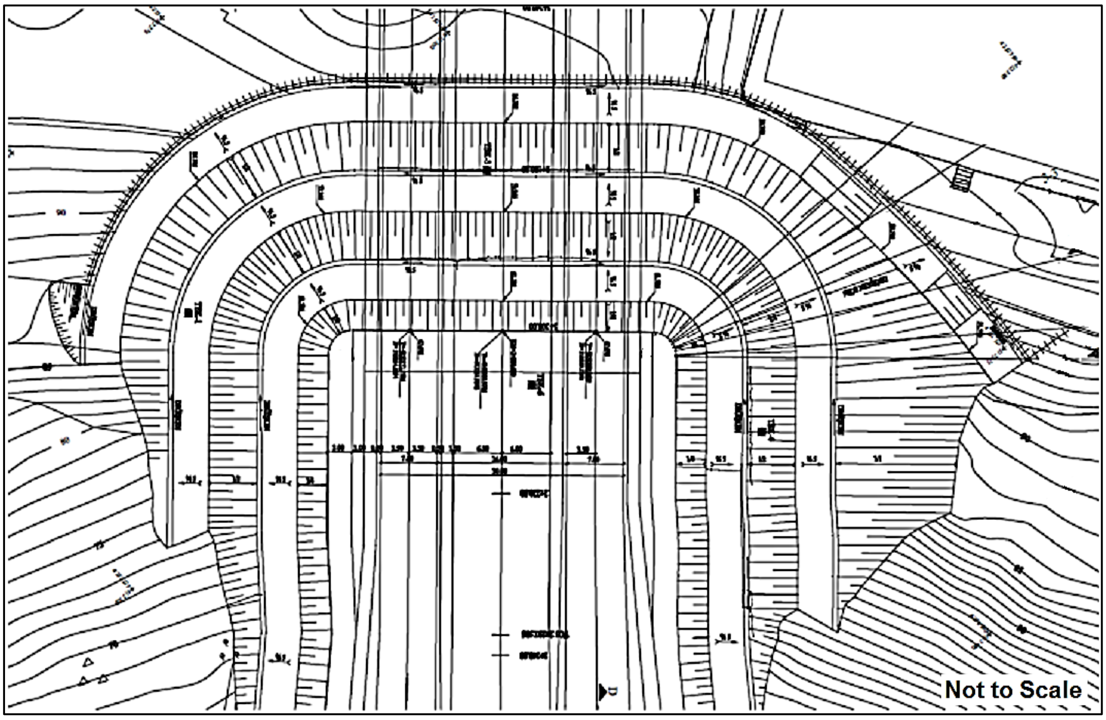


Figure 30: Excavation boundaries of cut slopes of the Konak Tunnel exit portal

According to the RMR classification, the rock mass around the exit portal was classified as “Poor Rock” in general (APPENDIX-D). The shear strength parameters of the rock mass have been assigned the mean value of “Poor Rock” in regards to friction angle and cohesion (Table 28). The average unit weight of the rock mass has been taken from laboratory test results. There is only one test result for the elastic modulus of intact rock and Poisson’s ratio, which are 5.88 GPa and 0.325, respectively. Besides, the water table and water conditions are another important parameter for the limit equilibrium analyses. Therefore all the related borehole logs were examined and the water level has been observed. Finally, the parameters of the selected fill material, whose unit weight, cohesion and internal friction angle values of 16 kN/m^3, 5 kPa and 32° respectively, have been taken from U.S. Department of Transportation - Federal Highway Administration, soil and foundations publication (2006).

Table 28: Recommended rock mass engineering geological parameters of the exit portal open cuts of the Konak Tunnel

Rock Mass Parameters	
Cohesion (kPa)	150
Friction Angle (°)	20
Unit Weight (kN/m^3)	20.90
Poisson's Ratio	0.325

2D circular failure limit equilibrium analyses of the exit portal of the Konak Tunnel have been carried out by the SLIDE v.6.00 software (Rocscience, 2015) and sample analyses and cross sections of open cut slopes are given in Figure 31. The results of the failure analyses are presented in APPENDIX-E and the safety factors of the cut slopes and portal face are given in Table 29. These analyses have been executed for three cases, namely, for static and dry, static with ground water and seismic load (horizontal acceleration - a_h = 0.2g suggested for study area, AASHTO, 2002) with ground water conditions.

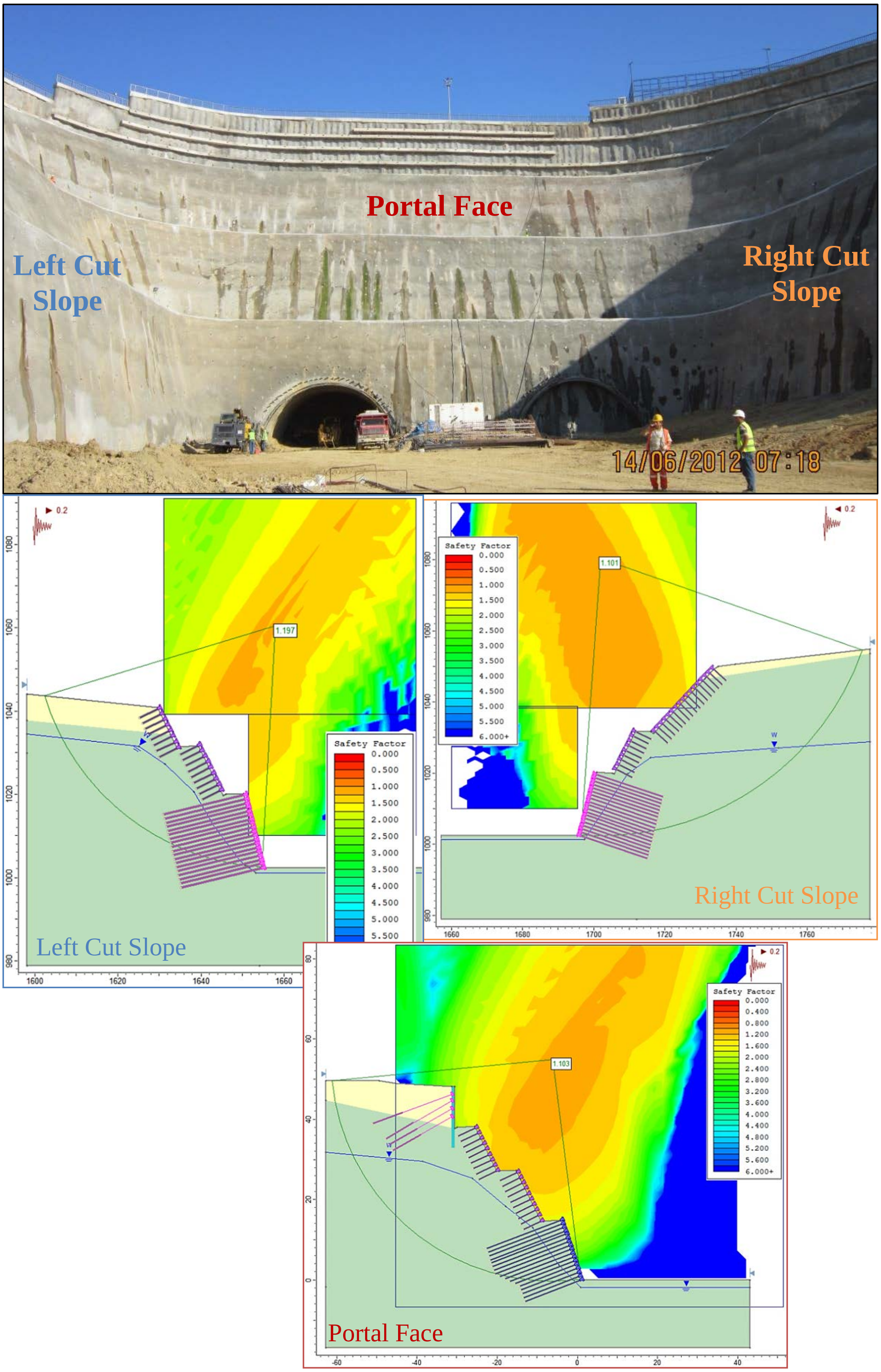


Figure 31: Open cut slopes analyses for the exit portal of the Konak tunnel

Table 29: Circular failure analyses of the Konak Tunnel exit portal

Location	Geotechnical Conditions								
	Dry and Static			With GW and Static			With GW and Seismic Load		
	Sim. Bish.	Spencer	Mor. & Pir.	Sim. Bish.	Spencer	Mor. & Pir.	Sim. Bish.	Spencer	Mor. & Pir.
Portal Face (FS)	1.688	1.690	1.684	1.420	1.426	1.417	1.105	1.132	1.103
Left Cut Slope (FS)	1.781	1.782	1.773	1.569	1.563	1.563	1.197	1.207	1.190
Right Cut Slope (FS)	1.614	1.615	1.609	1.468	1.471	1.470	1.100	1.109	1.095

* Analyzing methods are Simplified Bishop, Spencer and Morgenstern & Price (GLA).
FS: Factor of safety; GW: ground water (taken from borehole measurements)
Horizontal acceleration for seismic load - a_h = 0.2g from AASHTO, 2002

According to the results of the limit equilibrium analyses, the exit portal of the Konak Tunnel is stable with the selected strength parameters, slope angles and support recommendations. The upper slope of the portal face has been designed with bored piles due to the instability of the fill material. The parameters of the bored pile section have been directly taken from AASHTO - Standard Specifications for Highway Bridges (SSHB, 2002), U.S Department of Transportation - Federal Highway Administration (Geotechnical Engineering Circular - Ground Anchors and Anchored Systems) and TS500 Concrete Constructions Design - Building Specifications. The supports at the second and third slope of cut slopes and portal face have been suggested for the constructive reasons. Actually, the most convenient support recommendation has been practiced on the lower slope of all exit portal cut slopes. In order to control the support system efficiency all open cut slope of exit portal has been analyzed without support and failure surface changing is determined (APPENDIX-E).

To sum up, avoiding the determined with analyses and unforeseen or unexpected negative effects of the nature dynamics, the following support systems have been recommended for the open cut excavations at the exit portal of the Konak Tunnel:

Portal Face Excavation

On the lower slope;

- Systematical, un-tensioned (passive) nails (grouted rock bolts) with 1.0 m split-spacing, diameter ϕ=32 mm and increasing length bottom to top L=15.00 to 20.00 m (190 kN tensile and plate capacity, 350 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

On the second and third slopes;

- Systematical, un-tensioned (passive), grouted rock bolts (nail) with 1.0 m split-spacing, diameter ϕ=32 mm and length L=5.00 m (190 kN tensile and plate capacity, 85 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

On the upper slope;

- Bored piles with diameter ϕ=80 cm and length L=15.50 m
- Four tensioned (active) 1.8 m split-spacing anchor at the depth of 2.00 m, 3.50 m, 5.50 m and 7.50 m with length L=21.00 m, 19.00 m, 18.00 m and 17.00 m respectively (300 kN tensile and plate capacity, 8 m bond length, 40 kN/m bond strength)

Left Cut Slope Excavation

On the lower slope;

- Systematical, un-tensioned (passive) nails (grouted rock bolts) with 1.0 m split-spacing, diameter ϕ=32 mm and increasing length bottom to top L= 20.00 m (190 kN tensile and plate capacity, 350 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh

On the second and upper slopes;

- Systematical, un-tensioned (passive), grouted rock bolts (nail) with 1.0 m split-spacing, diameter ϕ=32 mm and length L=5.00m (190 kN tensile and plate capacity, 85 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

Right Cut Slope Excavation

On the lower slope;

- Systematical, un-tensioned (passive), grouted rock bolts (nail) with 1.0 m split-spacing, diameter ϕ=32 mm and increasing length bottom to top L= 20.00 m (190 kN tensile and plate capacity, 350 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

On the second and upper slopes;

- Systematical, un-tensioned (passive) grouted rock bolts (nail) with 1.0 m split-spacing, diameter ϕ=32 mm and length L=5.00m (190 kN tensile and plate capacity, 85 kN/m bond strength).
- 10 cm (5+5 cm) thick shotcrete with steel wire mesh.

Before moving on the next chapter, types of the reinforcement elements have been recalled shortly. According to engineers' manual of US Army Corps of Engineers (1994) "un-tensioned (passive) reinforcement elements such as nails or bolts provide resistance to dilation within a rock mass and along potentially unstable contact surfaces". Moreover, the progress of tensile forces reacting dilation, passive resistance against sliding have been developed when lateral forces occur lateral strains. The interaction of reinforcement elements and rock mass brings the cohesion and friction development around the bond of support and the rock. In general, passive type of reinforcement elements should not be used for gravity structures stabilization.

On the other hands, a compression zone has been occurred within the influence zone of reinforcement elements when tensioned (active) ones examined closely. According to engineers’ manual of US Army Corps of Engineers (1994) “upon tensioning, load is transferred from the tensioning element, through the grout, to the surrounding rock mass”. To put it more clearly, directly pull or torqueing should be applied for retaining tension between reinforcement elements and rock units.

CHAPTER 7

MONITORING AND EXCAVATION CONDITIONS DURING CONSTRUCTION STAGE

In the recent years, an important part of tunnel construction, especially for a tunnel that is designed and constructed via empirical methods, displacement monitoring by various geodetic measurements have been utilized extensively (Schubert et al., 2002). Monitoring displacement is the key to verify the design of the tunnel support, and to prepare for unpredicted conditions that may require excavation modification along with modifications related to stabilization and support systems. A further objective is last but not least, to prevent significant deviations from estimated completion costs and dates.

As for as the tape extensometer method is concerned, considering the advantage and improvement in the optical technology, the determination of the horizontal, vertical and longitudinal components of the displacement vector at the individual measurement points results in the dimensional and transitory variation of each component with great accuracy. It provides better estimation of the relative conditions ahead of the face even when the magnitudes of displacements are minute. These measurements generally require to regulation and correction processes due to the negligence and obligations occurred during construction. In terms of measurement accuracy, only the vertical displacements have been examined and evaluated.

Vertical displacement monitoring in both tubes was practiced in 7 to 11 months periods by the optical method on the top heading and benches. Five measurement points were installed on each section located on the tunnel surface depending on the ground conditions. The tunnel excavation started with tube-2 and continued with tube-1. The resultant vertical displacements at each monitoring point are presented in Figure 32 and Figure 33 and the raw data are supplemented in APPENDIX-F for the Konak Tunnel tube-1 and tube-2. The first three measuring points (1-2-3) on the section are the top heading ones and the remaining two points (4-5) are at the bench level. Owing to the staged excavation, the smaller deformations have been obtained at the bench level (Table 30). It should be noted that the monitoring points at each section could be installed after at least one round of excavation (blasting) cycle was completed and the initial support components were installed.

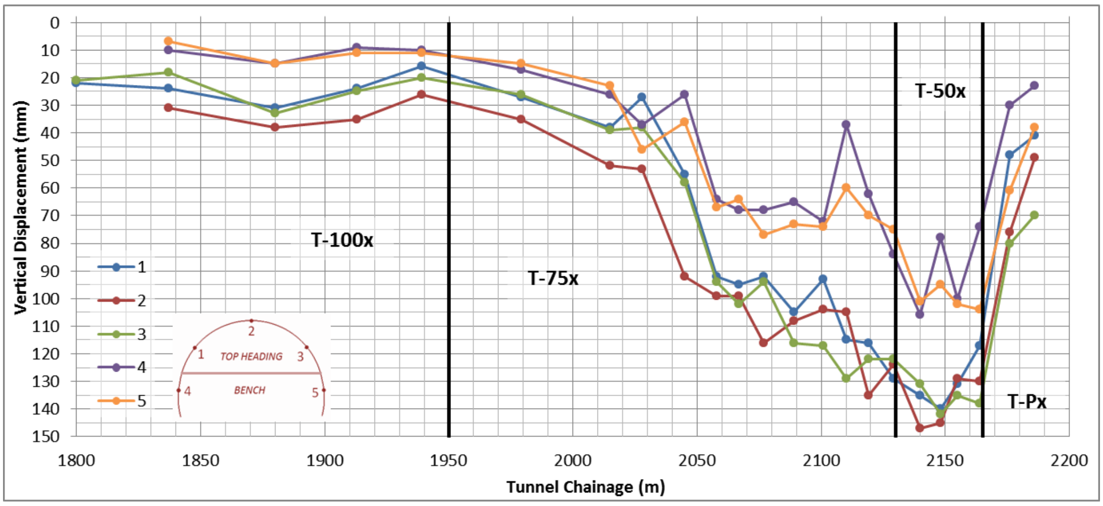


Figure 32: The cumulative vertical displacement profiles of the five monitoring points of tube-2

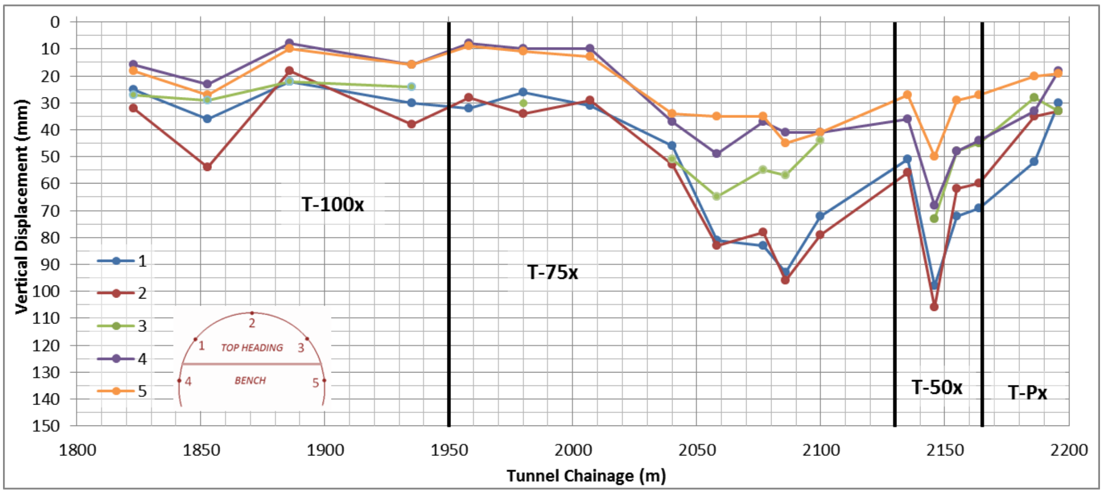
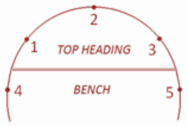


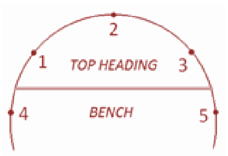
Figure 33: The cumulative vertical displacement profiles of the five monitoring points of tube-1

Table 30: The cumulative vertical displacement measurements of the Konak Tunnel

VERTICAL DISPLACEMENT MEASUREMENTS of THE KONAK TUNNEL															
Tube 2								Tube 1							
Geotechnical Section	Reading Section KM	Vertical Dis. (mm) Points					Support Type	Geotechnical Section	Reading Section KM	Vertical Dis. (mm) Points					Support Type
		1	2	3	4	5				1	2	3	4	5	
T-Px	2+186	41	49	70	23	38	C1	T-Px	2+196	30	33	33	18	19	C1
	2+176	48	76	80	30	61	C1		2+186	52	35	28	33	20	C1
	2+164	117	130	138	74	104	C1		2+164	69	60	45	44	27	C1
T-50x	2+155	131	129	135	100	102	B3	T-50x	2+155	72	62	48	48	29	B3
	2+148	140	145	142	78	95	B3		2+146	98	106	73	68	50	B3
	2+140	135	147	131	106	101	B3		2+135	51	56	f	36	27	B3
	2+129	129	124	122	84	75	B3	T-75x	2+100	72	79	44	41	41	B2
T-75x	2+119	116	135	122	62	70	B2		2+086	93	96	57	41	45	B2
	2+110	115	105	129	37	60	B2		2+077	83	78	55	37	35	B2
	2+101	93	104	117	72	74	B2		2+058	81	83	65	49	35	B2
	2+089	105	108	116	65	73	B2		2+040	46	53	51	37	34	B2
	2+077	92	116	94	68	77	B2		2+007	31	29	f	10	13	B2
	2+067	95	99	102	68	64	B2		1+980	26	34	30	10	11	B2
	2+058	92	99	94	64	67	B2		1+958	32	28	f	8	9	B2
	2+045	55	92	58	26	36	B2	T-100x	1+935	30	38	24	16	16	B1
	2+028	27	53	38	37	46	B2		1+886	22	18	22	8	10	B1
	2+015	38	52	39	26	23	B2		1+853	36	54	29	23	27	B1
	1+979	27	35	26	17	15	B2		1+823	25	32	27	16	18	B1
T-100x	1+939	16	26	20	10	11	B1								
	1+913	24	35	25	9	11	B1								
	1+880	31	38	33	15	15	B1								
	1+837	24	31	18	10	7	B1								
	1+800	22	f	21	f	f	B1								
f: failed															

The average cumulative vertical displacements of each point on the geotechnical sections are illustrated in Table 31. This summary table was prepared through considering the boundaries of the critical sections and the overburden depths. The most important issue of monitoring the vertical displacement at five points is the contrasting condition about the displacement ranges in the top heading and bench sections despite the larger displacements. The reason for this condition is attributed to the errors related to the equipment, operator and tunnel conditions. To evaluate the trends of figures which are given above in tunnel conditions, it is necessary to create reference points in reference overburden depths for changing displacement vectors of various scenarios. Through the excavation, an alternating zone, softer or poorer and harder rock mass domains are simplified scenario samples for relative changes in the magnitudes of vertical displacement. Therefore, major geological changes have been recorded along both tubes during the excavation and illustrated in APPENDIX-A.

Table 31: The average cumulative vertical displacements of each point on the geotechnical sections

Geotechnical Section	Tube 2					Tube 1					
	Average Ver. Dis. (mm) Points					Average Ver. Dis. (mm) Points					
	1	2	3	4	5	1	2	3	4	5	
T-Px	69	85	96	42	68	71	61	47	46	28	
T-50x	134	136	133	92	93	62	68	60	38	34	
T-75x	27	35	26	17	15	31	33	24	12	12	
T-100x	23	31	23	11	11	25	32	27	16	18	

The presence of a relatively weak rock mass at the exit portal and grading into better rock mass conditions which were volcanic rock masses is indicated by the measured vertical displacement vectors in the top heading (points 1, 2 and 3). When the excavation advanced to the un-weathered andesite unit (approaching the exit portal), the trend of the displacement is reversed from increasing to decreasing. The vicinity of a weak rock mass is identified by the end of the T-Px section to the head of the T-75x section. The similar behavior of the two pairs (2-4 and 3-5) of the monitoring points on the tunnel walls have been reflected by the vertical displacements. At about KM 2+030, a significant shift was observed in all monitoring points due to the thick andesite units. Depending on the temporal displacement patterns and small displacement magnitudes, the deformation rate did not decrease when the monitoring ended. The vertical displacement component was very close to its ultimate value at point 1 according to the raw data (APPENDIX-F).

CHAPTER 8

FINITE ELEMENT (2D) MODELING

It is known from previous tunneling studies that because of the weight of the overlying strata and locked in stresses of tectonism, the rock at depth is subjected to stresses, which are the induced or in-situ stresses found in the artificially undisturbed rock before the excavation processes. Right after the excavation, new sets of stresses are induced in the rock surrounding the opening due to the disruption of the initial stress field. For most of the cases, the strength of the rock is exceeded and the resulting instability can have undesired consequences on the behavior of the excavation. Hence, the main components of the underground excavation design are the magnitudes and the directions of in situ and induced stresses.

8.1 In-Situ Stresses

In respect of in-situ stresses, the Swiss geologist Heim concluded that the tunnels are highly stressed in all directions. Heim assumed that the vertical component of stress is proportionally related to the overburden weight on the tunnel and added that there is also a horizontal component of this stress. According to him, the in-situ stresses are geologically originated and the horizontal stress components are greater than the vertical ones at the mountain ridges and under the large overburden (Jaeger, 1979).

The vertical stress related to the overburden weight at a particular depth can be determined by the simple equation (Eqn. (32)). On the other hand, in order to understand the horizontal stress behavior at shallow and larger depth, Sheorey (1994) developed a stress model of the earth. His model includes elastic constants and depth which is considered with density and thermal expansion. As a result, a simple equation has been suggested for the horizontal stress to vertical stress as a ratio “k” (Eqn. (33)):

$$\sigma_v = \gamma z \qquad (32)$$

In this equation;

σ_v = the vertical stress

γ = the unit weight of the overburden rock

z = the depth below the surface

$$k = 0.25 + 7E_h\left(0.001 + \frac{1}{z}\right) \qquad (33)$$

In this equation;

E_h = the average deformation modulus of the overburden rock

z = the depth below surface

8.2 Induced Stresses

When underground excavation starts in the rock mass, the stress conditions around the opening are reshaped. For such a case, an analytical solution for the stress distribution in an elastic plate with a circular hole has been proposed by Kirsch (1898). Kirsch’s solution formed the basis for rock behavior around tunnels and is used widely in rock mechanics.

These solutions still have an extensive value for understanding the conceptual behavior and for calibration of the numerical models. Nonetheless, in the design stage, these models present very simple geometries and material models.

8.3 Numerical Modelling

In order to control the efficiency of the selected support classes, finite element modeling of tunnel excavation has been performed in plain strain solution. The 2D finite element software Phase2 (Rocscience, 2015) has been used for these analyses. Because of the varying overburden height from 35 m to 100 m, the actual ground surface has been used to describe the upper boundary of the model. The stress ratio “k” has been calculated from Eqn. (33) for all of the sections separately and it was observed that the k values were compatible with the tectonic model of region (extensional tectonics). The boundary conditions and geometry with finite element discretization through 6 noded – triangular elements of the critical sections are illustrated in APPENDIX-G. The vertical displacement and support capacity plots are also presented in APPENDIX-G. Since the tunnel excavation has started with tube-2, the tube-2 excavation is always assumed to lead that of the tube-1.

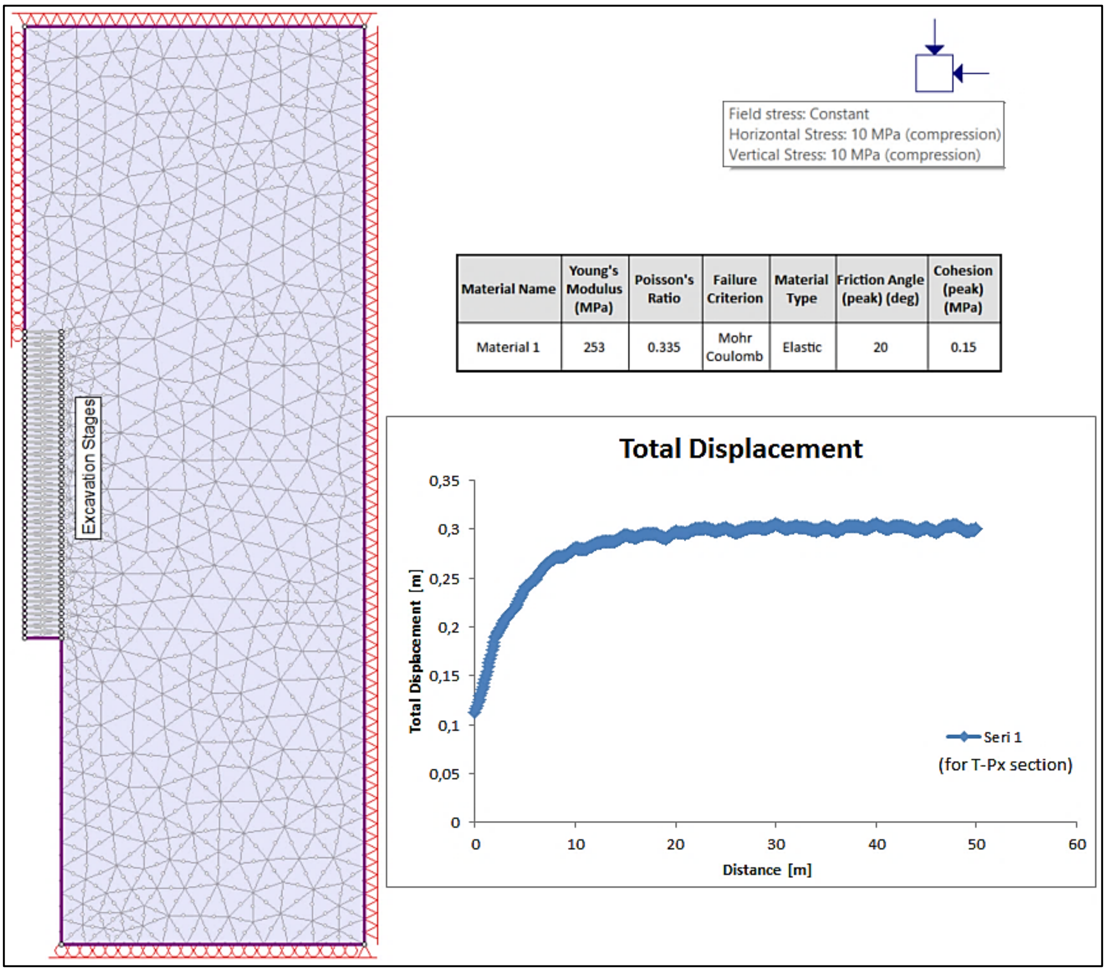
The rock mass has been assumed to be an isotropic, homogeneous and elasto-plastic material which has been used with the Mohr - Coulob failure criterion. Estimation of the rock mass deformation modulus and the failure criterion parameters has been determined from the rock mass classification systems and empirical equations. The average elastic modulus of the intact rock has been obtained from the uniaxial tests on the andesitic specimens. The relevant rock mass properties have been summarized in Table 32. The input shear strength parameters have been derived from the RMR classification results and deformation modulus calculated by Eqn. (11).

Table 32: Rock mass properties of the tunnel geotechnical sections

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
UCS (MPa)	10	15	40	45
Q	0.06	0.11	3.33	8.33
RMR	23.0	33.5	46.5	57
Average E_i* (GPa)	6.42			
Average γ* (kN/m^3)	23.84			
Average Poissons Ratio*	0.335			
E_d** (GPa)	0.253	0.453	0.832	1.286
Max. Overburden (m)	35	50	75	100
$c^{(1)}$ (MPa)	0.150	0.150	0.200	0.250
$\phi^{(1)}$ (°)	20	20	25	30
Total Stress Ratio*** (k)	0.30	0.32	0.33	0.35
* Laboratory test result *** Sheorey - 1994	** Nicholson & Bieniawski - 1990 (1) RMR			

A tunnel excavation route starts converging ahead before the excavation face reaches that section and converging affects move a distance of several tunnel radiuses at least. This stepwise attitude has appeared as a response of blasting cycles and round lengths. The effect of the convergence means that the monitoring points at given section can be installed after the outstanding displacements have taken place and 2D numerical models do not capture this deformation pattern and measurements cannot be compared with it. This deficiency can be eliminated by the softening approach which is suggested by Rocscience (2015) in Phase2 tutorials. According to this approach, to take into account the preliminary displacements and converging effects, the deformation modulus of the rock mass has been reduced on the excavation section. The axisymmetric modelling has been used for determining the reduction amount of the deformation modulus in all excavation sections (Figure 34 and APPENDIX-H). “The axisymmetric models allow analyzing a 3D excavation that is rotationally symmetric about an axis. The input parameters are for 2D, however the results apply to a 3D problem (Rocscience, 2015).” A 50 staged excavation, each of which has a 1 meter length was modelled for this analyses and displacement vs. excavation stage chart was obtained (Figure 34 and APPENDIX-H). Only the field stresses effects on a 6 noded triangular mesh and elastic type of material which has cohesion, internal friction angle and Poisson’s ratio have been used in these analyses.

According to the results of the axisymmetric analyses, as approaching the study section, 20 to 30 % of the cumulative displacement has occurred. At 1 m to 2 m ahead of the face, the displacement ratio reaches 50 to 65 % of the cumulative displacement. Accordingly, the softening ratios are selected from these preliminary displacement ratios and round length of excavation (1 to 3 m for the NATM classes) for the deformation modulus of the rock mass (APPENDIX-H). The results of the analyses for all of the critical geotechnical sections are illustrated in Table 33.



Field stress: Constant
Horizontal Stress: 10 MPa (compression)
Vertical Stress: 10 MPa (compression)

Material Name	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
Material 1	253	0.335	Mohr Coulomb	Elastic	20	0.15

Figure 34: Sample axisymmetric model for T-Px section of the Konak Tunnel

Table 33: The axisymmetric analyses results of the critical sections

Geotechnical Section	Distance to Excavation Face	Total Displacement	Softening Ratio	Deformation Modulus	
				in-situ	induced
	m	m	%	MPa	MPa
T-Px	0.0	0.11287	0.373138	253	158.6
	0.5	0.13796	0.456079		137.6
	1.0	0.15990	0.528597		119.3
	1.5	0.17818	0.589055		104.0
	2.0	0.19777	0.653787		87.6
	2.5	0.21002	0.694293		77.3
	50.0	0.30250	1.000000		0.0
T-50x	0.0	0.06304	0.373138	453	284.0
	0.5	0.07705	0.456079		246.4
	1.0	0.08931	0.528597		213.5
	1.5	0.09952	0.589055		186.2
	2.0	0.11045	0.653787		156.8
	2.5	0.11731	0.694293		138.5
	50.0	0.16894	1.000000		0.0
T-75x	0.0	0.03492	0.379760	832	516.0
	0.5	0.04177	0.454316		454.0
	1.0	0.04745	0.516082		402.6
	1.5	0.05359	0.582756		347.1
	2.0	0.06043	0.657143		285.3
	2.5	0.06419	0.698100		251.2
	50.0	0.09195	1.000000		0
T-100x	0.0	0.02259	0.379760	1 286	797.6
	0.5	0.02703	0.454316		701.7
	1.0	0.03070	0.516082		622.3
	1.5	0.03467	0.582756		536.6
	2.0	0.03910	0.657143		440.9
	2.5	0.04153	0.698100		388.3
	50.0	0.05950	1.000000		0.0

8.3.1 Numerical Analyses Results

Numerical analyses are needed for the simplification of the real conditions of nature to variable extents, and for the estimation of behavior of the model under the specific conditions. In this thesis, the measured cumulative vertical displacements have been compared with the predicted total vertical displacement distribution around both tubes from numerical analyses.

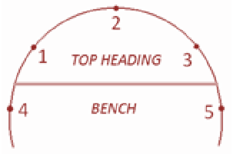
The properties of the support elements, which have been applied in the numerical analyses, are presented in Table 34. The tensile strength of the shotcrete was taken as 12 % of the compressive strength of concrete according to engineering practice (Dorf, 2005). The shear strength of the steel wire mesh was neglected. The type of rock bolts was selected as the plain strand cable with face plates.

Table 34: The properties of the tunnel support elements applied in the analyses

Material Type	**E (MPa)**	**Poisson's Ratio, υ**	**Comp. Strength (MPa)**	**Tensile Strength (MPa)**	**Dimensions**
Shotcrete	15000	0.20	20	2.4	15.0 to 22.5 cm
Rock Bolt	210000	-	365	365	Ø28 (L=4.0 m)
Steel Ribs	210000	0.20	365	365	I150 (1.0 m Spacing)

The change in the total vertical displacement calculated during numerical analysis at the final stage of tunnel excavation for the supported sections is summarized in Table 35 and a comparison and discussion of field data and results from numerical model is presented in the “Discussion and Conclusion” Chapter.

Table 35: Summary table of total vertical displacements calculated from numerical analyses for both tubes at all monitoring points

Geoechnical Section	**Tube 2**					**Tube 1**					
	Total Ver. Dis. (mm) Points					**Total Ver. Dis. (mm) Points**					
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	
T-Px	69.0	81.0	78.0	42.0	48.0	75.0	81.0	69.0	51.0	42.0	
T-50x	64.0	72.0	69.3	32.0	34.7	69.3	69.3	64.0	37.3	32.0	
T-75x	36.7	41.7	40.0	13.3	15.0	40.0	41.7	36.7	15.0	11.7	
T-100x	28.0	33.3	29.3	16.0	18.7	29.3	33.3	28.0	17.3	16.0	

According to the map of earthquake zone of Turkey (Earthquake Research Center, 2015) the tunnel is located in a zone of high seismicity (Zone 1). Hence, the seismic load effects need to be taken into account in modeling and construction stages. The Earthquake Research Center suggests that the effective ground acceleration coefficient could be taken as 0.4g for this region. The horizontal component of seismic load is taken as 0.2g for analyses (AASHTO, 2002). However, the finite element model was not able to estimate any rock mass failure or considerable increase of vertical displacement and strength factor (APPENDIX-G).

CHAPTER 9

DISCUSSION AND CONCLUSION

In order to decide whether the proposed support design is satisfactory or not for the studied tunnel sections, an evaluation has been performed through taking into account the monitoring readings. The change in the total vertical displacement calculated during numerical analysis at the final stage of tunnel excavation for the supported sections is summarized in Table 35 and a comparison of the field data and the results of the numerical model are given in Figure 35 and Figure 36 with respect to their overburden height. All monitoring points at both tubes have been observed separately and detailed illustrations are given in APPENDIX-G.

The displacements calculated from the numerical analysis have been observed to be mostly consistent with the monitoring measurements. Except from the geotechnical section T-50x, the trends for the displacement change at the analyzed sections were observed to be parallel and consistent with the monitoring measurements. The resultant vertical displacements of the finite element model have been interpreted with the monitoring measurements of the construction stage. All of the displacement patterns examined at the five points in each critical section are given graphically in Figure 35 and Figure 36.

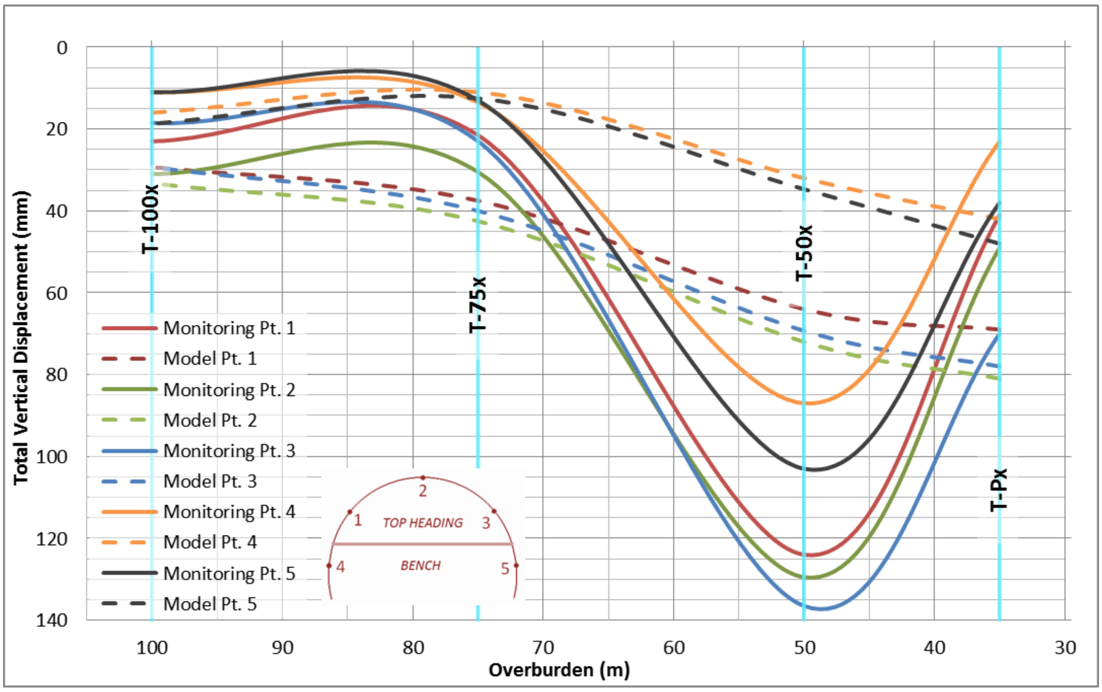


Figure 35: Comparison of the total vertical stresses measured during field monitoring and calculated from numerical modeling for tube-2

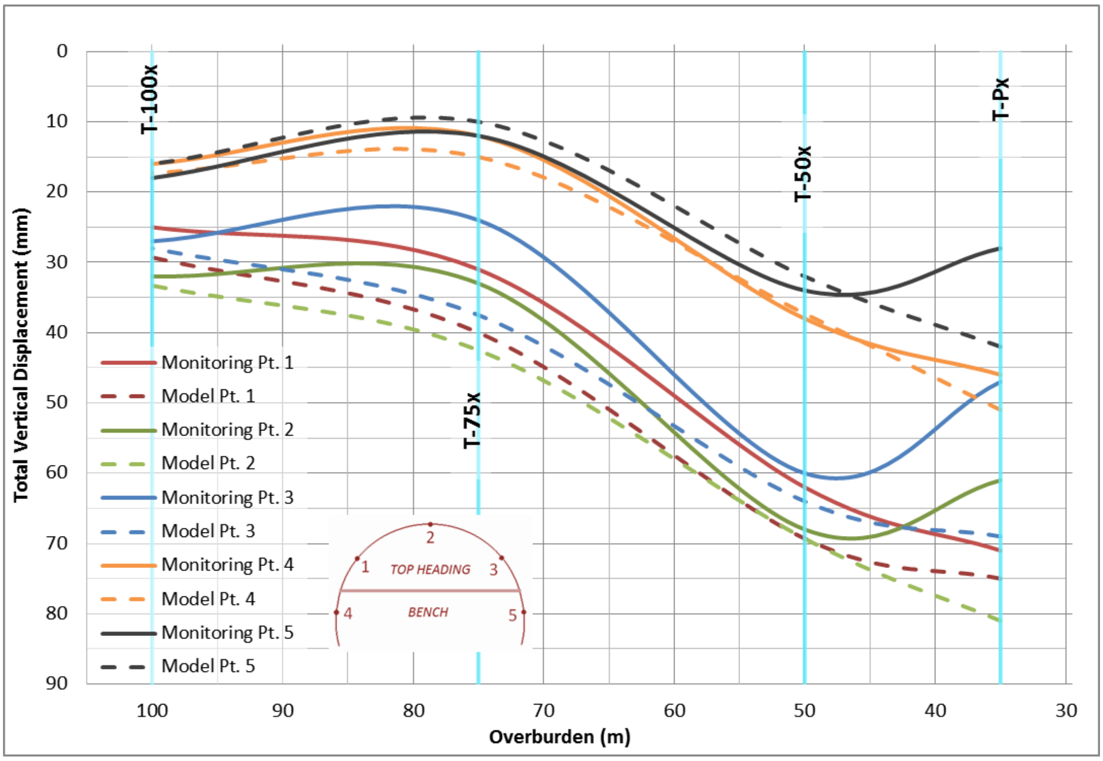
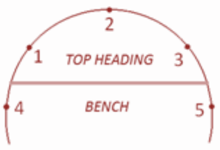


Figure 36: Comparison of the total vertical stresses measured during field monitoring and calculated from numerical modeling for tube-1

According to this comparison, tube-1 illustrates more compatible trend at all sections and through all reading points. On the other hand, tube-2 shows higher inconsistency, especially on the T-50x geotechnical section due to the existence of a relatively weak rock mass (weathering degree is higher than the expected conditions). Table 36 gives a summary of comparison between observed and calculated total vertical displacement ratios for all monitoring points. The negative (-) values in table means that the higher expectation of total vertical displacement, in other words, calculated displacement values exceed the construction stages monitoring data. Similarly, the positive (+) values represent the lower expectation of total vertical displacements at the excavation stage. When the monitoring points on the critical sections are evaluated individually, 70 % of the points ensure the predicted displacement limits (predicted displacement limit = calculated displacement ± 30 %). Additionally, only 12.5 % of the displacements mismatch ratio is higher than the 50 % and great majority of these mismatches are especially related to the T-50x geotechnical section. When the T-100x section is evaluated individually, the calculated vertical displacements on the bench measuring points (4 and 5) are higher than the observed measurement points especially on tube-2. The most probable reason for this may be because the systematic bolting application has been performed at the bench level of the tunnel during the construction stage. This application has been performed as a consequence of the request of the constructor because of safety reasons. However, this application did not suggested with in this study.

Table 36: Comparison of observed and calculated total vertical displacements at the monitoring points

Technical Section	Tube-2					Tube-1					
	Comparison of Observed and Calculated Total Ver. Dis. at Monitoring Points (%)					Comparison of Observed and Calculated Total Ver. Dis. at Monitoring Points (%)					
	1	2	3	4	5	1	2	3	4	5	
T-Px	0.0	4.7	18.8	0.0	29.4	-5.6	-32.8	-46.8	-10.9	-50.0	
T-50x	52.2	47.1	47.9	65.2	62.7	-11.8	-1.9	-6.7	1.8	5.9	
T-75x	-35.9	-19.1	-53.8	21.8	0.0	-29.0	-26.4	-52.9	-25.0	2.5	
T-100x	-21.7	-7.4	-27.4	-45.5	-70.0	-17.2	-4.1	-3.7	-8.1	11.1	
Note: Negative (-) values represent the higher expectetaion of total vertical displacement. Positive (+) values represent the lower expectetaion of total vertical displacement.											

Furthermore, the observed and calculated displacements have been evaluated as related to the general trends lines for each tube and measurement points (Figure 37 and Figure 38). This study shows that both the observed and calculated vertical displacement measurement curves fit each other closely. Additionally, the general trends of the displacement curves are decreasing with respect to the increasing overburden height and the decreasing weathering degree of the rock mass.

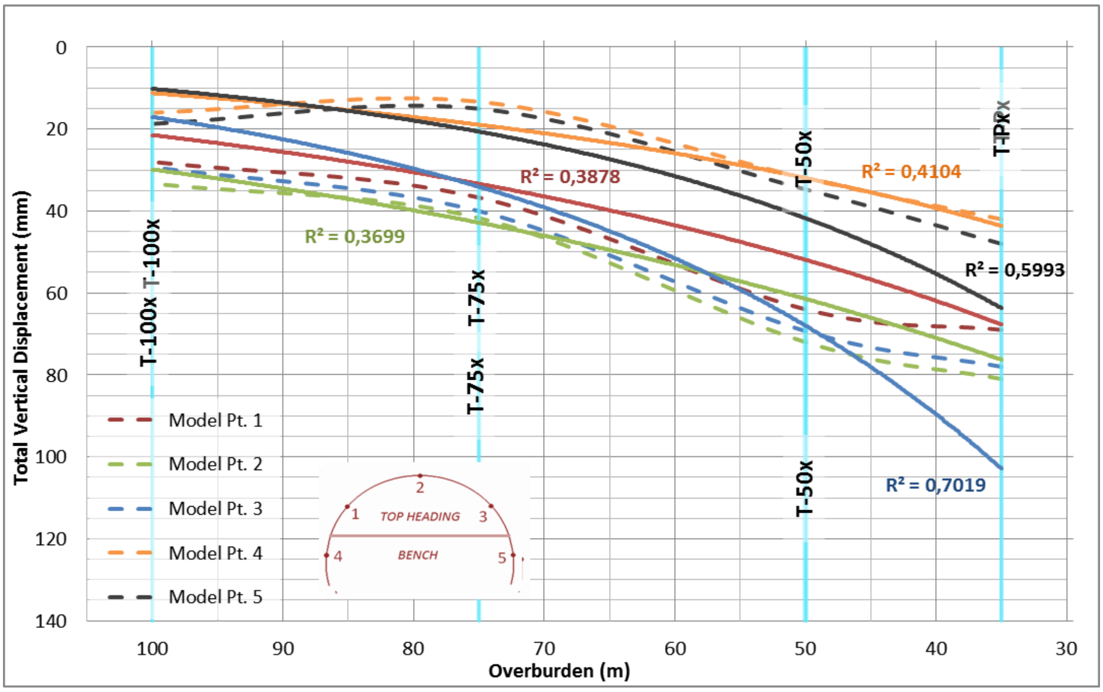


Figure 37: General trend lines of the observed measurements and a comparison of the calculated measurements for tube-2

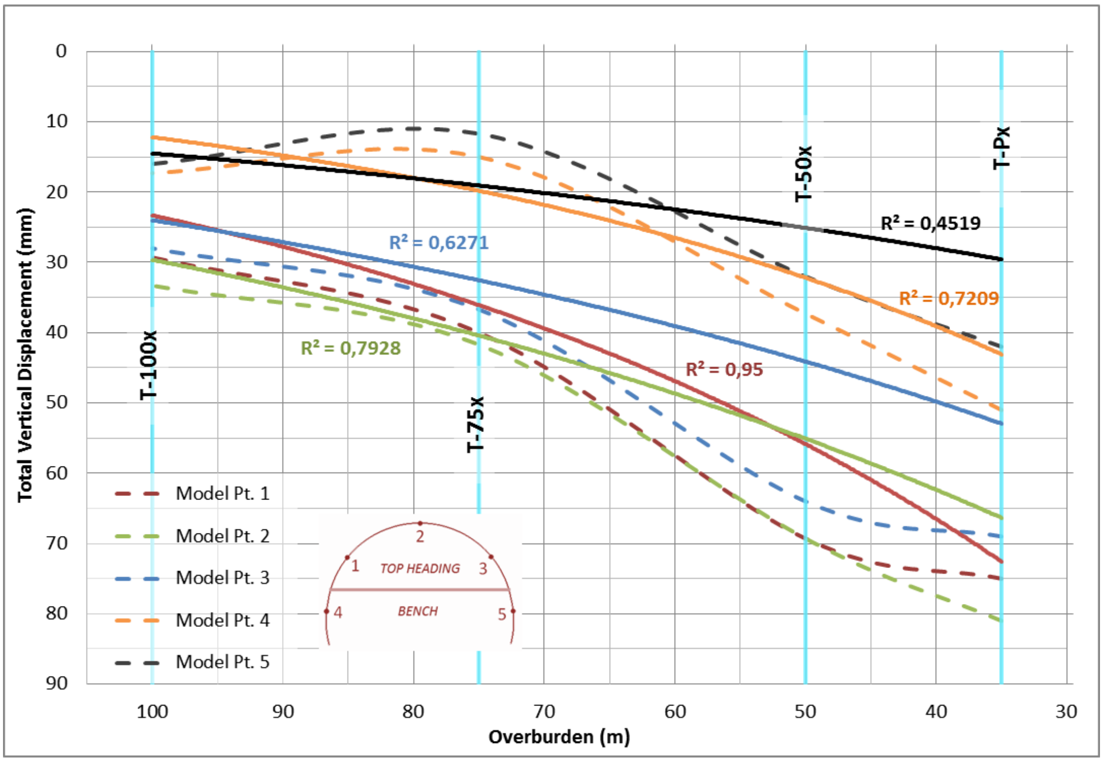


Figure 38: General trend lines of the observed measurements and a comparison of the calculated measurements for tube-1

Interpretations of the results of numerical analyses as compared with the monitoring readings have been made as follows;

- The total vertical displacement vectors on the bench level are smaller than the ones on the top heading and side walls. This difference in the displacement magnitudes could be explained by stress distribution.

- The displacement trends illustrate that the excavation of the second tube has a minor influence on vertical displacement. Generally, the tube excavated first has a little more vertical displacement and when the distance between the two tubes increases, the effect of the tubes on each other decreases.

- When comparing the displacement values, which have been taken from the numerical analyses and monitoring data, tube-1 illustrates more compatible trend at each section and through the entire reading points. On the other hand, tube-2 shows higher inconsistency, especially on the T-50x geotechnical section (Figure 35). The possible causes of this problem will be poor estimation of rock mass parameters, improper monitoring, excavation method, support timing, etc.

- Both the support system elements and the rock mass have not been yielded due to the redistribution of stress conditions (APPENDIX-G).

In the exit portal stability analyses, the shear strength parameters of the poor rock have been obtained from the basic RMR classification. The open cut slopes directions and excavation boundaries are specified by the consultant and these boundaries have been determined with respect to the settlement in the area. For the highly weathered either volcanic or sedimentary rocks, a circular type of failure analyses has been performed with the computer program SLIDE 6.0 (Rocscience, 2015) since these highly weathered rock masses are expected to behave like a residual soil from an engineering geological point of view. Due to the staged excavation, different types of support applications on the upper to lower slopes have been recommended. At the lower slopes of the right, left and portal face, 20 m length nails have been recommended; on the other hand, for second, third and upper slopes of the portal excavation, 5 m length nails have been recommended. Additionally, for the upper slope of the portal face, four anchored bored piles type of support have been recommended. At the end of the calculations, it was observed that all of the slopes were stable with the pre-determined slope angles and support suggestions were provided for dynamic conditions. However, if the constructor specified the excavation boundaries, the exit portal location offsetting on more reliable rock mass conditions such as the north east of current location.

CHAPTER 10

RECOMMENDATIONS

It is suggested that continuous deformation measurements should be made during the construction stage of the excavation due to the interactive nature of the Q-system, RMR, GSI and NATM classification systems. Especially in NATM installation, the required support elements at the right time are a significant matter in terms of pace and economy. In order to control additional cost overrun, the existing rock mass conditions should be correctly classified and the local engineering geological setting should be correctly specified at the investigation stage. According to the results of the investigation stages, the support and excavation suggestions should be determined for the construction stage. The most important advantage of the interactive tunneling methods is realizing lower costs when high sensitivity monitoring could be integrated into the excavation and support decisions. Therefore, instrumentation and producing monitoring data made and commented at the excavation stage accompanies the success of these methods and support suggestions. Nevertheless, the accuracy of the measurements to be made is crucial for the success of such studies. Hence, the equipment and operator errors affecting this accuracy should be minimized during the optical measurements observing at the tunneling stage.

In the scope of this study only the vertical displacements have been examined and justified with 2D finite element model. However, the total displacements have two components, which are vertical and horizontal displacements, and the best way to model total displacement should be 3D modelling option. The compatibility of the calculated total displacements from the 3D model and measuring displacements in both vertical and horizontal directions would be more reliable.

Another issue about this study is the absence of reliable groundwater data. The relation between water and rock mass and coupled effects on displacements could not been determined. If such data would be available, numerical model considering groundwater effects will be more reliable.

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APPENDICIES

APPENDIX-A: GEOLOGICAL MAPS AND PROFILES

Figures in APPENDIX-A show the geological plans and profiles of the study area.

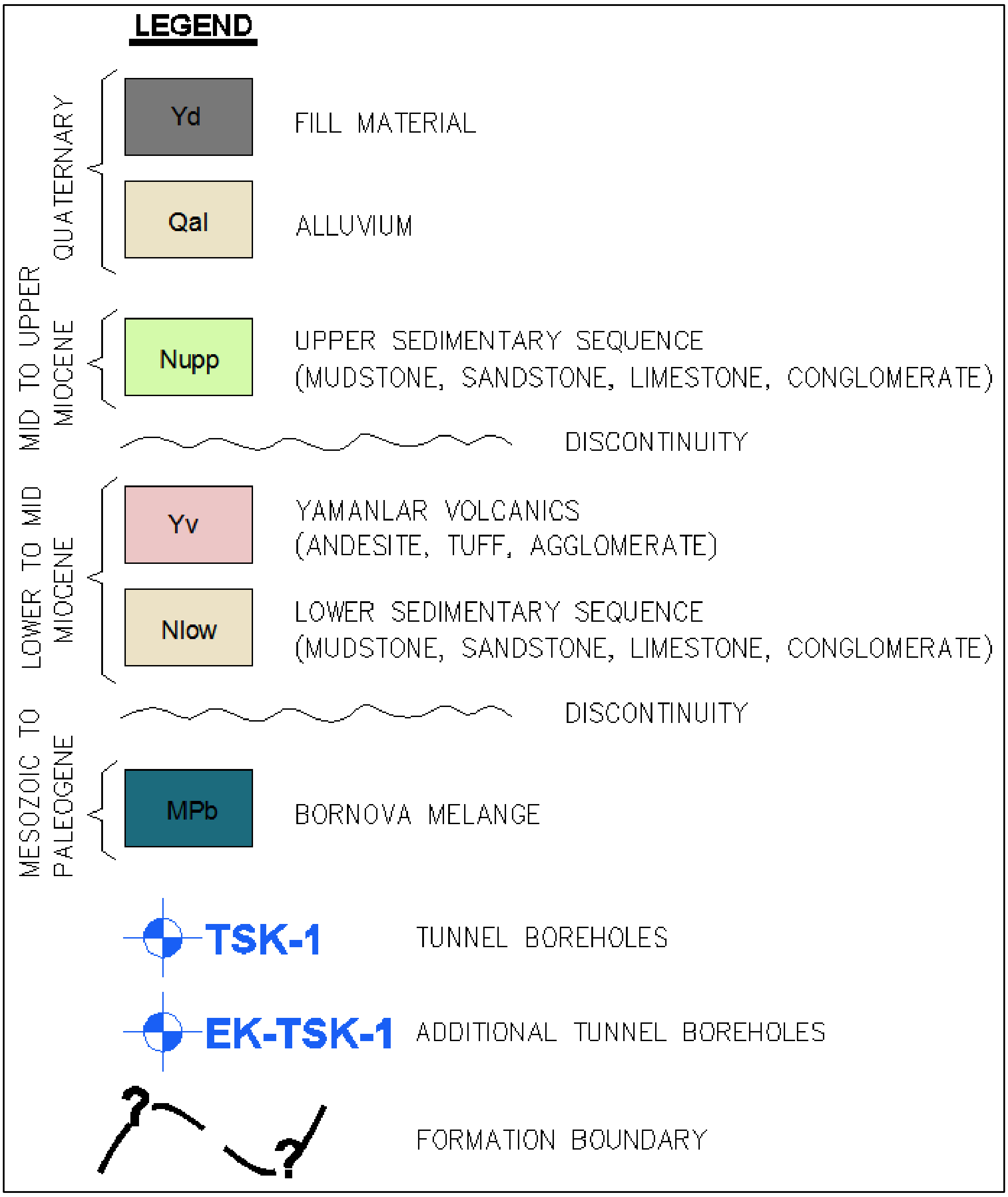


Figure A.1: Legend of the geological map of region

Figure A.2: Geological map of the Konak Tunnel

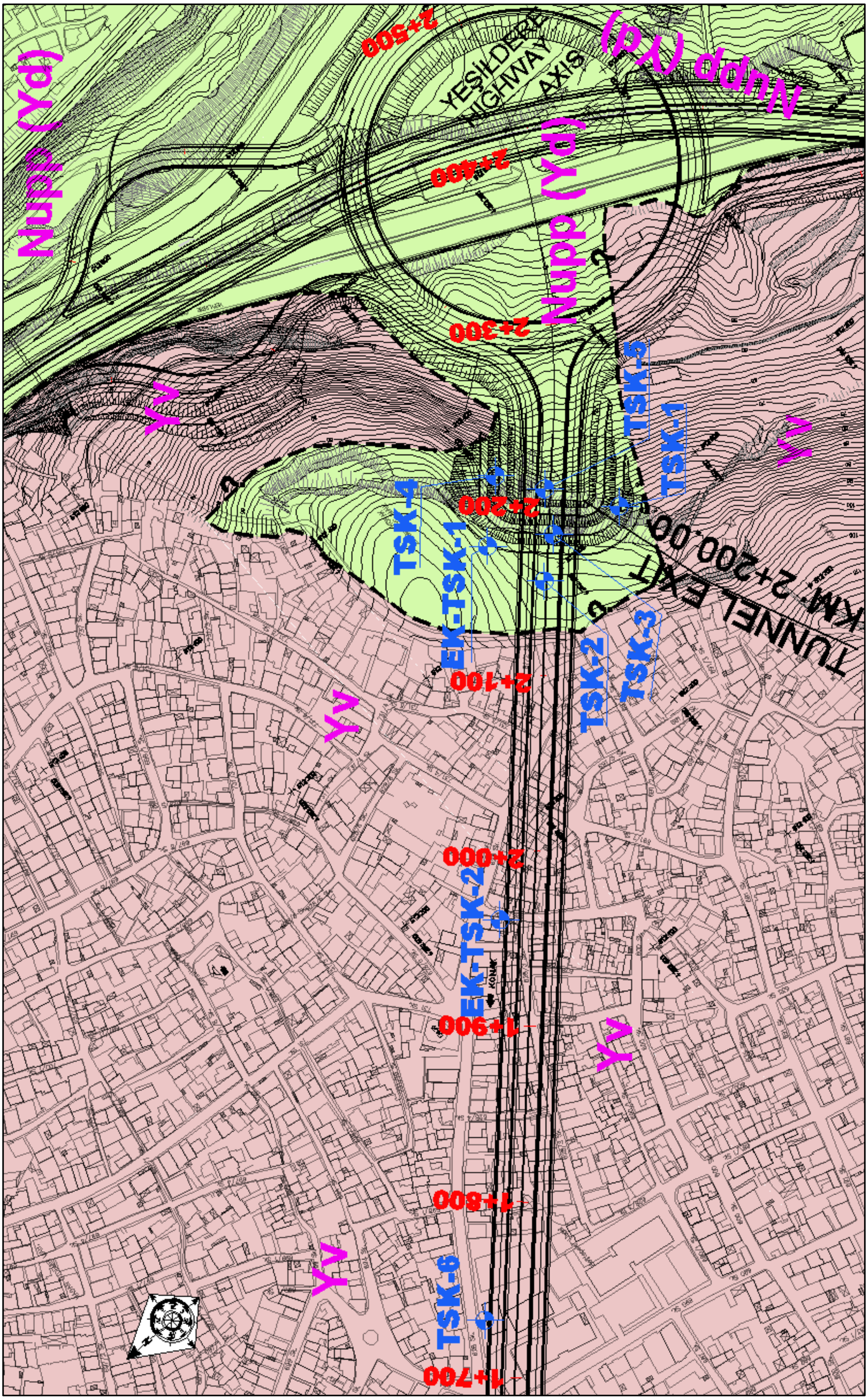


Figure A.3: Geological map of study area

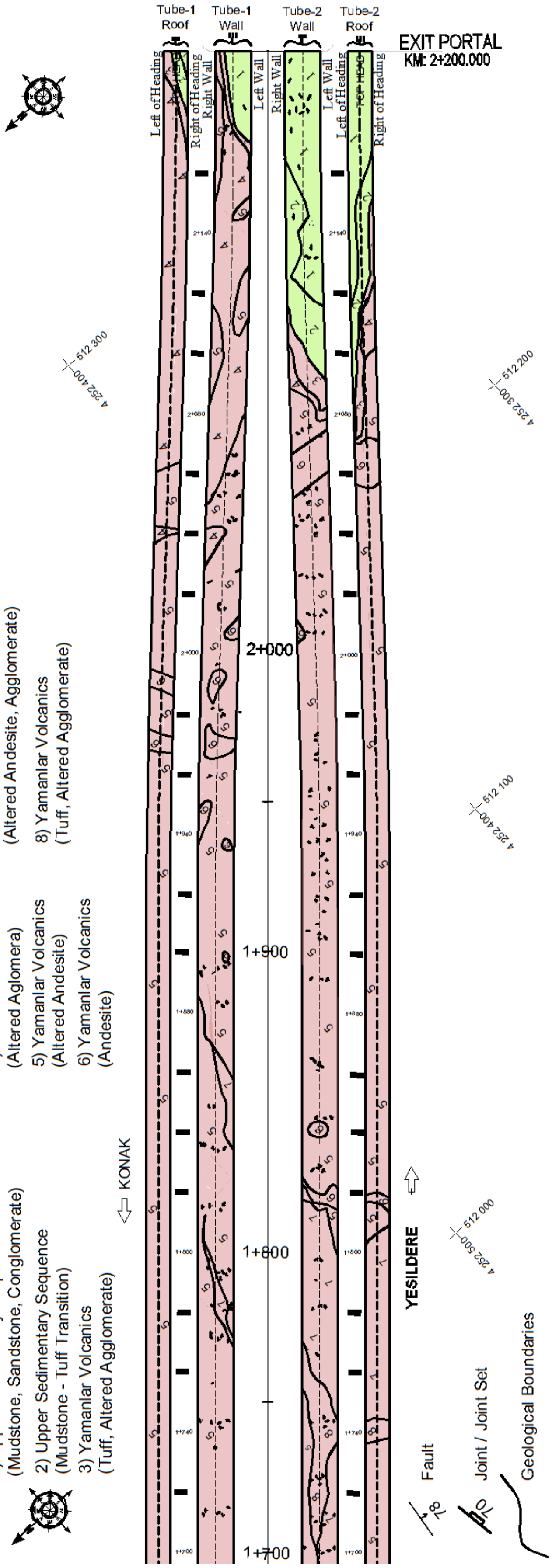


Figure A.4: Tunnel geological map

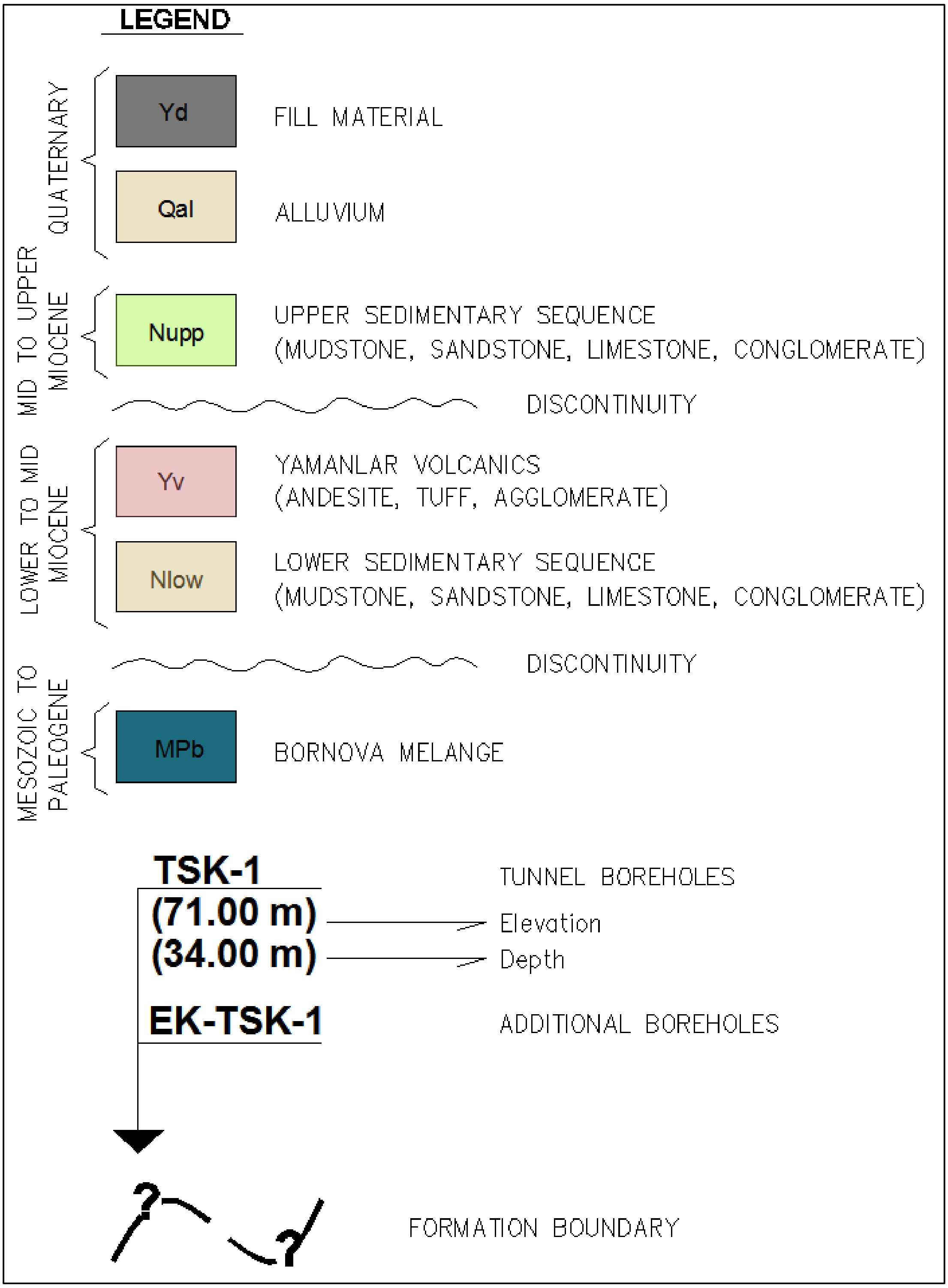


Figure A.5: Legend of the profile

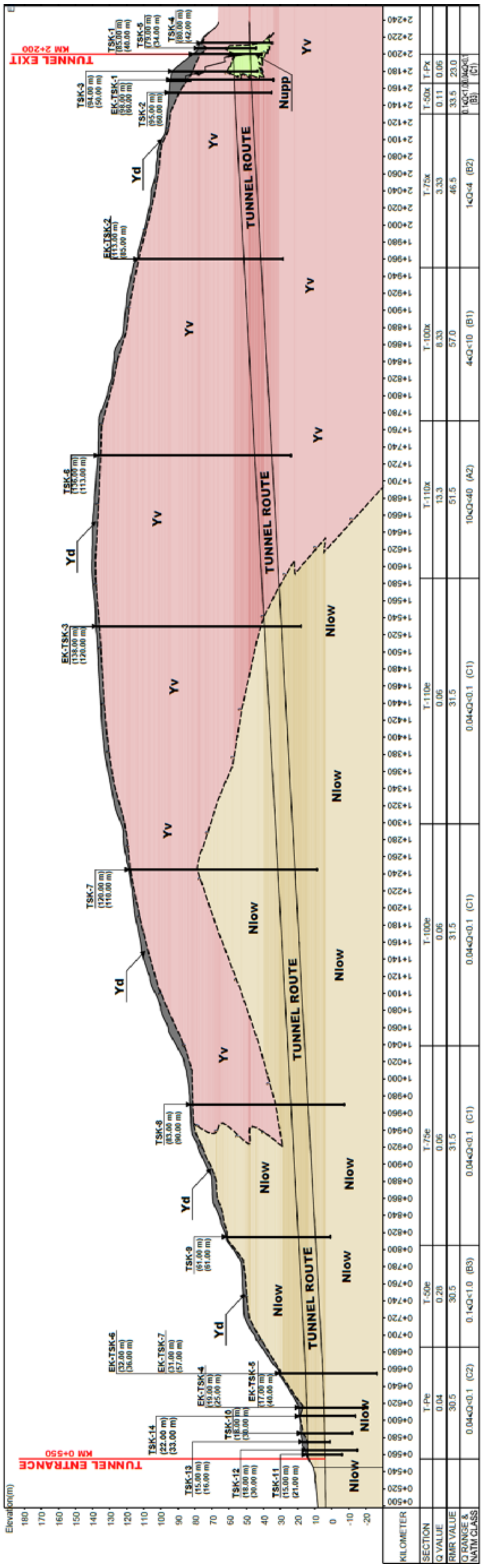


Figure A.6: Generalized geological profile of the Konak Tunnel

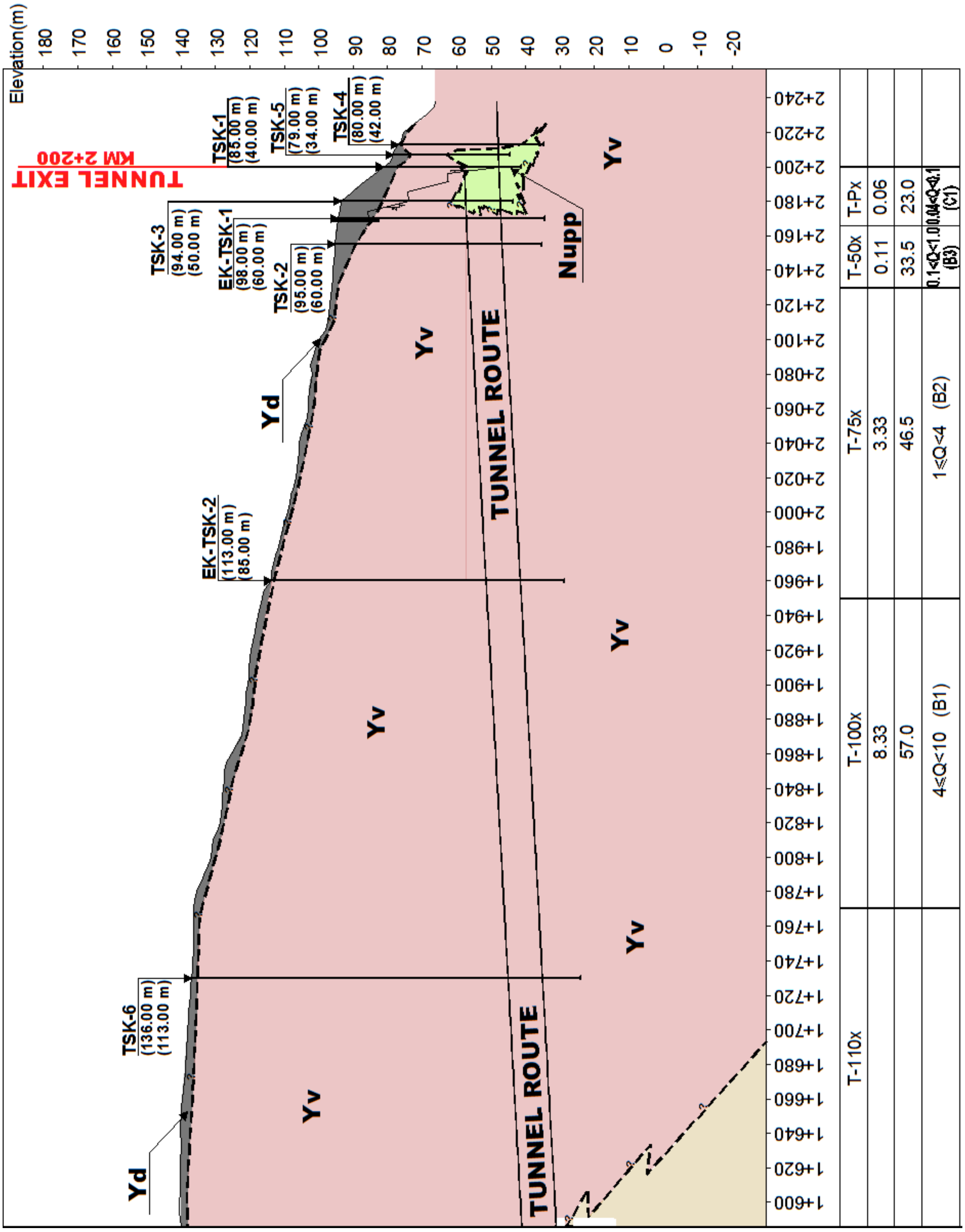


Figure A.7: Geological profile of the Konak Tunnel

APPENDIX-B: DRILLING LOGS AND PHOTOES

Detailed information about the borehole logs and core box photos are given in APPENDIX-B.

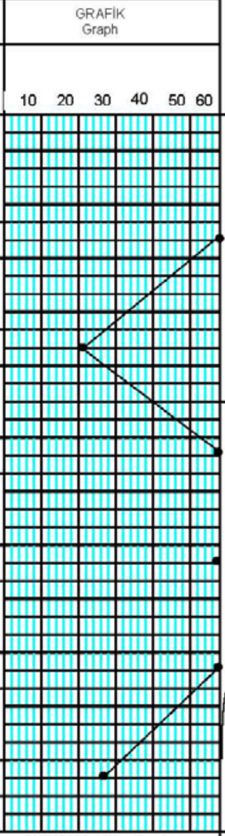
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE District	No :	Sayfa No: 1/3
SONDAJ Borehole	No : **TSK-1**	
SONDÖR Driller :	**Abidin KARATAŞ**	

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	**DELİK ÇAPI / Hole Diameter**	: 89mm-74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	**YERALTI SUYU / Groundwater**	: -
KİLOMETRE / Chainage	: -	**MUH.BOR.DER. / Casing Depth**	: 9.00 m.
SONDAJ DER. / Boring Depth	: 40.00 m	**BAŞ.BİT.TAR. / Start Finish Date**	: 21/11/2011 - 30/11/2011
SONDAJ KOTU / Elevation	: 91 m.	**KOORDİNAT / Coordinate (N-S) y**	: 4252430
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	**KOORDİNAT / Coordinate (E-W) x**	: 0512350

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Sample Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI Numb. of Blows 0-15 cm	15-30 cm	30-45 cm	N
1						
2	SPT-1	1.50 1.60	50/10			
3	SPT-2	3.00 3.45	7	8	13	21
4						
5	SPT-3	4.50 4.55	50/5			
6	SPT-4	6.00 6.02	50/2			
7						
8	SPT-5	7.50 7.53	50/3			
9	SPT-6	9.00 9.45	11	11	17	28
10						



JEOTEKNİK TANIMLAMA Geotechnical Description
0,00 - 4,00 **Yapay Dolgu Malzeme**
4,00 - 9,00 m. **AGLOMERA** Sarımsı gri renkli, orta dayanımlı, orta derecede ayrışmış, çok parçalı kırıklı
9.00 - 10.50 m. **Çok-Tamamen Ayrışmış Andezitik TÜF** Yeşilimsi kahve rengimsi gri renkli, zayıf çok zayıf dayanımlı, çok tamamen ayrışmış

DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
			13		
			15		
			44		
II	III	Cr			0
II	III	Cr	31		0
II	III	Cr	23		0
II	III	Cr	25		0
IV-V	IV-V	Cr	33		0

DAYANIMLILIK / Strength			**AYRIŞMA / Weathering**			**İNCE DANELİ / Fine Grained**			**İRİ DANELİ/Coarse Grained**		
I	DAYANIMLI	Strong	I	TAZE	Fresh	N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.	N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.	N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.	N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.	N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
						N : >30	SERT	Hard			

KAYA KALİTESİ TANIMI - RQD			**KIRIKLAR - 30 cm / Fractures**			**ORANLAR - Proportions**					
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)	% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)	% 5-15	AZ	Little	% 5-20	AZ	Little
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)	% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)	% 35 >	VE	And			
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)						

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample	LOGU YAPAN Logged By	KONTROL Checked By
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test	İSIM Name: Buket UCA	Lütfullah KANTAR
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test	IMZA Sign	

efol

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No : District		Sayfa No: 2/3
SONDAJ Borehole	No : **TSK-1**	
SONDÖR Driller	: Abidin KARATAŞ	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test					JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T. Core	KAROT%(SCR)/S.Cor	RQD %
			DARBE SAYISI				GRAFİK Graph								
			0 - 15 cm	15-30 cm	30-45 cm	N	10 20 30 40 50 60								
								Tanımlama sayfa 1/3'de							
11	SPT-7	10.50 10.57	50/7					**10.50-12.00 m.** **ANDEZİT** Kırmızımsı gri renkli, orta dayanımlı, orta derecede ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı		II	III	Cr	76		11
12										II	III	Cr	48		0
13								**12,00-15,00 m** **AGLOMERA** Sarımsı gri renkli, orta-orta zayıf dayanımlı, orta-çok ayrışmış, parçalı kırıklı çatlaklı		II-III	III-IV	Cr	82		0
14										II-III	III-IV	Cr	45		11
15										II-III	III-IV	Cr	66		0
16								**15,00-15,80 m.** **ANDEZİT** Kırmızımsı gri renkli, orta dayanımlı orta-çok ayrışmış, parçalı kırıklı çatlaklı		II	III-IV	Cr	63		10
17								**15.80-24.50 m.** **Çok-Tamamen Ayrışmış** **TÜF** Açık sarımsı kahve renkli, çok zayıf-zayıf dayanımlı, çok tamamen ayrışmış, yer yer killeşmiş		IV-V	IV-V	Cr	68		0
18										IV-V	IV-V	Cr	70		20
19										IV-V	IV-V	Cr	50		22
20										IV-V	IV-V	Cr	68		12
21										IV-V	IV-V	Cr	82		0
22										IV-V	IV-V	Cr	45		0
23										IV-V	IV-V	Cr	55		20
24										IV-V	IV-V	Cr	33		10

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
IMZA Sign		

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No : District		Sayfa No: 3/3
SONDAJ Borehole	No : **TSK-1**	
SONDÖR Driller	: Abidin KARATAŞ	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI Numb. of Blows: 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph: 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description
25								Tanımlama sayfa 2/3'de
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								**Kuyu Sonu 40,00 m.**

24.50-40.00 m
ÜST TORTUL SERİ

***24.50-30.00 m. Çamurtaşı-Kumtaşı Ardalanması**
Açık sarımsı kahverenkli, zayıf-çok zayıf dayanımlı, orta-çok ayrışmış, yer yer tamamen ayrışmış

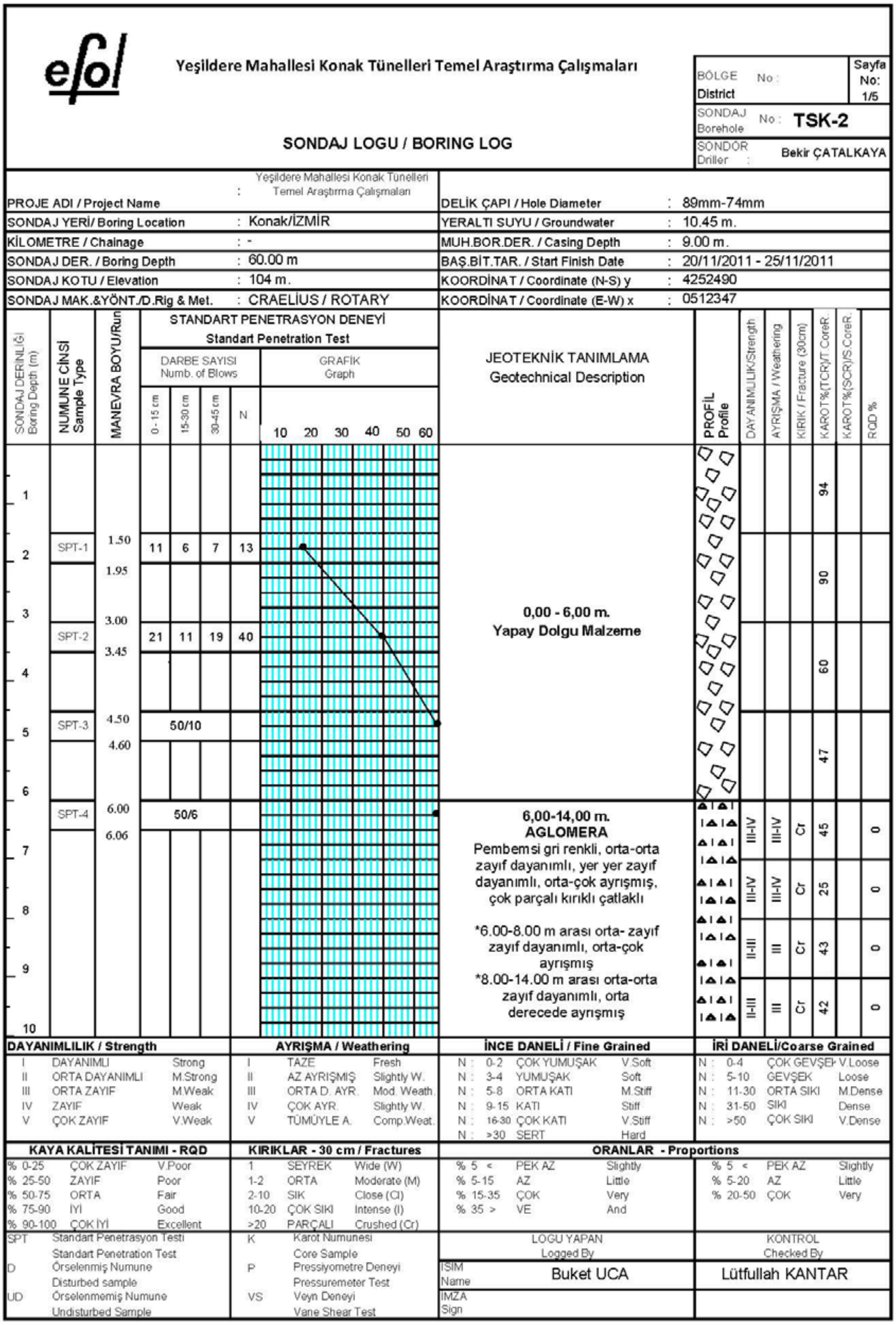
***30.00-31.50 m. Çakıltaşı**
Kahverengimsi gri renkli, 1-4 cm arasında değişen boyutlarda, köşeli-yarı yuvarlağımsı, kireçtaşı orijinli

***31.50-39.00 m. Kumtaşı**
Açık sarımsı kahve renkli, orta-çok ayrışmış, orta zayıf- zayıf dayanımlı, yer yer çok zayıf dayanımlı

***39.00-40.00 m. Kiltaşı**
Açık sarımsı kahverenkli, zayıf-çok zayıf dayanımlı, orta-çok ayrışmış

PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
	IV-V	III-IV	Cr	44		20
	IV-V	III-IV	Cr	43		0
	IV-V	IV-V	Cr	43		0
	IV-V	IV-V	Cr	40		0
	IV-V	IV-V	Cr	69		0
	IV-V	III-IV	Cr	32		0
	IV-V	III-IV	Cr	50		0
	III-IV	III-IV	Cr	50		10
	III-IV	III-IV	Cr	70		12
	III-IV	III-IV	I	93		60
	III-IV	III-IV	Cr	77		0
	III-IV	III-IV	Cr	61		10
	III-IV	III-IV	I	67		16
	III-IV	III-IV	Cl	70		37
	III-IV	III-IV	Cl	76		38
	IV-V	III-IV	Cr	88		10

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		



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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE District	No :	Sayfa No: 1/5
SONDAJ Borehole	No : **TSK-2**	
SONDÖR Driller :	**Bekir ÇATALKAYA**	

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	**DELİK ÇAPI / Hole Diameter**	: 89mm-74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	**YERALTI SUYU / Groundwater**	: 10.45 m.
KİLOMETRE / Chainage	: -	**MUH.BOR.DER. / Casing Depth**	: 9.00 m.
SONDAJ DER. / Boring Depth	: 60.00 m	**BAŞ.BİT.TAR. / Start Finish Date**	: 20/11/2011 - 25/11/2011
SONDAJ KOTU / Elevation	: 104 m.	**KOORDİNAT / Coordinate (N-S) y**	: 4252490
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	**KOORDİNAT / Coordinate (E-W) x**	: 0512347

STANDART PENETRASYON DENEYİ
Standart Penetration Test

NUMUNE CİNSİ Sample Type	MANEVRA BOYU/Run	DARBE SAYISI Numb. of Blows 0-15 cm	15-30 cm	30-45 cm	N
SPT-1	1.50 1.95	11	6	7	13
SPT-2	3.00 3.45	21	11	19	40
SPT-3	4.50 4.60	50/10			
SPT-4	6.00 6.06	50/6			

JEOTEKNİK TANIMLAMA
Geotechnical Description

0,00 - 6,00 m.
Yapay Dolgu Malzeme

6,00-14,00 m.
AGLOMERA
Pembemsi gri renkli, orta-orta zayıf dayanımlı, yer yer zayıf dayanımlı, orta-çok ayrışmış, çok parçalı kırıklı çatlaklı

*6.00-8.00 m arası orta- zayıf zayıf dayanımlı, orta-çok ayrışmış
*8.00-14.00 m arası orta-orta zayıf dayanımlı, orta derecede ayrışmış

DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
			94		
			90		
			60		
			47		
III-IV	III-IV	Cr	45		0
III-IV	III-IV	Cr	25		0
II-III	III	Cr	43		0
II-III	III	Cr	42		0

DAYANIMLILIK / Strength			**AYRIŞMA / Weathering**		
I	DAYANIMLI	Strong	I	TAZE	Fresh
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.

İNCE DANELİ / Fine Grained			**İRİ DANELİ/Coarse Grained**		
N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
N : >30	SERT	Hard			

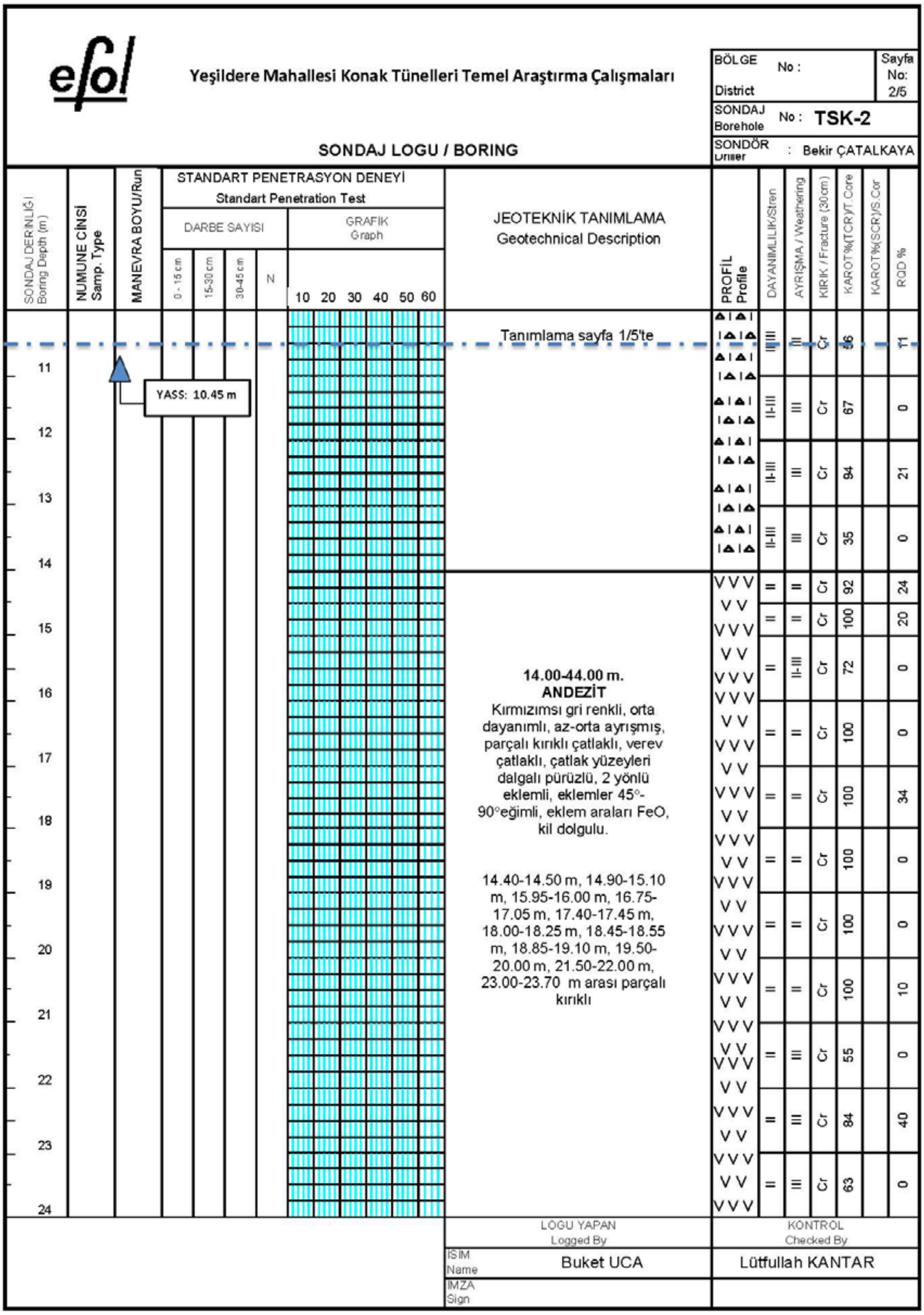
KAYA KALİTESİ TANIMI - RQD			**KIRIKLAR - 30 cm / Fractures**		
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)

ORANLAR - Proportions

% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 5-15	AZ	Little	% 5-20	AZ	Little
% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 35 >	VE	And			

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
IMZA Sign		



Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No : District
Sayfa No: 2/5
SONDAJ Borehole No : **TSK-2**
SONDÖR Driller : Bekir ÇATALKAYA

STANDART PENETRASYON DENEYİ
Standart Penetration Test

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30 cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.Cor	RQD %
								Tanımlama sayfa 1/5'te	▲I▲I	II-III	III	Cr	46		11
11		YASS: 10.45 m							▲I▲I	II-III	III	Cr	67		0
12									▲I▲I	II-III	III	Cr	94		21
13									▲I▲I	II-III	III	Cr	35		0
14								**14.00-44.00 m.** **ANDEZİT** Kırmızımsı gri renkli, orta dayanımlı, az-orta ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 45°-90°eğimli, eklem araları FeO, kil dolgulu. 14.40-14.50 m, 14.90-15.10 m, 15.95-16.00 m, 16.75-17.05 m, 17.40-17.45 m, 18.00-18.25 m, 18.45-18.55 m, 18.85-19.10 m, 19.50-20.00 m, 21.50-22.00 m, 23.00-23.70 m arası parçalı kırıklı	V V V	II	II	Cr	92		24
									V V V	II	II	Cr	100		20
15									V V V	II	II-III	Cr	72		0
16									V V V	II	II	Cr	100		0
17									V V V	II	II	Cr	100		34
18									V V V	II	II	Cr	100		0
19									V V V	II	II	Cr	100		0
20									V V V	II	II	Cr	100		10
21									V V V	II	III	Cr	55		0
22									V V V	II	III	Cr	84		40
23									V V V	II	III	Cr	63		0
24															

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :

Sayfa No: 3/5

SONDAJ Borehole No : **TSK-2**

SONDÖR Driller : **Bekir ÇATALKAYA**

SONDAJ DERİNLİĞİ Boring Depth (m) | **NUMUNE CİNSİ Samp. Type** | **MANEVRA BOYU/Run** | STANDART PENETRASYON DENEYİ Standart Penetration Test: DARBE SAYISI Numb. of Blows (0 - 15 cm, 15-30 cm, 30-45 cm, N); GRAFİK Graph (10 20 30 40 50 60) | JEOTEKNİK TANIMLAMA Geotechnical Description | **PROFİL Profile**

Depth: 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41

Tanımlama sayfa 2/5'te

*24.20-25.50 m, 25.60-25.90 m, 26.00-27.00 m, 27.30-27.85, 28.50-29.00 m, 29.10-31.50 m, 32.00-32.20 m, 32.40-32.65 m, 33.00-33.10 m, 33.85-34.00 m, 35.50-35.90 m, 36.00-36.80 m, 38.15-38.25 m, 40.10-40.70 m, 40.90-41.00 m, 42.00-42.50 m arası parçalı kırıklı

DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T Cor	KAROT%(SCR)/S Core	RQD %
II	III	Cr	59		12
II	III	Cr	73		0
II	III	Cr	70		0
II	III	Cr	100		0
II	III	Cr	60		0
II	III	Cr	54		0
II	III	Cr	55		0
II	III	Cr	70		14
II	III	Cr	85		0
II	III	Cr	60		0
II	III	I	66		29
II	III	I	53		18
II	III	Cr	61		0
II	III	I	69		21
II	II	Cl	100		62
II	II-III	Cr	66		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :	Sayfa No: 4/5
SONDAJ Borehole No :	**TSK-2**
SONDÖR Driller	Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0-15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
42								Tanımlama sayfa 2/5'te	V V	II	III	Cr	46		0
43									V V	II	III	Cr	65		0
44								**44,00-46,00 m.** **AGLOMERA** Açık pembemsi gri renkli, orta-orta zayıf dayanımlı, orta derecede ayrışmış, çok parçalı kırıklı çatlaklı *44.00-45.00 m, 45.20-45.50 m arası parçalı kırıklı	V V	II	III	Cr	52		13
45									▲I▲I	II-III	III	Cr	48		0
46									▲I▲I	II-III	III	Cr	65		12
47								**46.00-60.00 m.** **Çok-Tamamen Ayrışmış TÜF** Yeşilimsi kahve rengimsi gri renkli, çok zayıf dayanımlı, çok tamamen ayrışmış, yer yer killeşmiş	II II	IV-V	IV-V	Cr	73		0
48 49									II II	IV-V	IV-V	Cr	59		0
50									II II	IV-V	IV-V	Cr	77		26
51									II II	IV-V	IV-V	Cr	62		0
52									II II	IV-V	IV-V	Cr	100		11
53									II II	IV-V	IV-V	Cr	100		0
54									II II	IV-V	IV-V	Cr	100		12
55									II II	IV-V	IV-V	Cr	100		35
56									II II	IV-V	IV-V	Cr	100		0
57 58									II II	IV-V	IV-V	Cr	100		23
									II II	IV-V	IV-V	Cr	100		13

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :
Sayfa No:	5/5
SONDAJ Borehole	No : **TSK-2**
SONDÖR Driller	**Bekir ÇATALKAYA**

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
59								Tanımlama sayfa 4/5'te		IV-V	III-IV	Cr	100		0
60										IV-V	III-IV	Cr	100		0
61								**Kuyu Sonu 60,00 m.**							
62															
63															
64															
65															
66															
67															
68															
69															
70															
71															
72															
73															
74															
75															

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 1/4
SONDAJ Borehole	No : **TSK-3**	
SONDÖR Driller :	Abidin KARATAŞ	

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	DELİK ÇAPI / Hole Diameter	: 89mm-74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	YERALTI SUYU / Groundwater	: 10.80 m.
KİLOMETRE / Chainage	: -	MUH.BOR.DER. / Casing Depth	: 15.00 m.
SONDAJ DER. / Boring Depth	: 50.00 m	BAŞ.BİT.TAR. / Start Finish Date	: 11/11/2011 - 20/11/2011
SONDAJ KOTU / Elevation	: 104 m.	KOORDİNAT / Coordinate (N-S) y	: 4252468
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	KOORDİNAT / Coordinate (E-W) x	: 0512359

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
1															
2	SPT-1	1.50 1.55	50/5				●								
3	SPT-2	3.00 3.05	50/5				●								
4															
5	SPT-3	4.50 4.55	50/5				●	**0,00 - 12,00** **Yapay Dolgu Malzeme**							
6	SPT-4	6.00 6.10	50/10				●								
7															
8	SPT-5	7.50 7.57	50/7				●								
9	SPT-6	9.00 9.05	50/5				●								
10															

DAYANIMLILIK / Strength			AYRIŞMA / Weathering			İNCE DANELİ / Fine Grained			İRİ DANELİ/Coarse Grained		
I	DAYANIMLI	Strong	I	TAZE	Fresh	N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.	N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.	N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.	N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.	N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
						N : >30	SERT	Hard			

KAYA KALİTESİ TANIMI - RQD			KIRIKLAR - 30 cm / Fractures			ORANLAR - Proportions					
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)	% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)	% 5-15	AZ	Little	% 5-20	AZ	Little
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)	% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)	% 35 >	VE	And			
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)						

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample	LOGU YAPAN Logged By	KONTROL Checked By
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test	İSİM Name: Buket UCA	Lütfullah KANTAR
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test	İMZA Sign	

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE / District No :

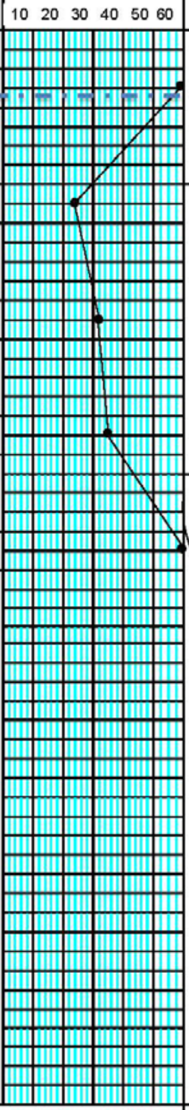
Sayfa No: 2/4

SONDAJ / Borehole No : **TSK-3**

SONDÖR / Driller : Abidin KARATAŞ

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N
11	SPT-7	10.50 10.60	50/10			
12	SPT-8	12.00 12.45	9	11	13	24
14	SPT-9	13.50 13.95	11	15	17	32
15	SPT-10	15.00 15.45	13	16	19	35
17	SPT-11	16.50 16.51	50/1			

GRAFİK Graph



YASS: 10.80 m

JEOTEKNİK TANIMLAMA
Geotechnical Description

Tanımlama sayfa 1/4'te

12.00-15.70 m.
Çok Tamamen Ayrışmış TÜF
Kırmızımsı kahve renkli-kahve renkli, çok tamamen ayrışmış, zayıf-çok zayıf dayanımlı

15.70-16.20 m AGLOMERA
Açık pembemsi gri renkli, orta-orta zayıf dayanımlı, orta derecede ayrışmış, çok parçalı kırıklı

16.20-30.50 m.
ANDEZİT
Kırmızımsı gri renkli, orta dayanımlı, orta derecede ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 30°-60°eğimli, eklem araları kil dolgulu, yer yer FeO alterasyonu gözlenmektedir.

DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.Cor	RQD %
II-III	III	Cr	78		0
II	III	Cr	42		0
II	III	Cr	53		12
II	III	Cr	85		18
II	II	I	87		37
II	III	Cl	65		0
II	III	Cl	92		24

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

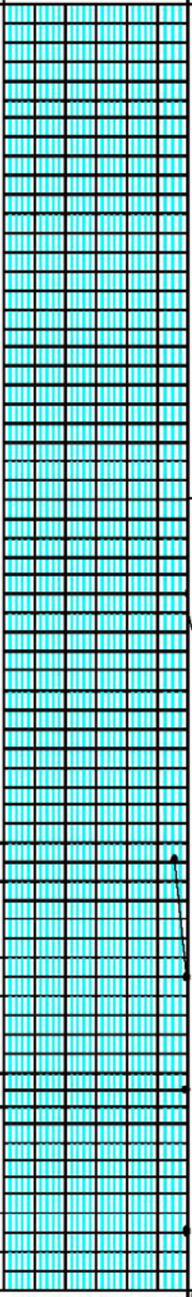
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE / District	No :	Sayfa No: 3/4
SONDAJ / Borehole	No : **TSK-3**	
SONDÖR / Driller	: **Abidin KARATAŞ**	

STANDART PENETRASYON DENEYİ / Standart Penetration Test

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N
35	SPT-12	35.00 35.45	12	23	34	55
36.5	SPT-13	36.50 36.60	50/10			
38	SPT-14	38.00 38.06	50/6			
40	SPT-15	40.00 40.13	50/13			



JEOTEKNİK TANIMLAMA
Geotechnical Description

Tanımlama sayfa 2/4'te

30.50-32.00 m
Çok-Tamamen Ayrışmış
TÜF
Beyazımsı-kahve renkli,zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış

32.00-50.00 m.
ÜST TORTUL SERİ

***32.00-39.00 m. Kumtaşı**
Yeşilimsi kahve renkli, zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış, 1-3 cm köşeli çakıllı

*38.00-39.00 m arası karbonat seviyeler içeren kumtaşı

DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T Cor	KAROT%(SCR)/S Core	RQD %
II	III	Cl	86		45
II	III	Cr	60		11
II	III	Cr	69		26
II	III	I	72		20
III-IV	III-IV	Cr	60		0
IV-V	IV-V	Cr	30		0
IV-V	IV-V	Cr	26		0
IV-V	IV-V	Cr	46		0
IV-V	IV-V	Cr	68		0
IV-V	IV-V	Cr	86		0
IV-V	IV-V	Cr	26		0
IV-V	IV-V	Cr	38		0
IV-V	IV-V	Cr	32		0
IV-V	IV-V	Cr	23		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

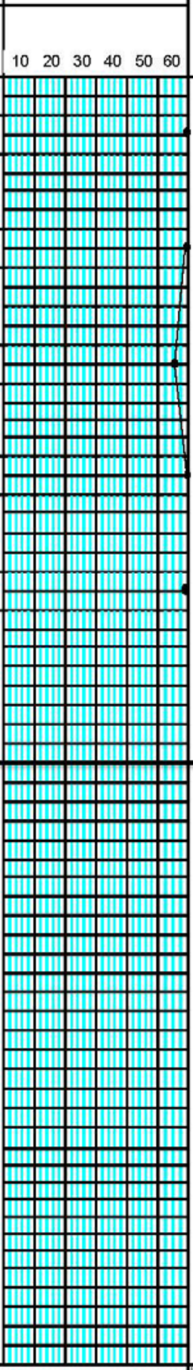
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

BÖLGE District	No :	Sayfa No: 4/4
SONDAJ Borehole	No : **TSK-3**	
SONDÖR Driller	Abidin KARATAŞ	

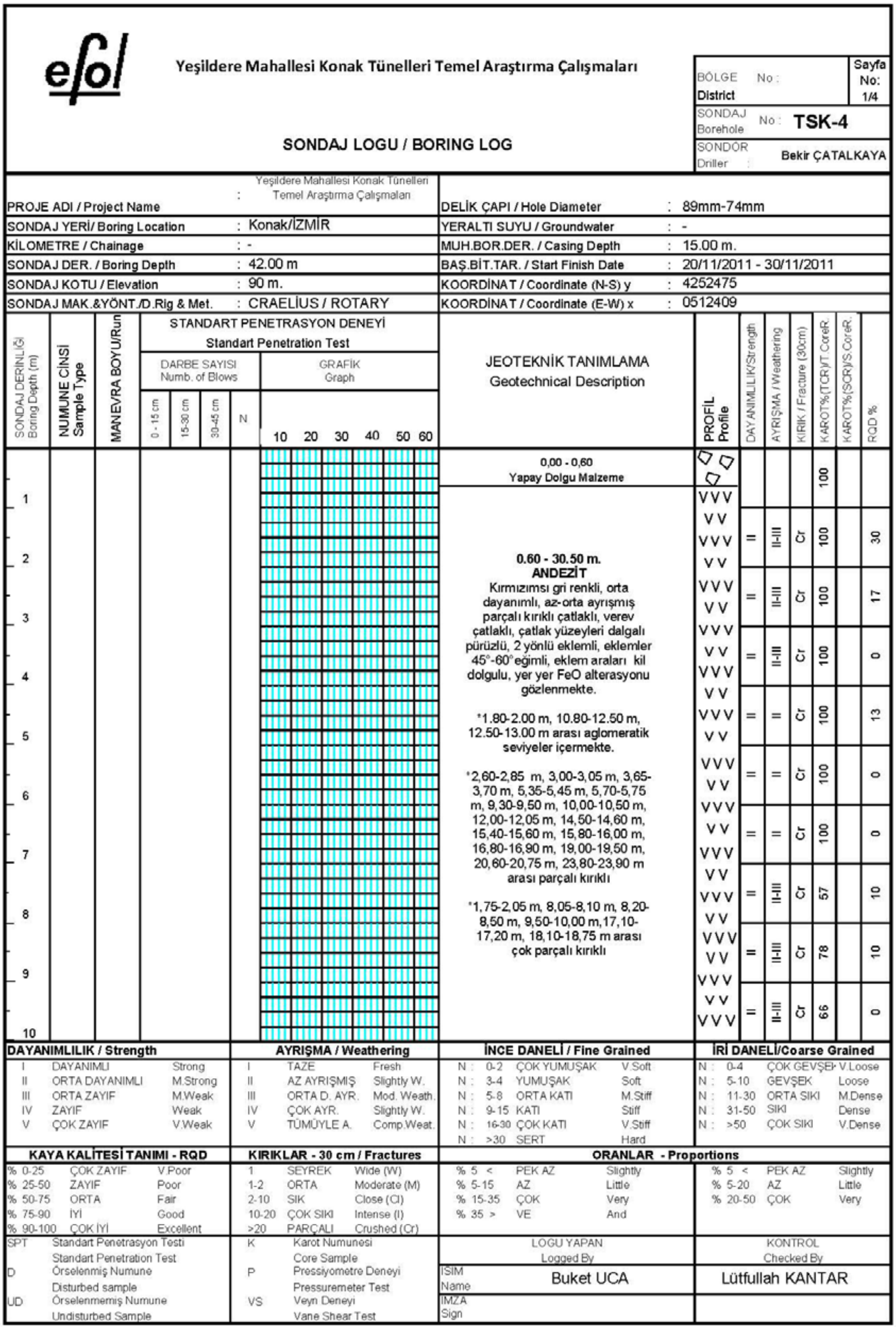
SONDAJ LOGU / BORING

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test – DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
							Tanımlama sayfa 3/4'te							
42	SPT-16	40.50 40.60	50/10											
43							***39.00-43.00 m Çamurtaşı** Kırmızımsı kahverenkli, zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış		IV-V	IV-V	Cr	31		0
	SPT-17	43.00 43.45	30	41	55	96								
44							***43.00-44.50 m Silttaşı** Yeşilimsi-kırmızımsı kahve renkli, zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış		IV-V	IV-V	Cr	46		0
									IV-V	IV-V	Cr	50		0
45	SPT-18	44.50 44.95	17	24	32	56								
46							***44.50-47.50 m Çamurtaşı** Koyu sarımsı-yeşilimsi kahve renkli, zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış		IV-V	IV-V	Cr	48		0
	SPT-19	46.00 46.45	27	37	45	82								
47							***47.50-50.00 m Çamurtaşı** Koyu sarımsı kahverenkli, zayıf-çok zayıf dayanımlı, çok-tamamen ayrışmış		IV-V	IV-V	Cr	26		0
48	SPT-20	47.50 47.57	50/7											
									IV-V	IV-V	Cr	46		0
49									IV-V	IV-V	Cr	36		0
50														
51							**Kuyu Sonu 50,00 m.**							
52														
53														
54														
55														
56														
57														
58														

GRAFİK Graph



İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		



Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE No : District	Sayfa No: 1/4
SONDAJ Borehole No :	**TSK-4**
SONDÖR Driller :	**Bekir ÇATALKAYA**

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	**DELİK ÇAPI / Hole Diameter**	: 89mm-74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	**YERALTI SUYU / Groundwater**	: -
KİLOMETRE / Chainage	: -	**MUH.BOR.DER. / Casing Depth**	: 15.00 m.
SONDAJ DER. / Boring Depth	: 42.00 m	**BAŞ.BİT.TAR. / Start Finish Date**	: 20/11/2011 - 30/11/2011
SONDAJ KOTU / Elevation	: 90 m.	**KOORDİNAT / Coordinate (N-S) y**	: 4252475
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	**KOORDİNAT / Coordinate (E-W) x**	: 0512409

SONDAJ DERİNLİĞİ Boring Depth (m) | **NUMUNE CİNSİ Sample Type** | **MANEVRA BOYU/Run**

STANDART PENETRASYON DENEYİ
Standart Penetration Test
DARBE SAYISI Numb. of Blows: 0 - 15 cm | 15-30 cm | 30-45 cm | N
GRAFİK Graph: 10 20 30 40 50 60

JEOTEKNİK TANIMLAMA
Geotechnical Description

0,00 - 0,60
Yapay Dolgu Malzeme

0.60 - 30.50 m.
ANDEZİT
Kırmızımsı gri renkli, orta dayanımlı, az-orta ayrışmış parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 45°-60°eğimli, eklem araları kil dolgulu, yer yer FeO alterasyonu gözlenmekte.

***1.80-2.00 m, 10.80-12.50 m, 12.50-13.00 m arası aglomeratik seviyeler içermekte.**

***2,60-2,85 m, 3,00-3,05 m, 3,65-3,70 m, 5,35-5,45 m, 5,70-5,75 m, 9,30-9,50 m, 10,00-10,50 m, 12,00-12,05 m, 14,50-14,60 m, 15,40-15,60 m, 15,80-16,00 m, 16,80-16,90 m, 19,00-19,50 m, 20,60-20,75 m, 23,80-23,90 m arası parçalı kırıklı**

***1,75-2,05 m, 8,05-8,10 m, 8,20-8,50 m, 9,50-10,00 m,17,10-17,20 m, 18,10-18,75 m arası çok parçalı kırıklı**

Boring Depth (m): 1 2 3 4 5 6 7 8 9 10

PROFİL Profile	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
◇ ◇ ◇				100		
VVV VV VVV	II	II-III	Cr	100		30
VV VVV VV	II	II-III	Cr	100		17
VVV VV VVV	II	II-III	Cr	100		0
VV VVV VV	II	II	Cr	100		13
VVV VV	II	II	Cr	100		0
VVV VV VVV	II	II	Cr	100		0
VV VVV VV	II	II-III	Cr	57		10
VVV VV VVV	II	II-III	Cr	78		10
VV VVV	II	II-III	Cr	66		0

DAYANIMLILIK / Strength		
I	DAYANIMLI	Strong
II	ORTA DAYANIMLI	M.Strong
III	ORTA ZAYIF	M.Weak
IV	ZAYIF	Weak
V	ÇOK ZAYIF	V.Weak

AYRIŞMA / Weathering		
I	TAZE	Fresh
II	AZ AYRIŞMIŞ	Slightly W.
III	ORTA D. AYR.	Mod. Weath.
IV	ÇOK AYR.	Slightly W.
V	TÜMÜYLE A.	Comp.Weat.

İNCE DANELİ / Fine Grained		
N : 0-2	ÇOK YUMUŞAK	V.Soft
N : 3-4	YUMUŞAK	Soft
N : 5-8	ORTA KATI	M.Stiff
N : 9-15	KATI	Stiff
N : 16-30	ÇOK KATI	V.Stiff
N : >30	SERT	Hard

İRİ DANELİ/Coarse Grained		
N : 0-4	ÇOK GEVŞEK	V.Loose
N : 5-10	GEVŞEK	Loose
N : 11-30	ORTA SIKI	M.Dense
N : 31-50	SIKI	Dense
N : >50	ÇOK SIKI	V.Dense

KAYA KALİTESİ TANIMI - RQD		
% 0-25	ÇOK ZAYIF	V.Poor
% 25-50	ZAYIF	Poor
% 50-75	ORTA	Fair
% 75-90	İYİ	Good
% 90-100	ÇOK İYİ	Excellent

KIRIKLAR - 30 cm / Fractures		
1	SEYREK	Wide (W)
1-2	ORTA	Moderate (M)
2-10	SIK	Close (Cl)
10-20	ÇOK SIKI	Intense (I)
>20	PARÇALI	Crushed (Cr)

ORANLAR - Proportions

% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 5-15	AZ	Little	% 5-20	AZ	Little
% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 35 >	VE	And			

SPT	Standart Penetrasyon Testi Standart Penetration Test
D	Örselenmiş Numune Disturbed sample
UD	Örselenmemiş Numune Undisturbed Sample
K	Karot Numunesi Core Sample
P	Pressiyometre Deneyi Pressuremeter Test
VS	Veyn Deneyi Vane Shear Test

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

efol

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

BÖLGE District	No :	Sayfa No: 2/4
SONDAJ Borehole	No : **TSK-4**	
SONDÖR Driller	: Bekir ÇATALKAYA	

SONDAJ LOGU / BORING

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.Cor	RQD %
11								Tanımlama sayfa 1/4'de	V V V V V V V V	II	II-III	I	80		30
12									V V V V V V V	II	II-III	Cr	95		0
13									V V V V V	II	II-III	Cr	80		11
14									V V V V V V V V	II	II-III	Cr	76		0
15									V V V V V V V	II	II-III	Cr	70		0
16									V V V V V V V V	II	II-III	Cr	72		10
17									V V V V V	II	II-III	Cr	76		25
18									V V V V V V V	II	II-III	Cr	52		0
19									V V V V V V V V	II	II-III	Cr	49		0
20									V V V V V V V	II	II-III	Cr	79		0
21									V V V V V	II	II-III	Cr	98		0
22									V V V V V V V V	II	II-III	Cr	90		36
23									V V V V V V V	II	II-III	Cr	84		20
24									V V V V V V V V	II	II	Cr	100		0

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

efol

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE / District	No :
Sayfa No:	3/4
SONDAJ / Borehole	No : **TSK-4**
SONDÖR / Driller	: **Bekir ÇATALKAYA**

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
25								Tanımlama sayfa 1/4'de	II	II	I	100		47
26									II	II	Cl	100		63
27									II	II	Cl	100		50
28									II	II	Cr	100		22
29									II	II	Cl	100		61
30									II	II	I	100		15
31								**30.50-34.50 m.** **Çok-Tamamen ayrışmış** **ANDEZİT** Kırmızımsı kahverenkli, zayıf-çok zayıf dayanımlı, çok - tamamen ayrışmış	III-IV	III-IV	Cr	76		0
32									IV-V	IV-V	Cr	55		0
33									IV-V	IV-V	Cr	70		0
34									IV-V	IV-V	Cr	100		0
35								**34,50-35,70 m** **Orta-Çok Ayrışmış** **Andezitik TÜF** Sarımsı beyaz renkli, zayıf dayanımlı, orta-çok ayrışmış	IV-V	IV-V	Cr	100		0
36									IV	III-IV	Cr	100		0
37								**35.70-41.00 m.** **ÜST TORTUL SERİ** ***35,70-36,50 m Kumtaşı** Koyu kırmızımsı kahverenkli, zayıf-çok zayıf dayanımlı, orta-çok ayrışmış ***36,50-36,80 m Çakıltaşı** Koyu kırmızımsı kahve renkli, çok ayrışmış, çok zayıf dayanımlı ***36,80-37,40 m Silttaşı** Açık sarımsı kahverenkli, zayıf dayanımlı, orta-çok ayrışmış ***37,40-38,50 m Çakıltaşı** Grimsi kahve renkli, karbonatlı çakıltaşı, zayıf dayanımlı, orta-çok ayrışmış ***38,50-41,00 m Kiltaşı** Koyu sarımsı gri renkli, zayıf dayanımlı, orta-çok ayrışmış	IV-V	III-IV	Cr	100		21
38									IV	III-IV	Cr	48		0
39									IV	III-IV	Cr	52		0
40									IV	III-IV	Cr	100		0
41									IV	III-IV	Cr	100		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

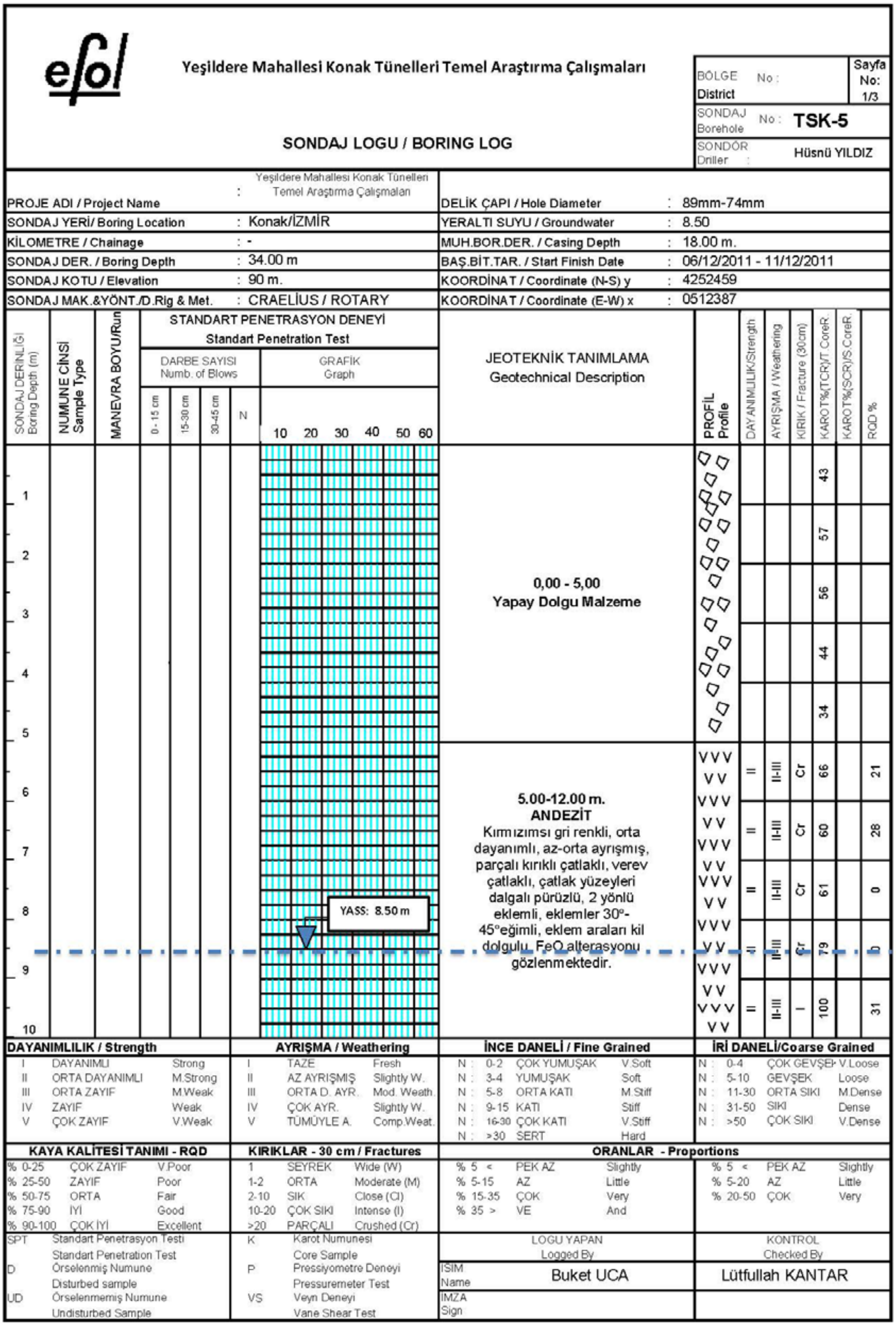
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :	Sayfa No: 4/4
SONDAJ Borehole No :	**TSK-4**
SONDÖR Driller	Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test					JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
			DARBE SAYISI				GRAFİK Graph								
			0 - 15 cm	15-30 cm	30-45 cm	N	10 20 30 40 50 60								
42								**41,00-42,00 m** **TÜF** Koyu sarımsı beyaz renkli, orta zayıf-zayıf dayanımlı, orta-çok ayrışmış		III-IV	III-IV	Cr	100		35
43								**Kuyu Sonu 42,00 m.**							
44															
45															
46															
47															
48															
49															
50															
51															
52															
53															
54															
55															
56															
57															
58															

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		



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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE District	No :	Sayfa No: 1/3
SONDAJ Borehole	No : **TSK-5**	
SONDÖR Driller :	Hüsnü YILDIZ	

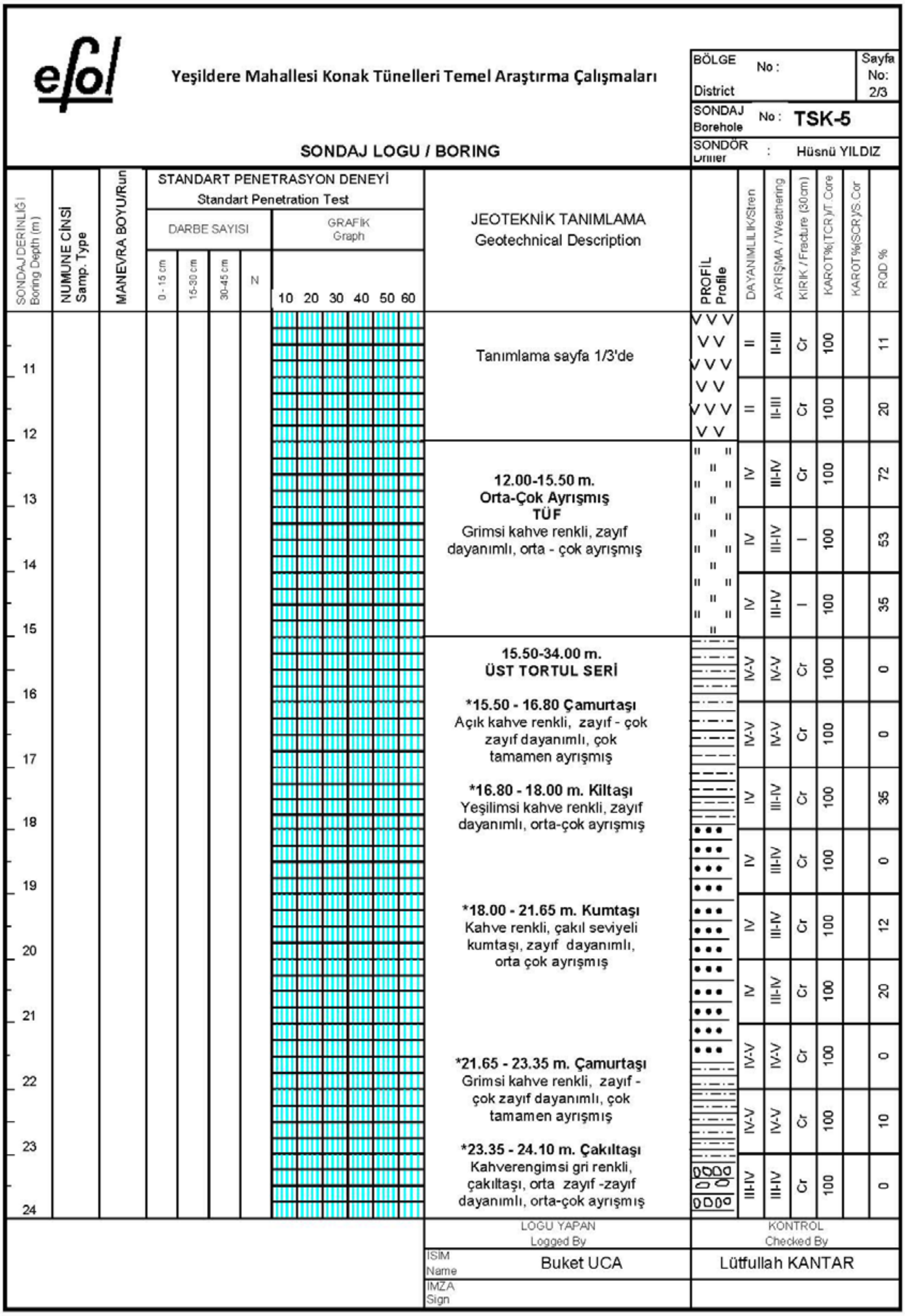
PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	**DELİK ÇAPI / Hole Diameter**	: 89mm-74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	**YERALTI SUYU / Groundwater**	: 8.50
KİLOMETRE / Chainage	: -	**MUH.BOR.DER. / Casing Depth**	: 18.00 m.
SONDAJ DER. / Boring Depth	: 34.00 m	**BAŞ.BİT.TAR. / Start Finish Date**	: 06/12/2011 - 11/12/2011
SONDAJ KOTU / Elevation	: 90 m.	**KOORDİNAT / Coordinate (N-S) y**	: 4252459
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	**KOORDİNAT / Coordinate (E-W) x**	: 0512387

SONDAJ DERİNLİĞİ Boring Depth (m)	**NUMUNE CİNSİ Sample Type**	**MANEVRA BOYU/Run**	**STANDART PENETRASYON DENEYİ Standart Penetration Test** DARBE SAYISI Numb. of Blows 0-15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	**PROFİL Profile**	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
1								**0,00 - 5,00** **Yapay Dolgu Malzeme**					43		
2													57		
3													56		
4													44		
5													34		
6								**5.00-12.00 m.** **ANDEZİT** Kırmızımsı gri renkli, orta dayanımlı, az-orta ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 30°-45°eğimli, eklem araları kil dolgulu, FeO alterasyonu gözlenmektedir.	VVV	II	II-III	Cr	66		21
7									VVV	II	II-III	Cr	60		28
8									VVV	II	II-III	Cr	61		0
9							YASS: 8.50 m		VVV	II	II-III	Cr	79		0
10									VVV	II	II-III	I	100		31

DAYANIMLILIK / Strength			**AYRIŞMA / Weathering**			**İNCE DANELİ / Fine Grained**			**İRİ DANELİ/Coarse Grained**		
I	DAYANIMLI	Strong	I	TAZE	Fresh	N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.	N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.	N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.	N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.	N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
						N : >30	SERT	Hard			

KAYA KALİTESİ TANIMI - RQD			**KIRIKLAR - 30 cm / Fractures**			**ORANLAR - Proportions**					
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)	% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)	% 5-15	AZ	Little	% 5-20	AZ	Little
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)	% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)	% 35 >	VE	And			
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)						

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample	LOGU YAPAN Logged By	KONTROL Checked By
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test	İSİM Name: Buket UCA	Lütfullah KANTAR
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test	IMZA Sign	



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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE / District No :
Sayfa No: 2/3
SONDAJ / Borehole No : **TSK-5**
SONDÖR / Driller : Hüsnü YILDIZ

JEOTEKNİK TANIMLAMA
Geotechnical Description

Tanımlama sayfa 1/3'de

12.00-15.50 m.
Orta-Çok Ayrışmış
TÜF
Grimsi kahve renkli, zayıf dayanımlı, orta - çok ayrışmış

15.50-34.00 m.
ÜST TORTUL SERİ

***15.50 - 16.80 Çamurtaşı**
Açık kahve renkli, zayıf - çok zayıf dayanımlı, çok tamamen ayrışmış

***16.80 - 18.00 m. Kiltaşı**
Yeşilimsi kahve renkli, zayıf dayanımlı, orta-çok ayrışmış

***18.00 - 21.65 m. Kumtaşı**
Kahve renkli, çakıl seviyeli kumtaşı, zayıf dayanımlı, orta çok ayrışmış

***21.65 - 23.35 m. Çamurtaşı**
Grimsi kahve renkli, zayıf - çok zayıf dayanımlı, çok tamamen ayrışmış

***23.35 - 24.10 m. Çakıltaşı**
Kahverengimsi gri renkli, çakıltaşı, orta zayıf -zayıf dayanımlı, orta-çok ayrışmış

DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.Cor	RQD %
II	II-III	Cr	100		11
II	II-III	Cr	100		20
IV	III-IV	Cr	100		72
IV	III-IV	I	100		53
IV	III-IV	I	100		35
IV-V	IV-V	Cr	100		0
IV-V	IV-V	Cr	100		0
IV	III-IV	Cr	100		35
IV	III-IV	Cr	100		0
IV	III-IV	Cr	100		12
IV	III-IV	Cr	100		20
IV-V	IV-V	Cr	100		0
IV-V	IV-V	Cr	100		10
III-IV	III-IV	Cr	100		0

	LOGU YAPAN / Logged By	KONTROL / Checked By
ISIM / Name	Buket UCA	Lütfullah KANTAR
IMZA / Sign		

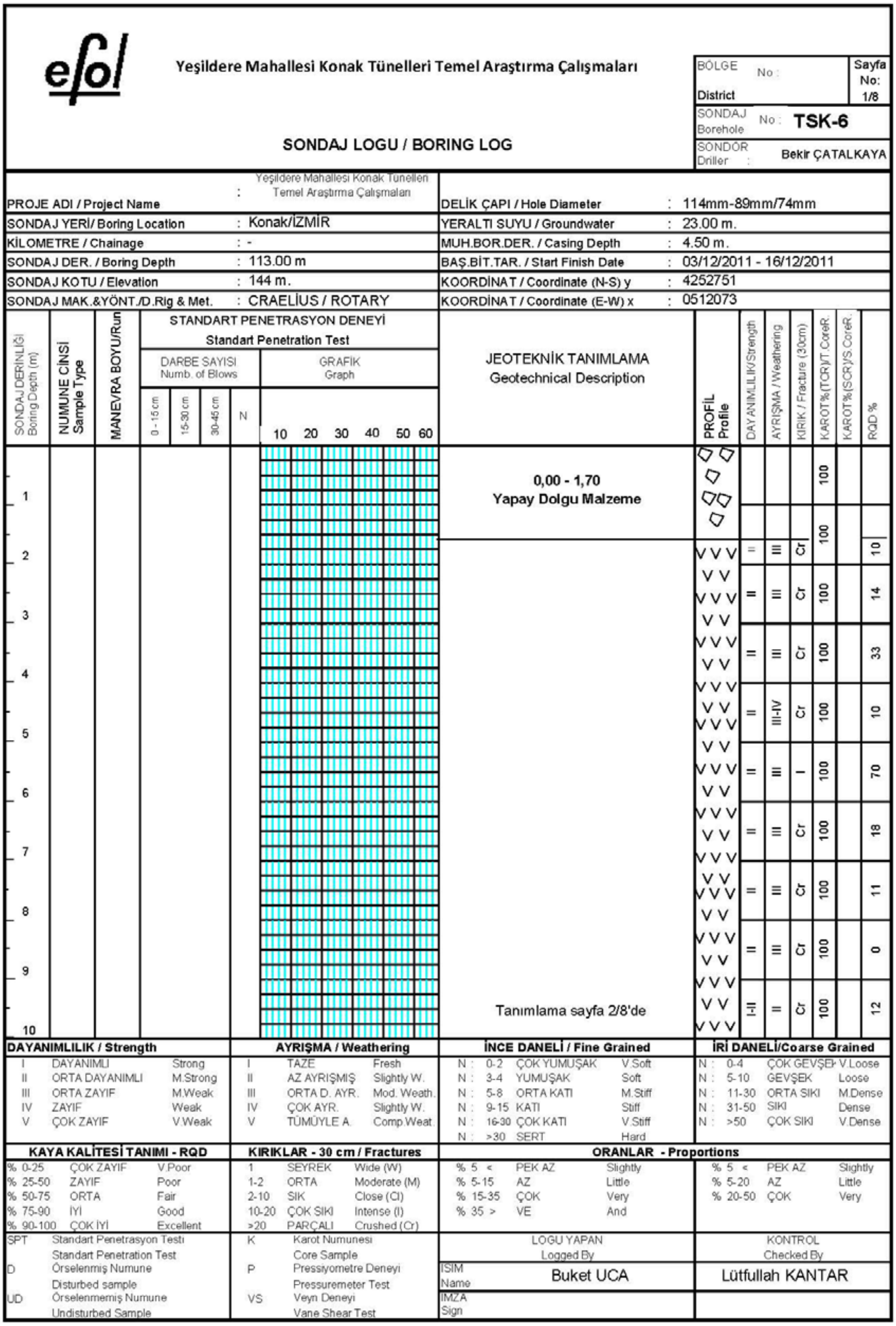
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :
Sayfa No:	3/3
SONDAJ Borehole	No : **TSK-5**
SONDÖR Driller	: Hüsnü YILDIZ

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 6	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL	DAYANIMLILIK/Streng	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
25								Tanımlama sayfa 2/3'de		IV-V	IV-V	Cr	82		0
26										IV-V	IV-V	Cr	82		0
27								***24.10 - 30.90 m. Çamurtaşı** Açık kahve renkli, zayıf - çok zayıf dayanımlı, çok tamamen ayrışmış		IV-V	IV-V	Cr	75		0
28										IV-V	IV-V	Cr	78		13
29										IV-V	IV-V	Cr	84		0
30										IV-V	IV-V	Cr	100		35
31								***30.90 - 33.20 m. Kumtaşı** Kahve renkli, siltli kum, orta zayıf -zayıf dayanımlı, orta-çok ayrışmış		IV-V	IV-V	Cr	75		45
32								**33.20 - 34.00 m. Silttaşı** Yeşilimsi kahve renkli, zayıf dayanımlı, orta-çok ayrışmış		III-IV	III-IV	Cr	97		40
33										III-IV	III-IV	Cr	77		0
34										IV	III-IV	I	67		0
35								**Kuyu Sonu 34,00 m.**							
36															
37															
38															
39															
40															

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		



Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE No: District	Sayfa No: 1/8
SONDAJ Borehole No:	**TSK-6**
SONDÖR Driller:	Bekir ÇATALKAYA

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	DELİK ÇAPI / Hole Diameter	: 114mm-89mm/74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	YERALTI SUYU / Groundwater	: 23.00 m.
KİLOMETRE / Chainage	: -	MUH.BOR.DER. / Casing Depth	: 4.50 m.
SONDAJ DER. / Boring Depth	: 113.00 m	BAŞ.BİT.TAR. / Start Finish Date	: 03/12/2011 - 16/12/2011
SONDAJ KOTU / Elevation	: 144 m.	KOORDİNAT / Coordinate (N-S) y	: 4252751
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	KOORDİNAT / Coordinate (E-W) x	: 0512073

SONDAJ DERİNLİĞİ Boring Depth (m) | NUMUNE CİNSİ Sample Type | MANEVRA BOYU/Run | STANDART PENETRASYON DENEYİ Standart Penetration Test: DARBE SAYISI Numb. of Blows (0 - 15 cm, 15-30 cm, 30-45 cm, N); GRAFİK Graph (10 20 30 40 50 60) | JEOTEKNİK TANIMLAMA Geotechnical Description | PROFİL Profile

Depth: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

0,00 - 1,70
Yapay Dolgu Malzeme

Tanımlama sayfa 2/8'de

DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
			100		
			100		
II	III	Cr			10
II	III	Cr	100		14
II	III	Cr	100		33
II	III-IV	Cr	100		10
II	III	I	100		70
II	III	Cr	100		18
II	III	Cr	100		11
II	III	Cr	100		0
I-II	II	Cr	100		12

DAYANIMLILIK / Strength

I	DAYANIMLI	Strong
II	ORTA DAYANIMLI	M.Strong
III	ORTA ZAYIF	M.Weak
IV	ZAYIF	Weak
V	ÇOK ZAYIF	V.Weak

AYRIŞMA / Weathering

I	TAZE	Fresh
II	AZ AYRIŞMIŞ	Slightly W.
III	ORTA D. AYR.	Mod. Weath.
IV	ÇOK AYR.	Slightly W.
V	TÜMÜYLE A.	Comp.Weat.

İNCE DANELİ / Fine Grained

N :	0-2	ÇOK YUMUŞAK	V.Soft
N :	3-4	YUMUŞAK	Soft
N :	5-8	ORTA KATI	M.Stiff
N :	9-15	KATI	Stiff
N :	16-30	ÇOK KATI	V.Stiff
N :	>30	SERT	Hard

İRİ DANELİ/Coarse Grained

N :	0-4	ÇOK GEVŞEK	V.Loose
N :	5-10	GEVŞEK	Loose
N :	11-30	ORTA SIKI	M.Dense
N :	31-50	SIKI	Dense
N :	>50	ÇOK SIKI	V.Dense

KAYA KALİTESİ TANIMI - RQD

% 0-25	ÇOK ZAYIF	V.Poor
% 25-50	ZAYIF	Poor
% 50-75	ORTA	Fair
% 75-90	İYİ	Good
% 90-100	ÇOK İYİ	Excellent

KIRIKLAR - 30 cm / Fractures

1	SEYREK	Wide (W)
1-2	ORTA	Moderate (M)
2-10	SIK	Close (Cl)
10-20	ÇOK SIKI	Intense (I)
>20	PARÇALI	Crushed (Cr)

ORANLAR - Proportions

% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 5-15	AZ	Little	% 5-20	AZ	Little
% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 35 >	VE	And			

SPT	Standart Penetrasyon Testi Standart Penetration Test
D	Örselenmiş Numune Disturbed sample
UD	Örselenmemiş Numune Undisturbed Sample
K	Karot Numunesi Core Sample
P	Pressiyometre Deneyi Pressuremeter Test
VS	Veyn Deneyi Vane Shear Test

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :

Sayfa No: 2/8

SONDAJ Borehole No : **TSK-6**

SONDÖR Driller : Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60
11 12 13 14 15 16 17 18 19 20 21 22 23 24		YASS: 23.00 m					

JEOTEKNİK TANIMLAMA
Geotechnical Description

1.70 - 113.00 m.
ANDEZİT
Kırmızımsı gri-gri renkli, orta-iyi dayanımlı, az-orta derecede ayrışmış, yer yer çok ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 30°-90°eğimli, eklem araları kil dolgulu

*1.70-9.00 m arası kırmızımsı-gri renkli, orta dayanımlı, orta-çok ayrışmış

*9.00-19.70 m arası gri renkli, orta-iyi dayanımlı, az ayrışmış

*19.70-24.20 m arası kırmızımsı kahve renkli, orta-iyi dayanımlı, orta derecede ayrışmış

*2.00-2.05 m, 2.60-2.70 m, 3.70-3.95 m, 6.35-6.65 , 7.15-7.25 m, 7.90-8.00 m, 8.25-8.30 m, 8.70-9.00 m, 9.15-9.25 m, 10.95-11.00 m, 18.40-18.50 m, 19.85-20.00 m, 20.40-20.50 m, 23.20-23.25 m arası parçalı kırıklı

*3.00-3.20 m, 4.35-4.55 m, 12.00-12.10 m, 12.45-12.60 m, 13.90-14.00 m, 15.80-15.90 m, 15.30-16.00 m, 17.53-17.60 m, 18.90-19.00 m, 20.25-20.40 m arası çok parçalı kırıklı

PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)T.Core	KAROT%(SCR)S.Cor	RQD %
V V V V V	I-II	II	Cr	100		15
V V V V V	I-II	II	I	100		20
V V V V V	II	II	Cr	100		12
V V V V V	II	II	Cr	100		40
V V V V V	II	II	Cr	100		26
V V V V V	II	II-III	Cr	100		0
V V V V V	I-II	II-III	Cl	100		54
V V V V V	I-II	II-III	Cr	100		28
V V V V V	I-II	II-III	Cr	100		22
V V V V V	I-II	II-III	Cr	100		12
V V V V V	II	III	Cr	100		42
V V V V V	I-II	III	I	100		48
V V V V V	I-II	III	Cr	100		12
V V V V V	I-II	III	Cr	100		10

LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name: Buket UCA	Lütfullah KANTAR
İMZA Sign	

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No : District		Sayfa No: 3/8
SONDAJ Borehole	No : **TSK-6**	
SONDÖR Driller	: Bekir ÇATALKAYA	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
25								Tanımlama sayfa 2/8' de	V V V V V V V V	I-II	III	Cr	100		27
26									V V V V V	I-II	III	Cr	100		20
27									V V V V V V V	I-II	II	I	100		17
28									V V V V V V V V	I-II	II	I	100		15
29								*24.20-26.00 m arası kırmızımsı gri-gri renkli, orta-iyi dayanımlı, orta derecede ayrışmış	V V V V V V V	I-II	II	Cr	100		30
30									V V V V V V V V	I-II	II	m	100		83
31								*26.00-51.40 m arası gri renkli, orta-iyi dayanımlı, az-orta ayrışmış	V V V V V	I-II	II	Cl	100		55
32								*28.05-28.15 m, 31.30-32.00 m, 34.40-34.60 m, 35.90-36.00 , 37.80-39.00 m arası parçalı kırıklı	V V V V V V V	I-II	II	Cr	100		0
33								*24.55-24.60 m, 25.65-25.70 m arası çok parçalı kırıklı	V V V V V V V V	I-II	II	I	100		40
34									V V V V V V V	I-II	II	I	100		28
35									V V V V V	I-II	II	Cr	100		24
36									V V V V V V V V	I-II	II	Cr	100		27
37									V V V V V V V	I-II	II	I	100		57
38									V V V V V V V V	I-II	II	Cr	100		12
39									V V V V V	I-II	II	I	100		78
40									V V V V V V V	I-II	II	Cr	100		27
41									V V V V V	I-II	II	Cr	100		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :	Sayfa No: 4/8
SONDAJ Borehole No :	TSK-6
SONDÖR Driller	Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58								Tanımlama sayfa 2/8'de

*26.00-51.40 m arası gri renkli, orta-iyi dayanımlı, az-orta ayrışmış

*51.40-65.00 m arası kırmızımsı gri renkli, orta dayanımlı, orta derecede ayrışmış

*42.25-42.30 m, 44.90-45.00 m, 45.15-45.25 m, 45.70-45.95 m, 46.40-46.80 m, 47.15-47.60 m, 48.00-49.00 m, 49.10-49.50 m, 50.05-50.15 m, 50.60-50.75 m, 51.70-52.50 m, 54.40-54.60 m, 55.30-55.40 m, 56.00-56.25 , 57.00-57.30 m, 57.80-58.00 m arası parçalı kırıklı

*53.00-53.20 m, 54.80-55.00 m arası çok parçalı kırıklı

PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T Core	KAROT%(SCR)/S CoreR	RQD %
V V V V V V V V	I-II	II	I	100		28
V V V V V V V	I-II	II	Cr	100		28
V V V V V V V V	I-II	II	I	100		58
V V V V V	I-II	II	I	100		76
V V V V V V V	I-II	II-III	Cr	100		18
V V V V V V V V	I-II	II-III	Cr	100		0
V V V V V	I-II	II-III	Cr	100		0
V V V V V V V	I-II	II-III	Cr	100		0
V V V V V V V V	I-II	II-III	Cr	100		0
V V V V V V V	I-II	II-III	Cr	100		10
V V V V V V V V	I-II	II-III	Cr	100		24
V V V V V	II	III	Cr	100		10
V V V V V V V V	II	III	Cr	100		17
V V V V V V V	II	III	Cr	100		0
V V V V V	II	III	Cr	100		47
V V V V V V V V	II	III	Cr	100		21
V V V V V V V	II	III	Cr	100		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :
Sayfa No:	5/8
SONDAJ Borehole	No : **TSK-6**
SONDÖR Driller	Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test					JEOTEKNİK TANIMLAMA Geotechnical Description
			DARBE SAYISI				GRAFİK Graph	
			0 - 15 cm	15-30 cm	30-45 cm	N	10 20 30 40 50 60	
59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75								Tanımlama sayfa 2/8'de *26.00-51.40 m arası gri renkli, orta-iyi dayanımlı, az-orta ayrışmış *51.40-65.00 m arası kırmızımsı gri renkli, orta dayanımlı, orta drecede ayrışmış *65.00-67.00 m arası kırmızımsı gri renkli, orta-orta-zayıf dayanımlı, orta-çok ayrışmış *67.00-90.00 m arası kırmızımsı gri renkli, orta dayanımlı, orta derecede ayrışmış *58.70-59.30 m, 59.40-59.75 m, 65.00-65.50 m, 67.00-67.15 m, 68.10-68.70 m, 69.70-70.10 m, 71.20-71.40 m, 76.00-76.10 m, 71.20-71.40 m arası parçalı kırıklı *65.50-67.00 m, 70.10-70.40 m arası çok parçalı kırıklı

PROFİL Profile	DAYANIMLILIK/Strengt.	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T. Core	KAROT%(SCR)/S. CoreR	RQD %
V V V	II	III	Cr	100		0
V V V	II	III	Cr	100		0
V V V	II	III	Cr	100		24
V V V	II	III	Cr	100		12
V V V	II	III	I	66		48
V V V	II	III	I	77		11
V V V	II	III	Cr	57		0
V V V	II-III	III-IV	Cr	52		0
V V V	II-III	III-IV	Cr	48		O
V V V	II	III	Cr	54		20
V V V	II	III	Cr	69		17
V V V	II	III	Cr	78		19
V V V	II	III	Cr	100		16
V V V	II	III	Cr	100		0
V V V	II	III	Cr	100		19
V V V	II	III	Cr	70		0
V V V	II	III	Cr	92		12

İSİM Name	Buket UCA	Lütfullah KANTAR
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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 6/8
SONDAJ Borehole	No : **TSK-6**	
SONDÖR Driller	**Bekir ÇATALKAYA**	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI 0-15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt.	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
76								Tanımlama sayfa 2/8'de	V V V V V V V V	II	III	Cr	94		32
77									V V V V V V V	II	III	Cr	88		0
78									V V V V V	II	III	Cr	91		0
79									V V V V V V V V	II	III	Cr	70		11
80									V V V V V V V	II	III	Cr	100		37
81								*67.00-90.00 m arası kırmızımsı gri renkli, orta dayanımlı, orta derecede ayrışmış	V V V V V	II	III	Cr	100		34
82								*90.00-93.00 m arası gri renkli, yer yer sarı renkli, orta-iyi dayanımlı, az ayrışmış	V V V V V V V V	II	III	Cr	100		39
83									V V V V V	II	III	Cr	100		0
84								*76.00-76.10 m, 77.00-77.60 m, 79.70-79.75 m, 81.00-81.05 m, 83.70-84.00 m arası parçalı kırıklı	V V V V V V V	II	III	Cr	100		0
85								*77.60-77.90 m arası çok parçalı kırıklı	V V V V V V V V	II	III	Cr	100		49
86									V V V V V V V	II	III	Cr	100		20
87									V V V V V	II	III	Cr	100		0
88									V V V V V V V V	II	III	Cr	100		0
89									V V V V V V V	II	III	Cr	100		0
90									V V V V V	II	III	Cr	100		10
91									V V V V V V V V	I-II	II	Cr	100		10
92									V V V V V V V	I-II	II	Cr	100		46

İSİM Name	Buket UCA	Lütfullah KANTAR
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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 7/8
SONDAJ Borehole	No : **TSK-6**	
SONDÖR Driller	**Bekir ÇATALKAYA**	

SONDAJ DERİNLİĞİ Boring Depth (m) | NUMUNE CİNSİ Samp. Type | MANEVRA BOYU/Run | STANDART PENETRASYON DENEYİ Standart Penetration Test: DARBE SAYISI (0 - 15 cm, 15-30 cm, 30-45 cm, N), GRAFİK Graph (10 20 30 40 50 60) | JEOTEKNİK TANIMLAMA Geotechnical Description | PROFİL Profile

Sondaj derinliği: 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109

JEOTEKNİK TANIMLAMA

Tanımlama sayfa 2/8'de

*90.00-93.00 m arası gri renkli, yer yer sarı renkli, orta-iyi dayanımlı, az ayrışmış

*93.00-113.00 m arası sarımsı-kırmızımsı-gri renkli, orta-iyi dayanımlı, az-orta ayrışmış

*84.00-84.15 m arası parçalı kırıklı

*88.00-88.10 m, 91.00-91.05 m, 101.95-102.00 m arası çok parçalı kırıklı

DAYANIMLILIK/Strengt.	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
I-II	II	I	100		40
I-II	II-III	Cl	100		66
I-II	II-III	Cr	100		35
I-II	II-III	Cl	100		70
I-II	II-III	I	100		35
I-II	II-III	I	100		32
I-II	II-III	Cr	100		43
I-II	II-III	Cl	100		35
I-II	II-III	I	100		18
I-II	II-III	Cr	100		56
I-II	II-III	Cr	100		10
I-II	II-III	Cr	100		0
I-II	II-III	Cl	100		82
I-II	II-III	Cl	100		70
I-II	II-III	m	100		79
I-II	II-III	Cr	100		52
I-II	II-III	Cr	100		70

İSİM Name	Buket UCA	Lütfullah KANTAR
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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 8/8
SONDAJ Borehole	No : **TSK-6**	
SONDÖR Driller	Bekir ÇATALKAYA	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test					JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
			DARBE SAYISI				GRAFİK Graph								
			0 - 15 cm	15-30 cm	30-45 cm	N	10 20 30 40 50 60								
110								Tanımlama sayfa 2/8'de	V V V V V V V V	I-II	II-III	Cr	100		10
111									V V V V V V V	I-II	II-III	Cl	100		48
112									V V V V V V V V	I-II	II-III	I	100		79
113									V V V V V V V	I-II	II-III	Cr	100		42
114								**Kuyu Sonu 113,00 m.**							
115															
116															
117															
118															
119															
120															
121															
122															
123															
124															
125															
126															

İSİM Name	Buket UCA	Lütfullah KANTAR
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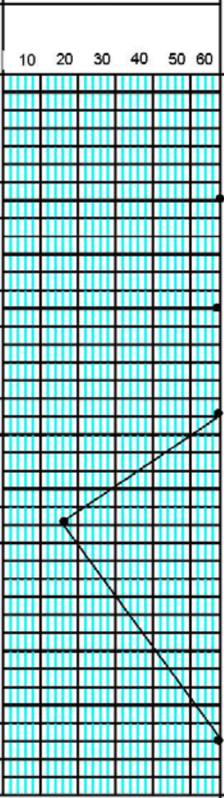
Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE District	No :	Sayfa No: 1/5
SONDAJ Borehole	No : EK-TSK-1	
SONDÖR Driller :	Hüsnü YILDIZ	

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	DELİK ÇAPI / Hole Diameter	: 114mm-89mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	YERALTI SUYU / Groundwater	: 13.17 m.
KİLOMETRE / Chainage	: -	MUH.BOR.DER. / Casing Depth	: 15.00 m.
SONDAJ DER. / Boring Depth	: 60.00 m	BAŞ.BİT.TAR. / Start Finish Date	: 03/01/2012 - 07/01/2012
SONDAJ KOTU / Elevation	: 98.00 m	KOORDİNAT / Coordinate (N-S) y	: 4252325
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	KOORDİNAT / Coordinate (E-W) x	: 512335

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Sample Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test – DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
1							**0,00 - 10,00** **Yapay Dolgu Malzeme**					100		
2	SPT-1	1.50 1.60	50/10									100		
3												100		
4	SPT-2	3.00 3.08	50/8									65		
5	SPT-3	4.50 4.53	50/3									35		
6												65		
7	SPT-4	6.00 6.45	6	7	10	17						35		
8												30		
9												40		
10	SPT-5	9.00 9.03	50/3									20		



DAYANIMLILIK / Strength			AYRIŞMA / Weathering			İNCE DANELİ / Fine Grained			İRİ DANELİ/Coarse Grained		
I	DAYANIMLI	Strong	I	TAZE	Fresh	N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.	N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.	N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.	N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.	N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
						N : >30	SERT	Hard			

KAYA KALİTESİ TANIMI - RQD			KIRIKLAR - 30 cm / Fractures			ORANLAR - Proportions					
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)	% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)	% 5-15	AZ	Little	% 5-20	AZ	Little
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)	% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)	% 35 >	VE	And			
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)						

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample	LOGU YAPAN Logged By	KONTROL Checked By
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test	ISIM Name: Buket UCA	Lütfullah KANTAR
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test	IMZA Sign	

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No : District
Sayfa No: 2/5
SONDAJ Borehole No : **EK-TSK-1**
SONDÖR Driller : Hüsnü YILDIZ

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)T.Core	KAROT%(SCR)S.Cor	RQD %
11								V V V V V V V V	II	III	Cr	60		0
12								V V V V V V V	II	III	I	70		28
13								V V V V V V	II	III	Cr	70		10
14								V V V V V V V	I-II	III	Cr	100		0
15								V V V V V V V V	I-II	II-III	Cr	100		35
16								V V V V V V V	I-II	II-III	Cr	100		33
17								V V V V V	I-II	II-III	Cl	100		65
18								V V V V V V V V	I-II	II-III	Cr	100		22
19								V V V V V V V	I-II	II-III	m	100		83
20								V V V V V V V V	I-II	II-III	Cr	100		25
21								V V V V V V V	I-II	II-III	Cr	100		45
22								V V V V V V V V	I-II	II-III	Cr	100		0
23								V V V V V	I-II	II-III	Cr	100		20
24								V V V V V V V	I-II	II-III	Cr	100		13

YASS: 13.17 m

JEOTEKNİK TANIMLAMA
Geotechnical Description

10.00 - 60.00 m.
ANDEZİT
Açık pembemsi-kırmızımsı gri renkli,orta-iyi dayanımlı, az-orta derecede ayrışmış, parçalı kırıklı çatlaklı, verev çatlaklı, çatlak yüzeyleri dalgalı pürüzlü, 2 yönlü eklemli, eklemler 45°-90°eğimli, eklem araları kil dolgulu, FeO alterasyonu gözlenmekte

*54.00-57.00 m arası eklem aralarında açık yeşil alterasyon yüzeyleri gözlenmekte.

* 10,00-11,00 m, 11,40-11,50 m, 12,20-12,60 m,13,00-13,30 m, 14,15-14,20 m, 15,15-15,50 m, 19,45-19,50 m, 19,75-19,80 m, 20,00-20,50 m, 21,00-21,55 m, 23,75-24,00 m arası parçalı kırıklı

* 13,85-14,00 m, 14,80-15,00 m, 17,05-17,40 m, 18,00-18,05 m, 22,70-22,75 m arası çok parçalı kırıklı

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 3/5
SONDAJ Borehole	No :	EK-TSK-1
SONDÖR Driller	:	Hüsnü YILDIZ

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
25								Tanımlama sayfa 2/5'te		I-II	II-III	Cr	100		0
26										I-II	II-III	Cr	100		36
27										I-II	II-III	Cr	100		53
28										I-II	II-III	Cr	100		57
29										I-II	II-III	Cr	100		40
30										I-II	II-III	Cr	100		0
31								* 24,75-24,95 m, 25,70-25,75 m, 26,95-27,00 m, 27,90-28,10 m, 29,80-30,10 m, 30,85-31,00 m, 32,95-33,00 m, 34,20-34,45 m, 35,25-35,45 m, 36,80-37,00 m, 37,20-37,40 m, 38,95-39,10 m, 39,30-39,60 m, 33,00-33,05 m, 33,90-34,00 m parçalı kırıklı *24,95-25,00 m arası çok parçalı kırıklı		I-II	II-III	Cr	100		31
32										I-II	II-III	I	100		30
33										I-II	II-III	I	100		55
34										I-II	II-III	Cr	100		40
35										I-II	II-III	Cr	100		30
36										I-II	II-III	Cr	100		18
37										I-II	II-III	Cr	100		13
38										I-II	II-III	Cr	100		22
39										I-II	II-III	Cr	100		36
40										I-II	II-III	Cr	100		0
41										I-II	II-III	I	100		31

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 4/5
SONDAJ Borehole	No : EK-TSK-1	
SONDÖR Driller	Hüsnü YILDIZ	

SONDAJ DERİNLİĞİ Boring Depth (m): 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58

NUMUNE CİNSİ Samp. Type | MANEVRA BOYU/Run | STANDART PENETRASYON DENEYİ Standart Penetration Test: DARBE SAYISI (0 - 15 cm, 15-30 cm, 30-45 cm, N); GRAFİK Graph (10 20 30 40 50 60)

JEOTEKNİK TANIMLAMA
Geotechnical Description

Tanımlama sayfa 2/5'te

41,00-41,20 m, 42,00-42,10 m, 44,70-44,75 m, 45,00-45,10 m, 45,90-46,07 m, 48,60-48,85 m, 54,90-55,00 m, 55,95-56,00 m, 58,55-58,70 m arası parçalı kırıklı

DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
I-II	II-III	Cr	100		12
I-II	II-III	Cr	100		13
I-II	II-III	Cr	100		28
I-II	II-III	Cr	100		33
I-II	II-III	Cr	100		0
I-II	II-III	Cl	100		22
I-II	II-III	Cr	100		82
I-II	II-III	Cr	100		50
I-II	II-III	Cl	100		68
I-II	II	Cl	100		29
I-II	II	I	100		26
I-II	II	W	100		100
I-II	II-III	Cl	100		80
I-II	II-III	Cr	100		15
I-II	II-III	Cr	100		43
I-II	II-III	Cl	100		40
I	II	Cr	100		23

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE No :
District

Sayfa No: 5/5

SONDAJ Borehole No : **EK-TSK-1**

SONDÖR Driller **Hüsnü YILDIZ**

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test					JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T Core	KAROT%(SCR)/S CoreR	RQD %
			DARBE SAYISI				GRAFİK Graph								
			0 - 15 cm	15-30 cm	30-45 cm	N	10 20 30 40 50 60								
59								Tanımlama sayfa 2/5'te	V V V V V V V V	I	II	Cr	100		26
60									V V V V V V V	I	II	I	101		58
61								**Kuyu Sonu 60,00 m.**							
62															
63															
64															
65															
66															
67															
68															
69															
70															
71															
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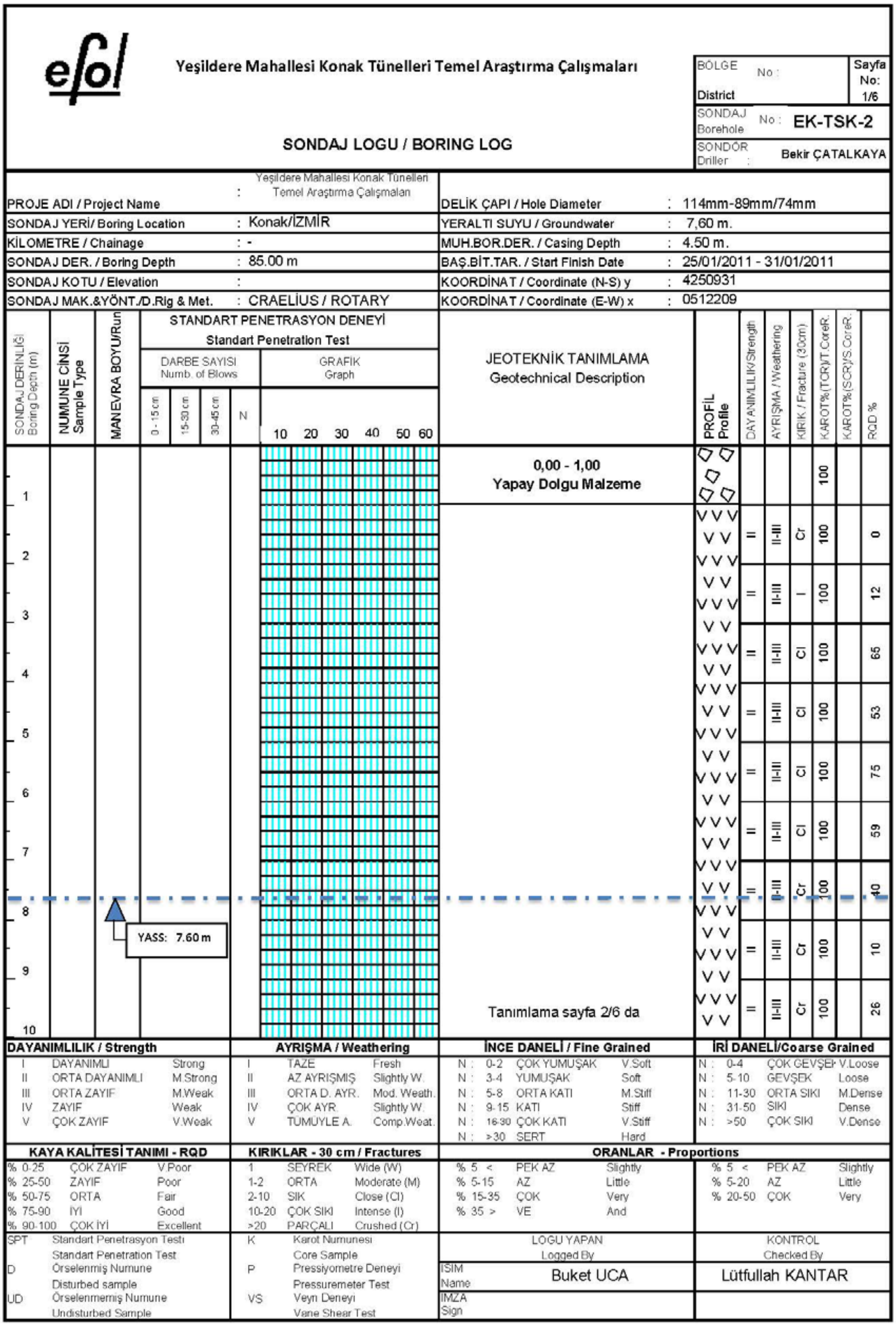
74															
75															

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		



Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING LOG

BÖLGE / District No :
Sayfa No: 1/6
SONDAJ / Borehole No : **EK-TSK-2**
SONDÖR / Driller : **Bekir ÇATALKAYA**

PROJE ADI / Project Name	: Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları	DELİK ÇAPI / Hole Diameter	: 114mm-89mm/74mm
SONDAJ YERİ/ Boring Location	: Konak/İZMİR	YERALTI SUYU / Groundwater	: 7,60 m.
KİLOMETRE / Chainage	: -	MUH.BOR.DER. / Casing Depth	: 4.50 m.
SONDAJ DER. / Boring Depth	: 85.00 m	BAŞ.BİT.TAR. / Start Finish Date	: 25/01/2011 - 31/01/2011
SONDAJ KOTU / Elevation	:	KOORDİNAT / Coordinate (N-S) y	: 4250931
SONDAJ MAK.&YÖNT./D.Rig & Met.	: CRAELİUS / ROTARY	KOORDİNAT / Coordinate (E-W) x	: 0512209

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Sample Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI Numb. of Blows 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR.	KAROT%(SCR)/S.CoreR.	RQD %
0-1								**0,00 - 1,00** **Yapay Dolgu Malzeme**					100		
1-2										II	II-III	Cr	100		0
2-3										II	II-III	I	100		12
3-4										II	II-III	Cl	100		65
4-5										II	II-III	Cl	100		53
5-6										II	II-III	Cl	100		75
6-7										II	II-III	Cl	100		59
7-8		YASS: 7.60 m								II	II-III	Cr	100		40
8-9										II	II-III	Cr	100		10
9-10								Tanımlama sayfa 2/6 da		II	II-III	Cr	100		26

DAYANIMLILIK / Strength			AYRIŞMA / Weathering			İNCE DANELİ / Fine Grained			İRİ DANELİ/Coarse Grained		
I	DAYANIMLI	Strong	I	TAZE	Fresh	N : 0-2	ÇOK YUMUŞAK	V.Soft	N : 0-4	ÇOK GEVŞEK	V.Loose
II	ORTA DAYANIMLI	M.Strong	II	AZ AYRIŞMIŞ	Slightly W.	N : 3-4	YUMUŞAK	Soft	N : 5-10	GEVŞEK	Loose
III	ORTA ZAYIF	M.Weak	III	ORTA D. AYR.	Mod. Weath.	N : 5-8	ORTA KATI	M.Stiff	N : 11-30	ORTA SIKI	M.Dense
IV	ZAYIF	Weak	IV	ÇOK AYR.	Slightly W.	N : 9-15	KATI	Stiff	N : 31-50	SIKI	Dense
V	ÇOK ZAYIF	V.Weak	V	TÜMÜYLE A.	Comp.Weat.	N : 16-30	ÇOK KATI	V.Stiff	N : >50	ÇOK SIKI	V.Dense
						N : >30	SERT	Hard			

KAYA KALİTESİ TANIMI - RQD			KIRIKLAR - 30 cm / Fractures			ORANLAR - Proportions					
% 0-25	ÇOK ZAYIF	V.Poor	1	SEYREK	Wide (W)	% 5 <	PEK AZ	Slightly	% 5 <	PEK AZ	Slightly
% 25-50	ZAYIF	Poor	1-2	ORTA	Moderate (M)	% 5-15	AZ	Little	% 5-20	AZ	Little
% 50-75	ORTA	Fair	2-10	SIK	Close (Cl)	% 15-35	ÇOK	Very	% 20-50	ÇOK	Very
% 75-90	İYİ	Good	10-20	ÇOK SIKI	Intense (I)	% 35 >	VE	And			
% 90-100	ÇOK İYİ	Excellent	>20	PARÇALI	Crushed (Cr)						

SPT	Standart Penetrasyon Testi Standart Penetration Test	K	Karot Numunesi Core Sample	LOGU YAPAN Logged By	KONTROL Checked By
D	Örselenmiş Numune Disturbed sample	P	Pressiyometre Deneyi Pressuremeter Test	İSİM Name: Buket UCA	Lütfullah KANTAR
UD	Örselenmemiş Numune Undisturbed Sample	VS	Veyn Deneyi Vane Shear Test	İMZA Sign	

efol

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District No :	Sayfa No: 2/6
SONDAJ Borehole No :	**EK-TSK-2**
SONDÖR Driller :	Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test – DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.Cor	RQD %
11								**1.00 - 85.00 m.** **ANDEZİT** Kırmızımsı kahverengimsi gri renkli, az-orta ayrışmış, orta-iyi dayanımlı, çatlak yüzeyleri dalgalı-pürüzlü, parçalı-kırıklı-çatlaklı, 2 yönlü eklemli, eklemler 30°-90°eğimli, eklem araları kil dolgulu, FeO alterasyonu *1.00-5.00 m arası gri renkli, orta-iyi dayanımlı, az-orta ayrışmış *5.00-11.00 m arası kırmızımsı kahverengimsi gri renkli, orta dayanımlı, orta ayrışmış *11.00-13.00 m arası kahverengimsi-kırmızı renkli, orta dayanımlı, orta derecede ayrışmış *13.00-18.00 m arası kırmızımsı kahverengimsi gri renkli, orta-iyi dayanımlı, orta ayrışmış *18.00-24.50 m arası kırmızımsı, kahverengimsi, gri renkli, orta-orta zatıf dayanımlı, orta ayrışmış	V V V V V	II	II-III	Cr	100		55
12									V V V V V V V V	II	II-III	Cr	100		0
13									V V V V V V V	II	II-III	Cr	100		45
14									V V V V V V V V	II	II-III	M	100		86
15									V V V V V V V	II	II-III	M	100		95
16									V V V V V	II	II-III	Cl	100		50
17									V V V V V V V V	II	II-III	Cr	100		37
18									V V V V V V V	II	II-III	Cr	100		14
19									V V V V V	II	III	Cr	100		0
20									V V V V V V V V	II	III	Cl	100		60
21									V V V V V V V	II	III	Cl	100		15
22									V V V V V V V V	II	III	Cr	100		0
23									V V V V V V V	II	III	Cr	100		0
24									V V V V V	II	III	Cr	100		25

	LOGU YAPAN Logged By	KONTROL Checked By
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :		Sayfa No: 3/6
SONDAJ Borehole	No :	**EK-TSK-2**	
SONDÖR Driller	:	Bekir ÇATALKAYA	

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI Numb. of Blows 0 - 15 cm	 15-30 cm	 30-45 cm	 N	 GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Stren	AYRIŞMA /	KIRIK / Fracture	KAROT%(TCR)/T.Cor	KAROT%(SCR)/S.Core	RQD %
25								*24,50-37,00 m arası kırmızımsı kahverengimsi gri renkli, orta ayrışmış, orta-iyi dayanımlı *37,00-82,80 m arası kırmızımsı gri renkli, orta-az ayrışmış, orta-iyi dayanımlı *1.00-2.10 m, 7.75-8.30 m, 10.65-11.00 m, 11.10-11.25 m, 12.30-12.36 m, 16.70-17.00 m, 17.70-17.80 m, 20.60 -20.75 m, 21.85-22.00 m, 26.95-27.00 m, 28.15-28.20 m, 37.95-38.00 m, 38.95-39.00 m arası parçalı kırıklı *8.30-8.45 m, 18.15-19.00 m, 21.00-21.15 m, 22.00-23.60 m, 24.00-24.45m, 28.80-29.00 m, 34.93-35.00 m arası çok parçalı kırıklı	V V V V V	II	III	Cr	100		15
26									V V V V V	II	III	Cl	100		76
27									V V V V V	II	III	Cl	100		73
28									V V V V V	II	III	Cl	100		50
29									V V V V V	II	III	Cr	100		14
30									V V V V V	II	III	Cl	100		30
31									V V V V V	II	III	Cl	100		66
32									V V V V V	II	III	Cl	100		72
33									V V V V V	II	III	Cl	100		73
34									V V V V V	II	III	Cl	100		62
35									V V V V V	II	III	Cr	100		70
36									V V V V V	II	III	Cl	100		66
37									V V V V V	II	III	Cl	100		85
38									V V V V V	II	II-III	Cl	100		77
39									V V V V V	II	II-III	I	100		49
40									V V V V V	II	II-III	Cl	100		30
41								Tanımlama sayfa 2/6 da	V V V V V	II	II-III	Cl	100		72

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

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Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

BÖLGE District No :

Sayfa No: 4/6

SONDAJ Borehole No : **EK-TSK-2**

SONDÖR Driller **Bekir ÇATALKAYA**

SONDAJ LOGU / BORING

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ Samp. Type	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test DARBE SAYISI 0 - 15 cm	 15-30 cm	 30-45 cm	 N	 GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
42								Tanımlama sayfa 2/6'da	V V V V V V V V	II	II-III	Cr	100		35
43									V V V V V V V	II	II-III	Cr	100		49
44									V V V V V V V V	II	II-III	Cr	100		40
45									V V V V V	II	II-III	I	100		12
46									V V V V V V V	II	II-III	M	100		69
47								*41.00-41.06 m, 41.30-41.40 m, 41.65-41.75 m, 42.00-42.22 m, 43.30-43.35 m, 44.80-44.85 m, 46.30-47.35 m, 49.90-50.00 m, 50.13-50.40 m, 51.50-51.63 m, 51.87- 52.00 m, 52.20-52.25 m, 52.93-53.00 m, 53.55-54.20 m, 54.30-54.70 m, 54.90-55.00 m, 55.90-56.00 m, 57.65- 57.70 m arası parçalı kırıklı	V V V V V V V V	II	II-III	Cr	100		0
48									V V V V V	II	II-III	Cr	100		22
49									V V V V V V V	II	II-III	I	100		24
50									V V V V V V V V	II	II-III	Cr	100		55
51								* 43.70-43.75 m, 51.63-51.87 m arası çok parçalı kırıklı	V V V V V V V	II	II-III	Cr	100		40
52									V V V V V V V V	II	II-III	Cr	100		23
53									V V V V V	II	II-III	Cr	100		19
54									V V V V V V V V	II	II-III	Cr	100		33
55									V V V V V V V	II	II-III	Cr	100		0
56									V V V V V	II	II-III	I	100		20
57									V V V V V V V V	II	II-III	Cl	100		26
58									V V V V V V V	II	II-III	I	100		0

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

efol	**Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları**	BÖLGE No : District	Sayfa No: 5/6
	SONDAJ LOGU / BORING	SONDAJ Borehole No :	**EK-TSK-2**
		SONDÖR Driller	: Bekir ÇATALKAYA

SONDAJ DERİNLİĞİ Boring Depth (m)	NUMUNE CİNSİ	MANEVRA BOYU/Run	STANDART PENETRASYON DENEYİ Standart Penetration Test — DARBE SAYISI 0 - 15 cm	15-30 cm	30-45 cm	N	GRAFİK Graph 10 20 30 40 50 60	JEOTEKNİK TANIMLAMA Geotechnical Description	PROFİL	DAYANIMLILIK/Strength	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.CoreR	KAROT%(SCR)/S.CoreR.	RQD %
59								Tanımlama sayfa 2/6' da		II	II-III	I	100		12
60										II	II-III	Cr	100		13
61										II	II-III	Cr	100		44
62										II	II-III	I	100		63
63										II	II-III	Cr	66		46
64										II	II-III	I	77		46
65								*58.95-59.05 m, 59.68- 59.75 m, 60.00-60.10 m, 62.85-63.00 m, 64.00-64.15 m, 66.65-67.00 m, 68.60-69.20 m, 69.60-69.80 m, 72.10-72.20 m, 72.50-73.60 m arası parçalı kırıklı		II	II-III	Cr	57		49
66										II	II-III	Cl	52		37
67										II	II-III	Cr	48		0
68										II	II-III	I	54		43
69										II	II-III	Cr	69		51
70										II	II-III	Cr	78		42
71										II	II-III	M	100		84
72										II	II-III	Cl	100		60
73										II	II-III	Cr	100		19
74										II	II-III	Cr	70		15
75										II	II-III	M	92		66

İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

efol

Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

SONDAJ LOGU / BORING

BÖLGE District	No :	Sayfa No: 6/6
SONDAJ Borehole	No : **EK-TSK-2**	
SONDÖR Driller	Bekir ÇATALKAYA	

SONDAJ DERİNLİĞİ Boring Depth (m) | NUMUNE CİNSİ Samp. Type | MANEVRA BOYU/Run | STANDART PENETRASYON DENEYİ Standart Penetration Test: DARBE SAYISI (0 - 15 cm, 15-30 cm, 30-45 cm, N); GRAFİK Graph (10 20 30 40 50 60) | JEOTEKNİK TANIMLAMA Geotechnical Description | PROFİL Profile | DAYANIMLILIK/Strengt | AYRIŞMA / Weathering | KIRIK / Fracture (30cm) | KAROT%(TCR)/T.Core | KAROT%(SCR)/S.CoreR | RQD %

76
77
78
79
80
81
82
83
84
85

Tanımlama sayfa 2/6'da

*82,80-85,00 m arası kahverengimsi-kırmızı renkli, orta dayanımlı, orta derecede ayrışmış

*75.50-76.00 m, 77.50-78.00 m, 81.40-81.50 m, 82.00-82.60 m arası parçalı kırıklı

*76.00-76.55 m, 78.00-78.50 m, 81.50-82.00 m arası çok parçalı kırıklı

PROFİL Profile	DAYANIMLILIK/Strengt	AYRIŞMA / Weathering	KIRIK / Fracture (30cm)	KAROT%(TCR)/T.Core	KAROT%(SCR)/S.CoreR	RQD %
V V V V V V V V	II	II-III	Cr	94		17
V V V V V V V	II	II-III	Cr	88		14
V V V V V	II	II-III	Cr	91		0
V V V V V V V V	II	II-III	Cr	70		22
V V V V V	II	II-III	Cl	100		60
V V V V V V V	II	II-III	Cl	100		50
V V V V V V V V	II	II-III	Cr	100		14
V V V V V V V	II	II-III	Cr	100		27
V V V V V	II	III	Cr	100		26
V V V V V V V V	II	III	Cr	100		40

Kuyu Sonu 85,00 m.

86
87
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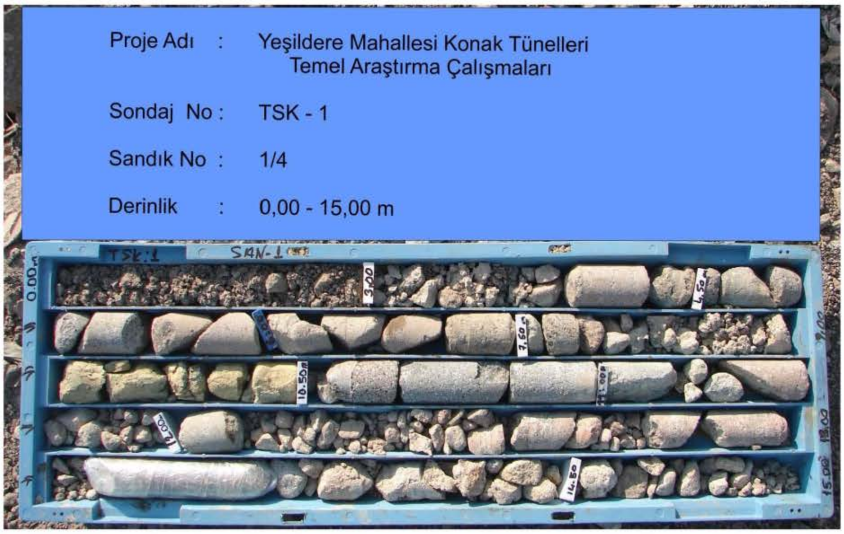
İSİM Name	Buket UCA	Lütfullah KANTAR
İMZA Sign		

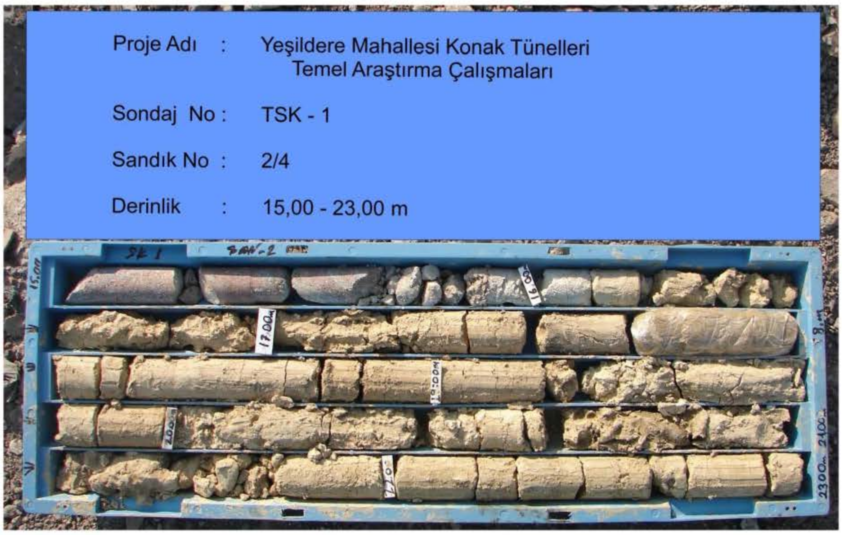


Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 1

Sandık No : 1/4

Derinlik : 0,00 - 15,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 1

Sandık No : 2/4

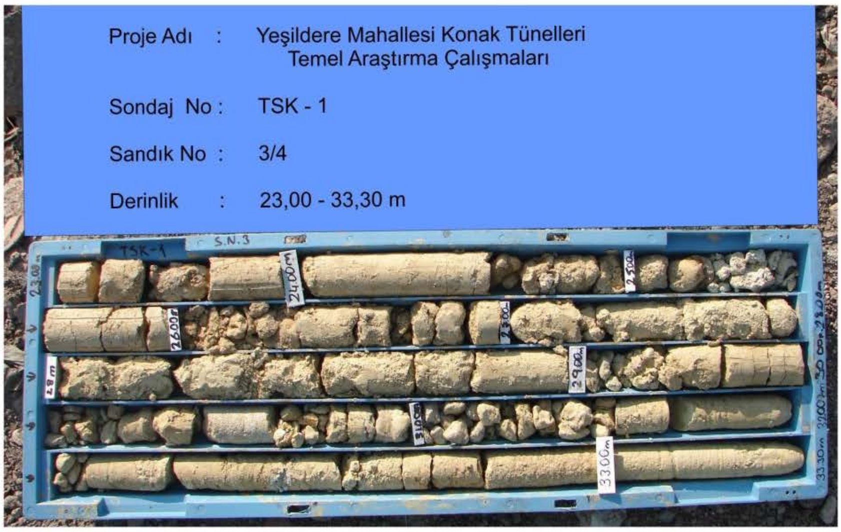
Derinlik : 15,00 - 23,00 m

TSK-1

Sayfa No.1/2

Page No. 1/2

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	1.50	1.60	SPT		11	14.50	15.00	0	66
2	3.00	3.45	SPT		12	15.00	16.00	10	63
3	4.50	4.55	SPT		13	16.00	17.00	0	68
4	6.00	6.02	SPT		14	17.00	18.00	0	70
5	7.50	7.53	SPT		15	18.00	19.00	0	50
6	9.00	9.45	SPT		16	19.00	20.00	0	68
7	10.50	10.57	SPT		17	20.00	21.00	0	82
8	10.57	12.00	0	48	18	21.00	22.00	0	45
9	12.00	13.00	0	82	19	22.00	23.00	0	55
10	13.00	14.50	11	45					



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 1

Sandık No : 3/4

Derinlik : 23,00 - 33,30 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 1

Sandık No : 4/4

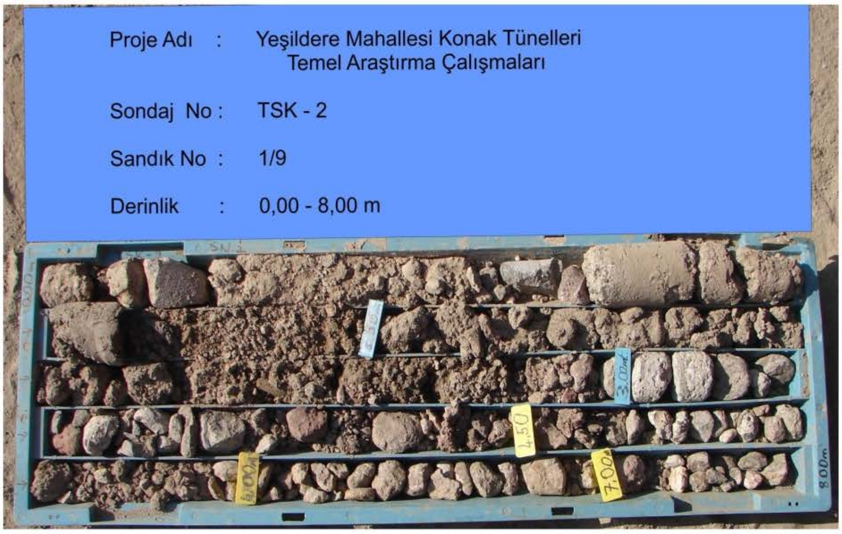
Derinlik : 33,30 - 40,00 m

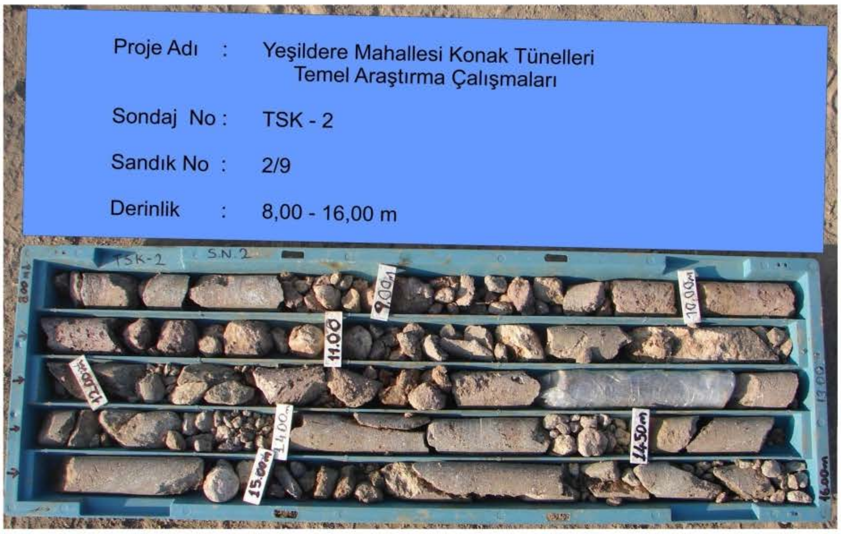
TSK-1

Sayfa No.2/2

Page No. 2/2

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
20	23.00	24.00	0	33	29	32.00	33.00	12	70
21	24.00	25.00	0	44	30	33.00	34.00	60	93
22	25.00	26.00	0	43	31	34.00	35.00	0	77
23	26.00	27.00	0	43	32	35.00	36.00	10	61
24	27.00	28.00	0	40	33	36.00	37.00	16	67
25	28.00	29.00	0	69	34	37.00	38.00	37	70
26	29.00	30.00	0	32	35	38.00	39.00	38	76
27	30.00	31.00	0	50	36	39.00	40.00	10	88
28	31.00	32.00	10	50					





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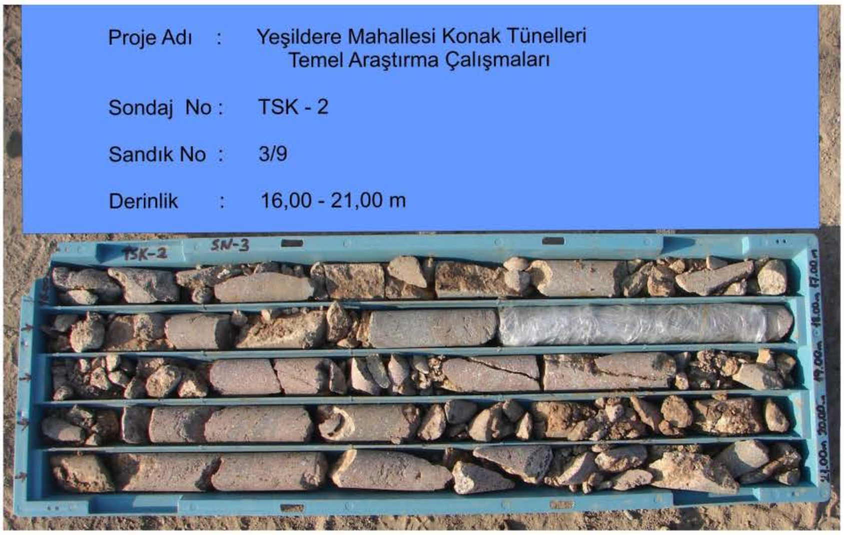
Sayfa No.1/5

Page No. 1/5

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	1.50	1.95	SPT		8	11.00	12.00	0	67
2	3.00	3.45	SPT		9	12.00	13.00	21	94
3	4.50	4.60	SPT		10	13.00	14.00	0	35
4	6.00	6.06	SPT		11	14.00	14.50	24	92
5	8.00	9.00	0	43	12	14.50	15.00	20	100
6	9.00	10.00	0	42	13	15.00	16.00	0	72
7	10.00	11.00	11	56					

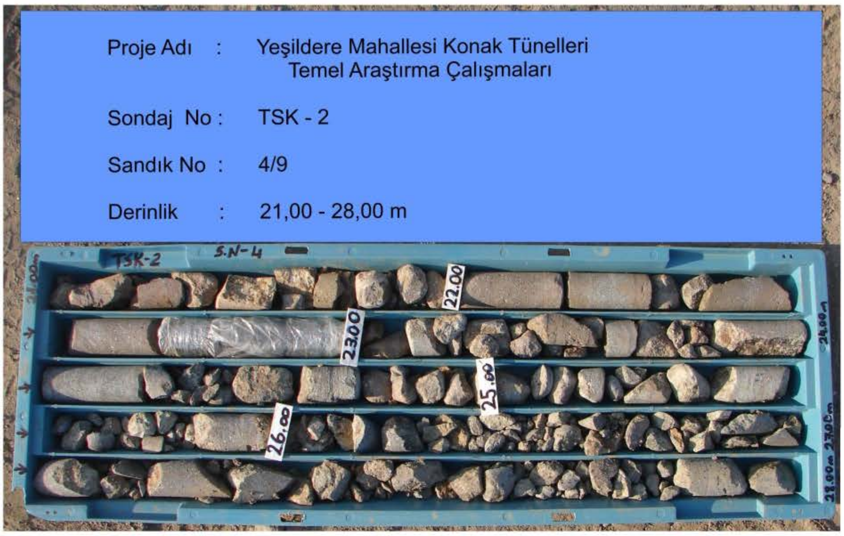


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 2

Sandık No : 3/9

Derinlik : 16,00 - 21,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 2

Sandık No : 4/9

Derinlik : 21,00 - 28,00 m

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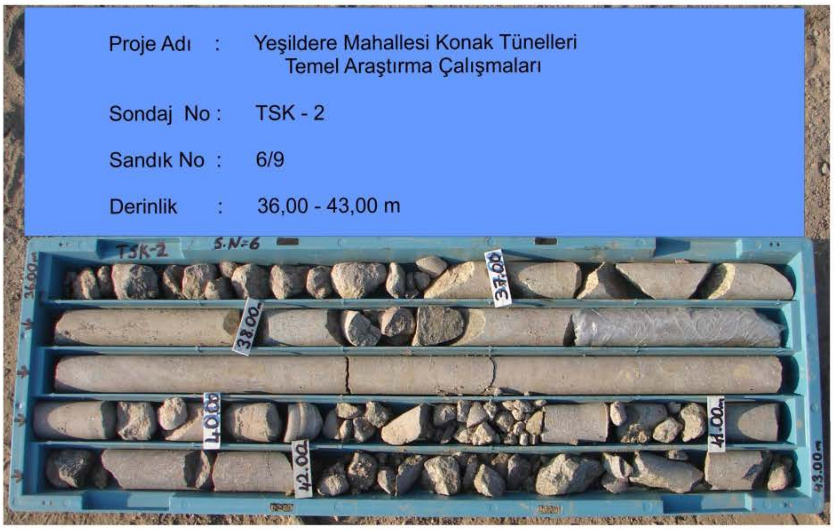
Sayfa No.2/5

Page No. 2/5

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
14	16.00	17.00	0	100	20	22.00	23.00	40	84
15	17.00	18.00	34	100	21	23.00	24.00	0	63
16	18.00	19.00	0	100	22	24.00	25.00	12	59
17	19.00	20.00	0	100	23	25.00	26.00	0	73
18	20.00	21.00	10	100	24	26.00	27.00	0	70
19	21.00	22.00	0	55	25	27.00	28.00	0	100



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Sayfa No.3/5

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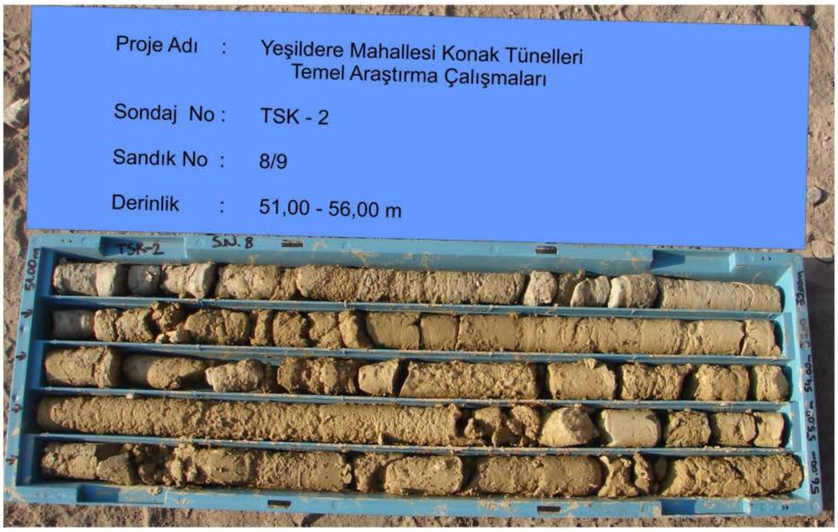
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
26	28.00	29.00	0	60	33	35.00	36.00	18	53
27	29.00	30.00	0	54	34	36.00	37.00	0	61
28	30.00	31.00	0	55	35	37.00	38.00	21	69
29	31.00	32.00	14	70	36	38.00	40.00	62	100
30	32.00	33.00	0	85	37	40.00	41.00	0	66
31	33.00	34.00	0	60	38	41.00	42.00	0	46
32	34.00	35.00	29	66	39	42.00	43.00	0	65

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 2

Sandık No : 7/9

Derinlik : 43,00 - 51,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 2

Sandık No : 8/9

Derinlik : 51,00 - 56,00 m

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Sayfa No.4/5

Page No. 4/5

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
40	43.00	44.00	13	52	46	50.00	51.00	0	62
41	44.00	45.00	0	48	47	51.00	52.00	0	100
42	45.00	46.00	12	65	48	52.00	53.00	0	100
43	46.00	47.50	0	73	49	53.00	54.00	0	100
44	47.50	49.00	0	59	50	54.00	55.00	0	100
45	49.00	50.00	0	77	51	55.00	56.00	0	100

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 2

Sandık No : 9/9

Derinlik : 56,00 - 60,00 m

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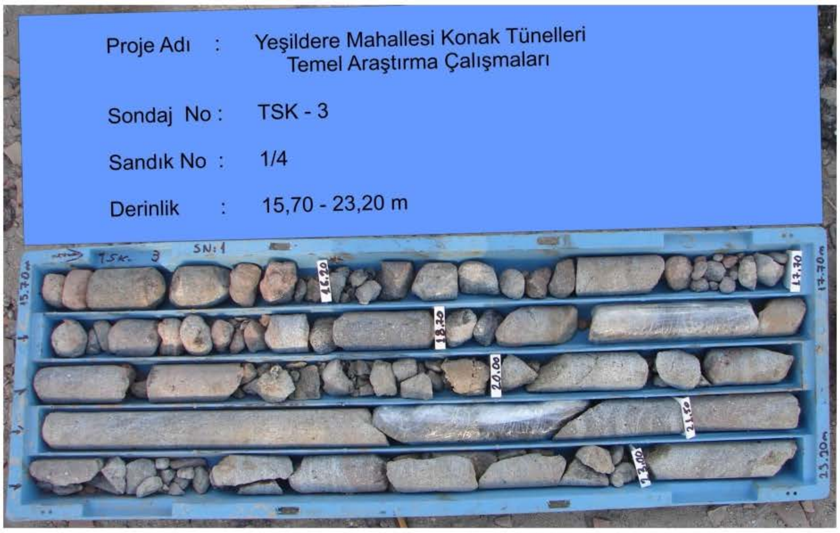
Sayfa No.5/5

Page No. 5/5

MANEVRA CORE RUN	**DERİNLİK (m) DEPTH (m)**		**RQD (%)**	**KAROT (%) CORE REC.**	**MANEVRA CORE RUN**	**DERİNLİK (m) DEPTH (m)**		**RQD (%)**	**KAROT (%) CORE REC.**
52	56.00	57.00	0	100	54	58.00	59.00	0	100
53	57.00	58.00	0	100	55	59.00	60.00	0	100



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 3

Sandık No : 1/4

Derinlik : 15,70 - 23,20 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 3

Sandık No : 2/4

Derinlik : 23,20 - 30,50 m

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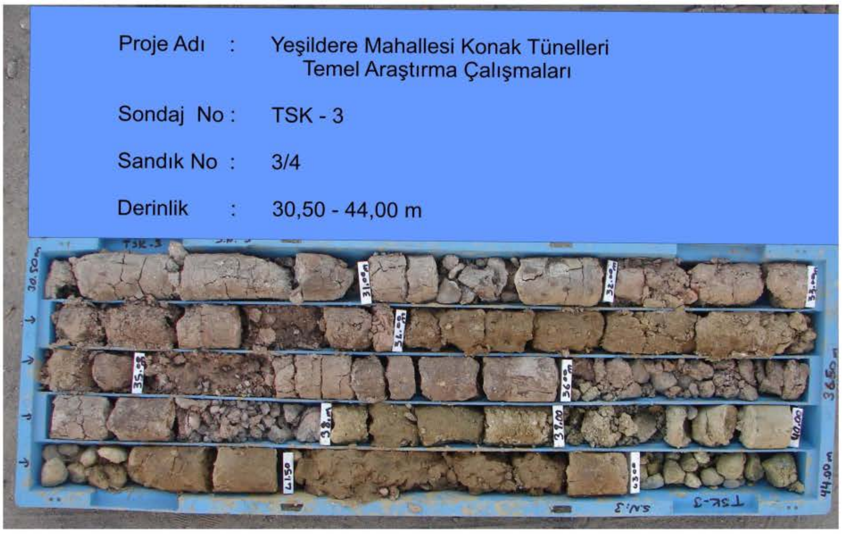
Sayfa No.1/2

Page No. 1/2

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	1.50	1.55	SPT		12	17.00	18.00	-	42
2	3.00	3.43	SPT		13	18.00	19.00	-	53
3	4.50	4.55	SPT		14	19.00	20.00	-	85
4	6.00	6.60	SPT		15	20.00	21.50	37	87
5	7.50	7.57	SPT		16	21.50	23.20	0	65
6	9.00	9.05	SPT		17	23.20	24.50	24	92
7	10.50	10.60	SPT		18	24.50	25.20	45	86
8	12.00	12.45	SPT		19	25.20	26.60	11	60
9	13.50	13.95	SPT		20	26.60	28.00	26	69
10	15.00	15.45	SPT		21	28.00	30.50	20	72
11	16.50	17.00	SPT						



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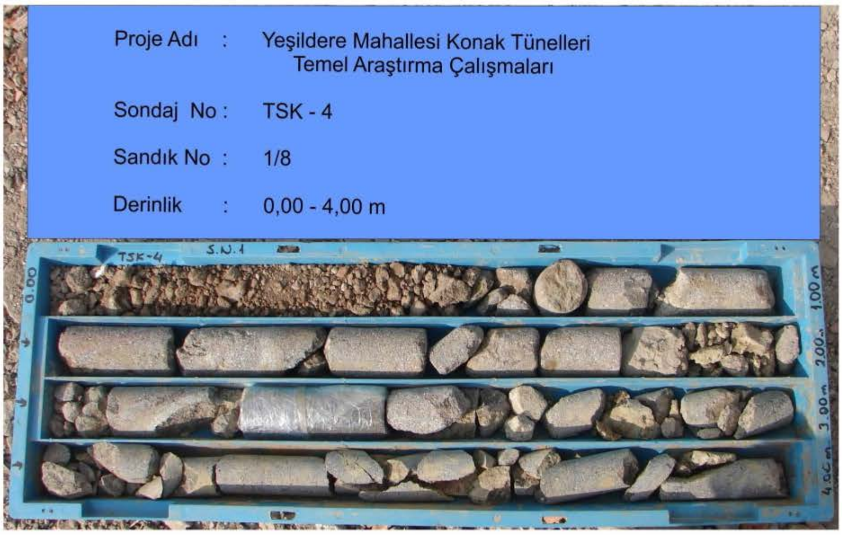
Sayfa No.2/2

Page No. 2/2

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
22	30.50	31.00	0	60	31	40.13	41.00	0	23
23	31.00	32.00	0	30	32	40.50	40.60	SPT	
24	32.00	33.00	0	26	33	43.00	43.45	SPT	
25	33.00	34.00	0	46	34	44.50	44.95	SPT	
26	34.00	35.00	0	58	35	46.00	46.45	SPT	
27	35.00	35.45	SPT		36	47.50	47.57	SPT	
28	36.50	36.60	SPT		37	47.57	48.50	0	46
29	38.00	38.06	SPT		38	48.50	50.00	0	36
30	40.00	40.13	SPT						

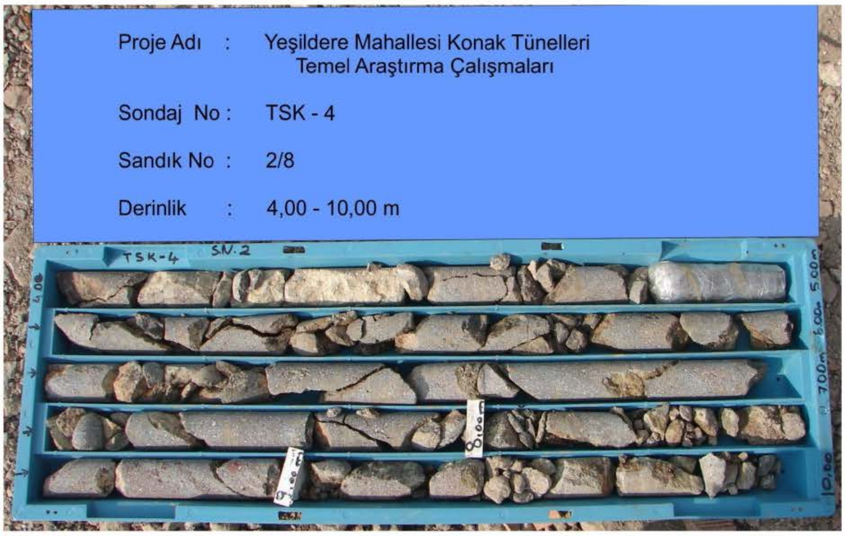


Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 4

Sandık No : 1/8

Derinlik : 0,00 - 4,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 4

Sandık No : 2/8

Derinlik : 4,00 - 10,00 m

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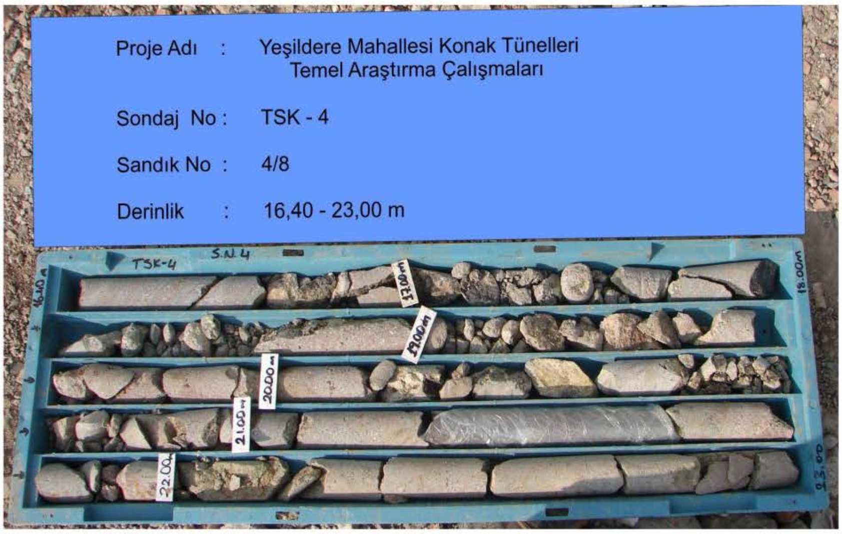
Sayfa No.1/4

Page No. 1/4

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	1.00	2.00	30	100	6	6.00	7.00	0	100
2	2.00	3.00	17	100	7	7.00	8.00	10	57
3	3.00	4.00	0	100	8	8.00	9.00	10	78
4	4.00	5.00	13	100	9	9.00	10.00	0	56
5	5.00	6.00	0	100					

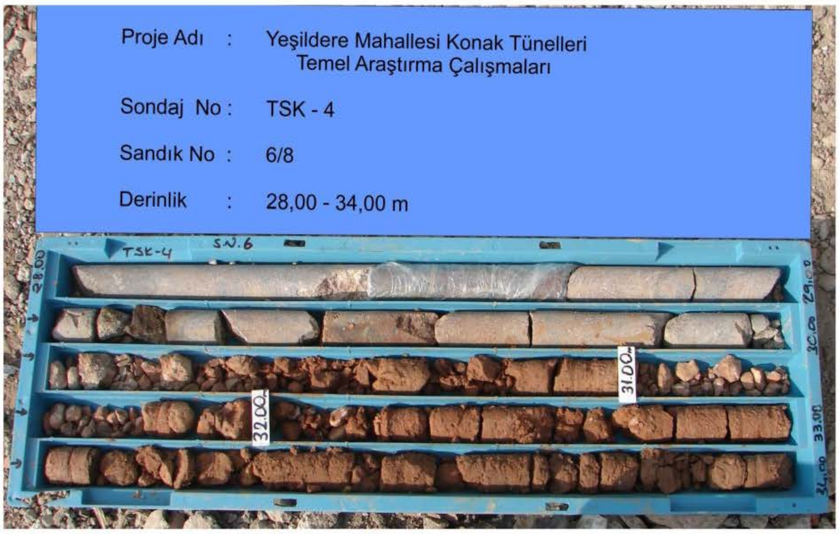


TSK-4

Sayfa No.2/4

Page No. 2/4

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
10	10.00	11.00	30	80	17	17.00	18.00	0	52
11	11.00	12.00	0	95	18	18.00	19.00	0	49
12	12.00	13.00	11	80	19	19.00	20.00	0	79
13	13.00	14.00	0	76	20	20.00	21.00	0	98
14	14.00	15.00	0	70	21	21.00	22.00	36	90
15	15.00	16.00	10	72	22	22.00	23.00	20	84
16	16.00	17.00	25	76					

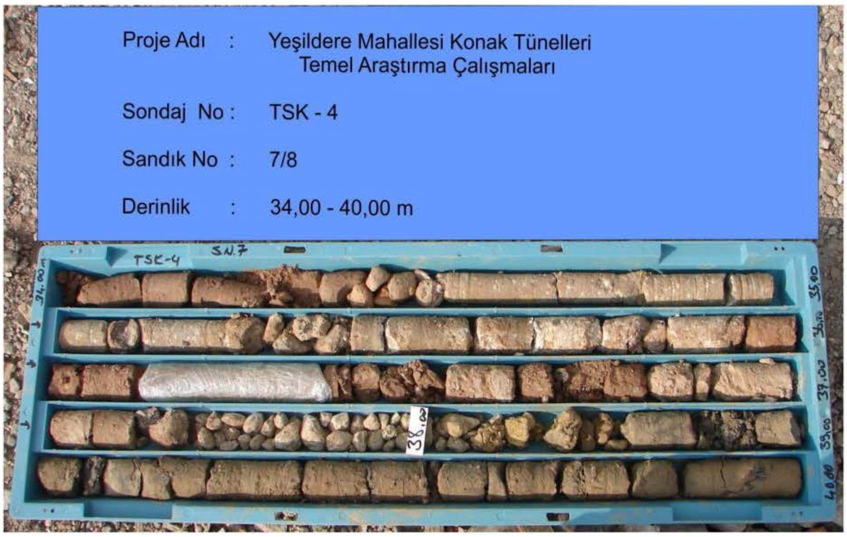


TSK-4

Sayfa No.3/4

Page No. 3/4

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
23	23.00	24.00	0	100	29	29.00	30.00	15	100
24	24.00	25.00	47	100	30	30.00	31.00	0	76
25	25.00	26.00	63	100	31	31.00	32.00	0	55
26	26.00	27.00	50	100	32	32.00	33.00	0	70
27	27.00	28.00	22	100	33	33.00	34.00	0	100
28	28.00	29.00	61	100					



Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 4

Sandık No : 7/8

Derinlik : 34,00 - 40,00 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 4

Sandık No : 8/8

Derinlik : 40,00 - 42,00 m

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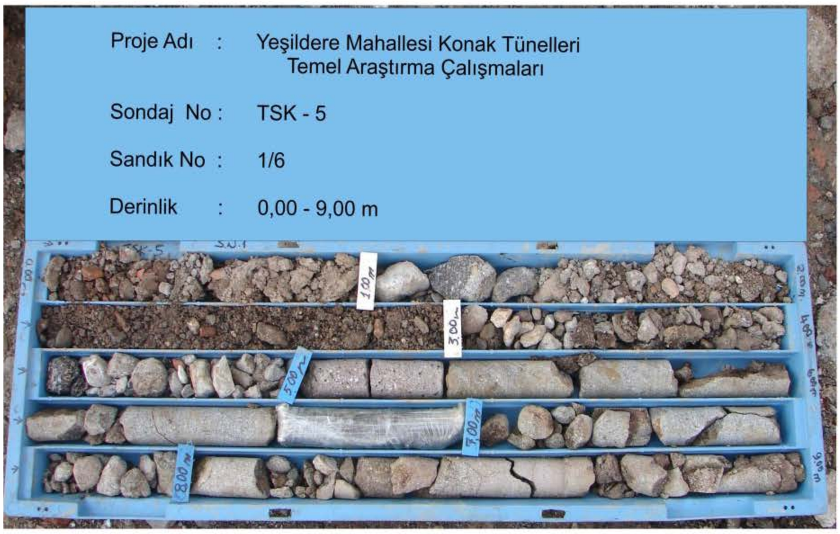
Sayfa No.4/4

Page No. 4/4

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
34	34.00	35.00	0	100	38	38.00	39.00	0	52
35	35.00	36.00	0	100	39	39.00	40.00	0	100
36	36.00	37.00	21	100	40	40.00	41.00	0	100
37	37.00	38.00	0	48	41	41.00	42.00	35	100

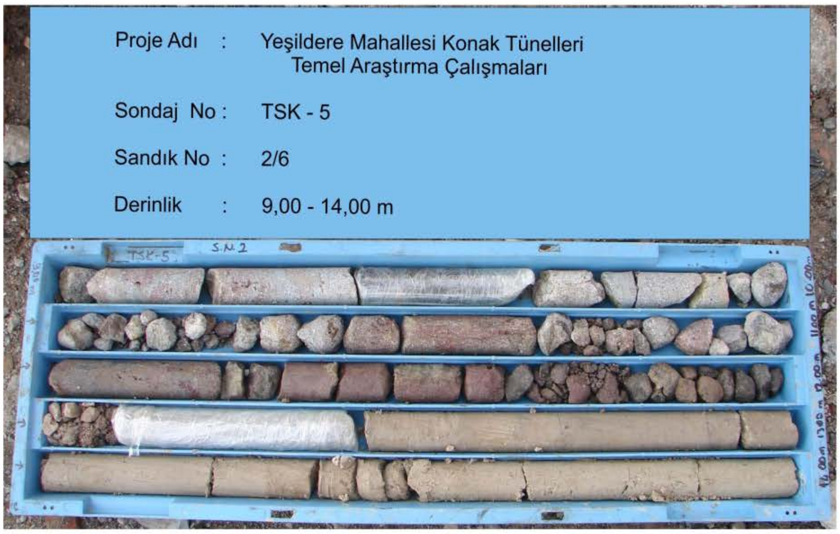


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 5

Sandık No : 1/6

Derinlik : 0,00 - 9,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 5

Sandık No : 2/6

Derinlik : 9,00 - 14,00 m

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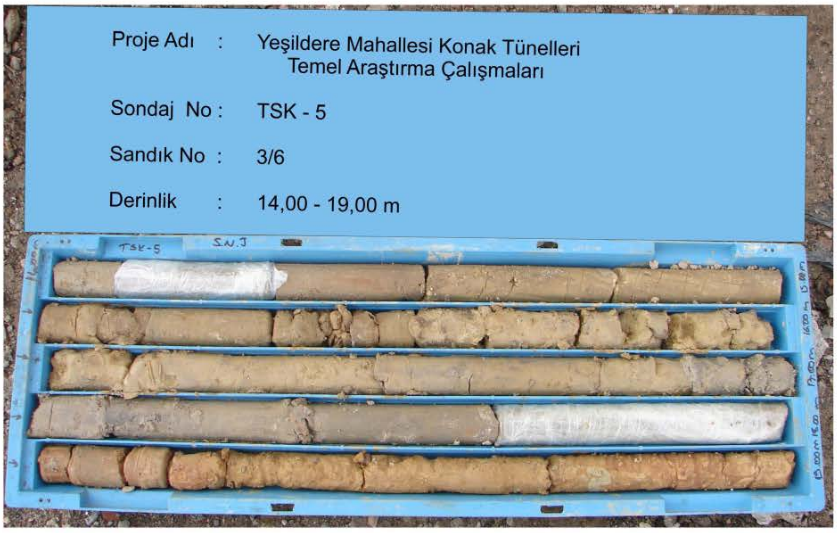
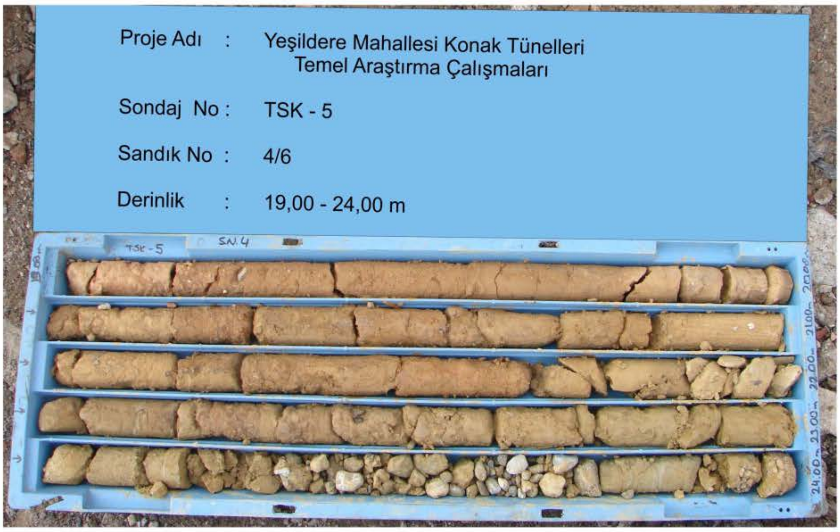
Sayfa No.1/3

Page No. 1/3

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	0.00	1.00	-	43	8	7.00	8.00	0	61
2	1.00	2.00	-	57	9	8.00	9.00	0	79
3	2.00	3.00	-	56	10	9.00	10.00	31	100
4	3.00	4.00	-	44	11	10.00	11.00	11	100
5	4.00	5.00	-	34	12	11.00	12.00	20	100
6	5.00	6.00	21	66	13	12.00	13.00	72	100
7	6.00	7.00	28	60	14	13.00	14.00	53	100





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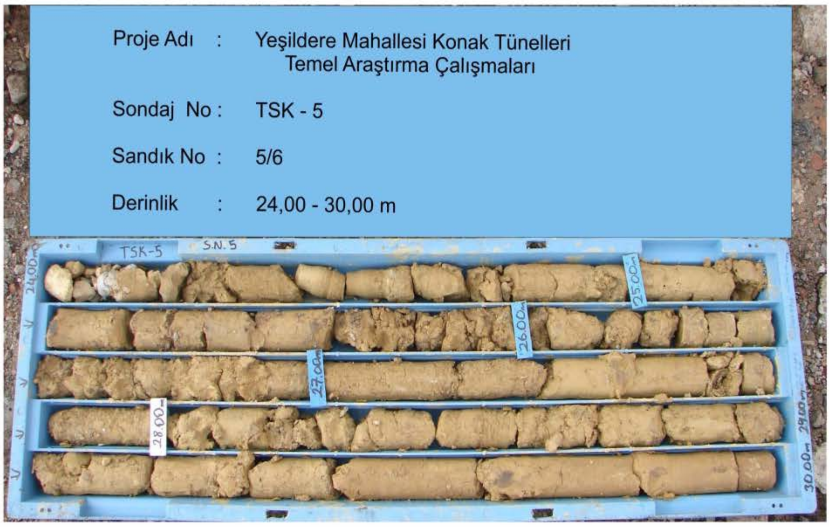
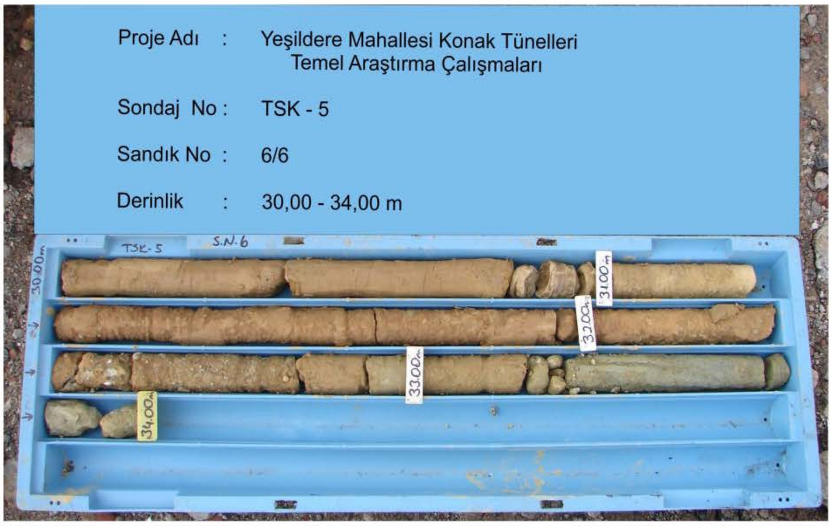
Sayfa No.2/3

Page No. 2/3

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
15	14.00	15.00	35	100	20	19.00	20.00	0	100
16	15.00	16.00	0	100	21	20.00	21.00	0	100
17	16.00	17.00	0	100	22	21.00	22.00	0	100
18	17.00	18.00	35	100	23	22.00	23.00	0	100
19	18.00	19.00	0	100	24	23.00	24.00	0	100





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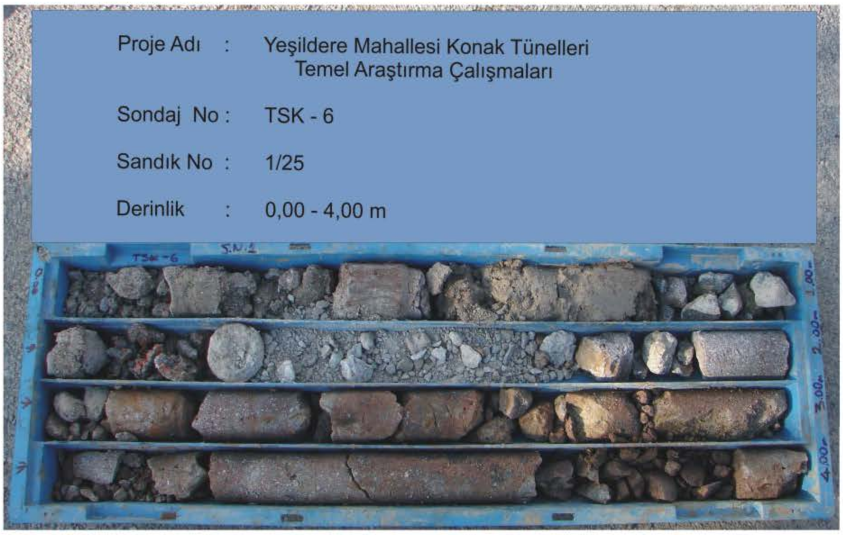
Sayfa No.3/3

Page No. 3/3

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
25	24.00	25.00	0	82	30	29.00	30.00	0	100
26	25.00	26.00	0	82	31	30.00	31.00	0	75
27	26.00	27.00	0	75	32	31.00	32.00	0	97
28	27.00	28.00	0	78	33	32.00	33.00	0	77
29	28.00	29.00	0	84	34	33.00	34.00	0	67



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 1/25

Derinlik : 0,00 - 4,00 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 2/25

Derinlik : 4,00 - 8,00 m

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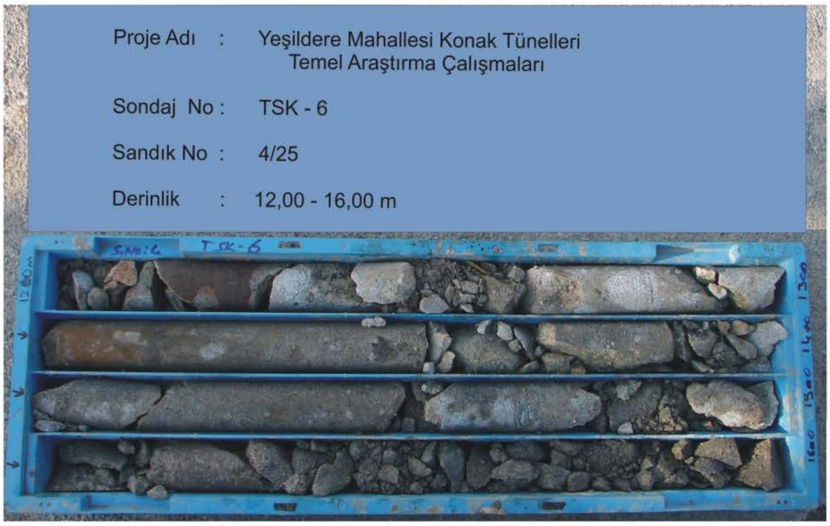
Sayfa No.1/13

Page No. 1/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	0.00	1.00	-	-	5	4.00	5.00	10	100
2	1.00	2.00	10	100	6	5.00	6.00	70	100
3	2.00	3.00	14	100	7	6.00	7.00	18	100
4	3.00	4.00	33	100	8	7.00	8.00	11	100



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Sayfa No.2/13

Page No. 2/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
9	8.00	9.00	0	100	13	12.00	13.00	12	100
10	9.00	10.00	12	100	14	13.00	14.00	40	100
11	10.00	11.00	15	100	15	14.00	15.00	26	100
12	11.00	12.00	20	100	16	15.00	16.00	0	100

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Sayfa No.3/13

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MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
17	16.00	17.00	54	100	21	20.00	21.00	42	100
18	17.00	18.00	28	100	22	21.00	22.00	48	100
19	18.00	19.00	22	100	23	22.00	23.00	12	100
20	19.00	20.00	12	100	24	23.00	24.00	10	100


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 7/25

Derinlik : 24,00 - 28,00 m


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 8/25

Derinlik : 28,00 - 32,00 m

TSK-6

Sayfa No.4/13

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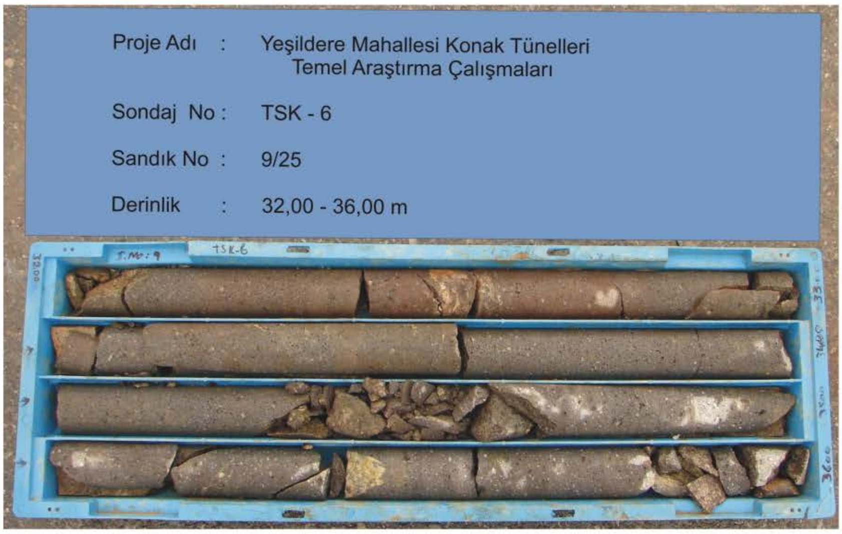
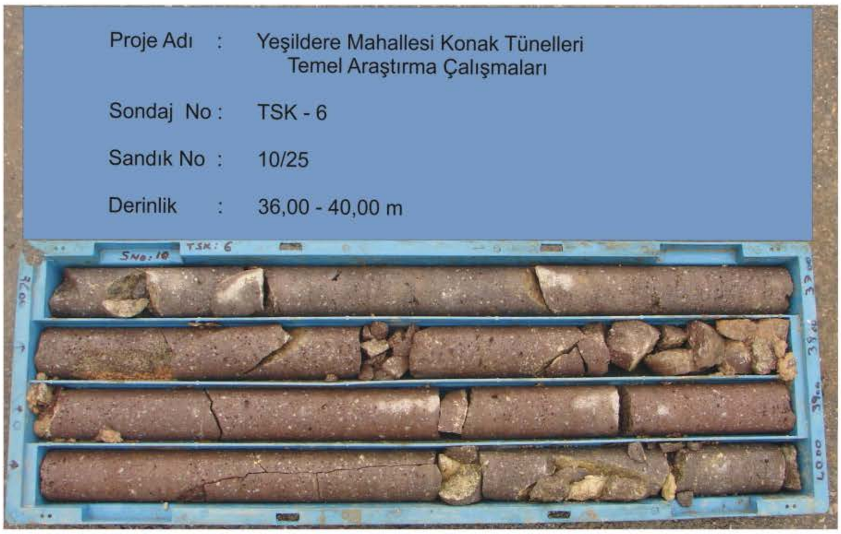
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
25	24.00	25.00	27	100	29	28.00	29.00	30	100
26	25.00	26.00	20	100	30	29.00	30.00	83	100
27	26.00	27.00	17	100	31	30.00	31.00	55	100
28	27.00	28.00	15	100	32	31.00	32.00	0	100





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Sayfa No.5/13

Page No. 5/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
33	32.00	33.00	40	100	37	36.00	37.00	57	100
34	33.00	34.00	28	100	38	37.00	38.00	12	100
35	34.00	35.00	24	100	39	38.00	39.00	78	100
36	35.00	36.00	27	100	40	39.00	40.00	27	100

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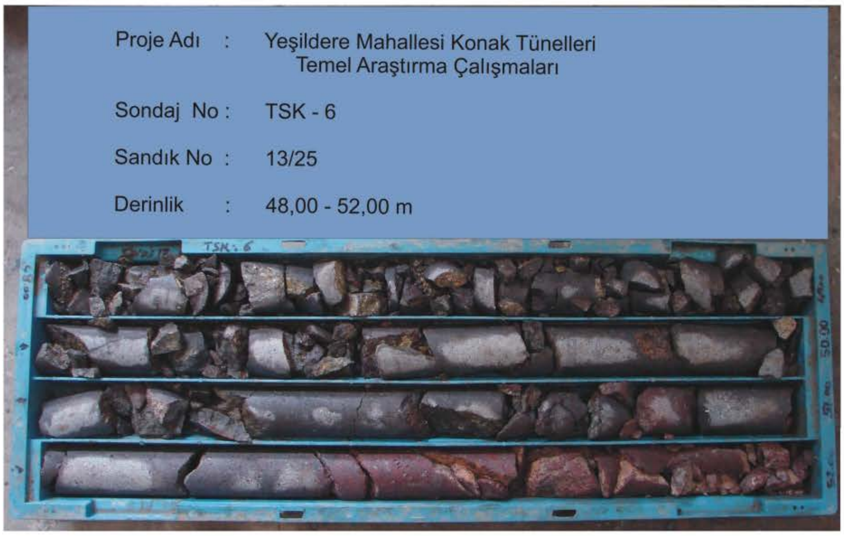
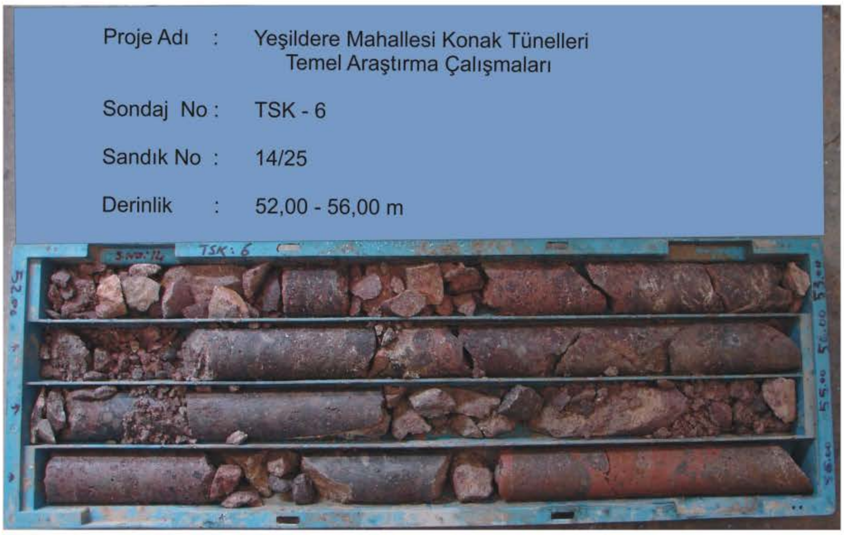
Sayfa No.6/13

Page No. 6/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
41	40.00	41.00	0	100	45	44.00	45.00	76	100
42	41.00	42.00	28	100	46	45.00	46.00	18	100
43	42.00	43.00	28	100	47	46.00	47.00	0	100
44	43.00	44.00	58	100	48	47.00	48.00	0	100



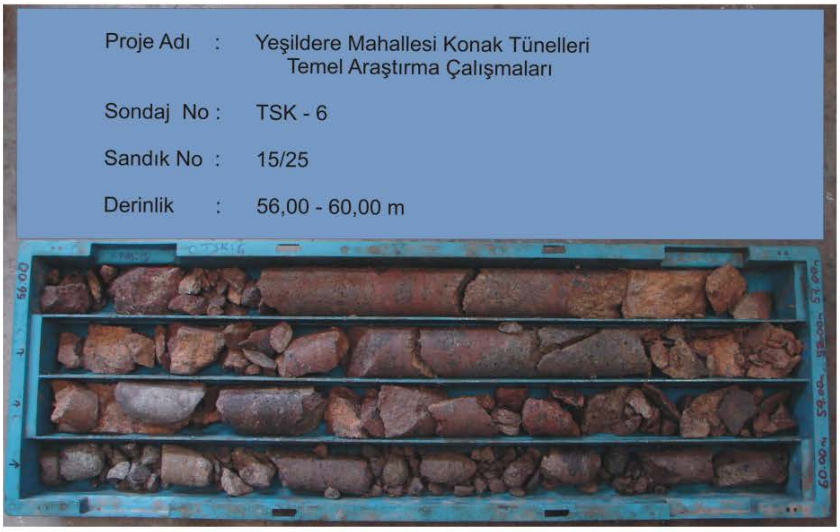


TSK-6

Sayfa No.7/13

Page No. 7/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
49	48.00	49.00	0	100	53	52.00	53.00	10	100
50	49.00	50.00	0	100	54	53.00	54.00	17	100
51	50.00	51.00	10	100	55	54.00	55.00	0	100
52	51.00	52.00	24	100	56	55.00	56.00	47	100

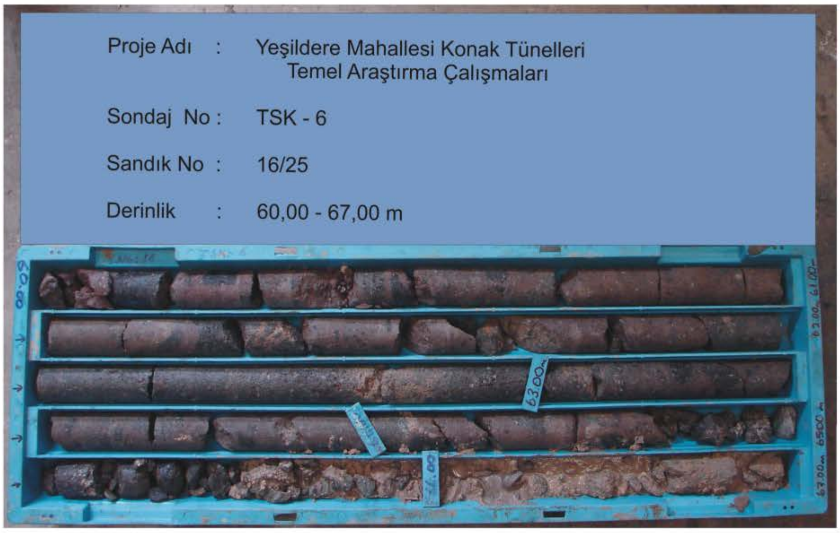


Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 15/25

Derinlik : 56,00 - 60,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 16/25

Derinlik : 60,00 - 67,00 m

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Sayfa No.8/13

Page No. 8/13

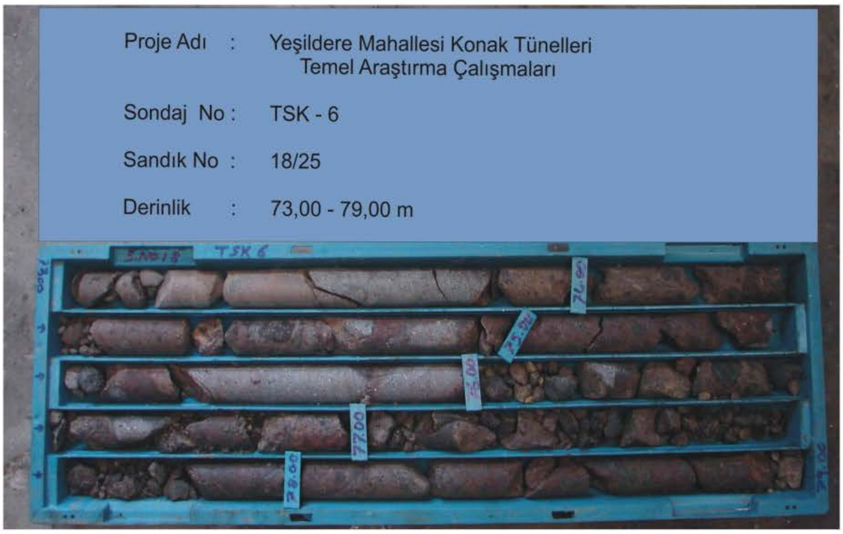
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
57	56.00	57.00	21	100	63	62.00	63.00	48	100
58	57.00	58.00	0	100	64	63.00	64.00	11	77
59	58.00	59.00	0	100	65	64.00	65.00	0	57
60	59.00	60.00	0	100	66	65.00	66.00	0	52
61	60.00	61.00	24	100	67	66.00	67.00	0	48
62	61.00	62.00	12	100					

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 17/25

Derinlik : 67,00 - 73,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 18/25

Derinlik : 73,00 - 79,00 m

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Sayfa No.9/13

Page No. 9/13

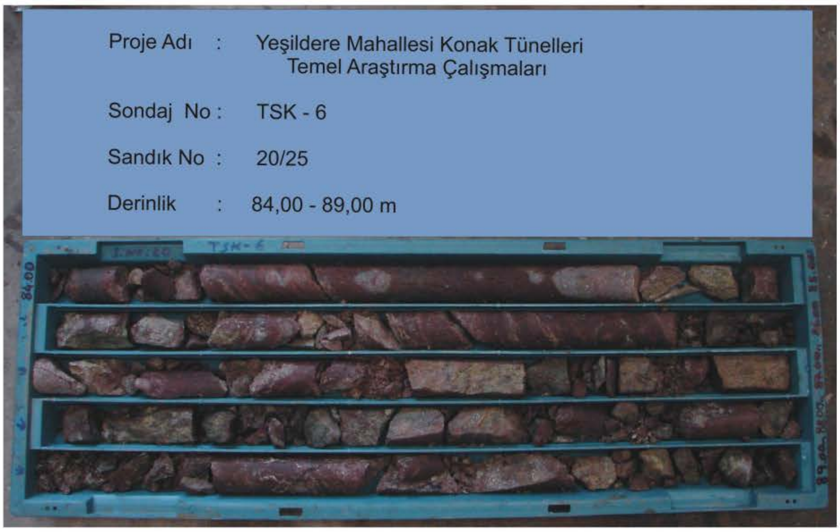
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
68	67.00	68.00	20	54	74	73.00	74.00	0	70
69	68.00	69.00	17	69	75	74.00	75.00	12	92
70	69.00	70.00	19	78	76	75.00	76.00	32	94
71	70.00	71.00	16	100	77	76.00	77.00	0	88
72	71.00	72.00	0	100	78	77.00	78.00	0	91
73	72.00	73.00	19	100	79	78.00	79.00	11	70


Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 19/25

Derinlik : 79,00 - 84,00 m


Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 20/25

Derinlik : 84,00 - 89,00 m

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Sayfa No.10/13

Page No. 10/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
80	79.00	80.00	37	100	85	84.00	85.00	49	100
81	80.00	81.00	34	100	86	85.00	86.00	20	100
82	81.00	82.00	39	100	87	86.00	87.00	0	100
83	82.00	83.00	0	100	88	87.00	88.00	0	100
84	83.00	84.00	0	100	89	88.00	89.00	0	100

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 21/25

Derinlik : 89,00 - 94,00 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 22/25

Derinlik : 94,00 - 99,00 m

TSK-6

Sayfa No.11/13

Page No. 11/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
90	89.00	90.00	10	100	95	94.00	95.00	35	100
91	90.00	91.00	10	100	96	95.00	96.00	70	100
92	91.00	92.00	46	100	97	96.00	97.00	35	100
93	92.00	93.00	40	100	98	97.00	98.00	32	100
94	93.00	94.00	66	100	99	98.00	99.00	43	100

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Sayfa No.12/13

Page No. 12/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
100	99.00	100.00	35	100	105	104.00	105.00	82	100
101	100.00	101.00	18	100	106	105.00	106.00	70	100
102	101.00	102.00	56	100	107	106.00	107.00	79	100
103	102.00	103.00	10	100	108	107.00	108.00	52	100
104	103.00	104.00	0	100	109	108.00	109.00	70	100

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : TSK - 6

Sandık No : 25/25

Derinlik : 109,00 - 113,00 m

TSK-6

Sayfa No.13/13

Page No. 13/13

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
110	109.00	110.00	10	100	112	111.00	112.00	79	100
111	110	111.00	48	100	113	112.00	113.00	42	100

Proje Adı : Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-1

Sandık No : 1/14

Derinlik : 0.00 - 5.00 m

Proje Adı : Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-1

Sandık No : 2/14

Derinlik : 5.00 - 13.00 m

EK-TSK-1

Sayfa No.1/7
Page No. 1/7

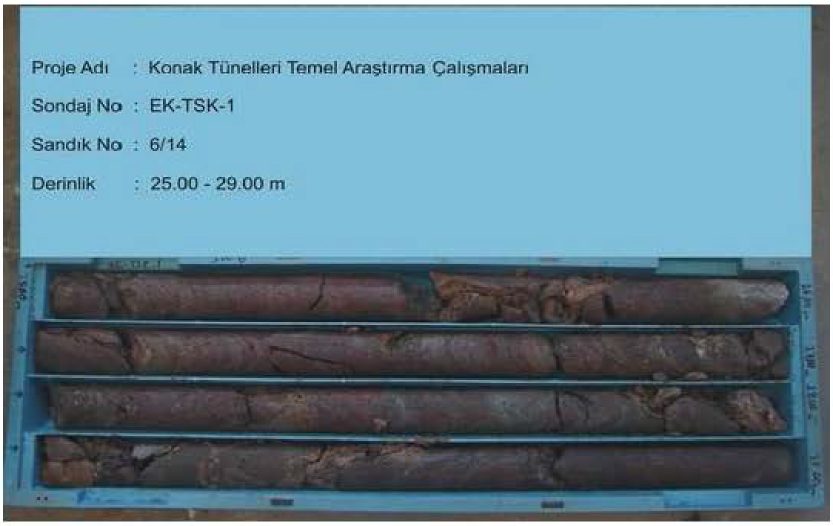
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
1	0.00	1.00	-	100	8	7.00	8.00	-	30
2	1.00	2.00	-	100	9	8.00	9.00	-	40
3	2.00	3.00	-	100	10	9.00	10.00	-	20
4	3.00	4.00	-	65	11	10.00	11.00	0	60
5	4.00	5.00	-	35	12	11.00	12.00	28	70
6	5.00	6.00	-	65	13	12.00	13.00	10	70
7	6.00	7.00	-	35					

EK -TSK-1

Sayfa No.2/7
Page No. 2/7

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
14	13.00	14.00	0	100	18	17.00	18.00	22	100
15	14.00	15.00	35	100	19	18.00	19.00	83	100
16	15.00	16.00	33	100	20	19.00	20.00	25	100
17	16.00	17.00	65	100	21	20.00	21.00	45	100

Proje Adı : Konak Tünelleri Temel Araştırma Çalışmaları
Sondaj No : EK-TSK-1
Sandık No : 5/14
Derinlik : 21.00 - 25.00 m



Proje Adı : Konak Tünelleri Temel Araştırma Çalışmaları
Sondaj No : EK-TSK-1
Sandık No : 6/14
Derinlik : 25.00 - 29.00 m

EK -TSK-I

Sayfa No. 3/7
Page No. 3/7

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
22	21.00	22.00	0	100	26	25.00	26.00	36	100
23	22.00	23.00	20	100	27	26.00	27.00	53	100
24	23.00	24.00	13	100	28	27.00	28.00	57	100
25	24.00	25.00	0	100	29	28.00	29.00	40	100

EK- SK-1

Sayfa No.4/7
Page No. 4/7

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
30	29.00	30.00	0	100	34	33.00	34.00	40	100
31	30.00	31.00	31	100	35	34.00	35.00	30	100
32	31.00	32.00	30	100	36	35.00	36.00	18	100
33	32.00	33.00	55	100	37	36.00	37.00	13	100

EK-TSK-I

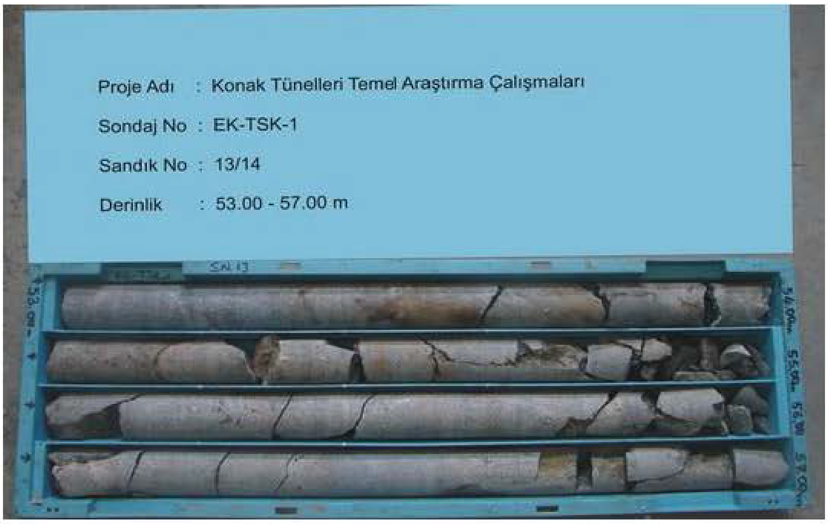
Sayfa No.5/7
Page No. 5/7

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
38	37.00	38.00	22	100	42	41.00	42.00	12	100
39	38.00	39.00	36	100	43	42.00	43.00	13	100
40	39.00	40.00	0	100	44	43.00	44.00	28	100
41	40.00	41.00	31	100	45	44.00	45.00	33	100

EK-TSK-1

Sayfa No.6/7
Page No. 6/7

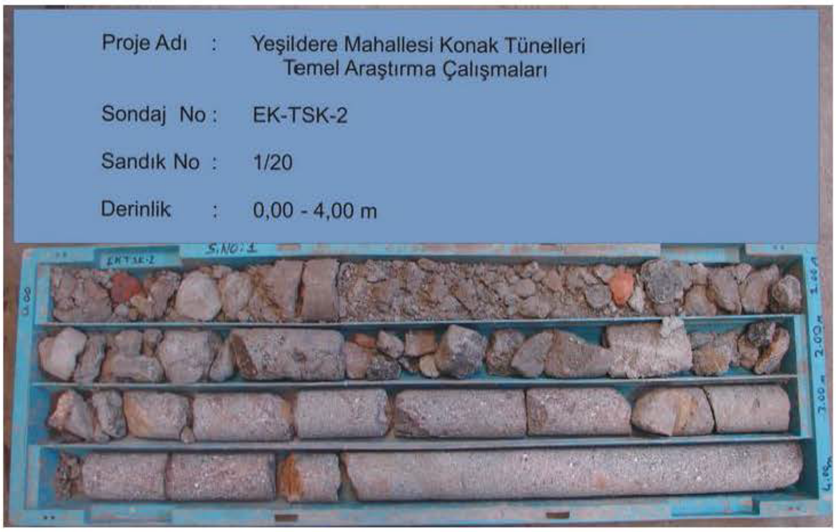
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
46	45.00	46.00	0	100	50	49.00	50.00	68	100
47	46.00	47.00	22	100	51	50.00	51.00	29	100
48	47.00	48.00	82	100	52	51.00	52.00	26	100
49	48.00	49.00	50	100	53	52.00	53.00	100	100



EK-TSK-1

Sayfa No.7/7
Page No. 7/7

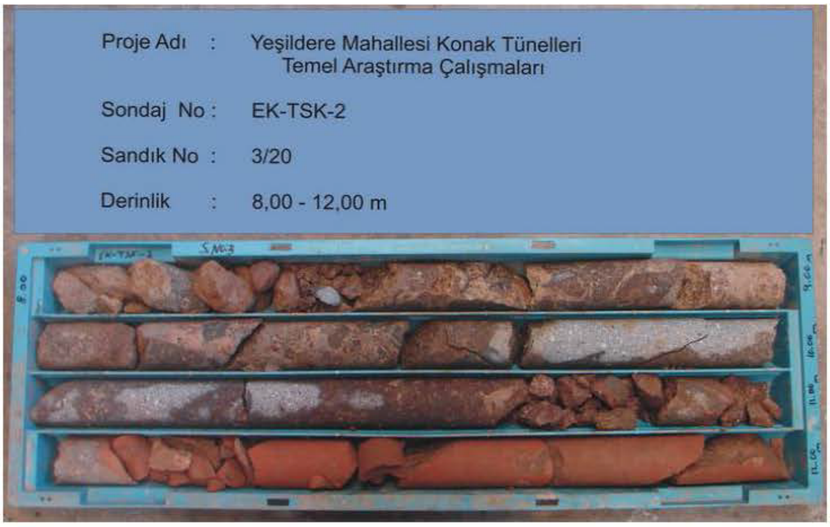
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
54	53.00	54.00	80	100	58	57.00	58.00	23	100
55	54.00	55.00	15	100	59	58.00	59.00	26	100
56	55.00	56.00	43	100	60	59.00	60.00	58	100
57	56.00	57.00	40	100					

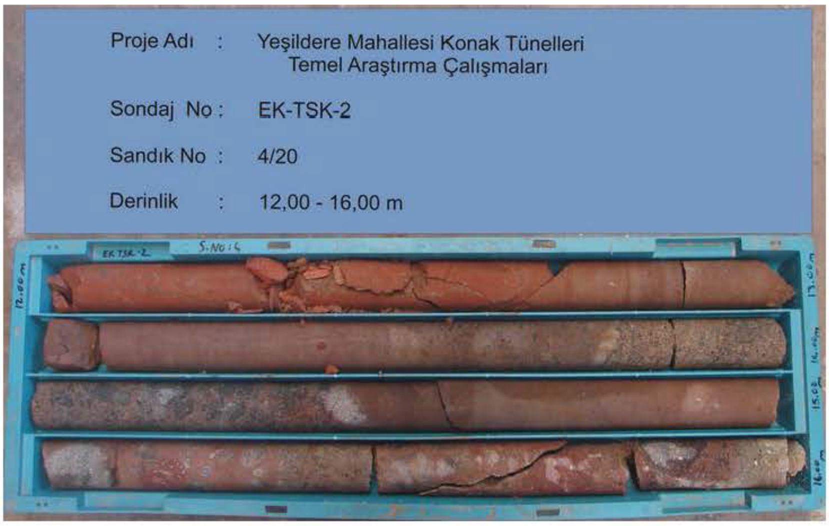


EK-TSK-2

Sayfa No.1/10
Page No. 1/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	**KAROT (%)** CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	**KAROT (%)** CORE REC.
1	0.00	1.00	-	100	5	4.00	5.00	53	100
2	1.00	2.00	0	100	6	5.00	6.00	75	100
3	2.00	3.00	12	100	7	6.00	7.00	59	100
4	3.00	4.00	65	100	8	7.00	8.00	40	100





EK-TSK-2

Sayfa No.2/10
Page No. 2/10

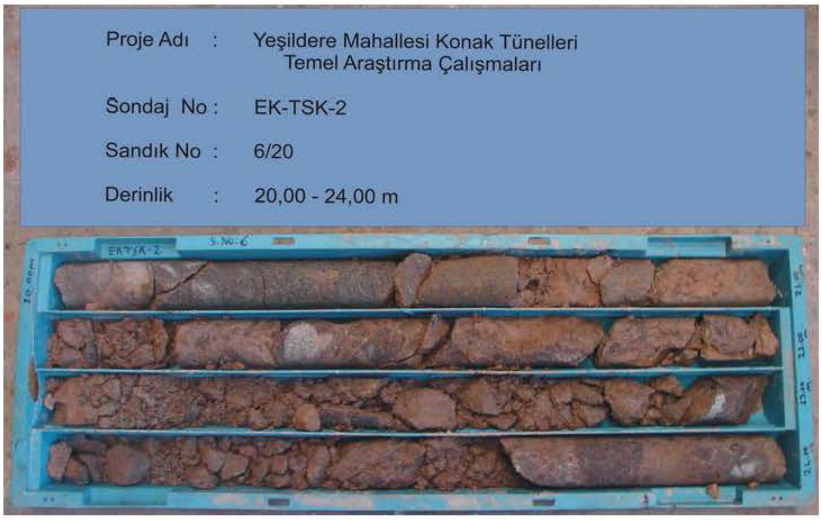
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
9	8.00	9.00	10	100	13	12.00	13.00	45	100
10	9.00	10.00	26	100	14	13.00	14.00	86	100
11	10.00	11.00	55	100	15	14.00	15.00	95	100
12	11.00	12.00	0	100	16	15.00	16.00	50	100

Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 5/20

Derinlik : 16,00 - 20,00 m



Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

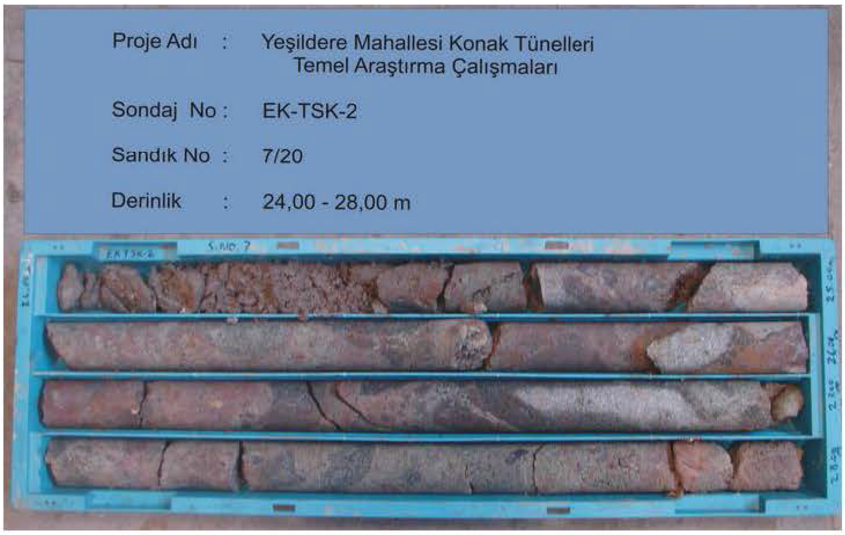
Sandık No : 6/20

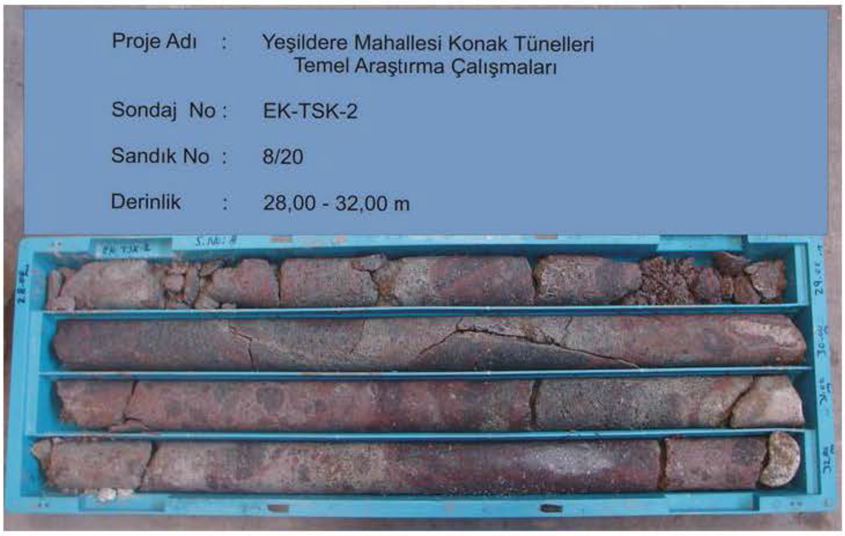
Derinlik : 20,00 - 24,00 m

EK-TSK-2

Sayfa No.3/10
Page No. 3/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
17	16.00	17.00	37	100	21	20.00	21.00	15	100
18	17.00	18.00	14	100	22	21.00	22.00	0	100
19	18.00	19.00	0	100	23	22.00	23.00	0	100
20	19.00	20.00	60	100	24	23.00	24.00	25	100

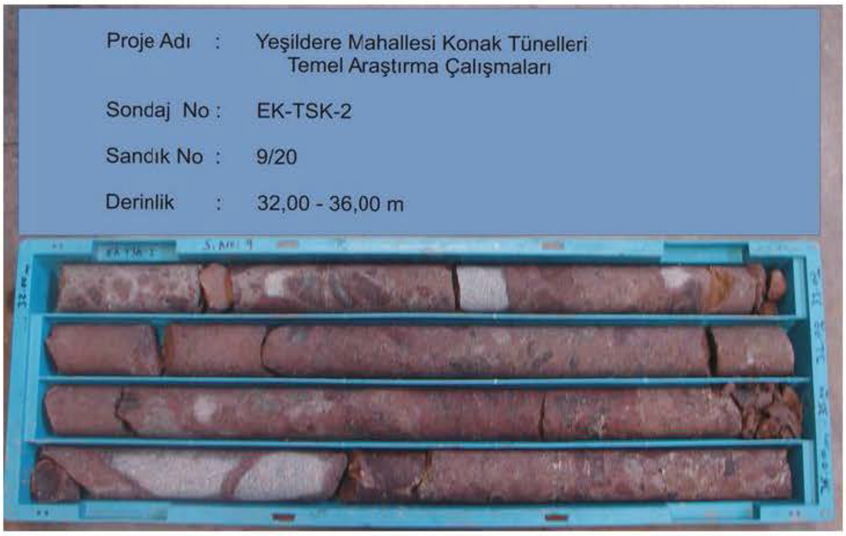




EK-TSK-2

Sayfa No.4/10
Page No. 4/10

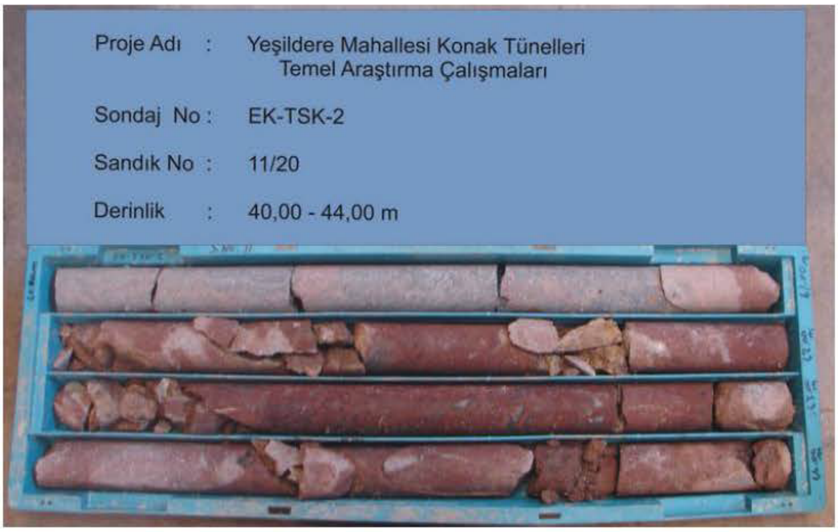
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
25	24.00	25.00	15	100	29	28.00	29.00	14	100
26	25.00	26.00	76	100	30	29.00	30.00	30	100
27	26.00	27.00	73	100	31	30.00	31.00	66	100
28	27.00	28.00	50	100	32	31.00	32.00	72	100

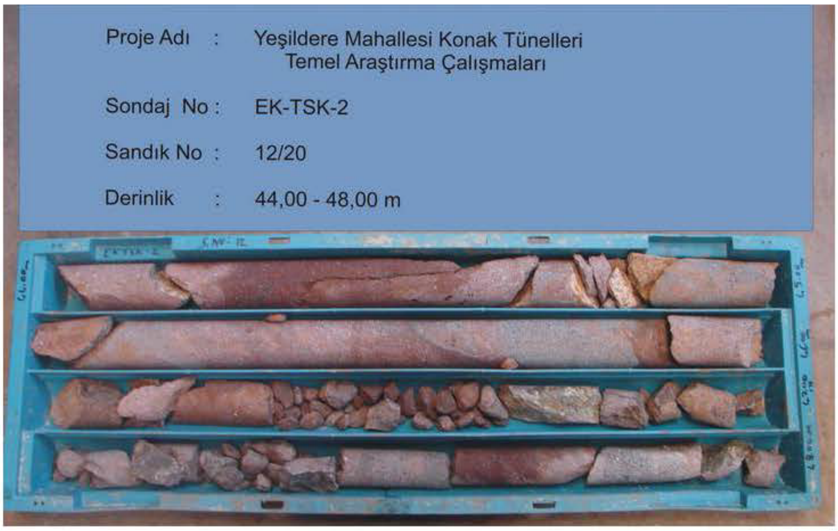


EK-TSK-2

Sayfa No.5/10
Page No. 5/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
33	32.00	33.00	73	100	37	36.00	37.00	85	100
34	33.00	34.00	62	100	38	37.00	38.00	77	100
35	34.00	35.00	70	100	39	38.00	39.00	49	100
36	35.00	36.00	66	100	40	39.00	40.00	30	100

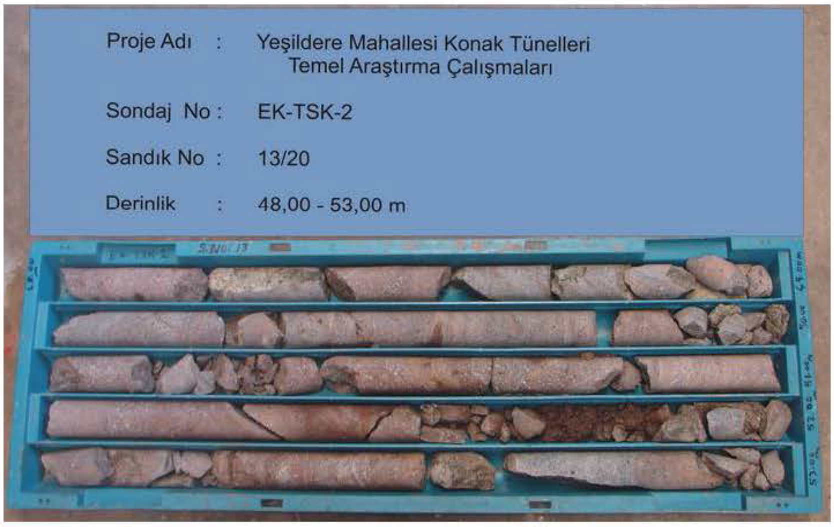




EK-TSK-2

Sayfa No.6/10
Page No. 6/10

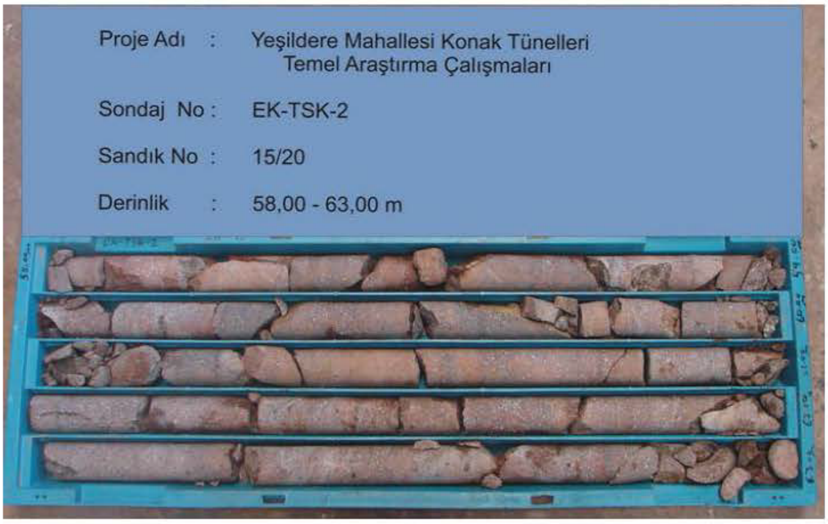
MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
40	40.00	41.00	72	100	44	44.00	45.00	12	100
41	41.00	42.00	35	100	45	45.00	46.00	69	100
42	42.00	43.00	49	100	46	46.00	47.00	0	100
43	43.00	44.00	40	100	47	47.00	48.00	22	100



EK-TSK-2

Sayfa No.7/10
Page No. 7/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	**KAROT (%)** CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	**KAROT (%)** CORE REC.
48	48.00	49.00	24	100	53	53.00	54.00	33	100
49	49.00	50.00	55	100	54	54.00	55.00	0	100
50	50.00	51.00	40	100	55	55.00	56.00	20	100
51	51.00	52.00	23	100	56	56.00	57.00	26	100
52	52.00	53.00	19	100	57	57.00	58.00	0	100


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 15/20

Derinlik : 58,00 - 63,00 m


Proje Adı : Yeşildere Mahallesi Konak Tünelleri
Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 16/20

Derinlik : 63,00 - 68,00 m

EK-TSK-2

Sayfa No.8/10
Page No. 8/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
58	58.00	59.00	12	100	63	63.00	64.00	46	77
59	59.00	60.00	13	100	64	64.00	65.00	49	57
60	60.00	61.00	44	100	65	65.00	66.00	37	52
61	61.00	62.00	63	100	66	66.00	67.00	0	48
62	62.00	63.00	46	66	67	67.00	68.00	43	54

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 17/20

Derinlik : 68,00 - 73,00 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 18/20

Derinlik : 73,00 - 78,00 m

EK-TSK-2

Sayfa No.9/10
Page No. 9/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
68	68.00	69.00	51	69	73	73.00	74.00	15	70
69	69.00	70.00	42	78	74	74.00	75.00	66	92
70	70.00	71.00	64	100	75	75.00	76.00	17	94
71	71.00	72.00	60	100	76	76.00	77.00	14	88
72	72.00	73.00	19	100	77	77.00	78.00	0	91

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 19/20

Derinlik : 78,00 - 83,00 m

Proje Adı : Yeşildere Mahallesi Konak Tünelleri Temel Araştırma Çalışmaları

Sondaj No : EK-TSK-2

Sandık No : 20/20

Derinlik : 83,00 - 85,00 m

EK -TSK-2

Sayfa No.10/10
Page No. 10/10

MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.	MANEVRA CORE RUN	DERİNLİK (m) DEPTH (m)		RQD (%)	KAROT (%) CORE REC.
78	78.00	79.00	22	70	82	82.00	83.00	27	100
79	79.00	80.00	60	100	83	83.00	84.00	26	100
80	80.00	81.00	50	100	84	84.00	85.00	40	100
81	81.00	82.00	14	100					

APPENDIX-C: LABORATORY TEST RESULTS

All detailed laboratory test results are given in APPENDIX-C.

AKADEMİ ZEMİN ve KAYA MEKANİĞİ LABORATUVARI

Alınteri Bulvarı, 1151.Sokak, Gül 86 Sitesi, No: 1/80 Ostim / ANKARA
Tel: 0 312 385 67 67, Faks: 0 312 385 59 52

KAYA DENEYLERİ SONUÇLAR FORMU

Sayfa No: 1 / 1
Num.Gel.Tarihi: 26,01,2012
Rapor Tarihi: 10,02,2012
Lab. Kayıt No: AKD-12 / 01-247
Bayındırlık K No: 2328790

FİRMA ADI : **TEMELSON MÜHENDİSLİK**
PROJE ADI : **KONAK YEŞİLDERE TÜNELİ ve BAĞLANTI YOLU, İZMİR**
PROJE TİPİ : **Jeolojik - Jeoteknik Etüt**

Sondaj No	Numune No	Derinlik (m)	Numune Boyu (mm)	Numune Çapı (mm)	Elastisite Modülü ε Gpa	Poisson Oranı V	Num. Ağırlığı (g)	Doğal Birim Hacim Ağırlık (kN/m³)	Numune Kesit Alanı (cm²)	Yenilme Yükü P (kg)	Tek Eksenli Basınç Deneyi q_u (kg/cm²)	Nokta Yükleme Deneyi I_s (kg/cm²)
TSK-1	KAROT	13,00-14,50	93	47			311,92	18,96	17,35	2927	169	
TSK-1	KAROT	17,00-18,00	Numune dağılgan yapıda olduğundan basınç deneyleri yapılamamış, zemin sınıflaması yapılmıştır.									
TSK-1	KAROT	33,00-33,30	91	46			309,18	20,06	16,62	591	36	
TSK-2	KAROT	49,50-50,00	47	47			173,55	20,88	17,35	127		5,7
TSK-2	KAROT	59,00-59,20	86	43			267,52	21,01	14,52	806	55	
TSK-3	KAROT	44,50-46,00	53	55			272,18	21,20	23,76	139		4,6
TSK-4	KAROT	21,00-22,00	94	47			383,17	23,05	17,35	3518	203	
TSK-4	KAROT	36,00-37,00	92	46			300,02	19,25	16,62	693	42	
TSK-4	KAROT	41,00-42,00	46	45			134,06	17,98	15,90	58		2,9
TSK-5	KAROT	17,00-18,00	96	48			400,97	22,64	18,10	479	26	
TSK-7	KAROT	85,00-86,00	46	46			166,47	21,36	16,62	76		3,6
TSK-7	KAROT	94,00-95,00	46	46			165,08	21,18	16,62	63		3,0
TSK-7	KAROT	102,00-103,00	94	47			367,80	22,12	17,35	387	22	
TSK-7	KAROT	104,00-105,00	46	46			156,98	20,14	16,62	86		4,1
TSK-8	KAROT	71,00-72,00	96	48			373,22	21,08	18,10	255	14	
TSK-8	KAROT	80,00-81,00	88	45			314,69	22,06	15,90	632	40	
TSK-8	KAROT	83,00-84,00	94	47			384,22	23,11	17,35	775	45	

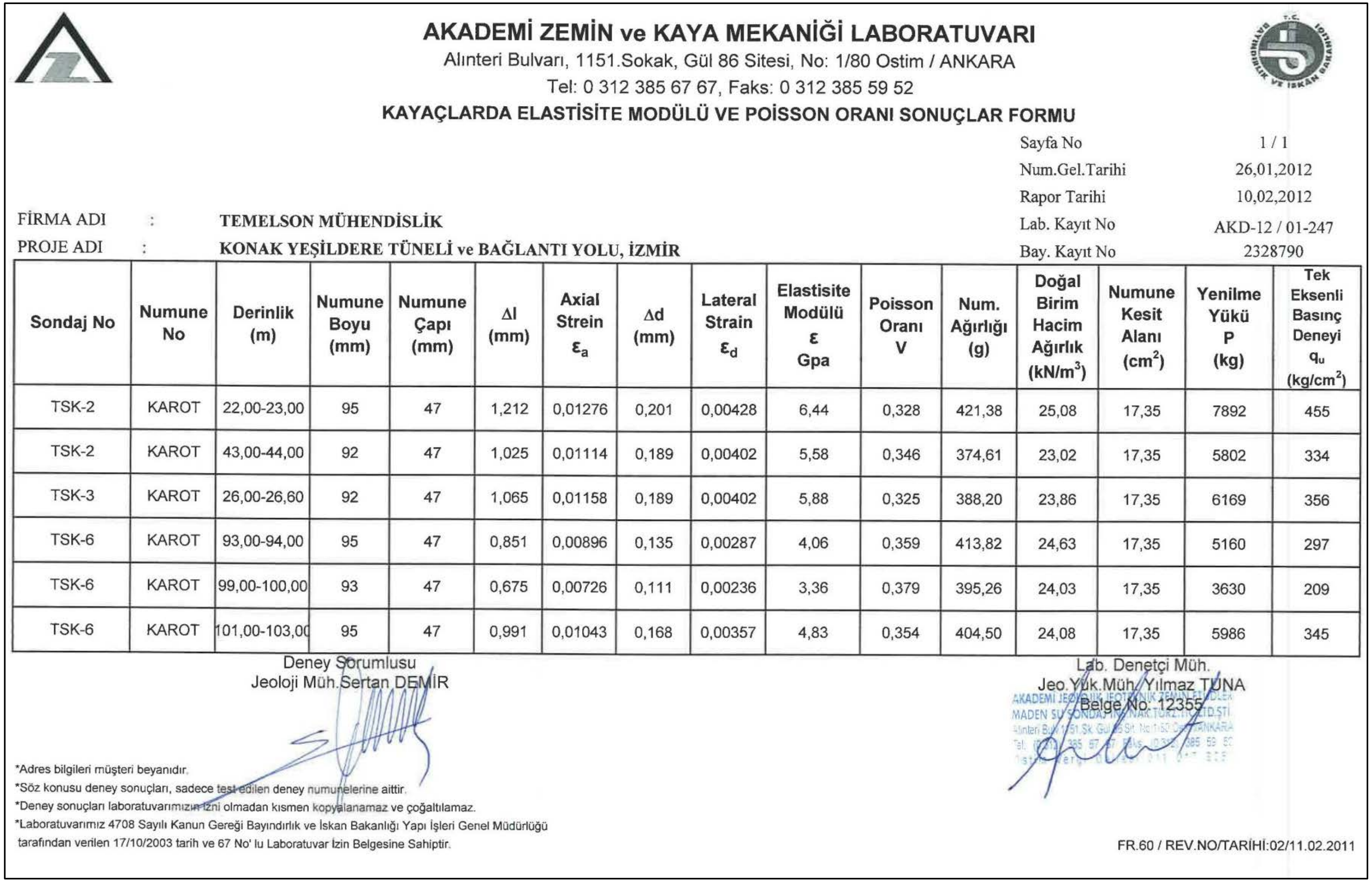
Elastisite Modülü ve Poisson oranı istenilen bazı numuneler dayanım yönünden oldukça zayıf yapılı olduğu için sadece Tek Eksenli Basınç deneyi yapılabilmiştir.

Deney Sorumlusu
Jeoloji Müh. Sertan DEMİR

Lab. Denetçi Müh.
Jeo.Yük.Müh. Yılmaz TUNA
Belge No: 12355

*Adres bilgileri müşteri beyanıdır.
*Söz konusu deney sonuçları, sadece test edilen deney numunelerine aittir.
*Deney sonuçları laboratuvarımızın izni olmadan kısmen kopyalanamaz ve çoğaltılamaz.
*Laboratuvarımız 4708 Sayılı Kanun Gereği Bayındırlık ve İskan Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 17/10/2003 tarih ve 67 No' lu Laboratuvar İzin Belgesine Sahiptir.

FR.61 / REV.NO/TARİHİ:03/24.10.2011



AKADEMİ ZEMİN ve KAYA MEKANİĞİ LABORATUVARI

Alınteri Bulvarı, 1151.Sokak, Gül 86 Sitesi, No: 1/80 Ostim / ANKARA
Tel: 0 312 385 67 67, Faks: 0 312 385 59 52

KAYAÇLARDA ELASTİSİTE MODÜLÜ VE POİSSON ORANI SONUÇLAR FORMU

Sayfa No 1 / 1
Num.Gel.Tarihi 26,01,2012
Rapor Tarihi 10,02,2012
Lab. Kayıt No AKD-12 / 01-247
Bay. Kayıt No 2328790

FİRMA ADI : **TEMELSON MÜHENDİSLİK**
PROJE ADI : **KONAK YEŞİLDERE TÜNELİ ve BAĞLANTI YOLU, İZMİR**

Sondaj No	Numune No	Derinlik (m)	Numune Boyu (mm)	Numune Çapı (mm)	Δl (mm)	Axial Strein ε_a	Δd (mm)	Lateral Strain ε_d	Elastisite Modülü ε Gpa	Poisson Oranı V	Num. Ağırlığı (g)	Doğal Birim Hacim Ağırlık (kN/m^3)	Numune Kesit Alanı (cm^2)	Yenilme Yükü P (kg)	Tek Eksenli Basınç Deneyi q_u (kg/cm^2)
TSK-2	KAROT	22,00-23,00	95	47	1,212	0,01276	0,201	0,00428	6,44	0,328	421,38	25,08	17,35	7892	455
TSK-2	KAROT	43,00-44,00	92	47	1,025	0,01114	0,189	0,00402	5,58	0,346	374,61	23,02	17,35	5802	334
TSK-3	KAROT	26,00-26,60	92	47	1,065	0,01158	0,189	0,00402	5,88	0,325	388,20	23,86	17,35	6169	356
TSK-6	KAROT	93,00-94,00	95	47	0,851	0,00896	0,135	0,00287	4,06	0,359	413,82	24,63	17,35	5160	297
TSK-6	KAROT	99,00-100,00	93	47	0,675	0,00726	0,111	0,00236	3,36	0,379	395,26	24,03	17,35	3630	209
TSK-6	KAROT	101,00-103,00	95	47	0,991	0,01043	0,168	0,00357	4,83	0,354	404,50	24,08	17,35	5986	345

Deney Sorumlusu
Jeoloji Müh.Sertan DEMİR

Lab. Denetçi Müh.
Jeo.Yük.Müh. Yılmaz TUNA
Belge No: 12355

*Adres bilgileri müşteri beyanıdır.
*Söz konusu deney sonuçları, sadece test edilen deney numunelerine aittir.
*Deney sonuçları laboratuvarımızın izni olmadan kısmen kopyalanamaz ve çoğaltılamaz.
*Laboratuvarımız 4708 Sayılı Kanun Gereği Bayındırlık ve İskan Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 17/10/2003 tarih ve 67 No' lu Laboratuvar İzin Belgesine Sahiptir.

FR.60 / REV.NO/TARİHİ:02/11.02.2011

AKADEMİ ZEMİN ve KAYA MEKANİĞİ LABORATUVARI

Alınteri Bulvarı, 1151.Sokak, Gül 86 Sitesi, No: 1/80-81 Ostim / ANKARA

Tel: 0 312 385 67 67, Faks: 0 312 385 59 52

KAYAÇLARDA ELASTİSİTE MODÜLÜ VE POİSSON ORANI SONUÇLAR FORMU

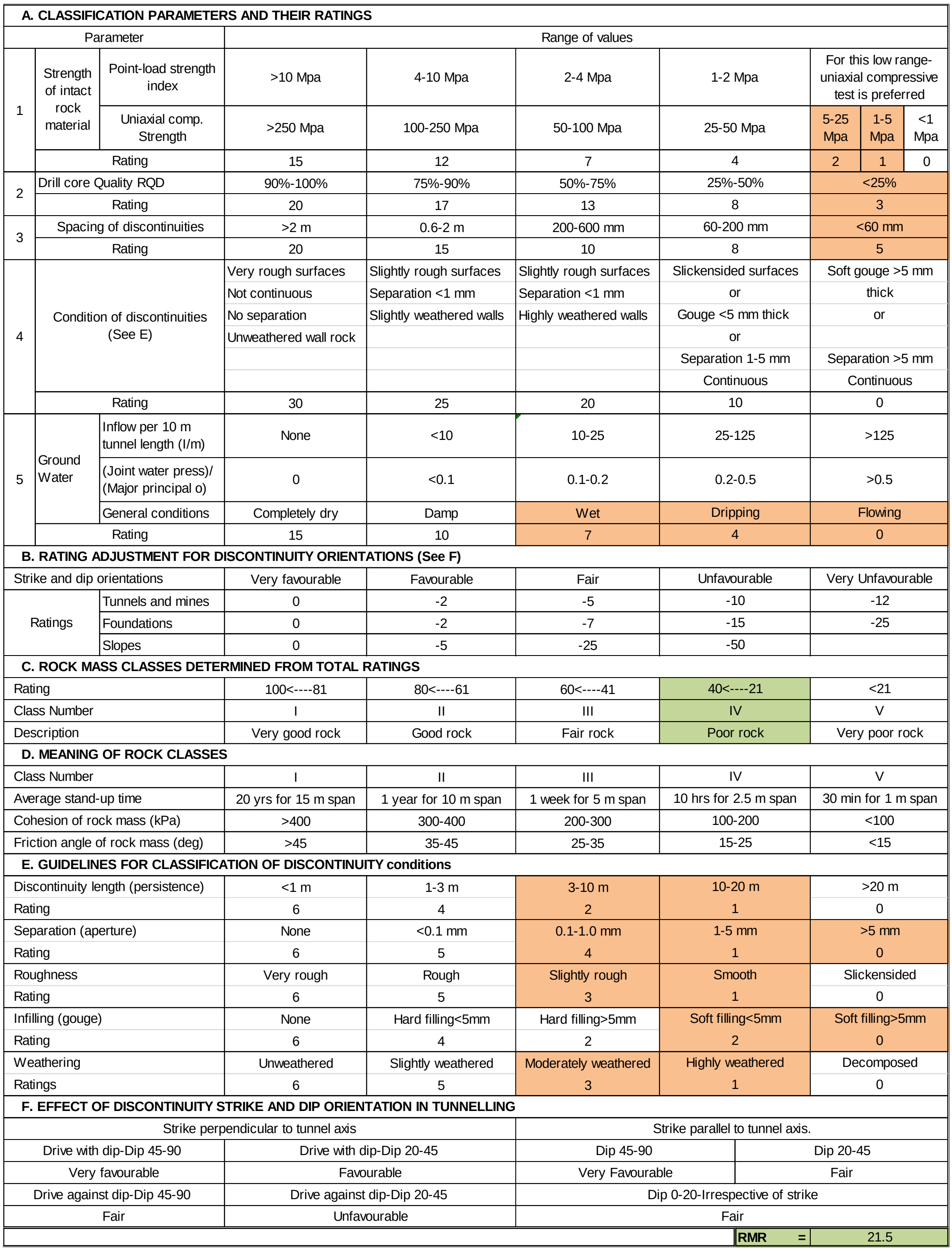
Firma Adı TEMELSU MÜHENDİSLİK

Proje Adı Konak Tüneli Ve Bağlantı Yolu - İZMİR

Sondaj No	Numune No	Derinlik (m)	Numune Boyu (mm)	Numune Çapı (mm)	Δl (mm)	Axial Strein ε_a	Δd (mm)	Lateral Strain ε_d	Elastisite Modülü ε Gpa	Poisson Oranı V	Num. Ağırlığı (g)	Doğal Birim Hacim Ağırlık (kN/m^3)	Numune Kesit Alanı (cm^2)	Yenilme Yükü P (kg)	Tek Eksenli Basınç Deneyi q_u (kg/cm^2)
SK-1	K-1	12,50-12,60	95	47	0,780	0,00821	0,138	0,00294	4,26	0,351	405,46	24,13	17,35	4476	258
YSK-1	K-1	8,65-9,00	96	47	1,030	0,01073	0,199	0,00423	6,90	0,338	384,57	22,65	17,35	7321	422
YSK-1	K-2	17,00-17,20	96	47	0,850	0,00885	0,170	0,00362	3,15	0,359	393,24	23,16	17,35	3435	198
EK-TSK-2	K-1	56,00-56,35	96	47	1,040	0,01083	0,213	0,00453	7,58	0,321	403,23	23,75	17,35	8848	510
EK-TSK-2	K-2	67,17-67,35	97	47	1,020	0,01052	0,172	0,00366	9,60	0,310	439,40	25,61	17,35	10219	589
EK-TSK-2	K-3	74,00-74,78	95	47	1,140	0,01200	0,207	0,00440	10,44	0,297	438,91	26,12	17,35	11052	637
EK-TSK-3	K-1	90,00-90,25	95	47	0,970	0,01021	0,152	0,00323	9,15	0,319	427,05	25,42	17,35	9681	558
EK-TSK-3	K-3	112,50-112,70	94	47	1,100	0,01170	0,223	0,00474	5,86	0,343	396,62	23,86	17,35	6315	364
EK-TSK-3	K-4	116,00-116,30	100	47	1,090	0,01090	0,176	0,00374	2,99	0,371	432,52	24,46	17,35	3661	211
EK-TSK-4	K-5	17,80-18,00	107	53	0,980	0,00916	0,200	0,00377	1,09	0,393	474,48	19,72	22,06	1235	56
EK-TSK-4	K-7	24,82-25,00	106	52	0,740	0,00698	0,142	0,00273	1,48	0,361	520,01	22,66	21,24	1572	74

APPENDIX-D: ROCK MASS RATING CHARTS

RMR calculation details are presented in APPENDIX-D for all geotechnical sections which are included with in this thesis.



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 (I/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

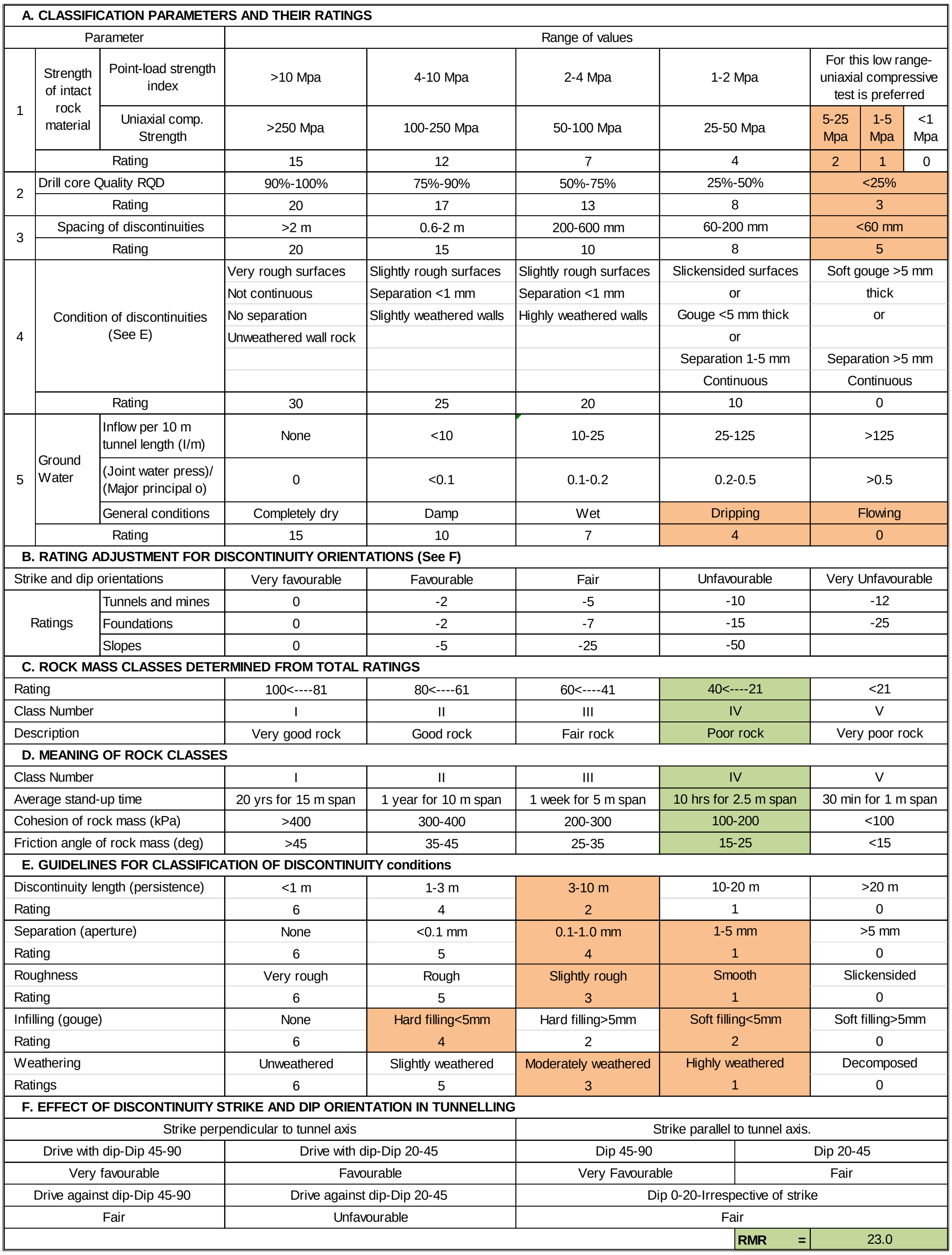
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

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 =	21.5

Figure D.1: RMR value of the exit portal open cuts (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 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

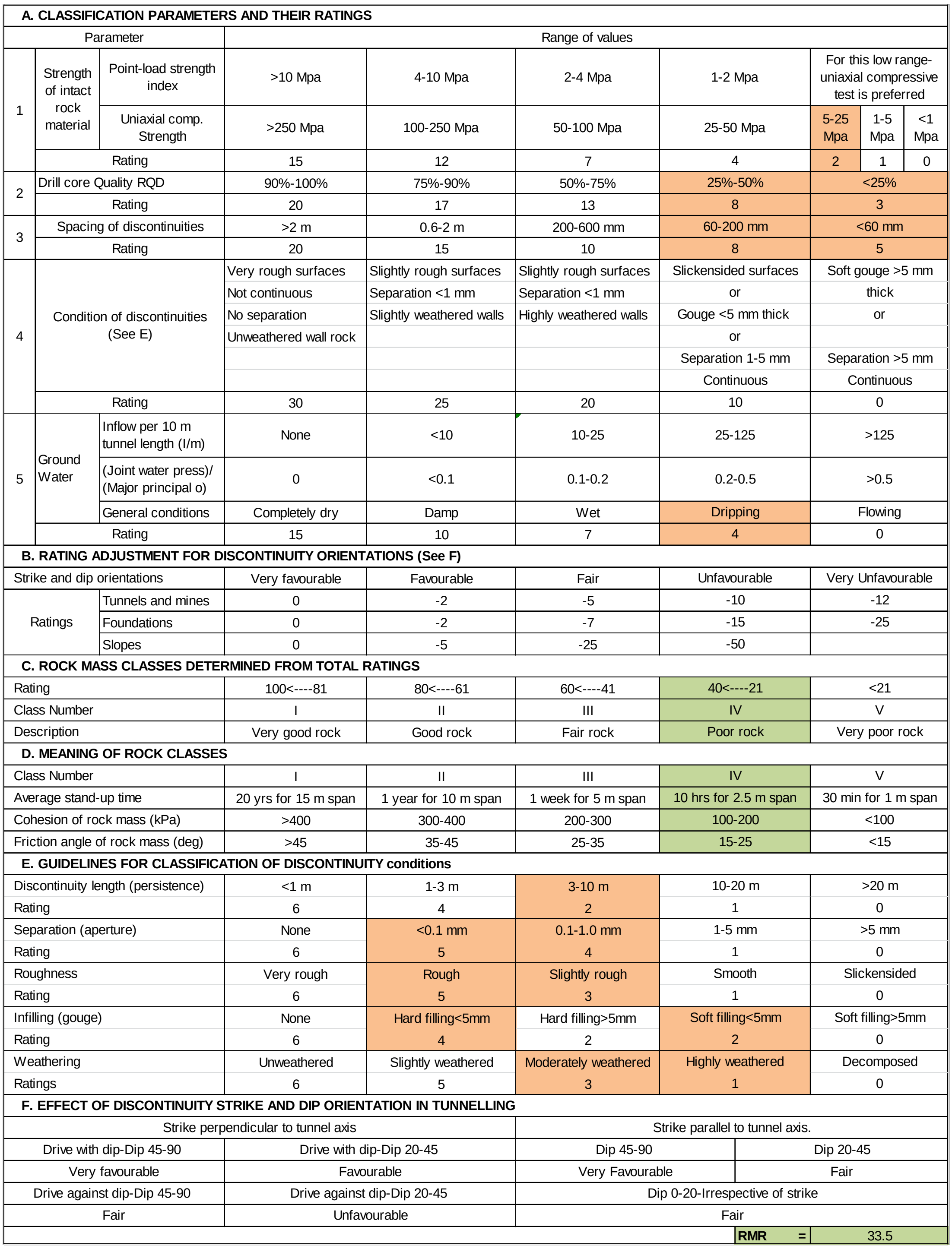
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

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 =	23.0

Figure D.2: RMR value of T-Px section (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 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 (I/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

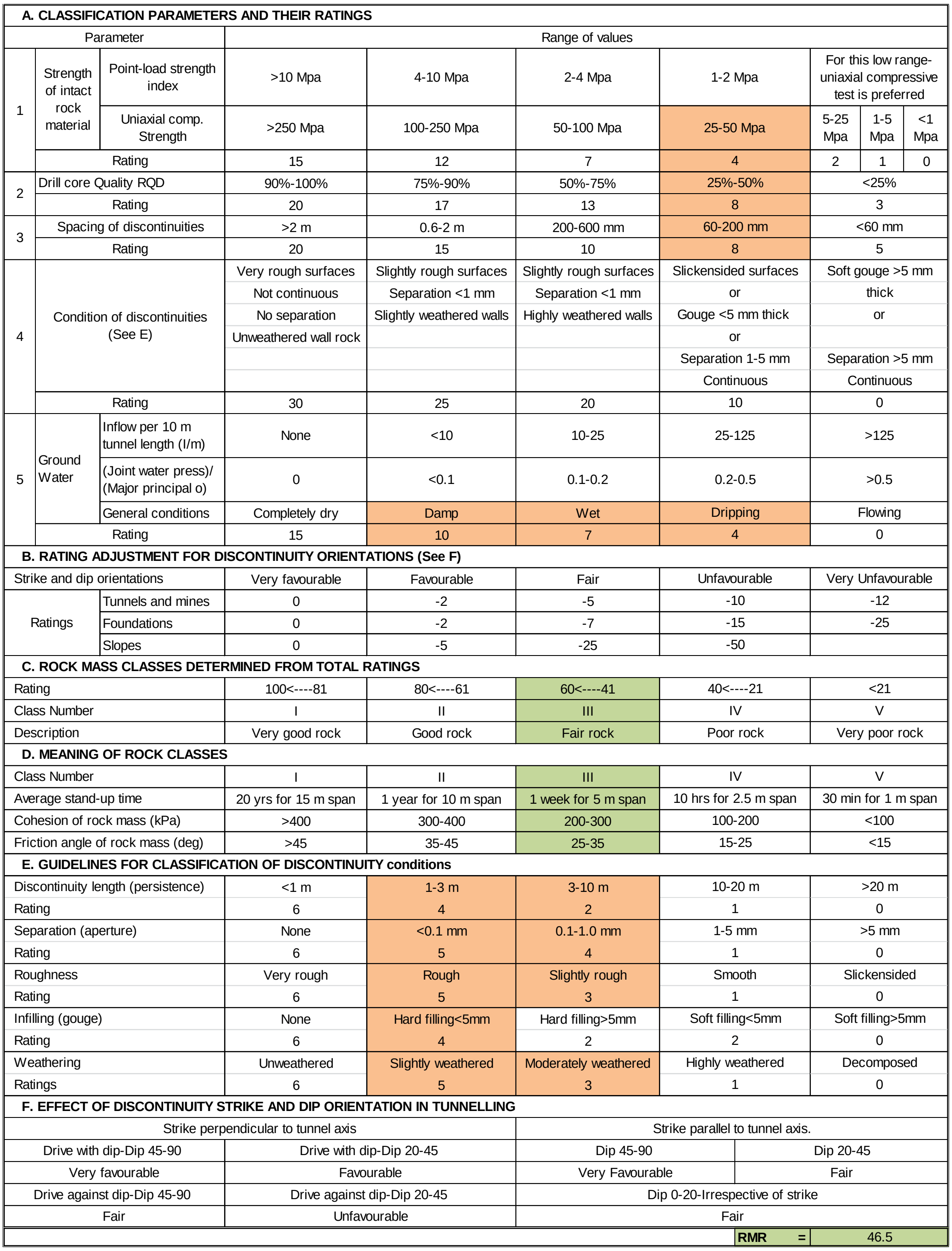
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

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 =	33.5

Figure D.3: RMR value of T-50x section (Bieniawski, 1989)



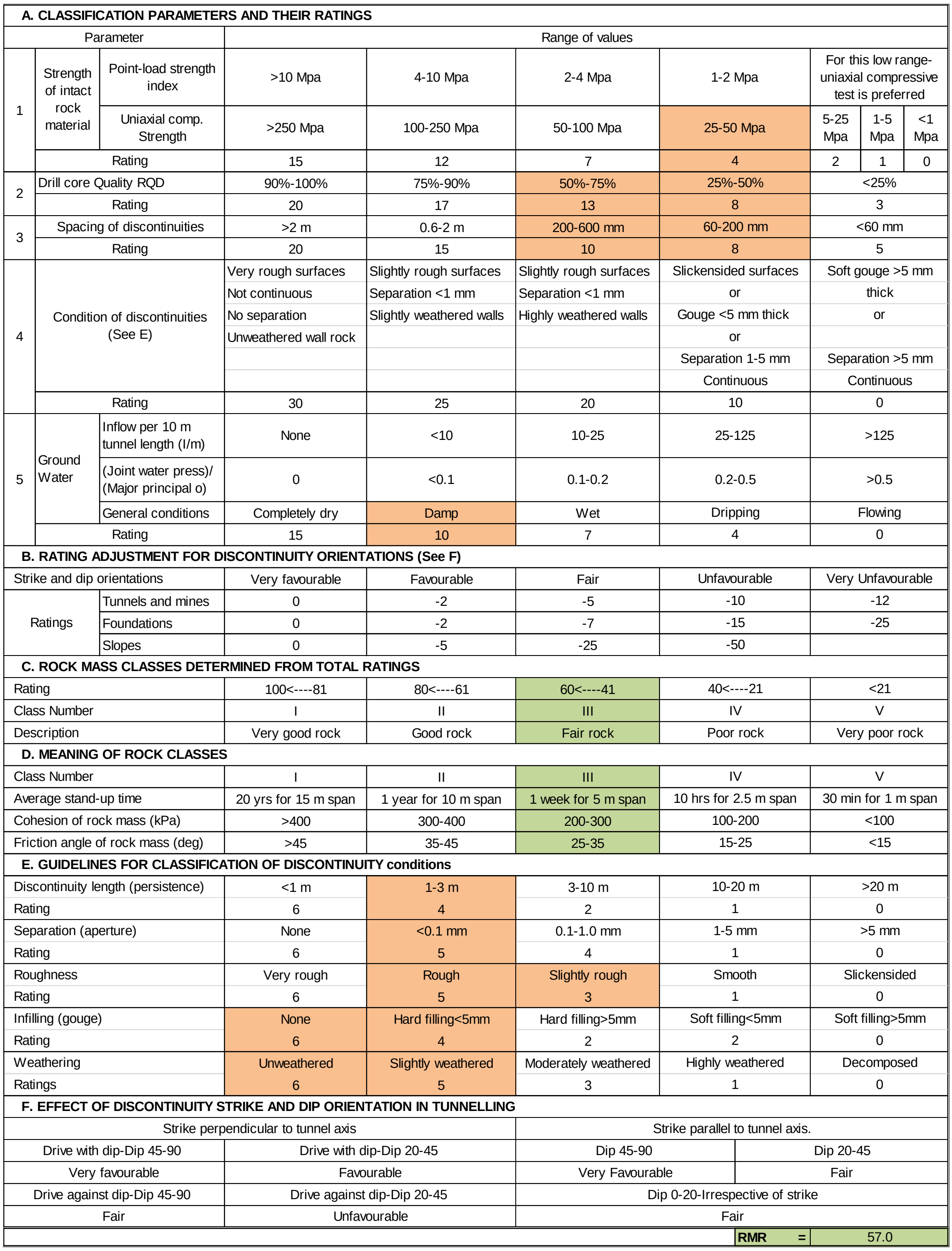
A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 Mpa	4-10 Mpa	2-4 Mpa	1-2 Mpa	For this low range-uniaxial compressive test is preferred		
		Uniaxial comp. Strength	>250 Mpa	100-250 Mpa	50-100 Mpa	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 =	46.5

Figure D.4: RMR value of T-75x section (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 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

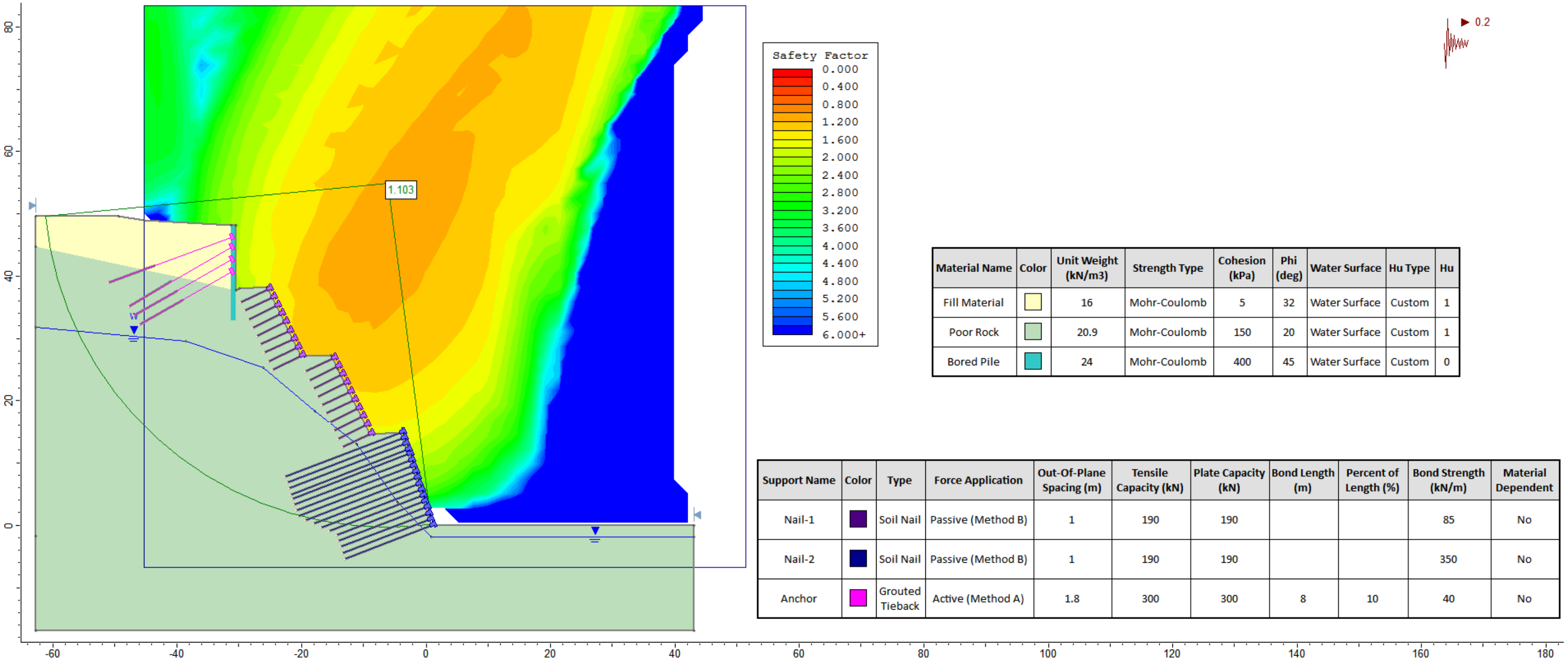
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis.	
Drive with dip-Dip 45-90	Drive with dip-Dip 20-45	Dip 45-90	Dip 20-45
Very favourable	Favourable	Very Favourable	Fair
Drive against dip-Dip 45-90	Drive against dip-Dip 20-45	Dip 0-20-Irrespective of strike	
Fair	Unfavourable	Fair	

RMR =	57.0

Figure D.5: RMR value of T-100x section (Bieniawski, 1989)

APPENDIX-E: CIRCULAR FAILURE ANALYSES RESULTS

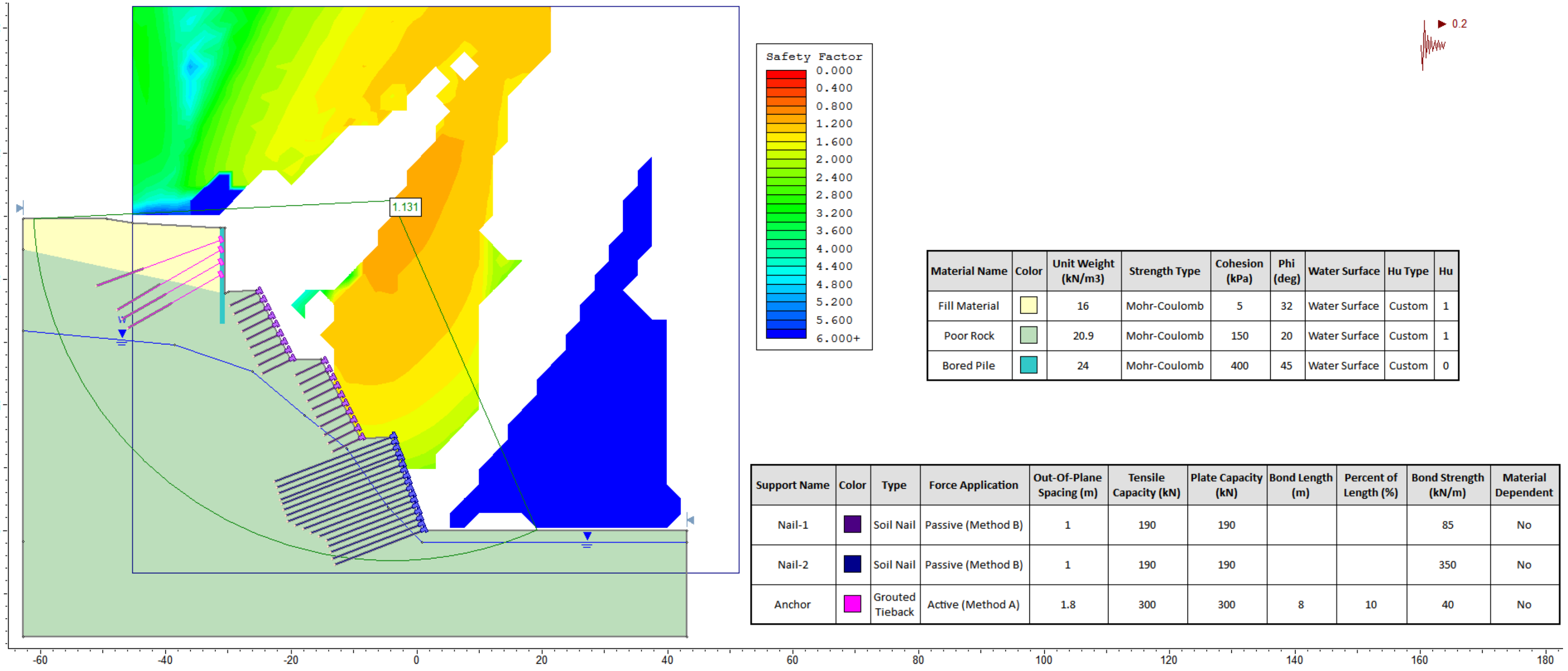
The results of the cut slopes and portal face failure analyses are presented in APPENDIX-E.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

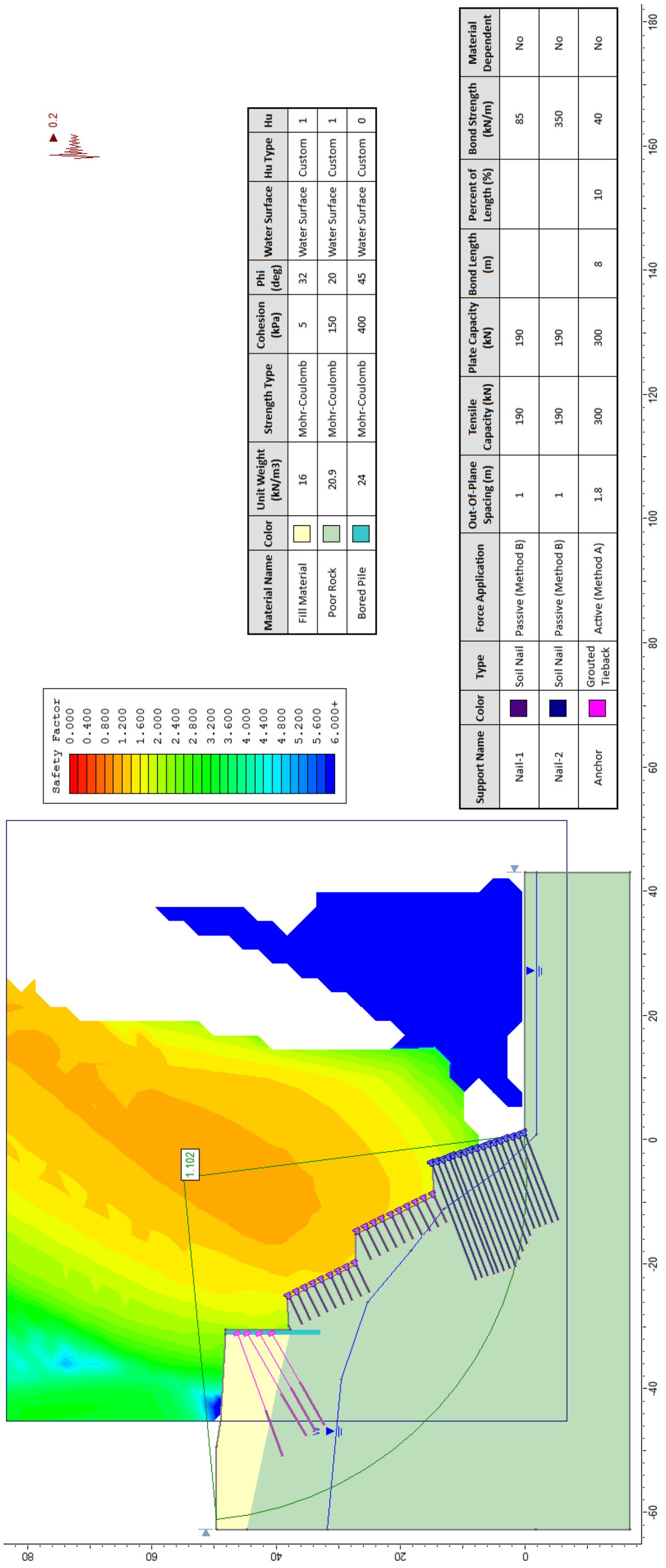
Figure E.1: Portal face analysis with Bishop Simp. method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

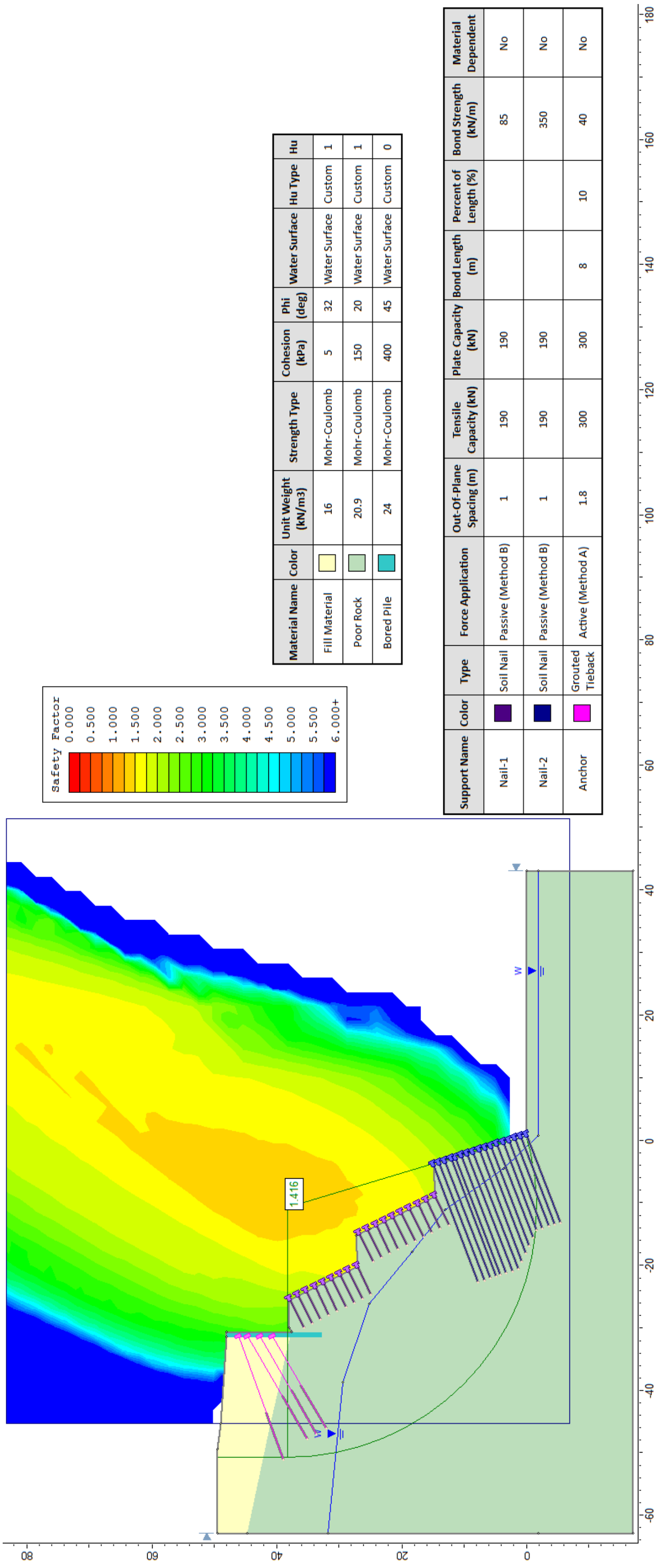
Figure E.2: Portal face analysis with Spencer method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

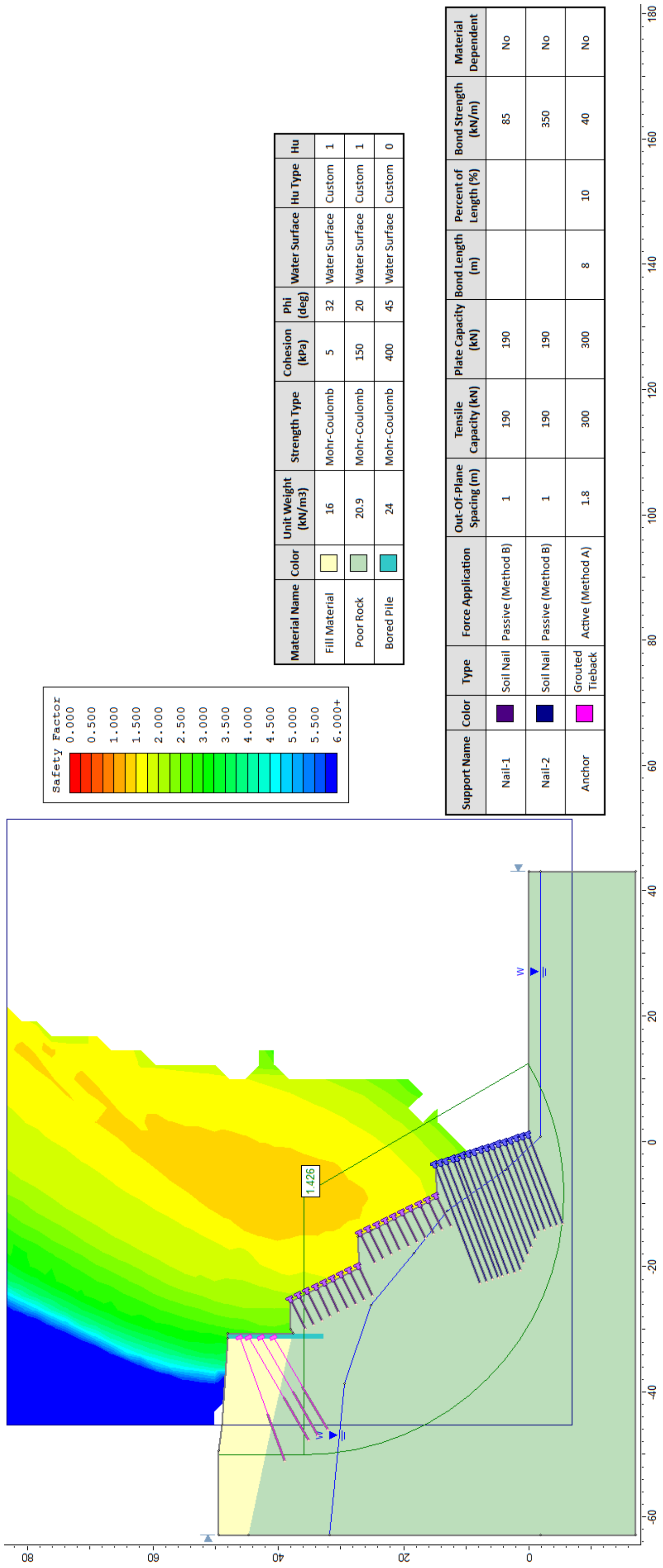
Figure E.3: Portal face analysis with Morgenstern method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

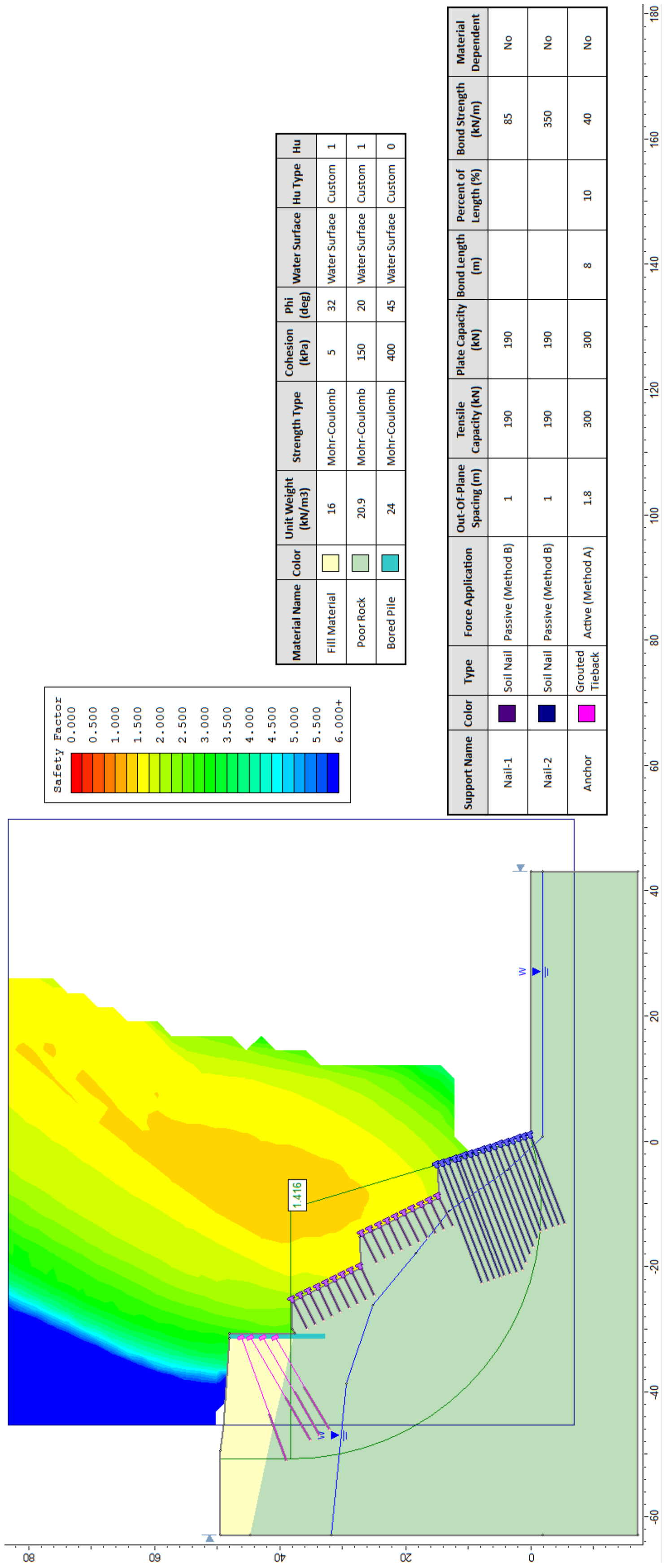
Figure E.4: Portal face analysis with Bishop Simp. method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

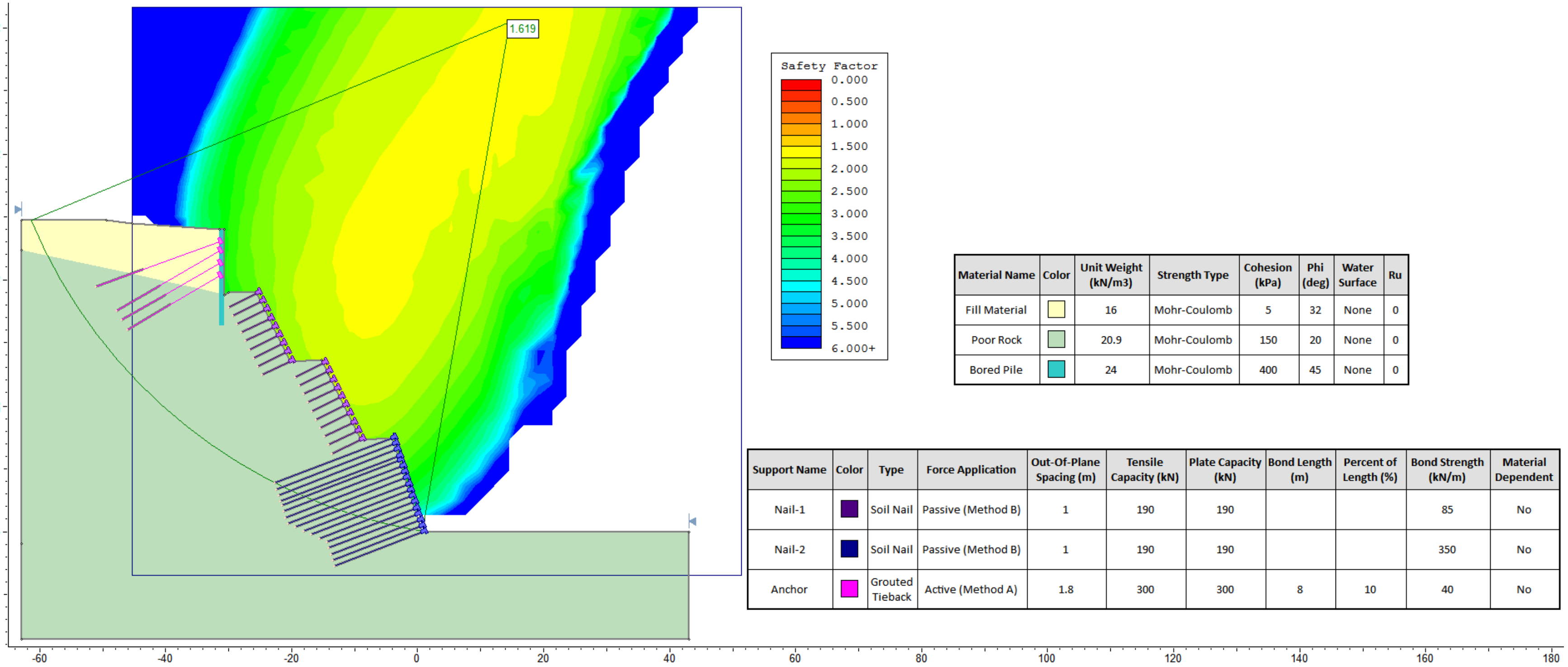
Figure E.5: Portal face analysis with Spencer method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1
Bored Pile	🟦	24	Mohr-Coulomb	400	45	Water Surface	Custom	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

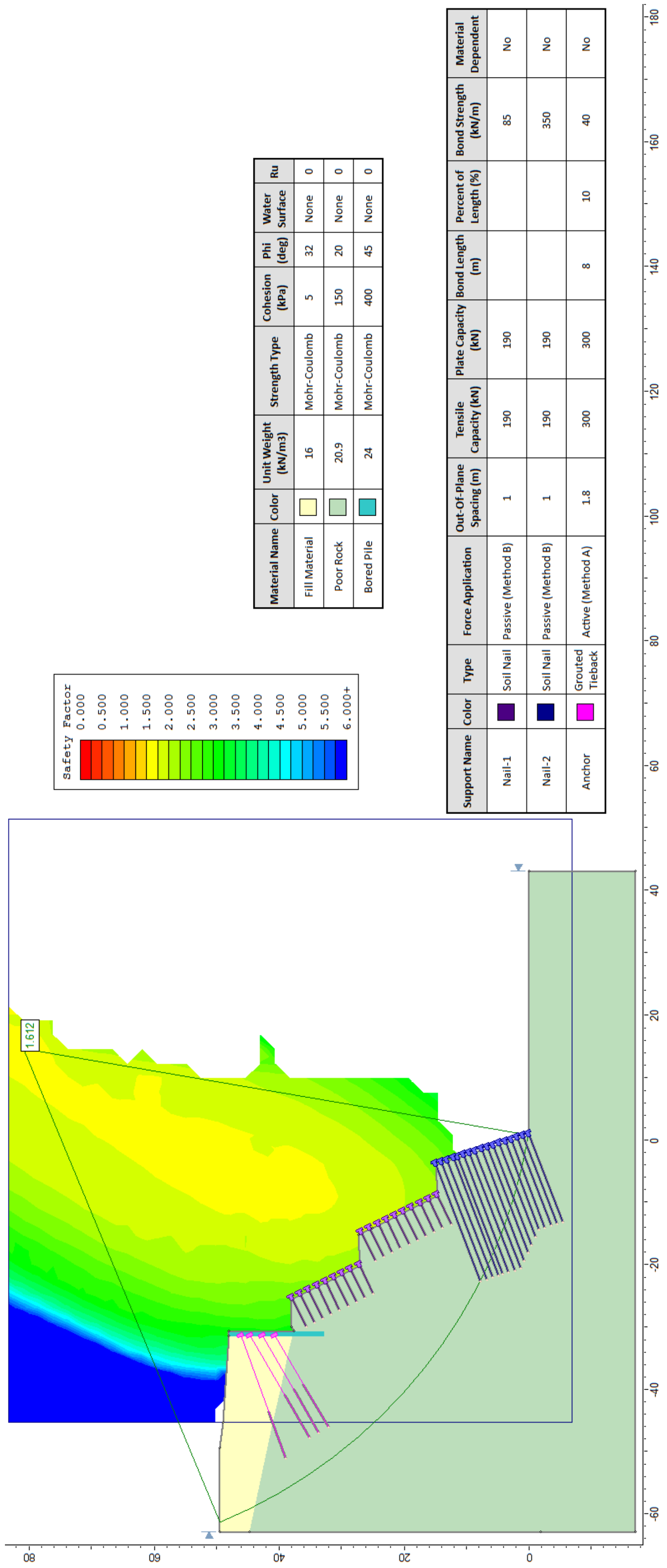
Figure E.6: Portal face analysis with Morgenstern method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0
Bored Pile	🟦	24	Mohr-Coulomb	400	45	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

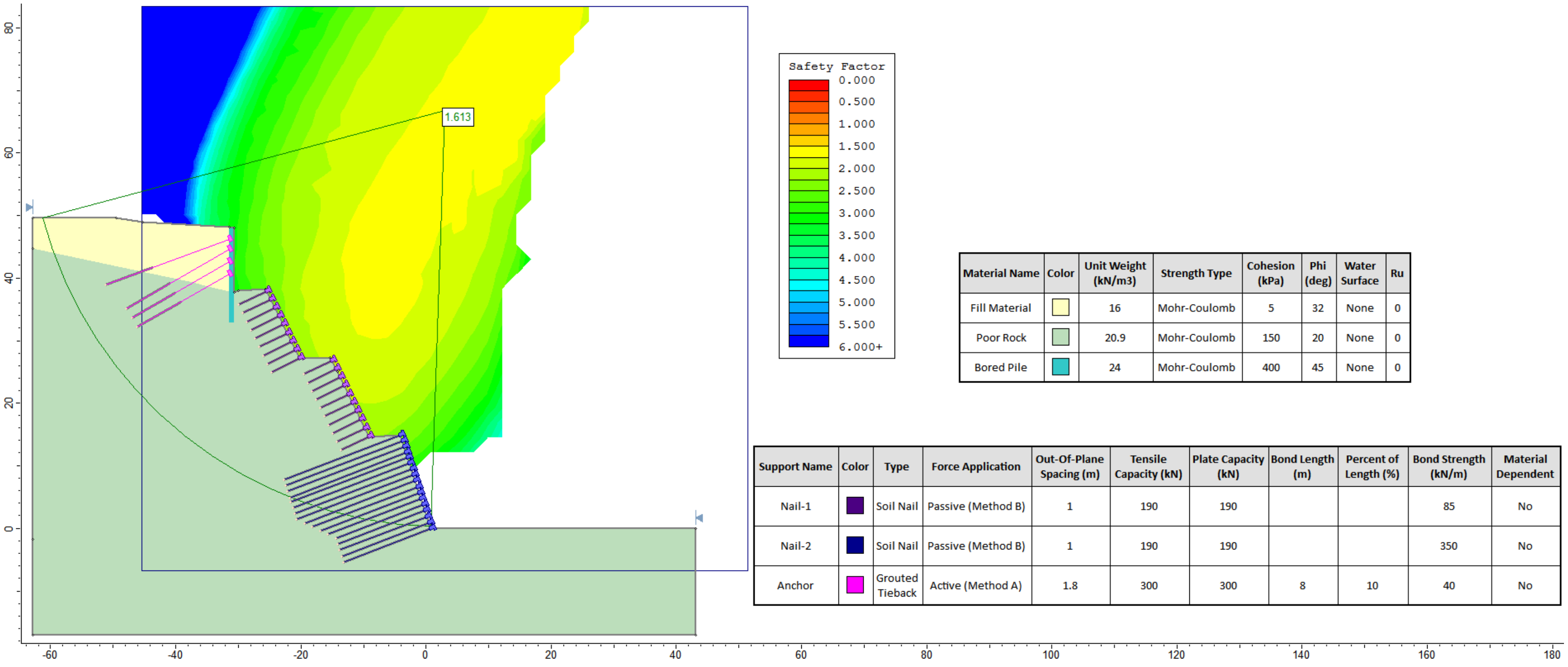
Figure E.7: Portal face analysis with Bishop Simp. method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0
Bored Pile	🟦	24	Mohr-Coulomb	400	45	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

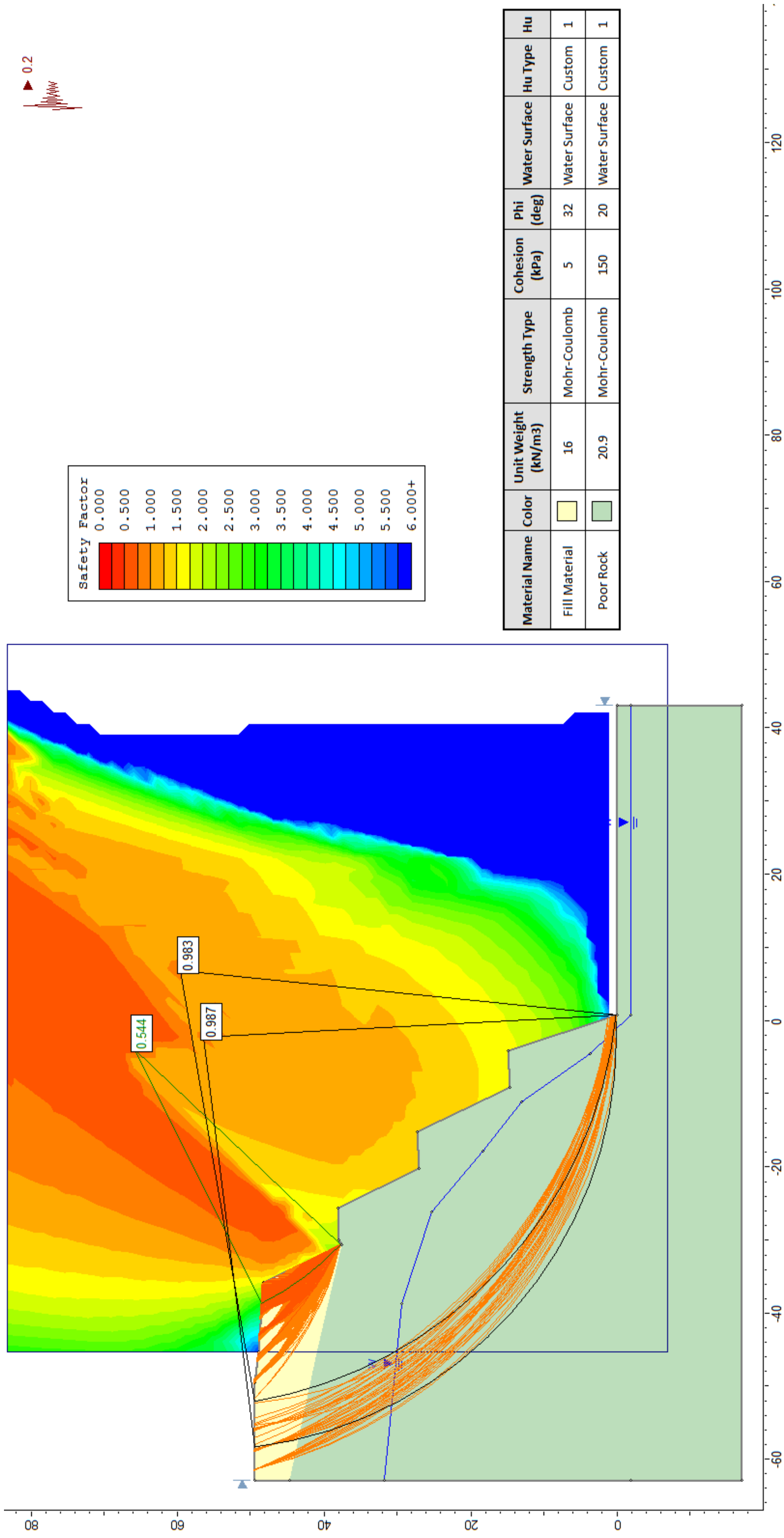
Figure E.8: Portal face analysis with Spencer method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0
Bored Pile	🟦	24	Mohr-Coulomb	400	45	None	0

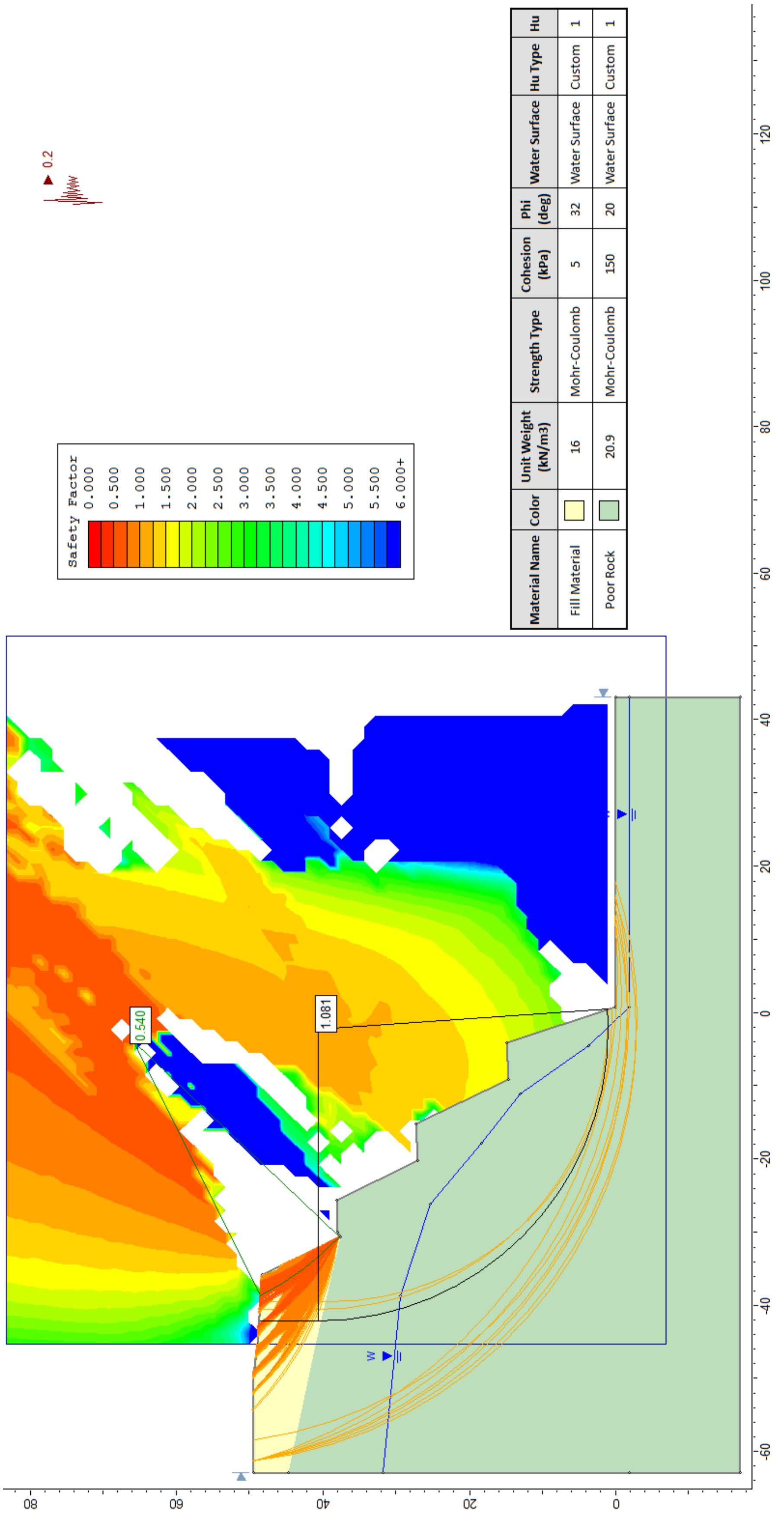
Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Length (m)	Percent of Length (%)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190			85	No
Nail-2	🟦	Soil Nail	Passive (Method B)	1	190	190			350	No
Anchor	🟪	Grouted Tieback	Active (Method A)	1.8	300	300	8	10	40	No

Figure E.9: Portal face analysis with Morgenstern method (Static)



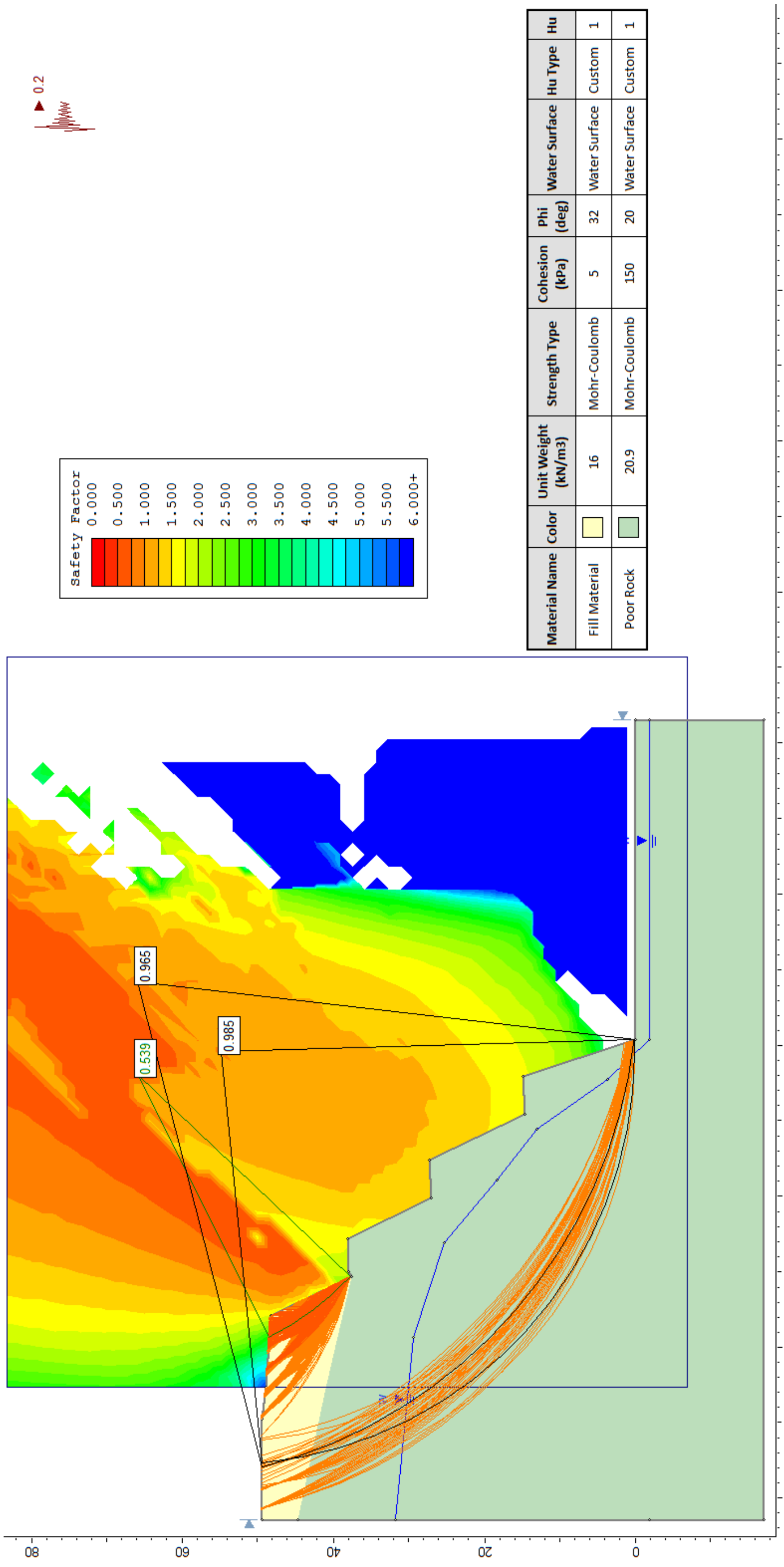
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.10: Portal face analysis with Bishop Simp. method (Unsupported)



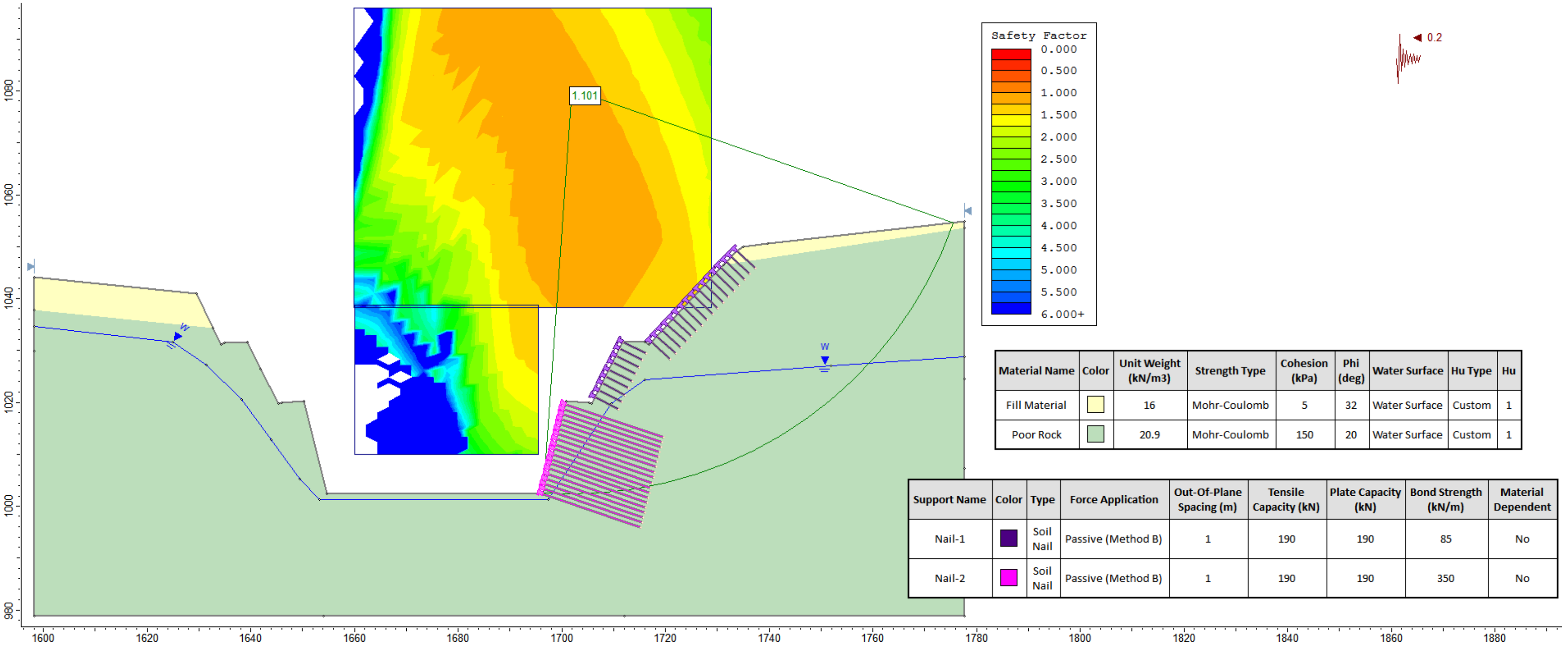
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.11: Portal face analysis with Spencer method (Unsupported)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

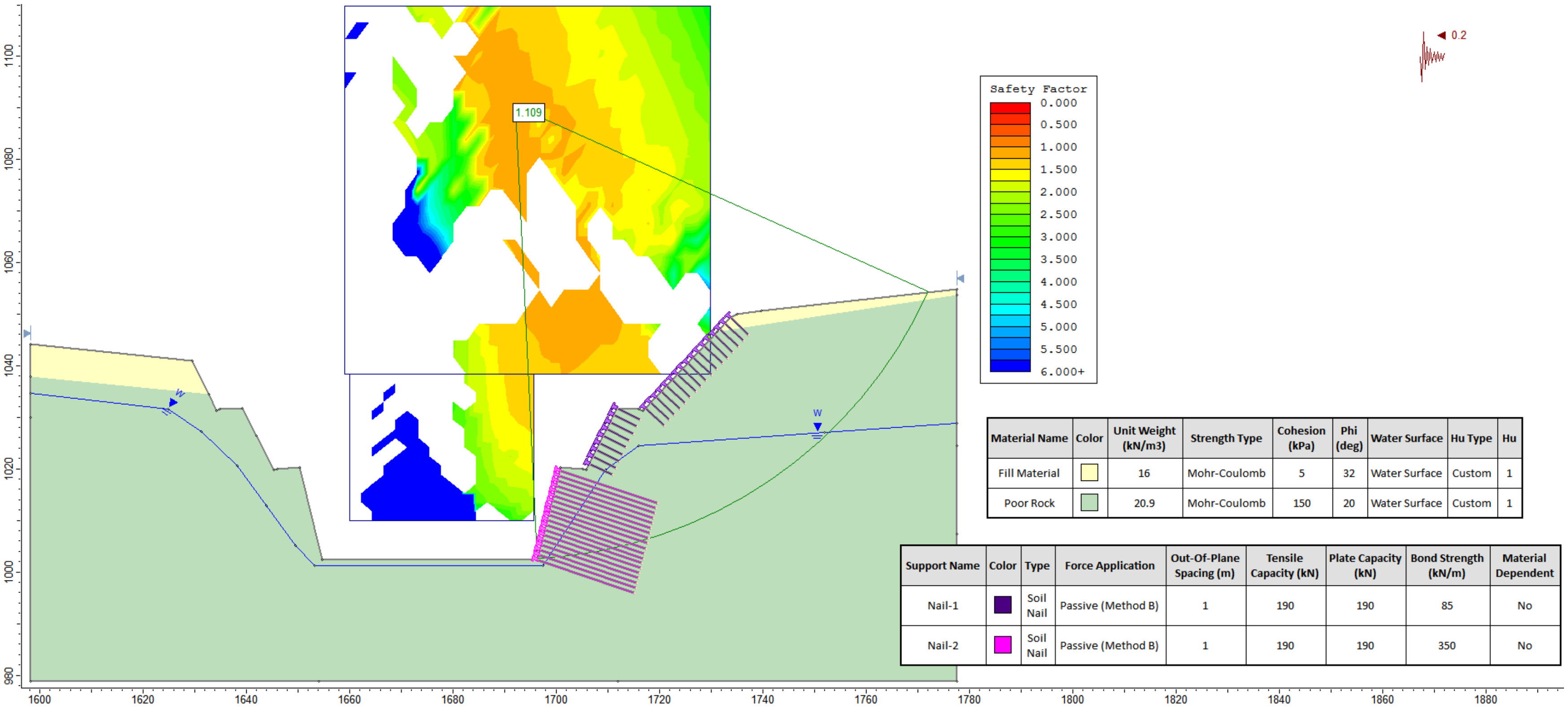
Figure E.12: Portal face analysis with Morgenstern method (Unsupported)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

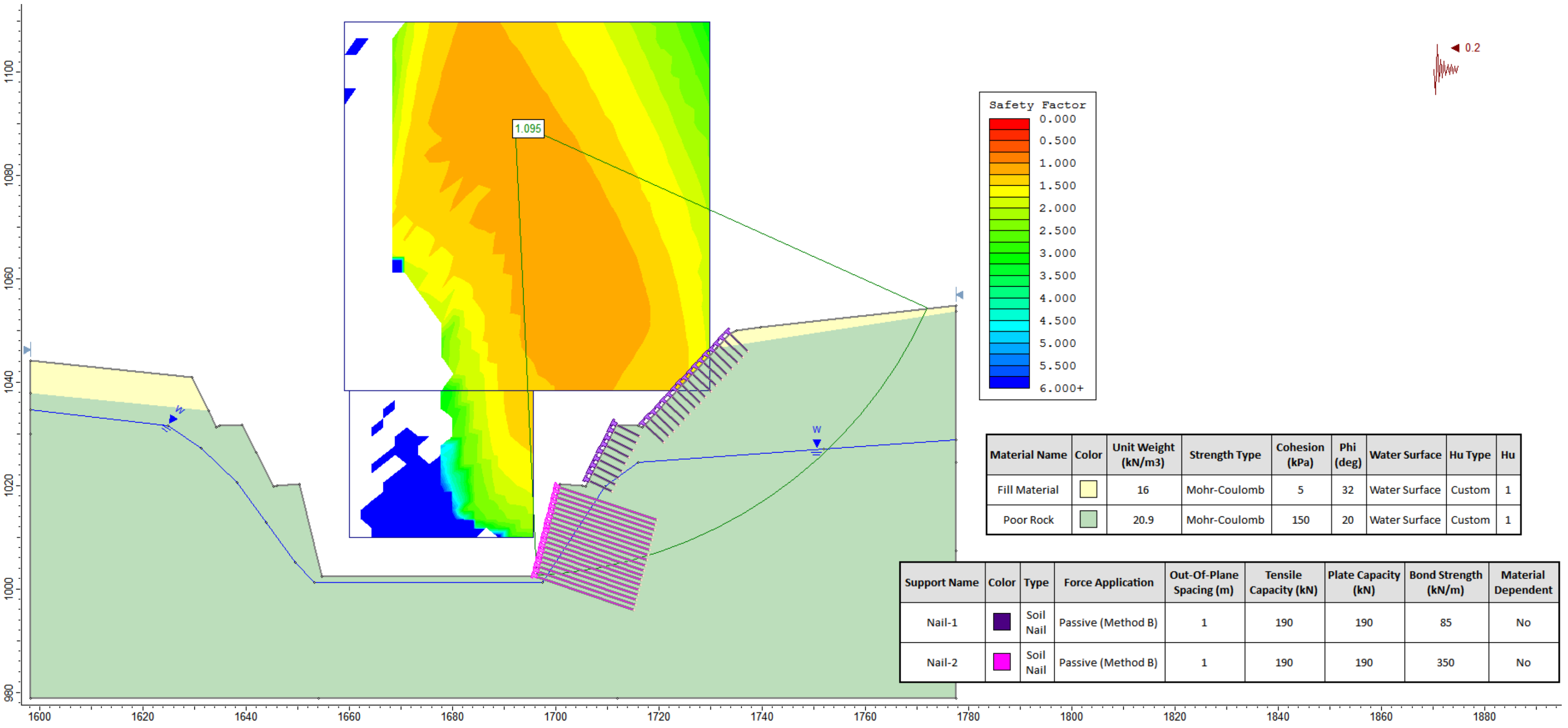
Figure E.13: Right cut slope analysis with Bishop Simp. method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

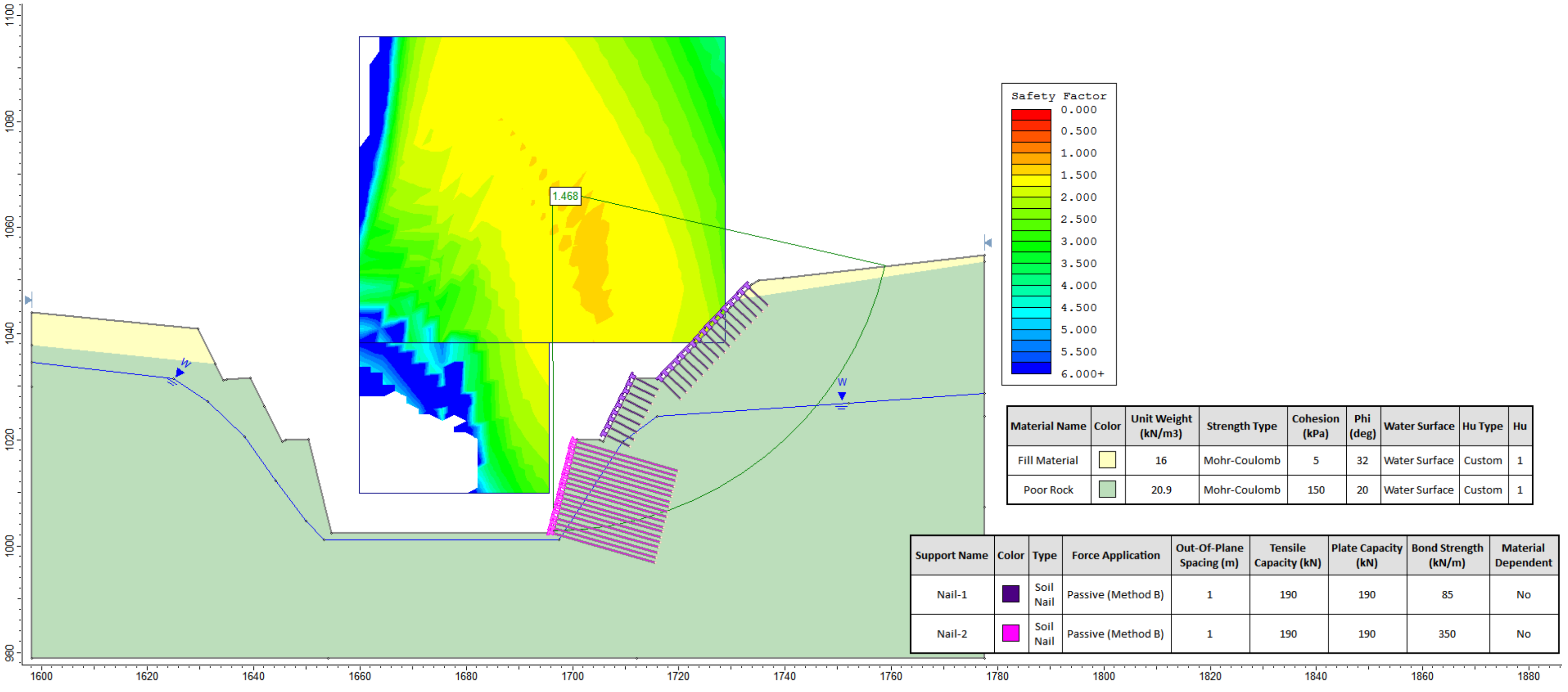
Figure E.14: Right cut slope analysis with Spencer method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

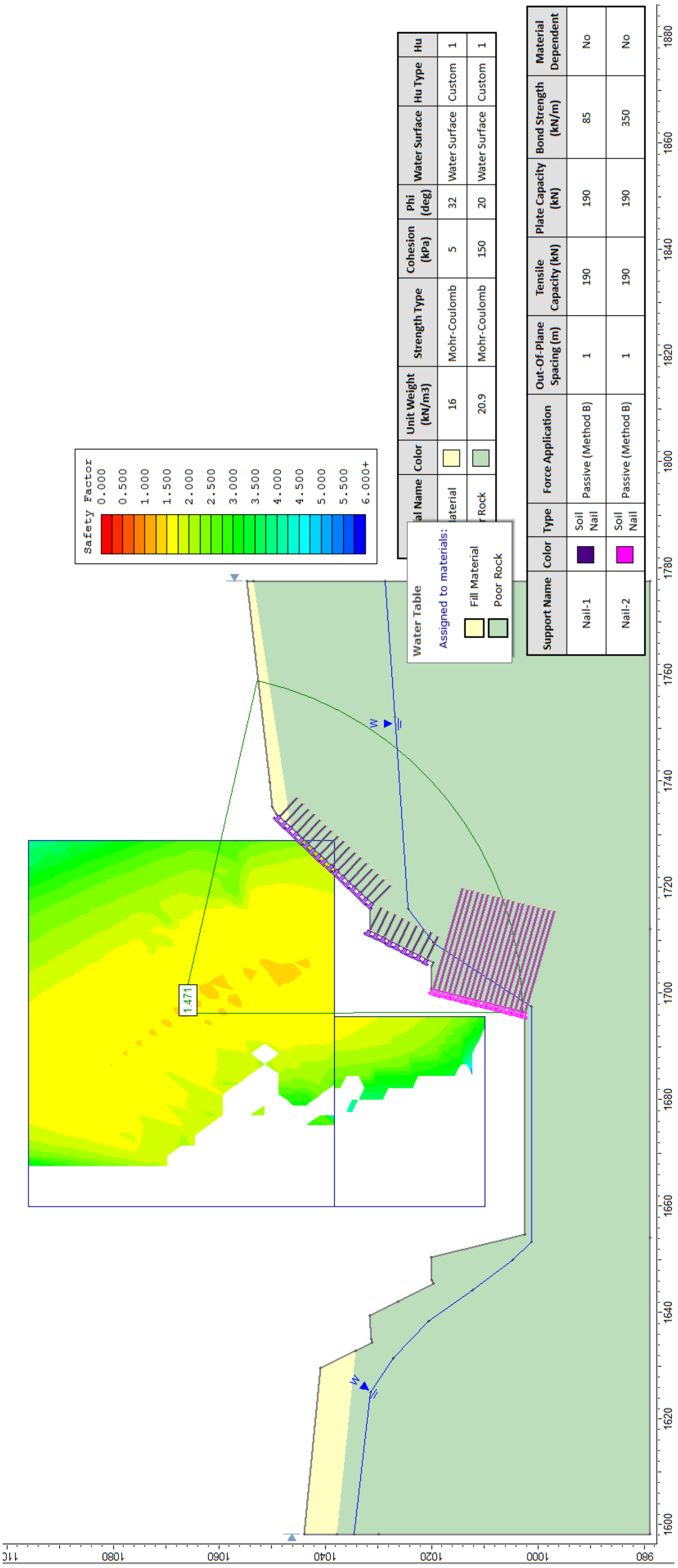
Figure E.15: Right cut slope analysis with Morgenstern method (GW and seismic load)

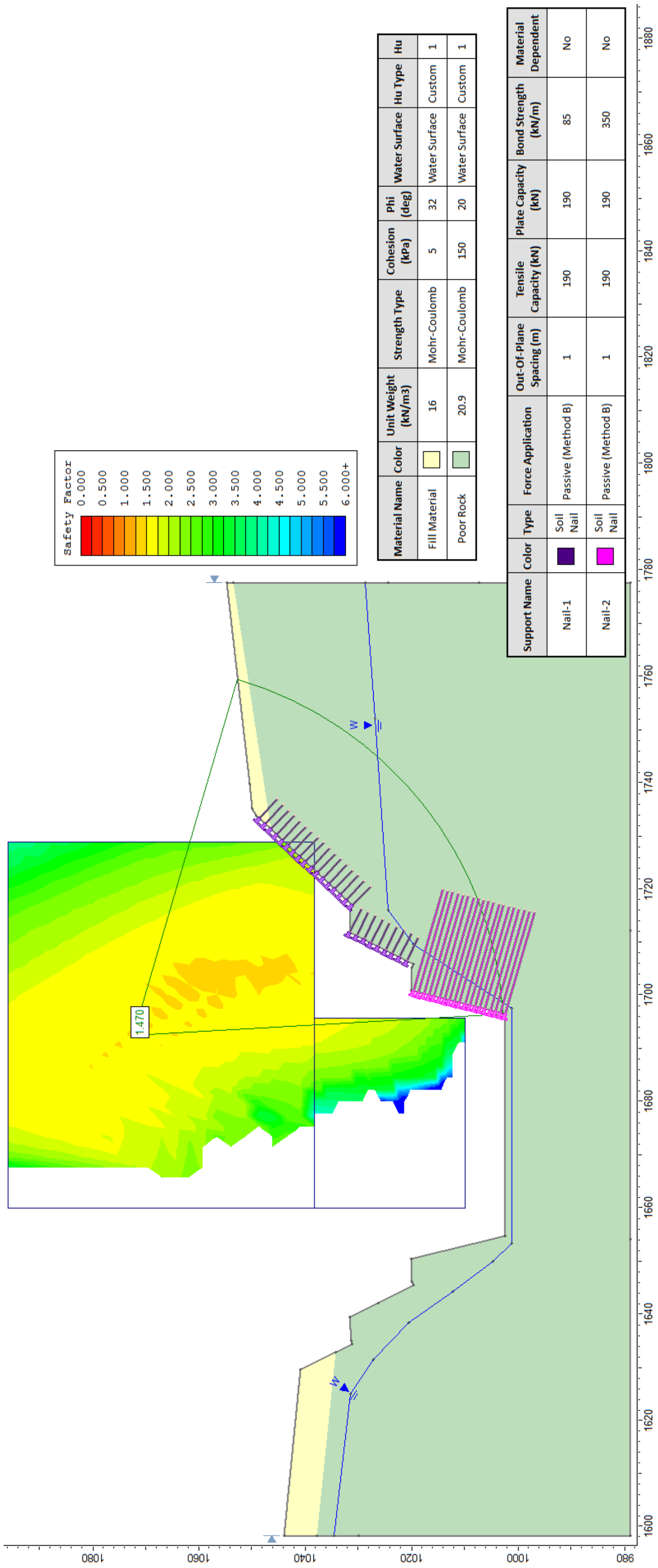


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

Figure E.16: Right cut slope analysis with Bishop Simp. method (GW)

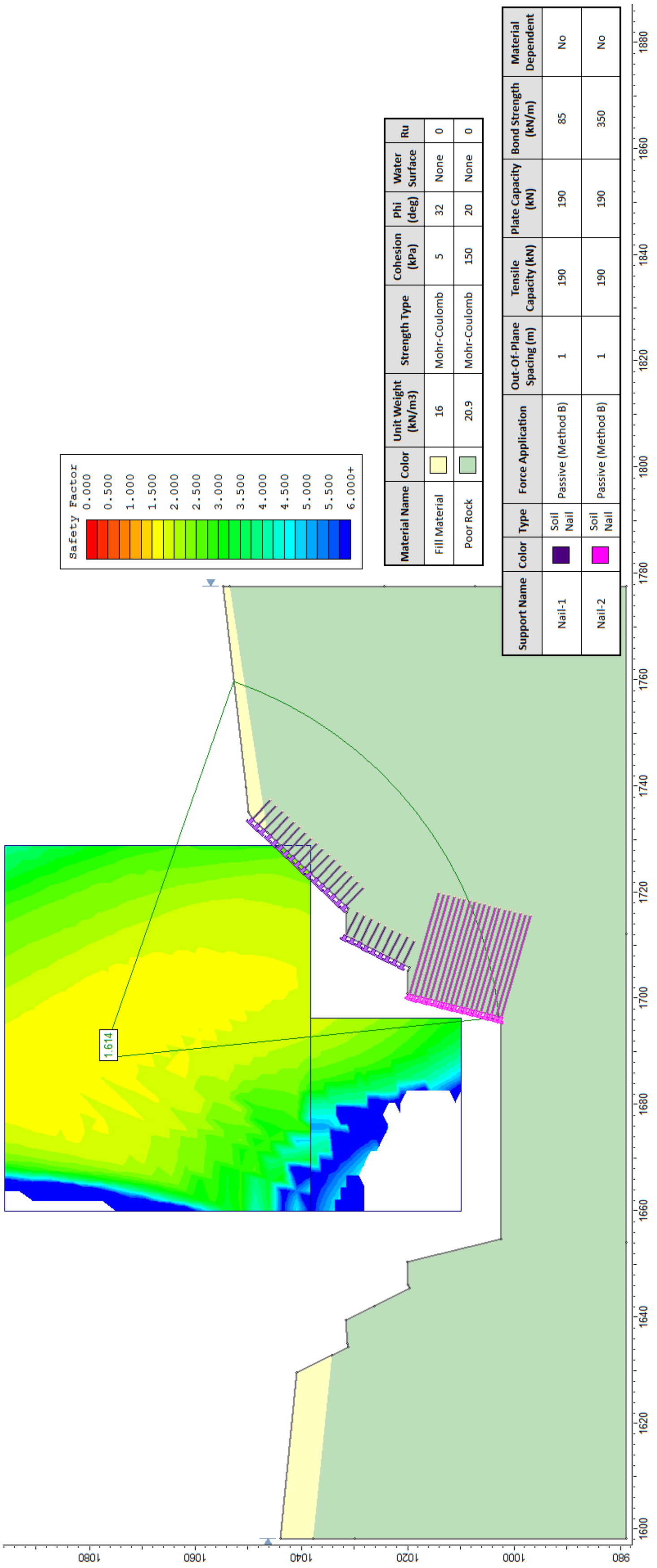




Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

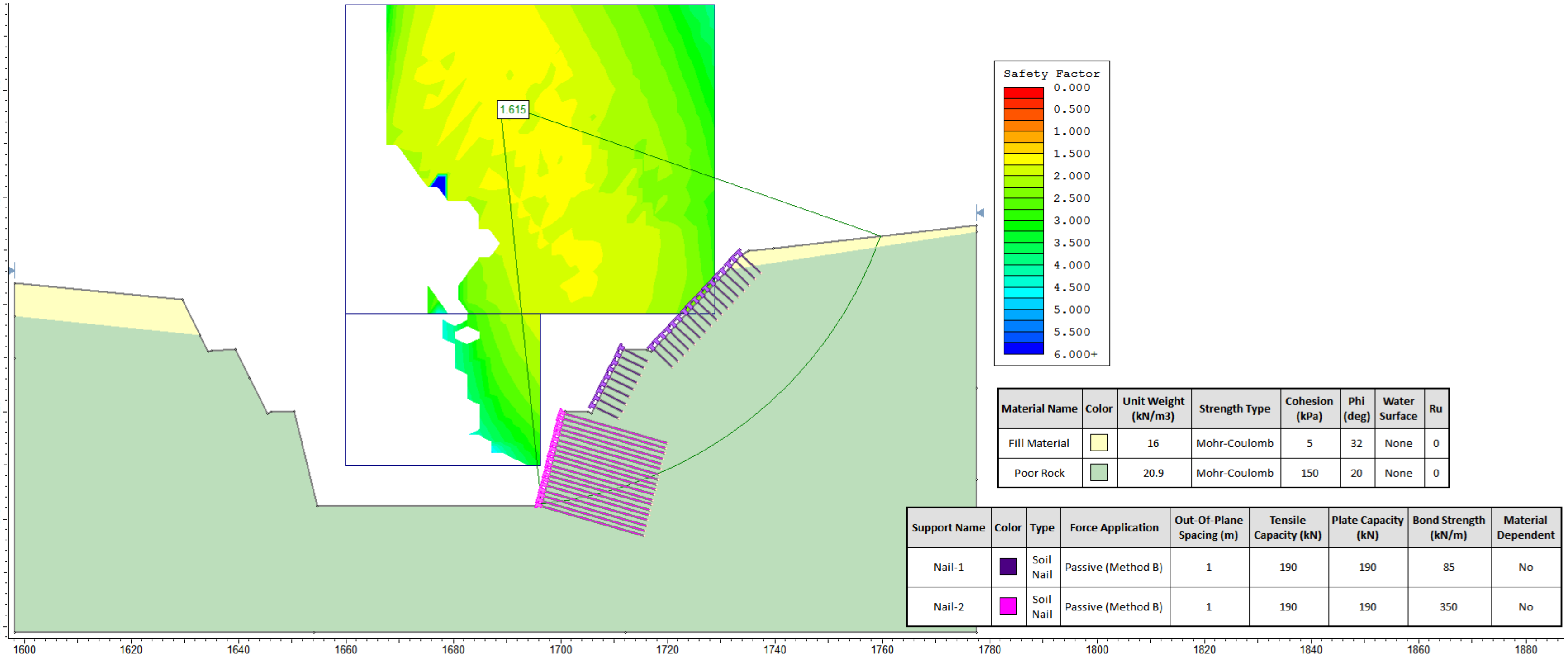
Figure E.18: Right cut slope analysis with Morgenstern method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

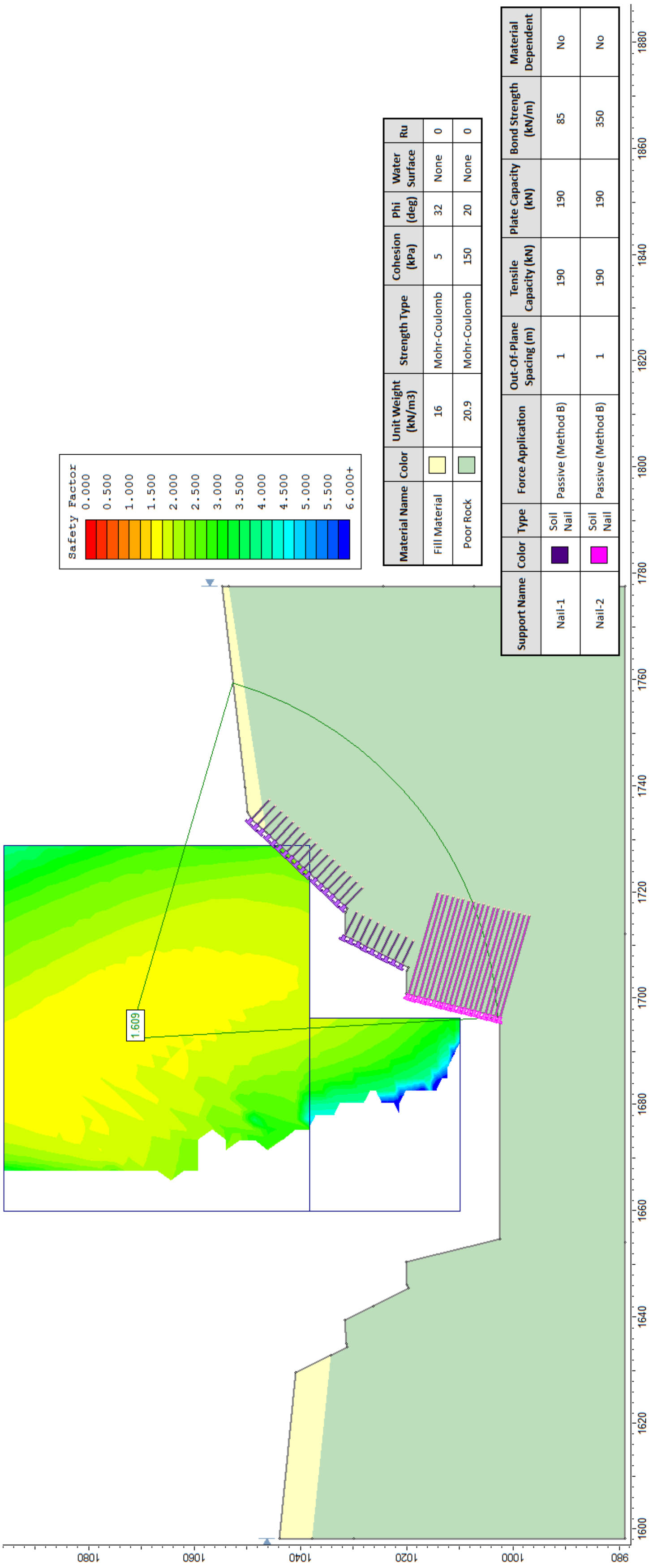
Figure E.19: Right cut slope analysis with Bishop Simp. method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

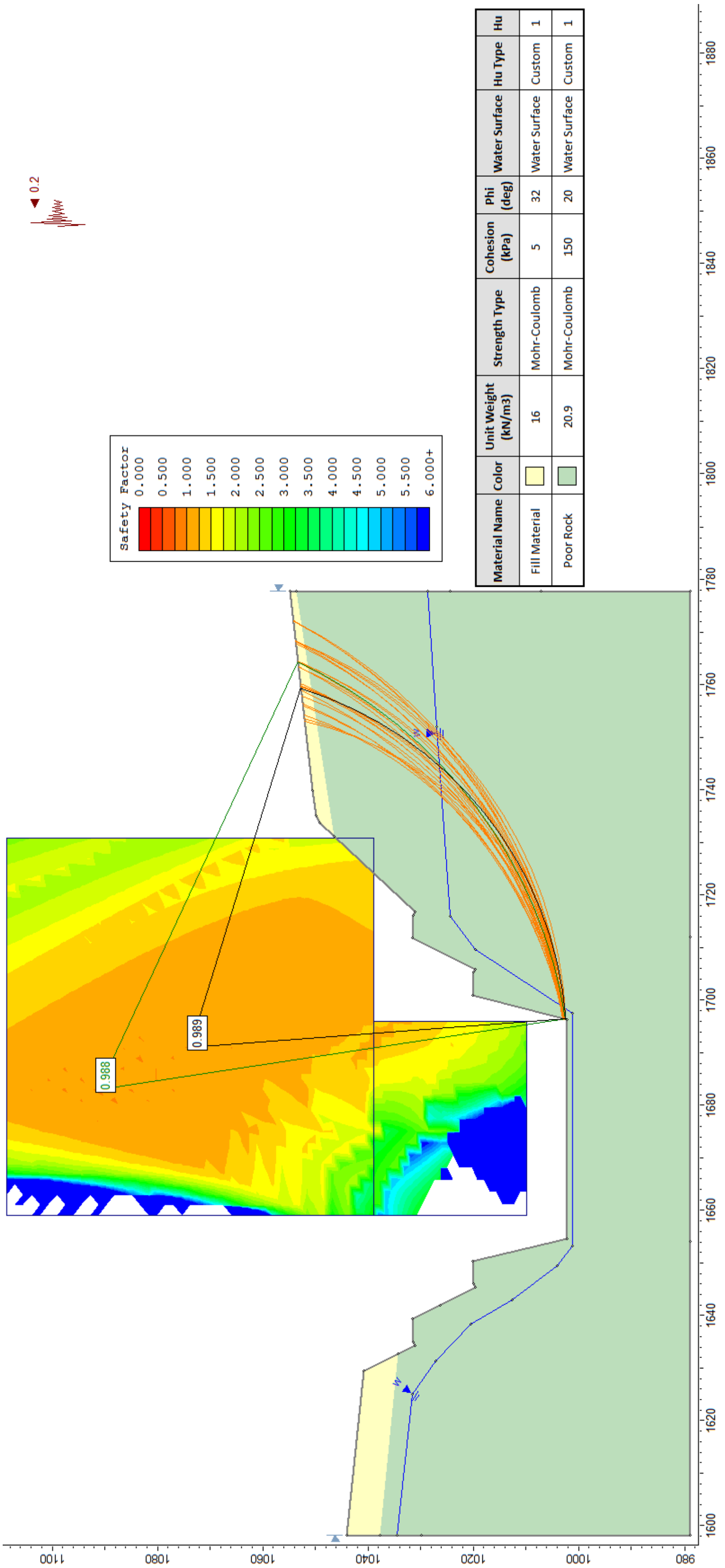
Figure E.20: Right cut slope analysis with Spencer method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

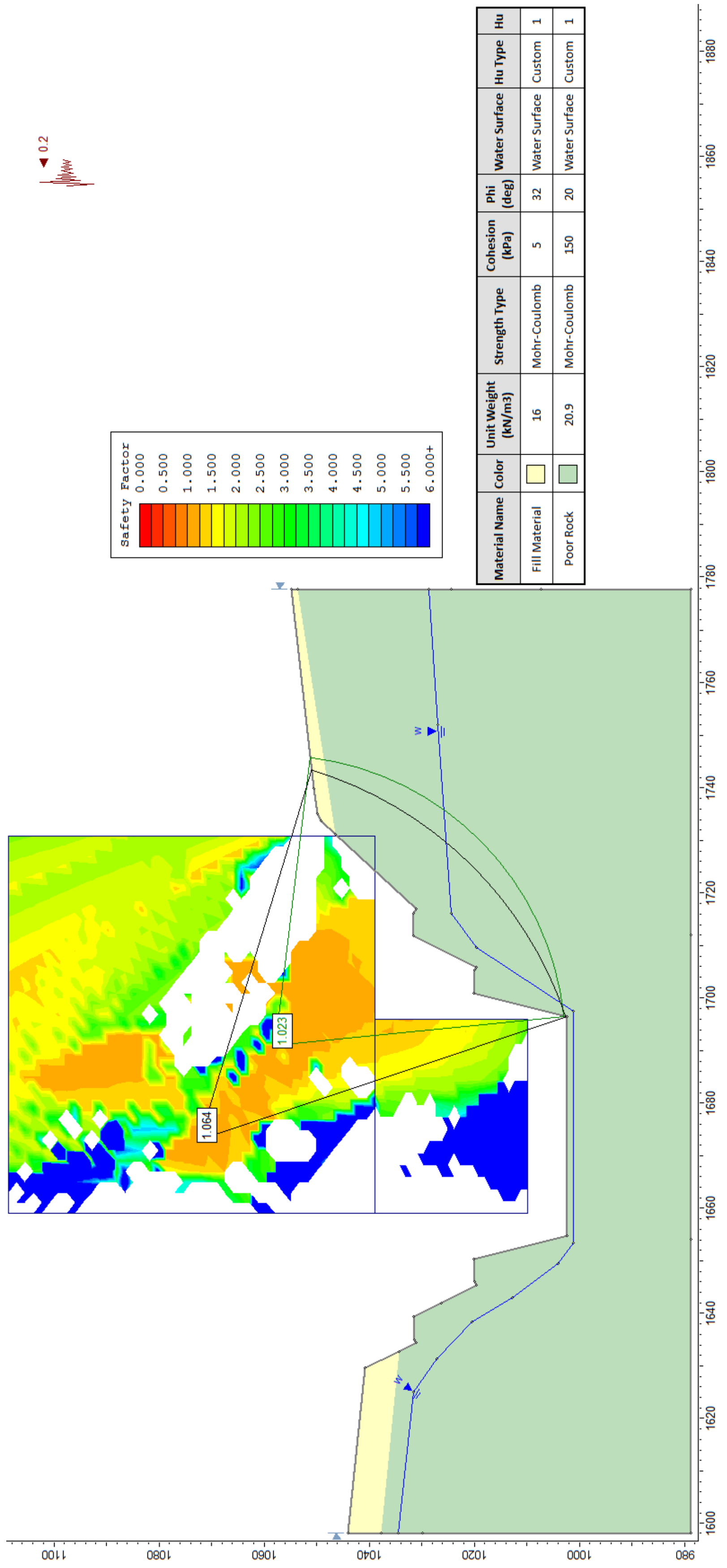
Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

Figure E.21: Right cut slope analysis with Morgenstern method (Static)



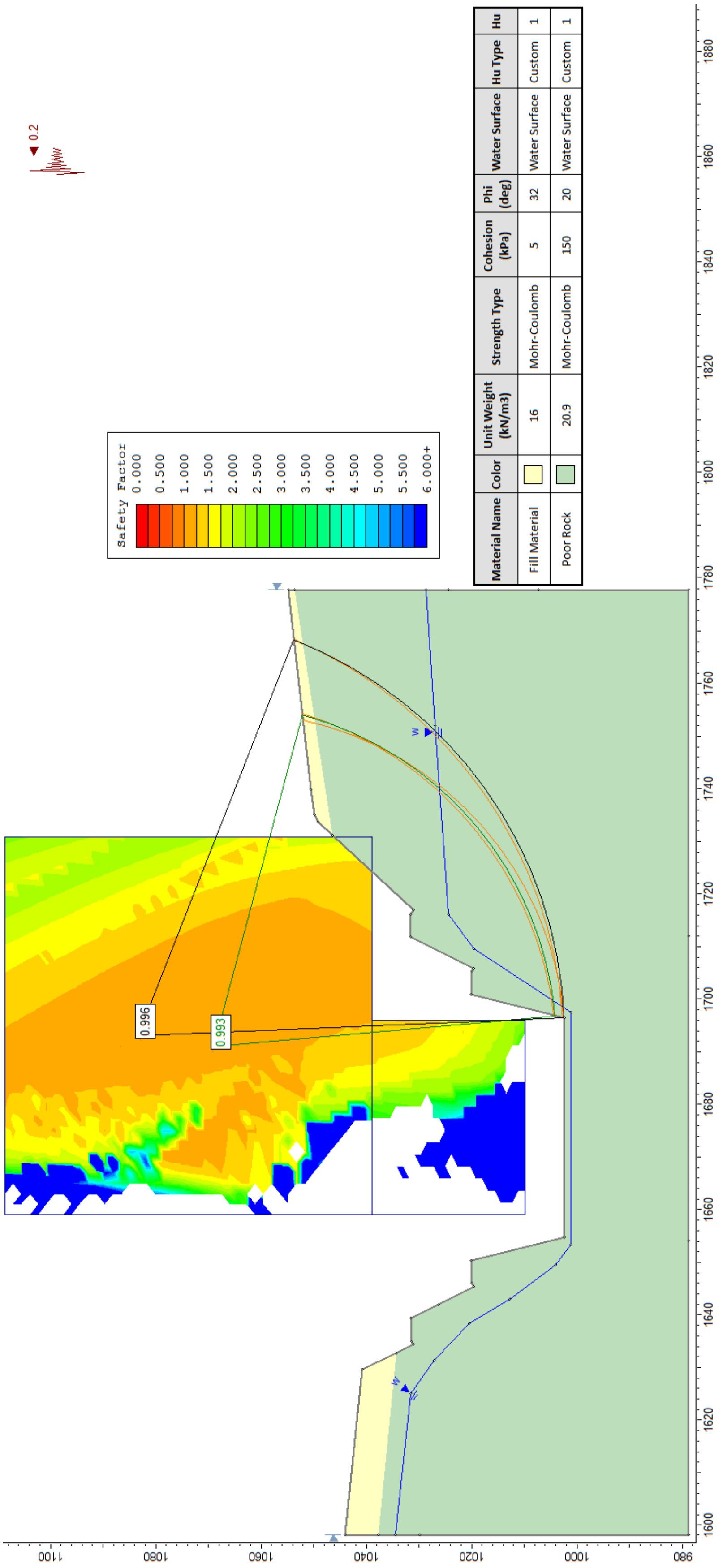
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.22: Right cut slope analysis with Bishop Simp. method (Unsupported)



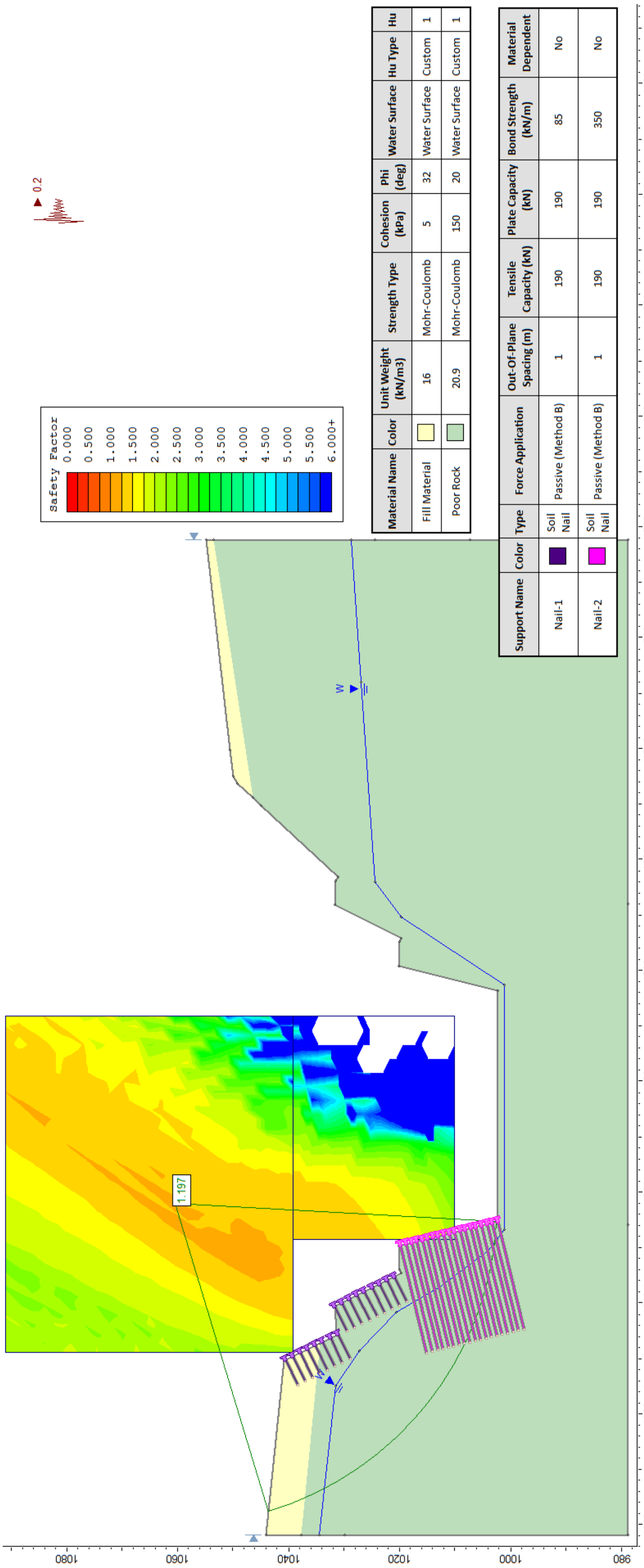
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.23: Right cut slope analysis with Spencer method (Unsupported)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

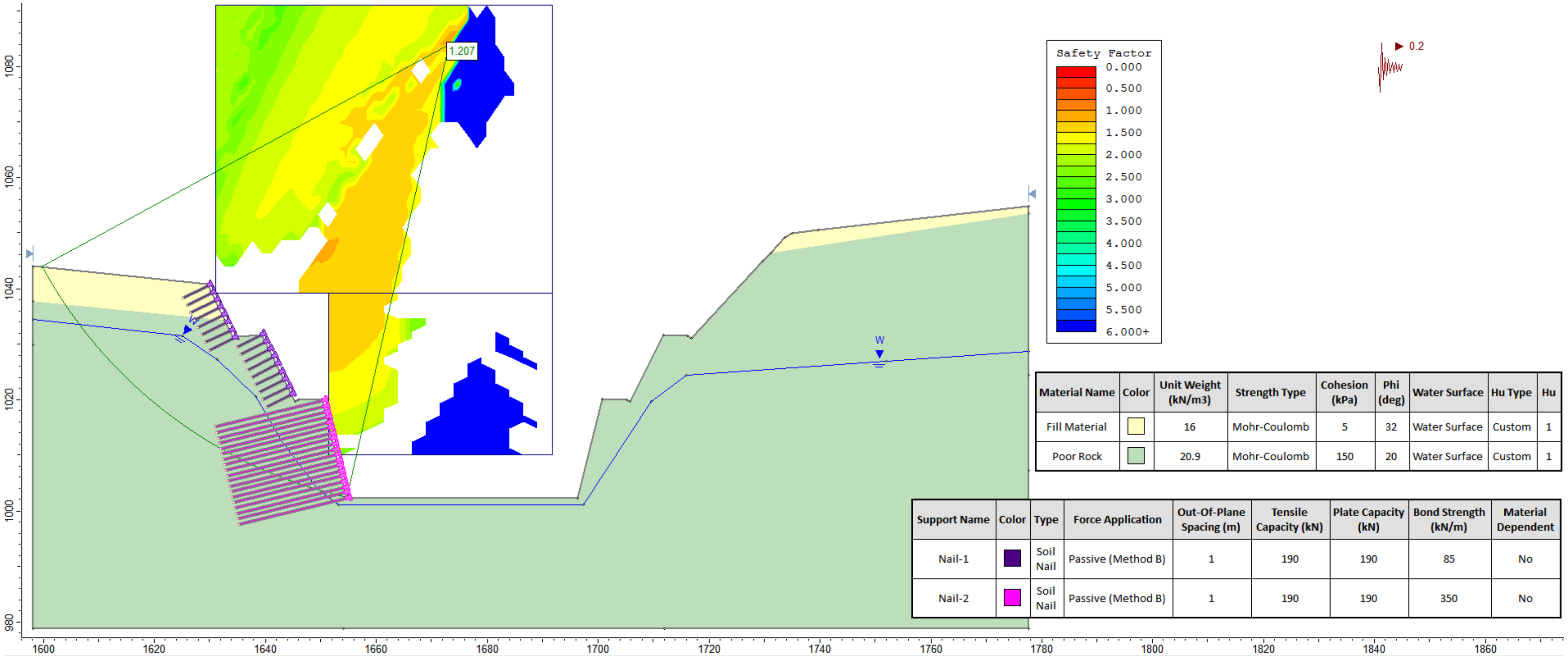
Figure E.24: Right cut slope analysis with Morgenstern method (Unsupported)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

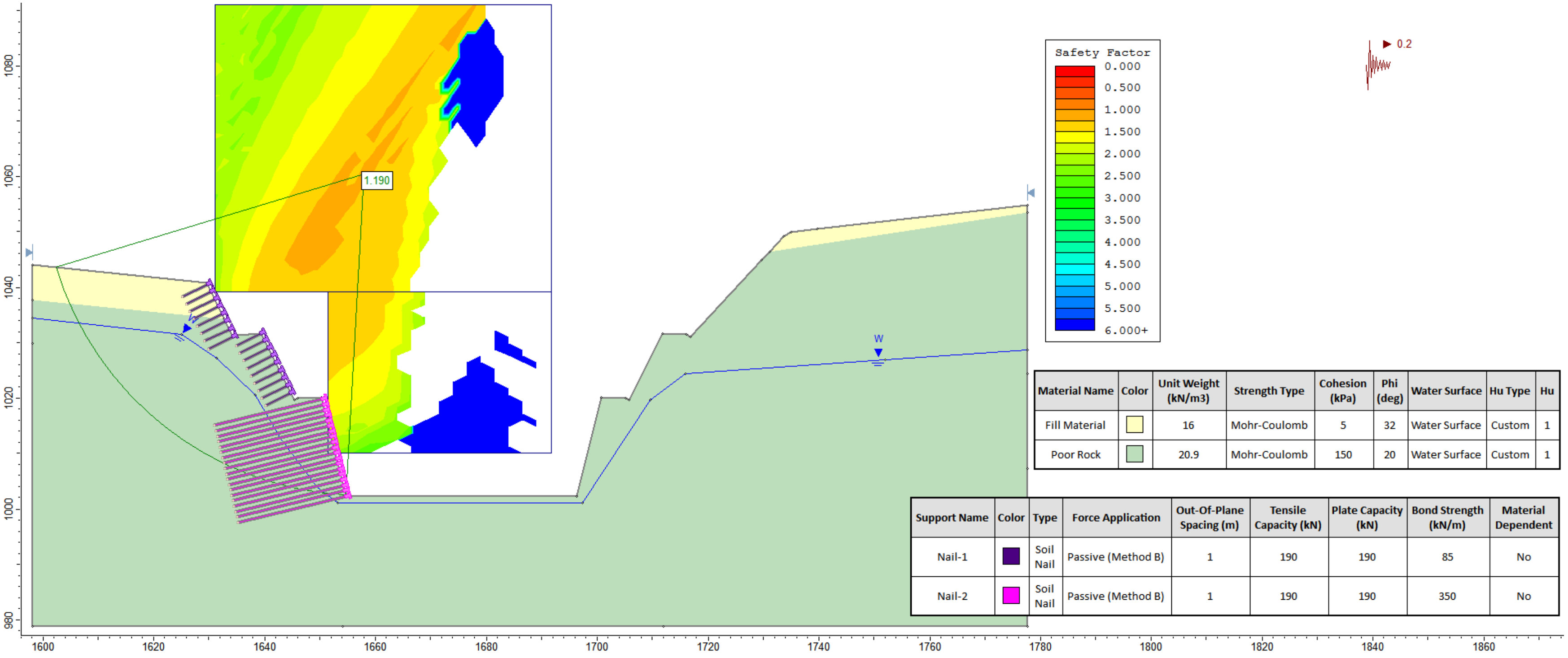
Figure E.25: Left cut slope analysis with Bishop Simp. method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

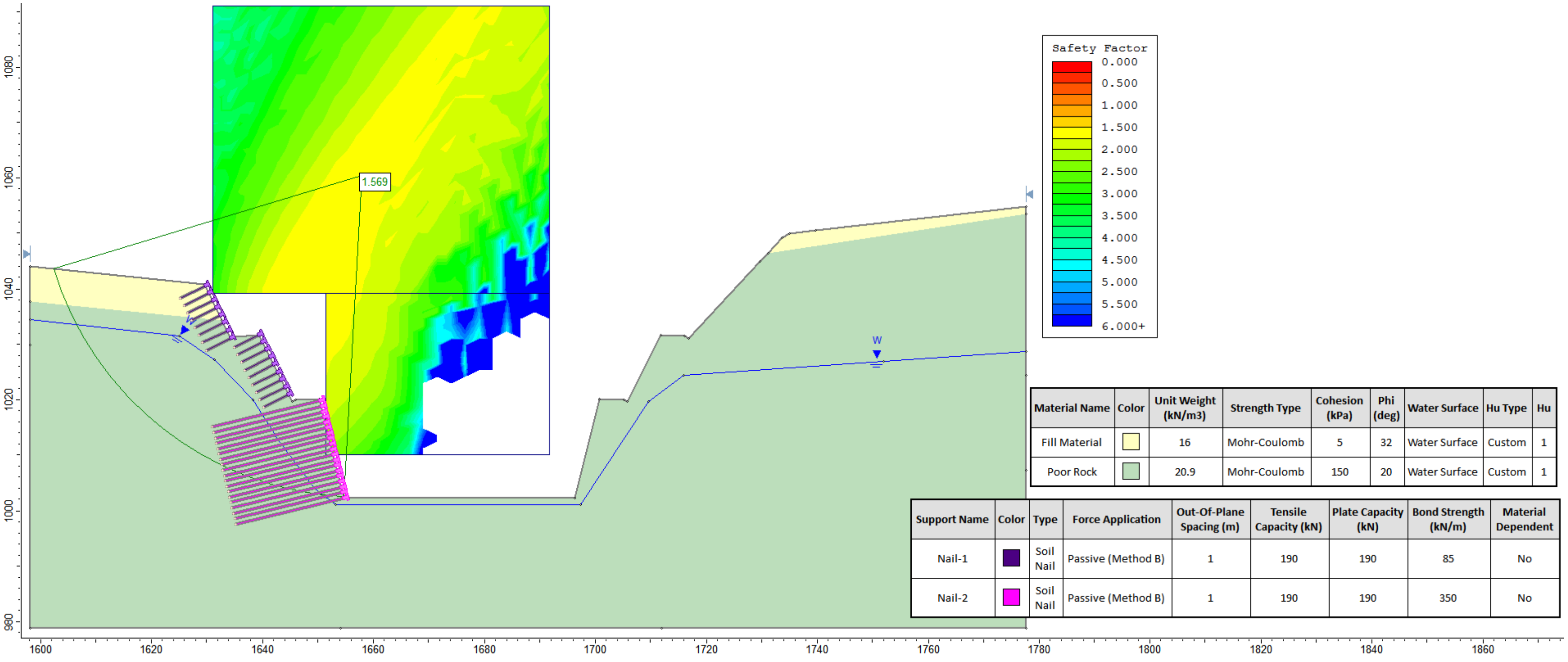
Figure E.26: Left cut slope analysis with Spencer method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

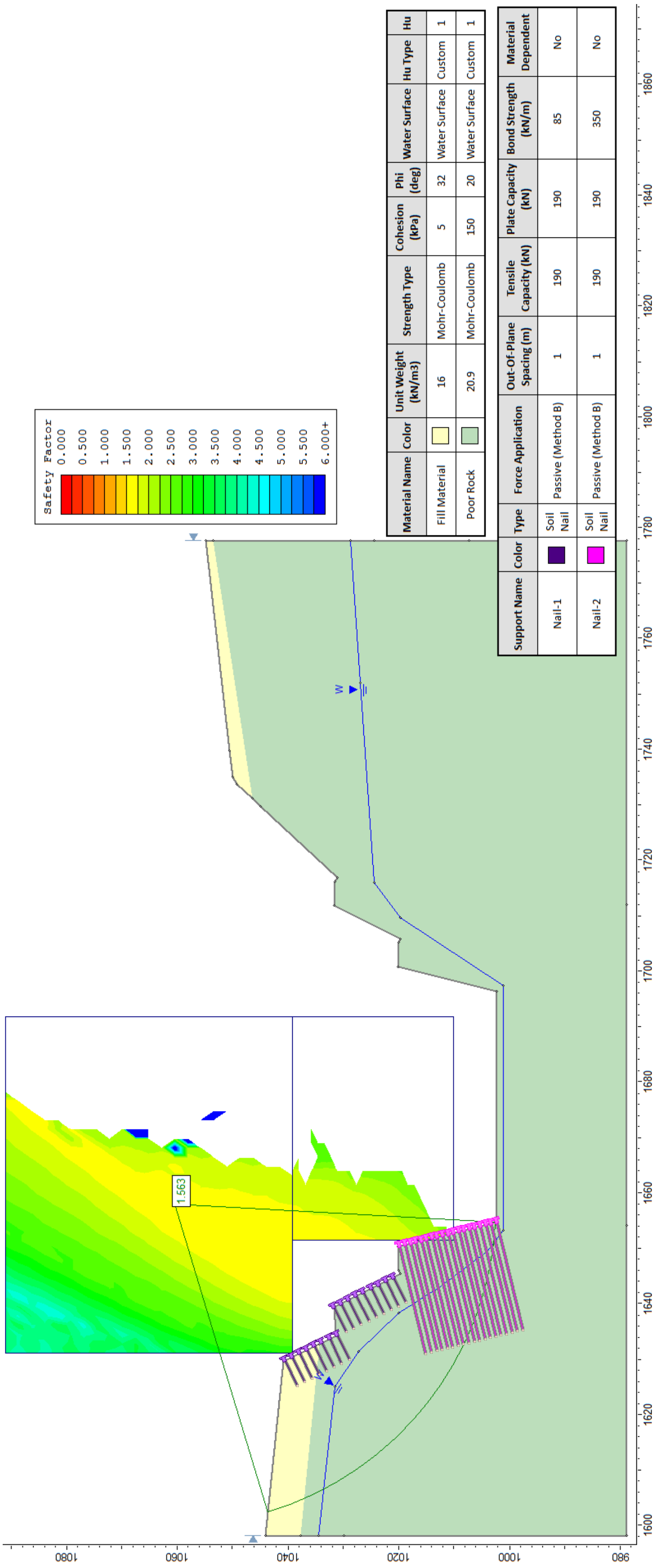
Figure E.27: Left cut slope analysis with Morgenstern method (GW and seismic load)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

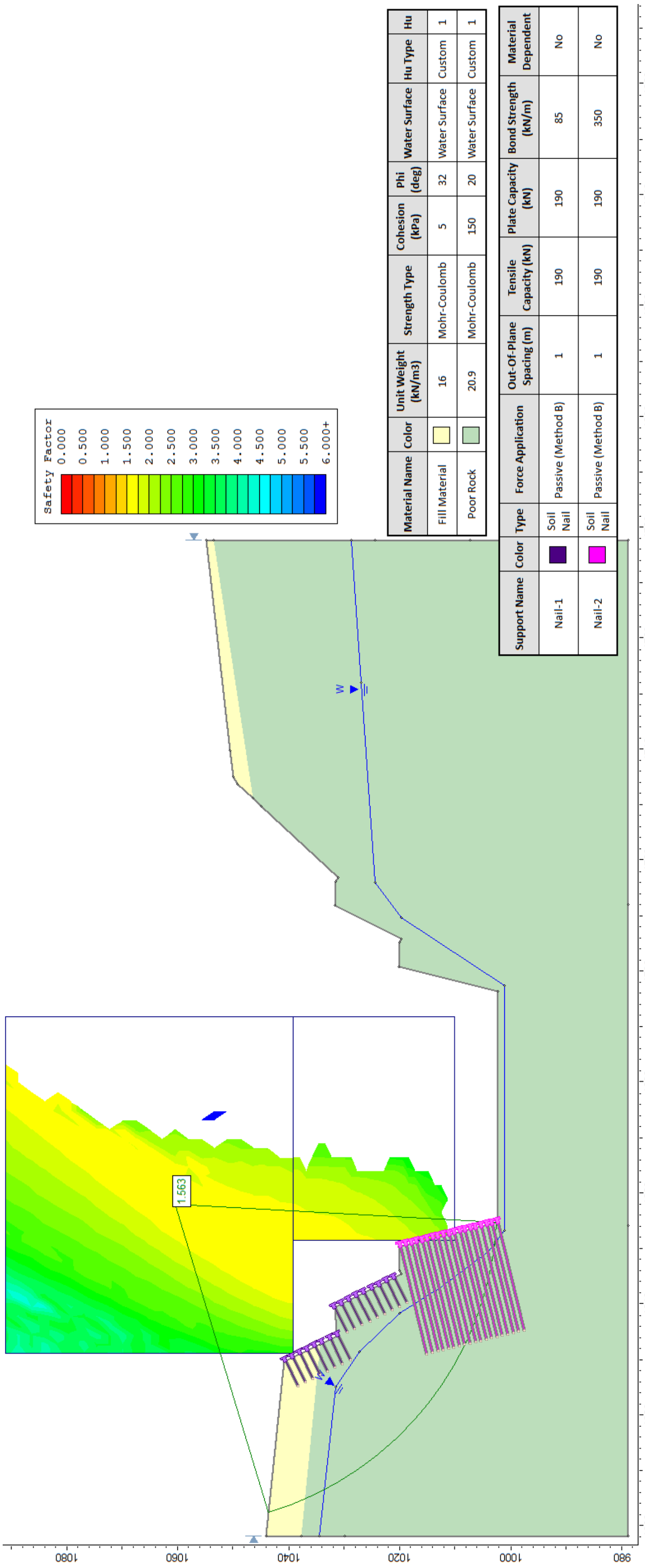
Figure E.28: Left cut slope analysis with Bishop Simp. method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

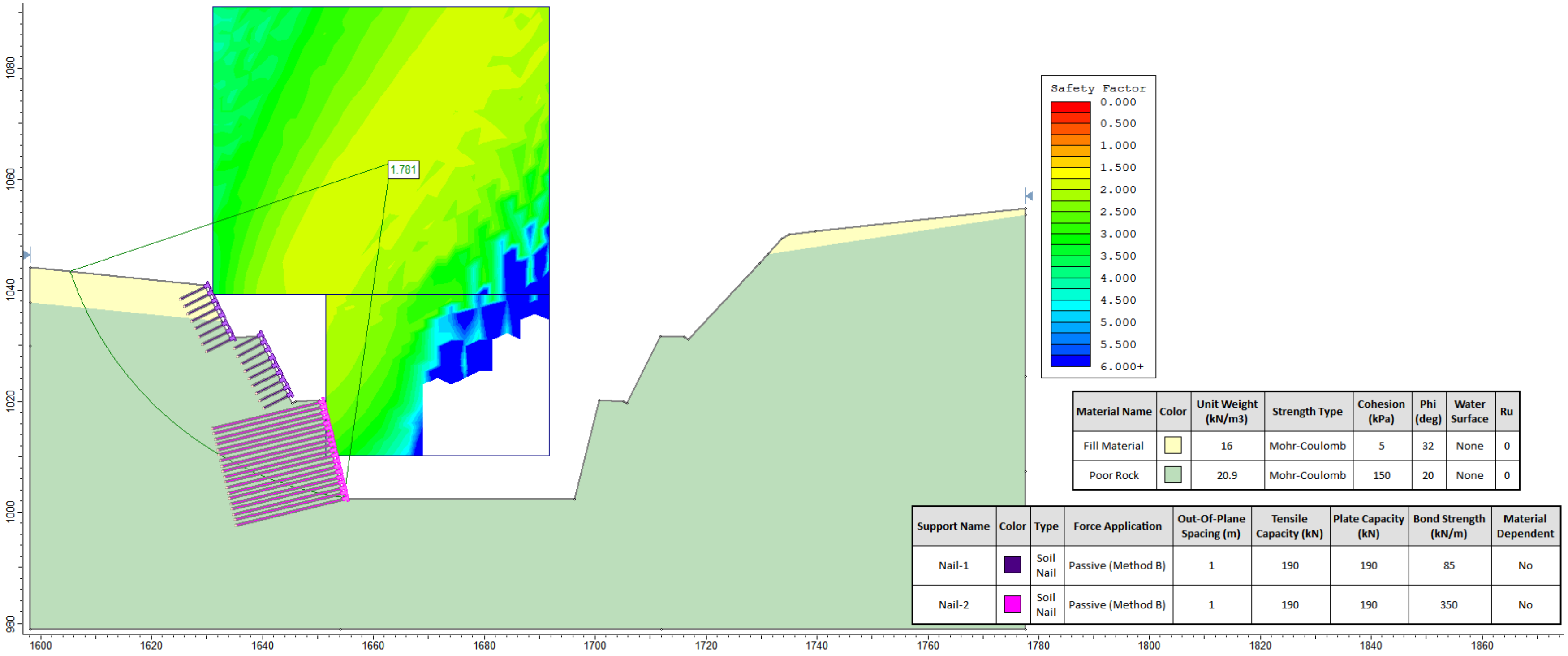
Figure E.29: Left cut slope analysis with Spencer method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

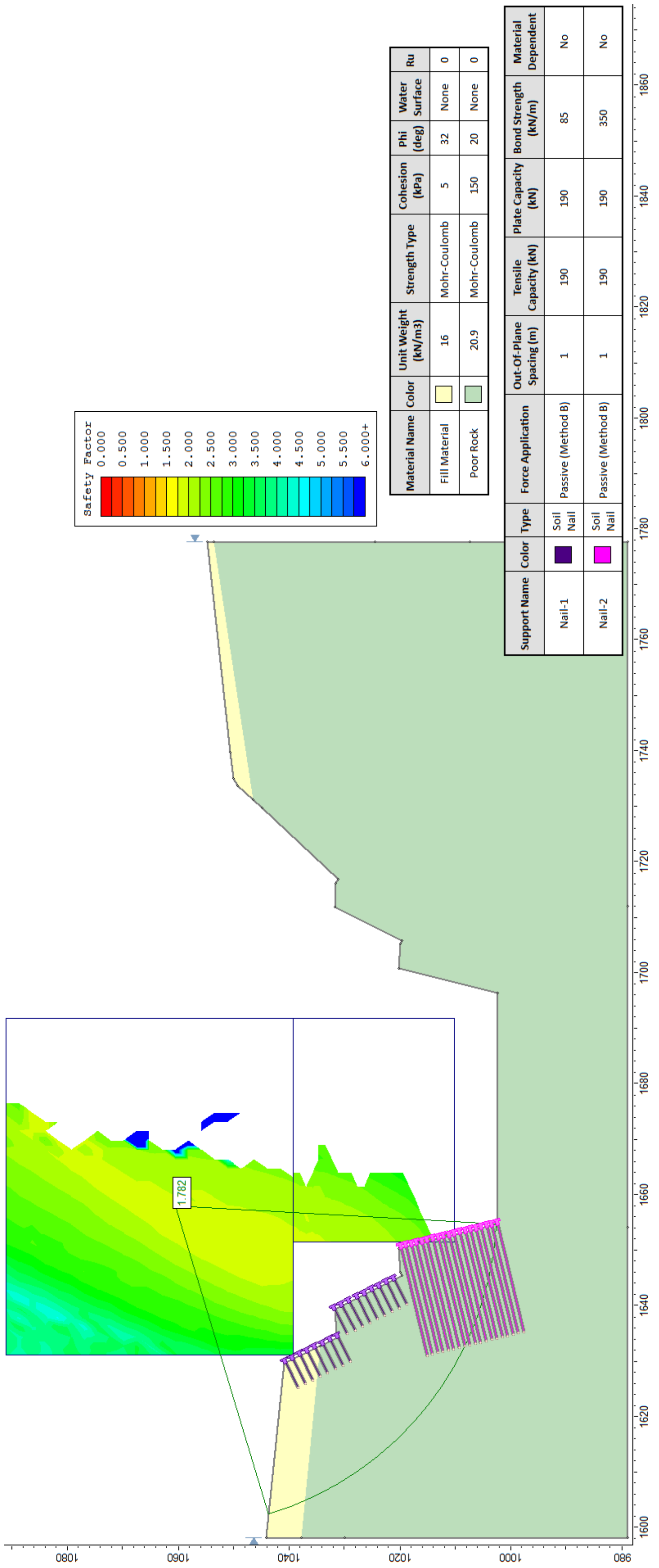
Figure E.30: Left cut slope analysis with Morgenstern method (GW)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

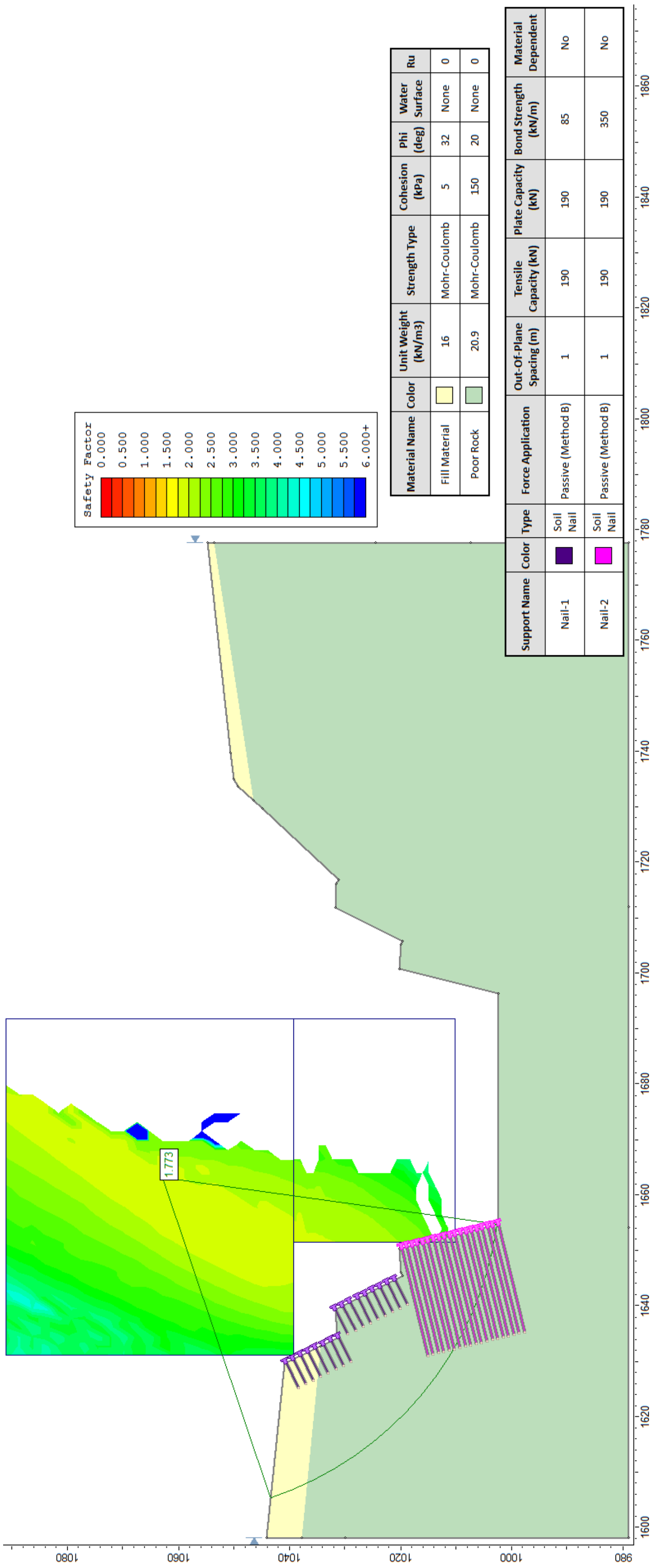
Figure E.31: Left cut slope analysis with Bishop Simp. method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

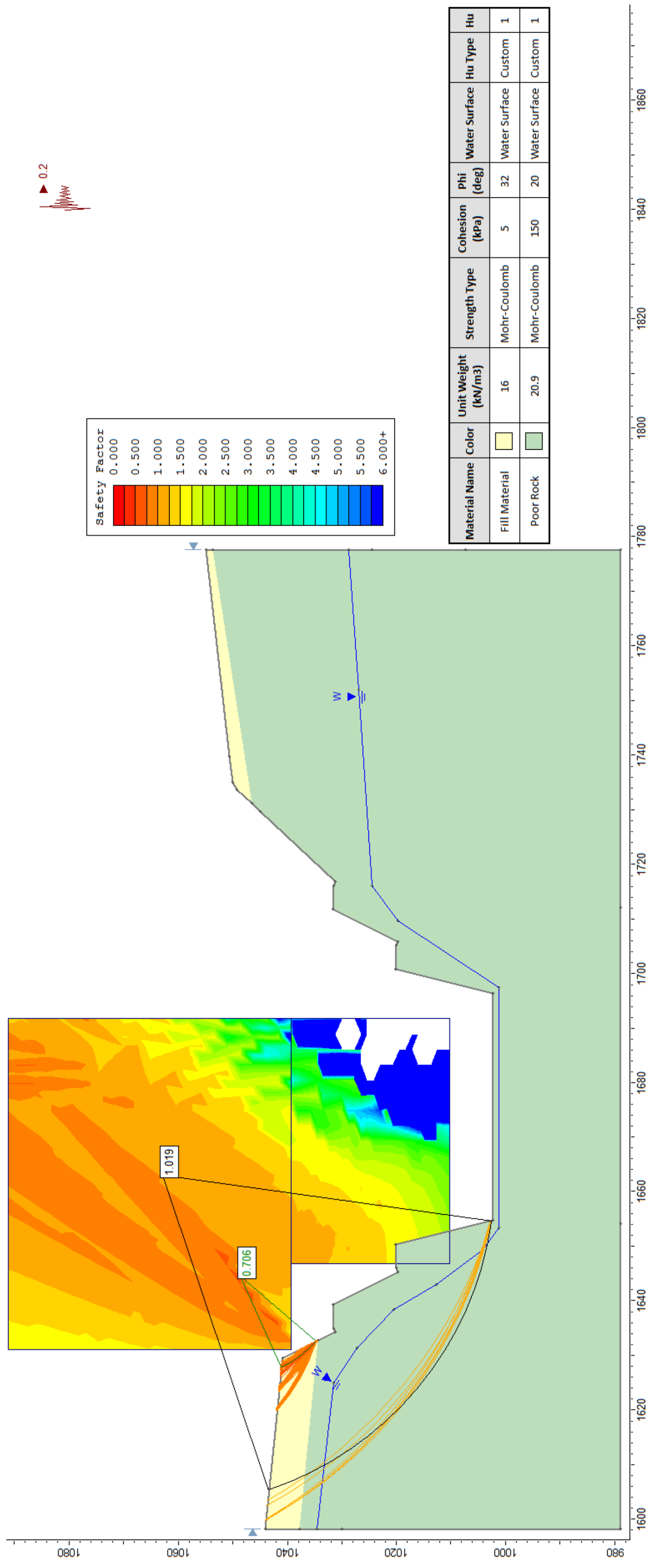
Figure E.32: Left cut slope analysis with Spencer method (Static)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Fill Material	🟨	16	Mohr-Coulomb	5	32	None	0
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	None	0

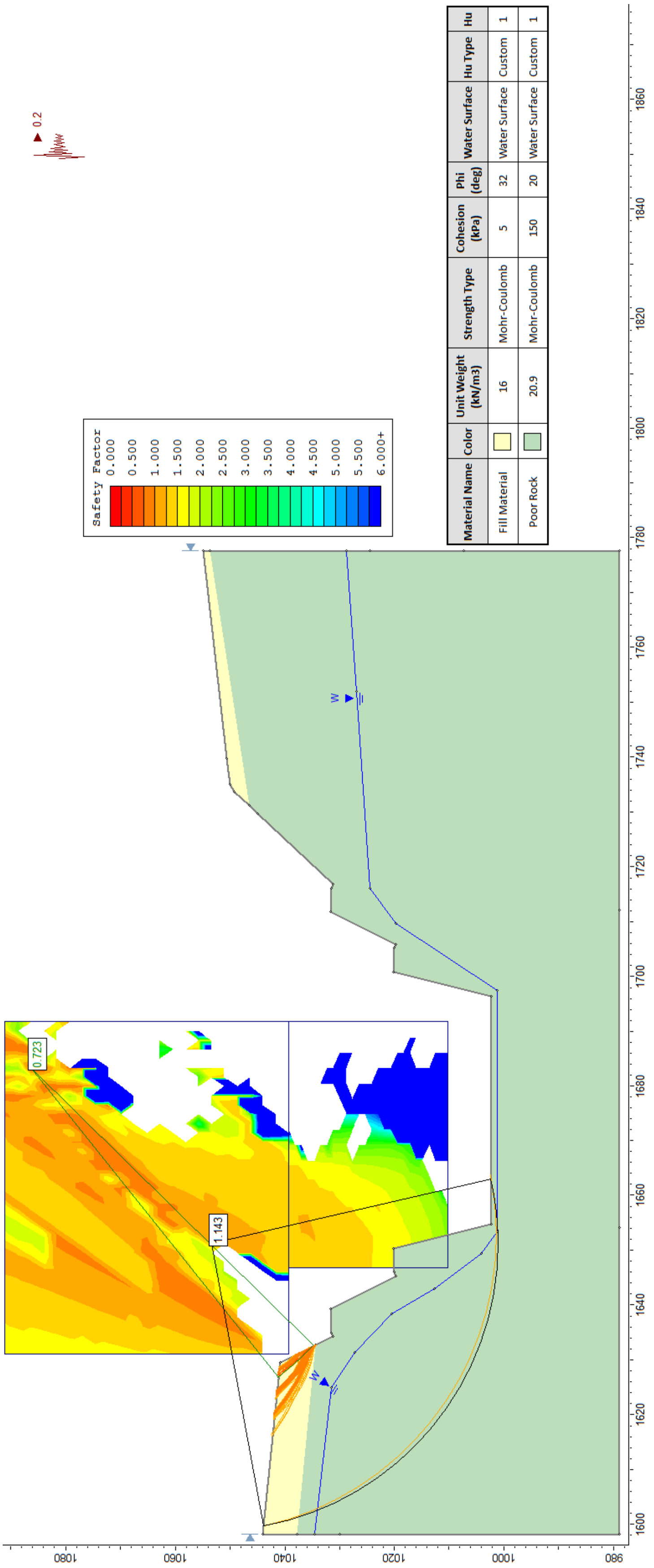
Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Nail-1	🟪	Soil Nail	Passive (Method B)	1	190	190	85	No
Nail-2	🟪	Soil Nail	Passive (Method B)	1	190	190	350	No

Figure E.33: Left cut slope analysis with Morgenstern method (Static)



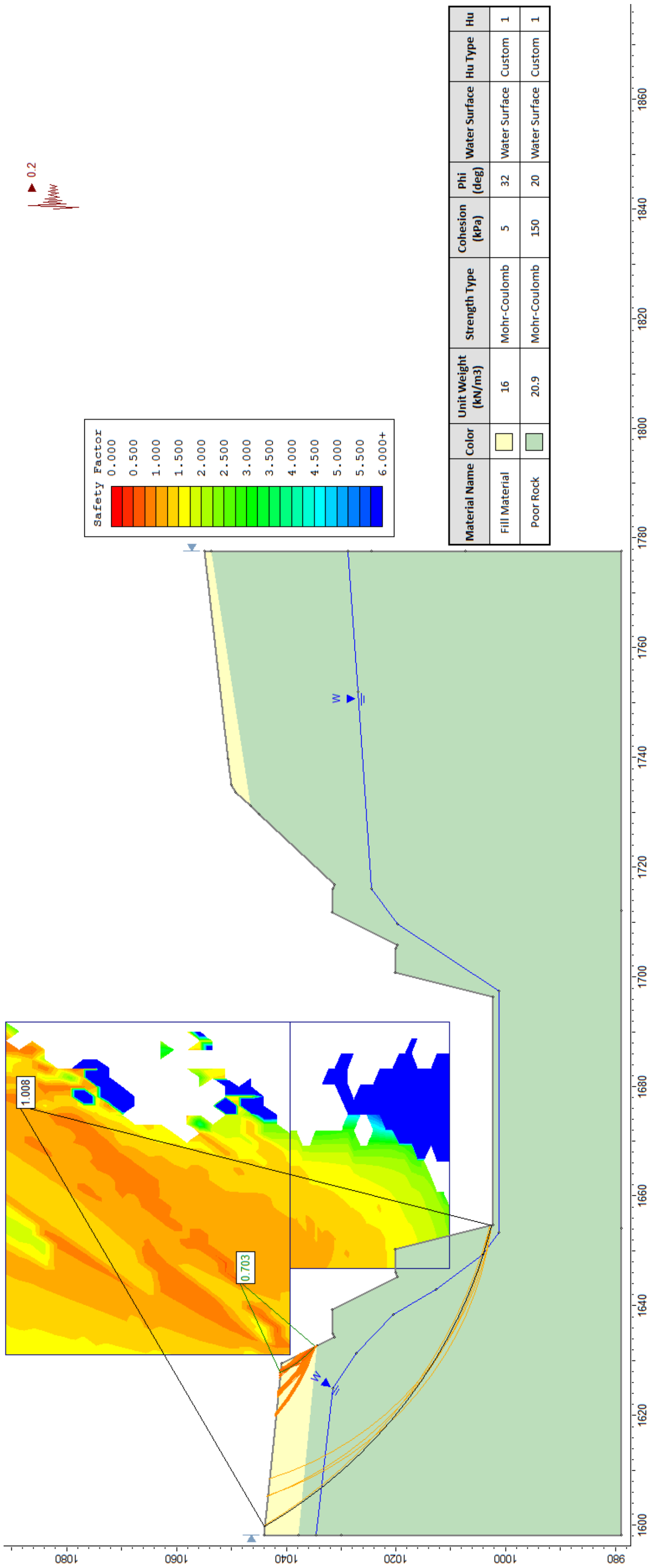
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.34: Left cut slope analysis with Bishop Simp. method (Unsupported)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.35: Left cut slope analysis with Spencer method (Unsupported)



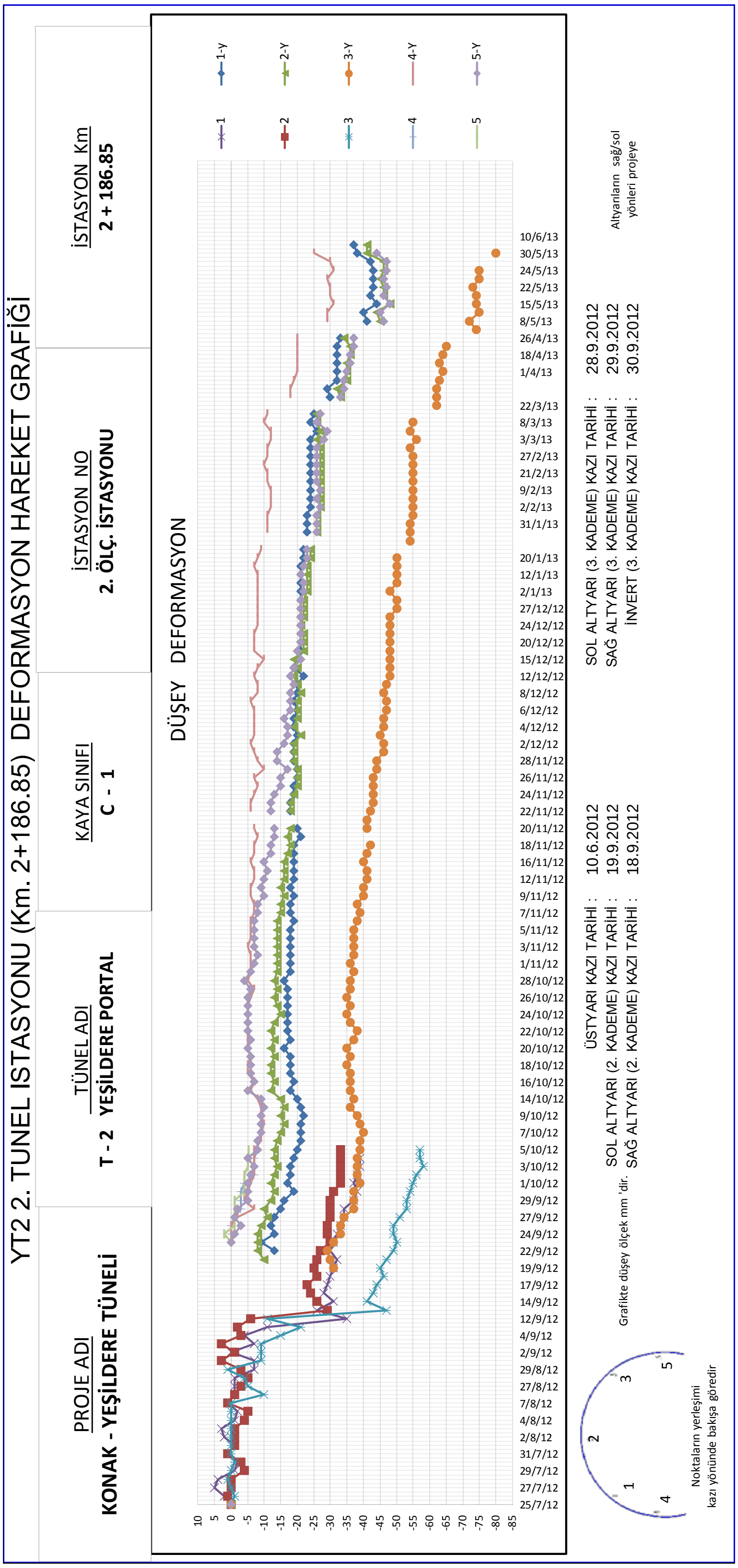
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Fill Material	🟨	16	Mohr-Coulomb	5	32	Water Surface	Custom	1
Poor Rock	🟩	20.9	Mohr-Coulomb	150	20	Water Surface	Custom	1

Figure E.36: Left cut slope analysis with Morgenstern method (Unsupported)

APPENDIX-F: RAW DATA OF MEASURED DISPLACEMENTS

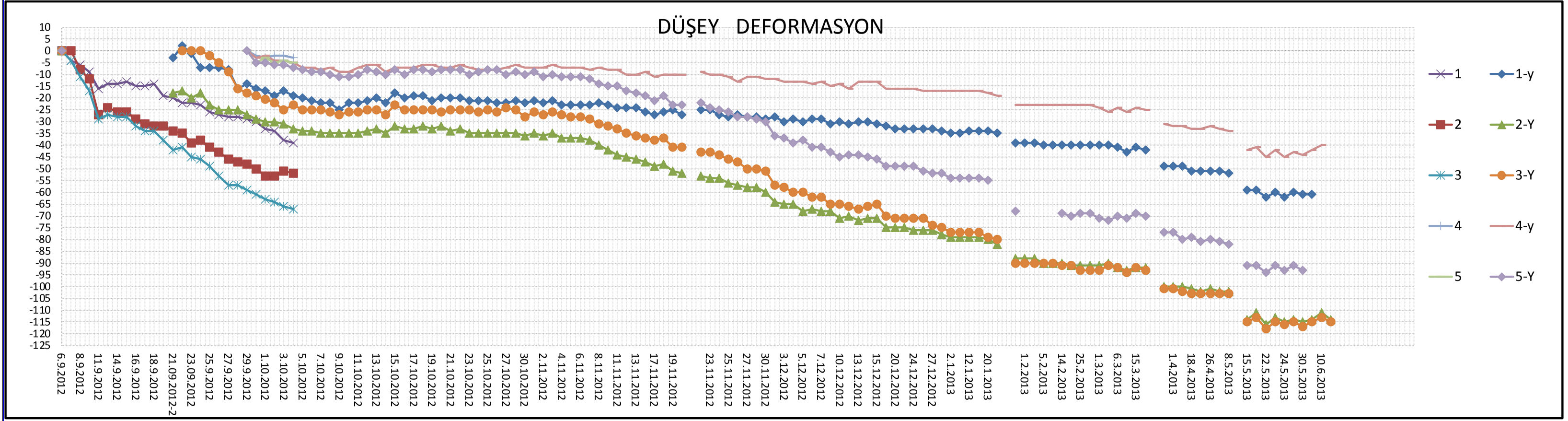
The resultant vertical displacements at each monitoring point are presented in APPENDIX-F.

Figure F.1 to F.23: Tube-2 measured vertical displacement graphs at given kilometers



YT2 3. TUNEL ISTASYONU (Km. 2+176.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 1**	**3. ÖLÇ. İSTASYONU**	**2 + 176.00**

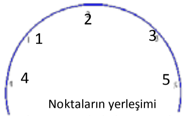


Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 4.9.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 26.9.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 27.9.2012

SOL ALTYARI (3. KADEME) KAZI TARİHİ : 28.9.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 29.9.2012
İNVERT (3. KADEME) KAZI TARİHİ : 30.9.2012

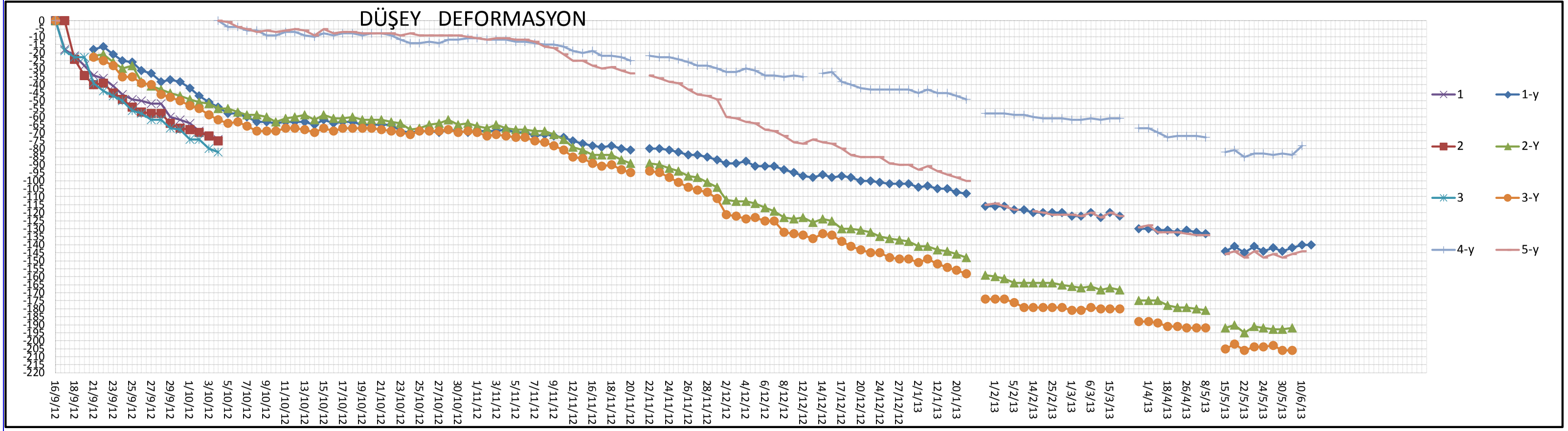
Altyarıların sağ/sol yönleri projeye göredir.

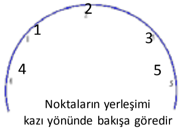


Noktaların yerleşimi kazı yönünde bakışa göredir

YT2 4. TUNEL ISTASYONU (Km. 2+164.35) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 1**	**4. ÖLÇ. İSTASYONU**	**2 + 164.35**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

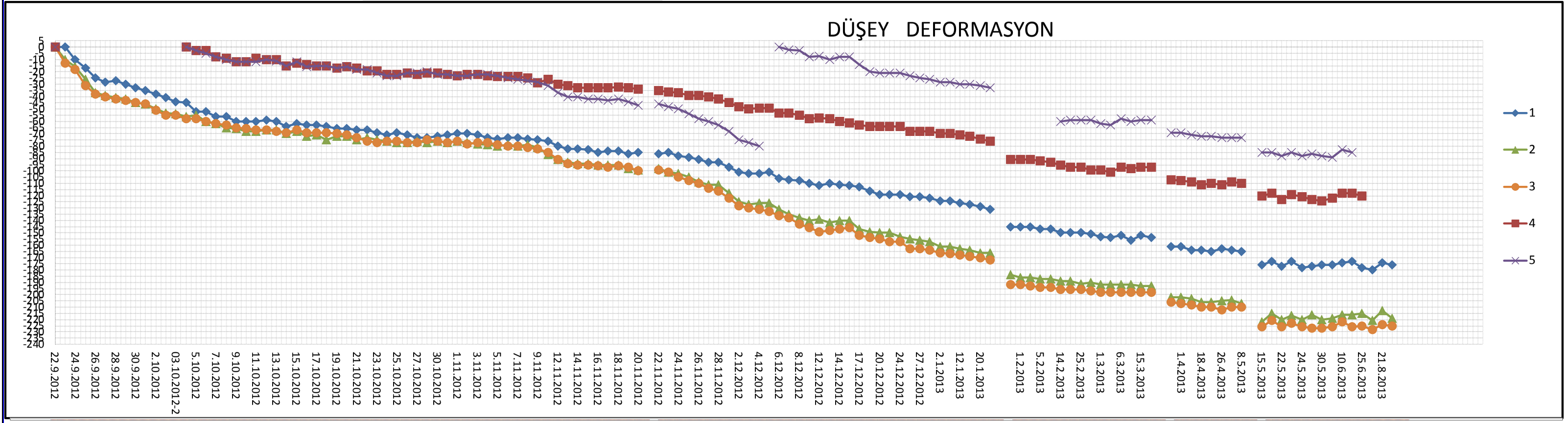
ÜSTYARI KAZI TARİHİ : 12.9.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 30.9.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 1.10.2012

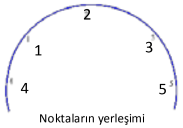
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 3.10.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 3.10.2012
İNVERT (3. KADEME) KAZI TARİHİ : 4.10.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 5. TUNEL ISTASYONU (Km. 2+155.40) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 3**	**5. ÖLÇ. İSTASYONU**	**2 + 155.40**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

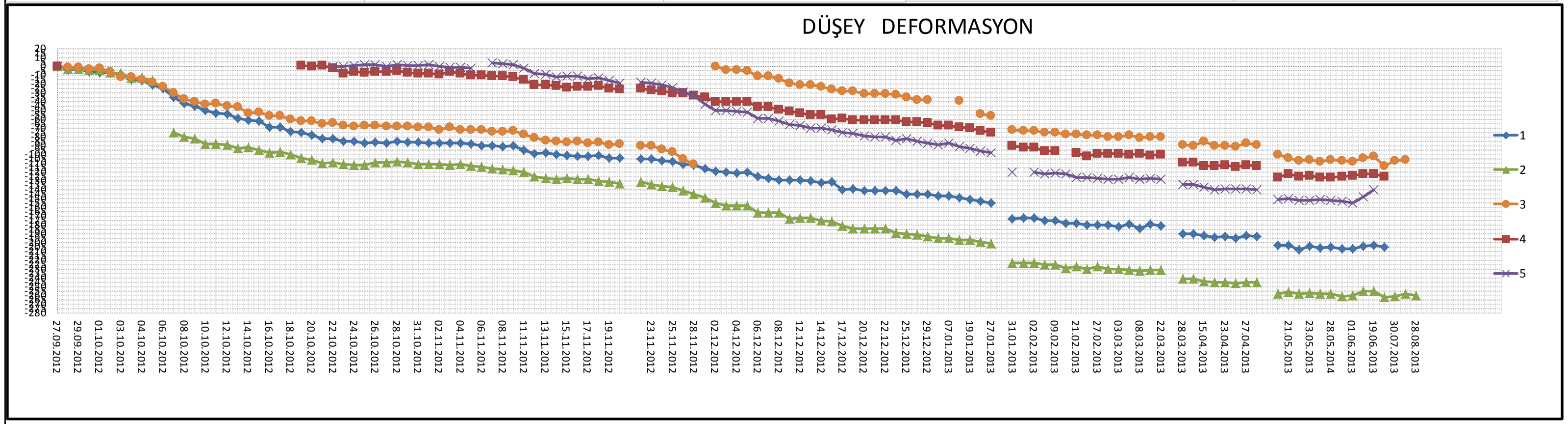
ÜSTYARI KAZI TARİHİ : 19.9.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 2.10.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 2.10.2012

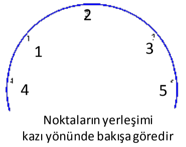
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 3.10.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 3.10.2012
İNVERT (3. KADEME) KAZI TARİHİ : 4.10.2012

Altyanların sağ/sol
yönleri projeye göredir.

YT2 6. TUNEL ISTASYONU (Km. 2+148.65) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**6.ÖLÇ. İSTASYONU**	**2 + 148.65**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 23.09.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 24.09.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 15.10.2012

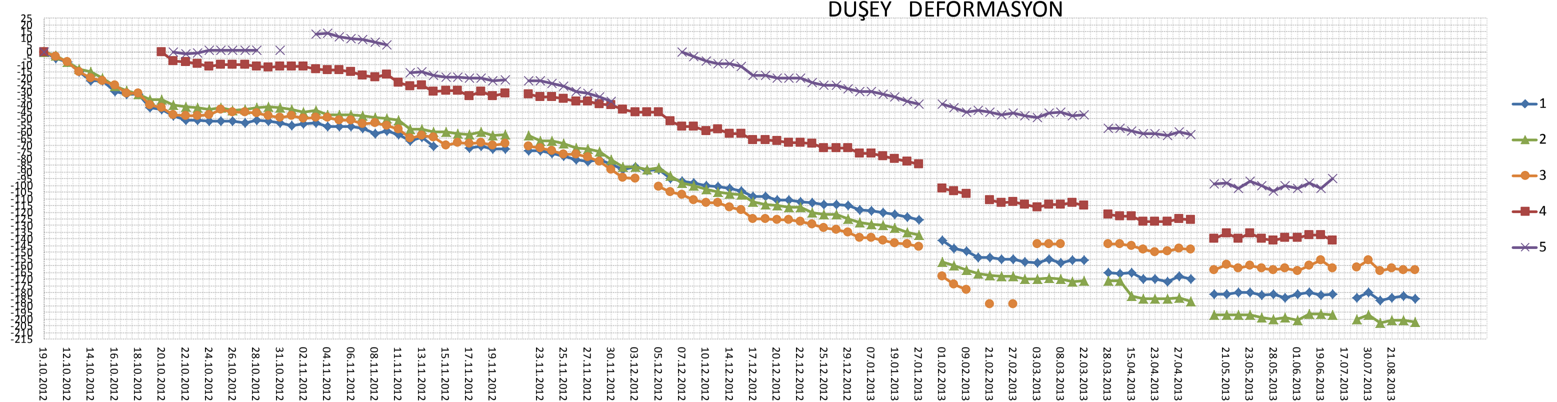
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.10.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 20.10.2012
İNVERT (3. KADEME) KAZI TARİHİ : 21.10.2012

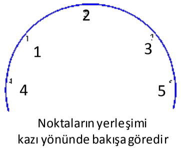
Altyarıların sağ/sol
yönleri projeye göredir.

YT2 7. TUNEL ISTASYONU (Km. 2+140.20) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**7.ÖLÇ. İSTASYONU**	**2 + 140.20**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

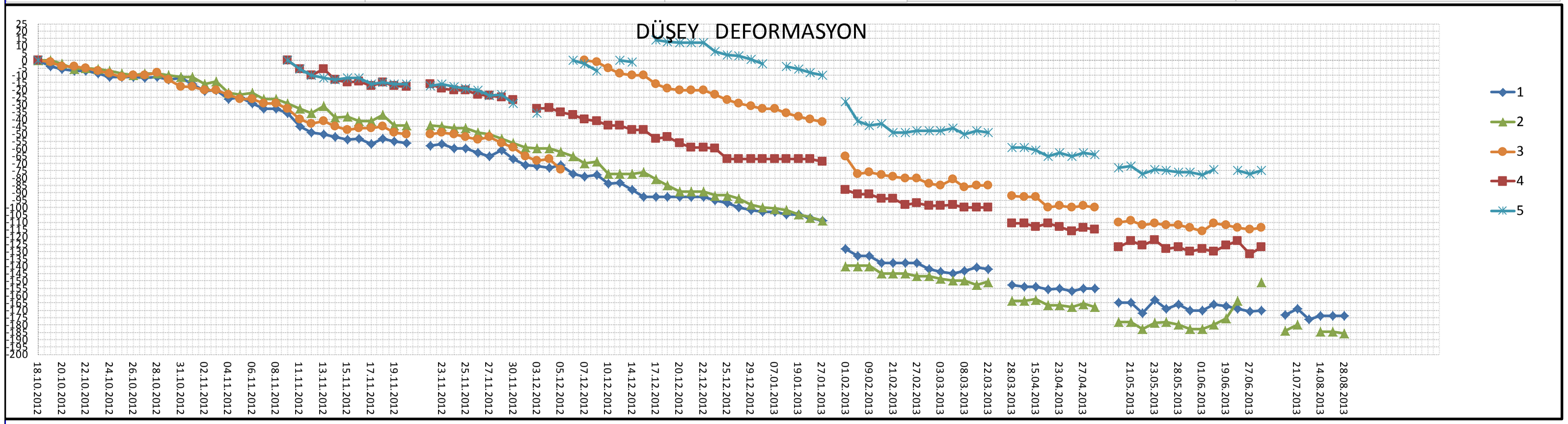
ÜSTYARI KAZI TARİHİ : 07.10.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 18.10.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 19.10.2012

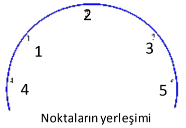
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.10.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 20.10.2012
İNVERT (3. KADEME) KAZI TARİHİ : 21.10.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 8. TUNEL ISTASYONU (Km. 2+129.15) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**8.ÖLÇ. İSTASYONU**	**2 + 129.15**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 14.10.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 08.11.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 08.11.2012

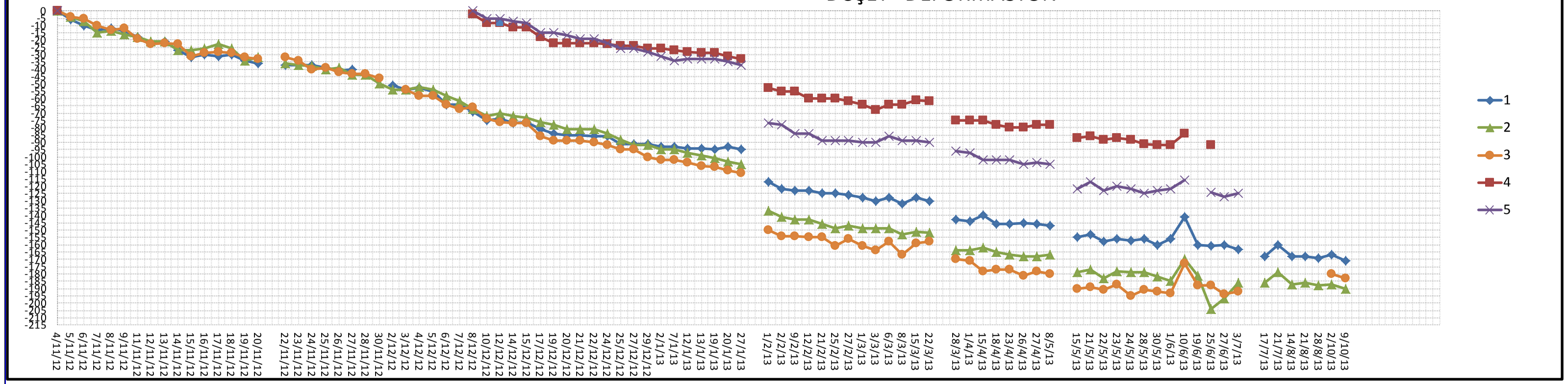
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 09.11.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 09.11.2012
İNVERT (3. KADEME) KAZI TARİHİ : 10.11.2012

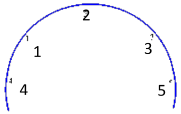
Altyarıların sağ/sol yönleri projeye göredir.

YT2 9. TUNEL ISTASYONU (Km. 2+119.21) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**9.ÖLÇ. İSTASYONU**	**2 + 119.21**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

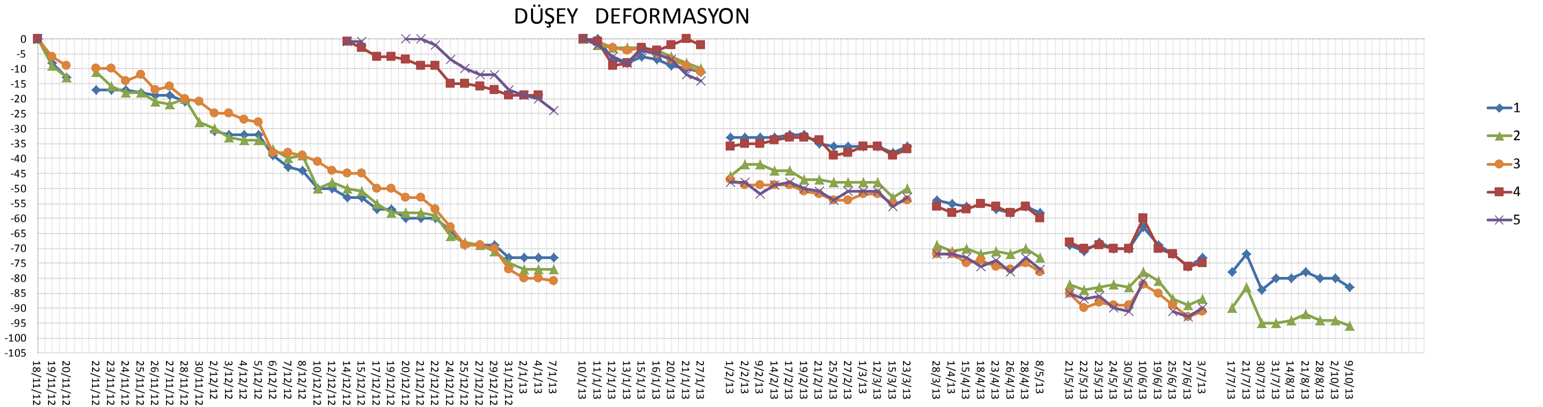
ÜSTYARI KAZI TARİHİ : 01.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 05.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 06.12.2012

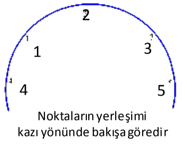
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 09.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 09.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 10.12.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 10. TUNEL ISTASYONU (Km. 2+110.85) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**10.ÖLÇ. İSTASYONU**	**2 + 110.85**


DÜŞEY DEFORMASYON



Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

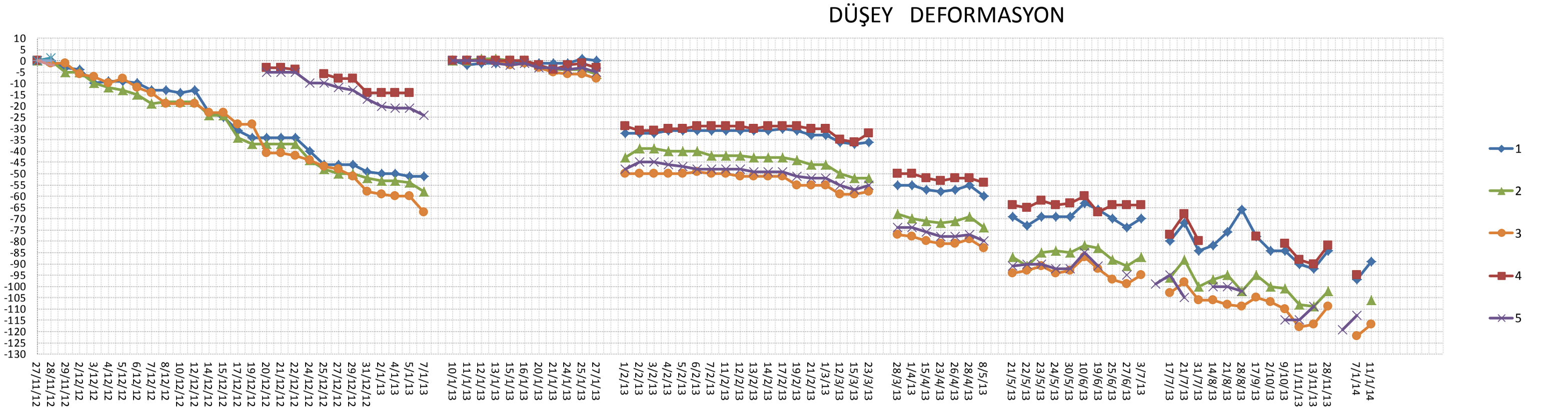
ÜSTYARI KAZI TARİHİ : 14.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 11.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 11.12.2012

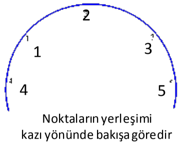
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 17.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 16.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 21.12.2012

Altyarıların sağ/sol yönleri projeye göredir.

YT2 11. TUNEL ISTASYONU (Km. 2+101.30) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**C - 2**	**11.ÖLÇ. İSTASYONU**	**2 + 101.30**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm'dir.

ÜSTYARI KAZI TARİHİ : 23.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 14.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 18.12.2012

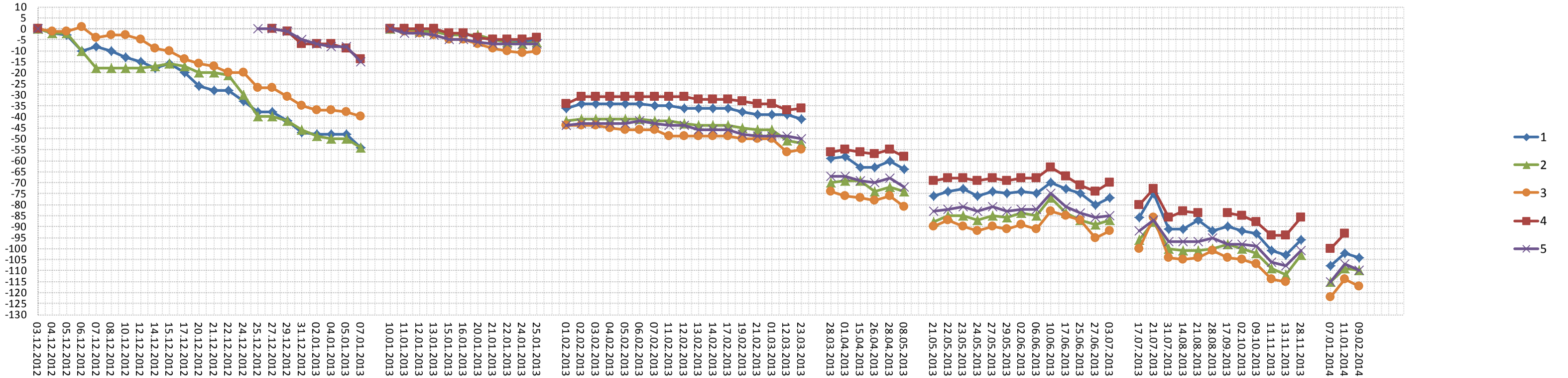
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 20.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 21.12.2012

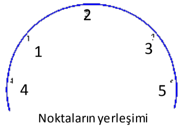
Altyarıların sağ/sol yönleri projeye göredir.

YT2 12. TUNEL ISTASYONU (Km. 2+089.50) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-b**	**12.ÖLÇ. İSTASYONU**	**2 + 089.50**

DÜŞEY   DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm'dir.

ÜSTYARI KAZI TARİHİ : 30.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 22.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 24.12.2012

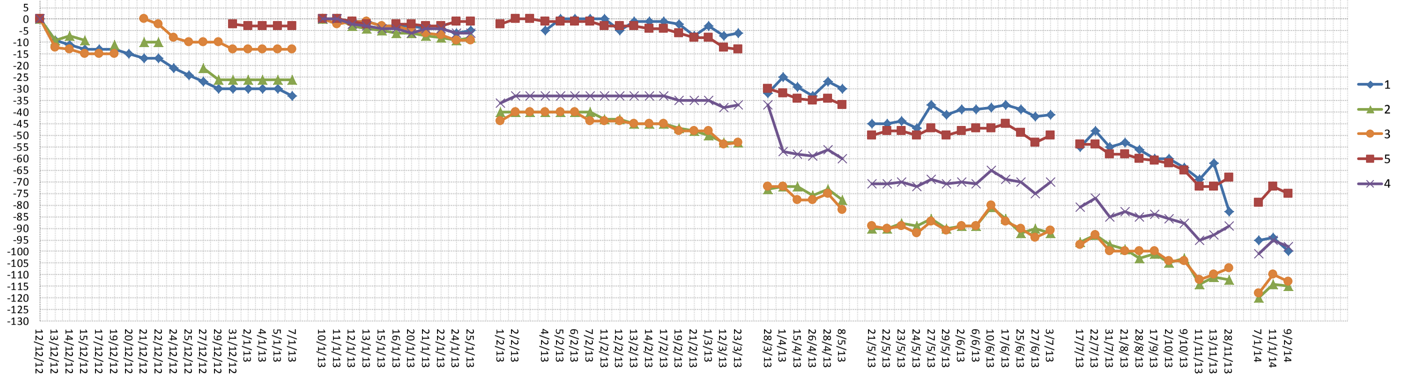
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 30.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 01.01.2013
İNVERT (3. KADEME) KAZI TARİHİ : 02.01.2013

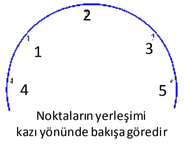
Altyarıların sağ/sol
yönleri projeye göredir.

YT2 13. TUNEL ISTASYONU (Km. 2+077.70) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-b**	**13.ÖLÇ. İSTASYONU**	**2 077.70**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

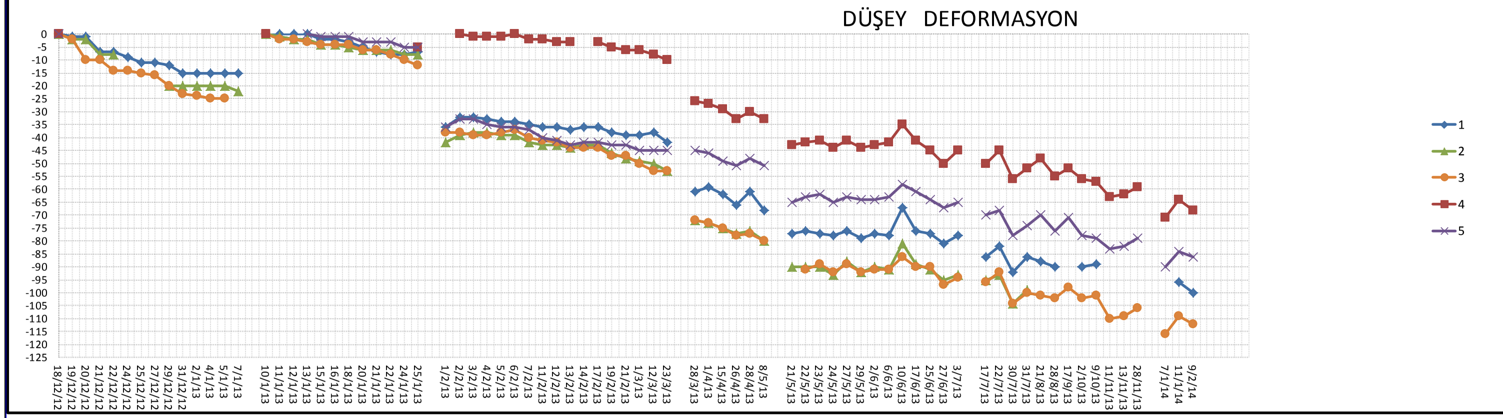
Grafikte düşey ölçek mm 'dir.

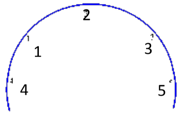
ÜSTYARI KAZI TARİHİ :	08.12.2021
SOL ALTYARI (2. KADEME) KAZI TARİHİ :	29.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ :	04.01.2013
SOL ALTYARI (3. KADEME) KAZI TARİHİ :	31.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ :	16.01.2013
İNVERT (3. KADEME) KAZI TARİHİ :	20.01.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 14. TUNEL ISTASYONU (Km. 2+067.60) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-b**	**14.ÖLÇ. İSTASYONU**	**2 067.60**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

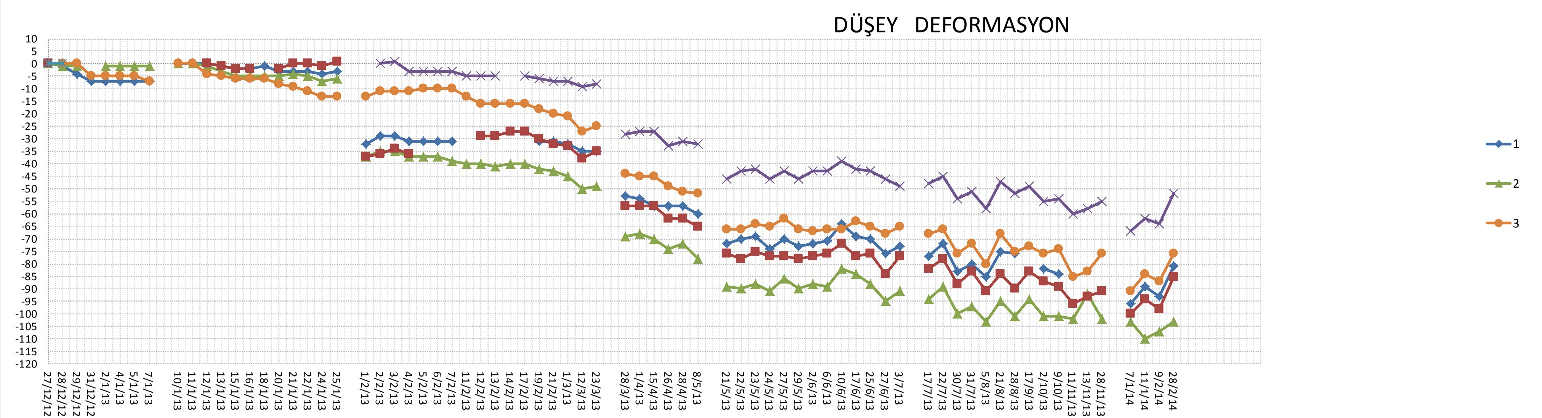
ÜSTYARI KAZI TARİHİ : 15.12.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 05.01.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 13.01.2013

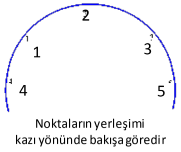
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 17.01.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 18.01.2013
İNVERT (3. KADEME) KAZI TARİHİ : 20.01.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 15. TUNEL ISTASYONU (Km. 2+058.65) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-b**	**15.ÖLÇ. İSTASYONU**	**2 058.65**





Grafikte düşey ölçek mm 'dir.

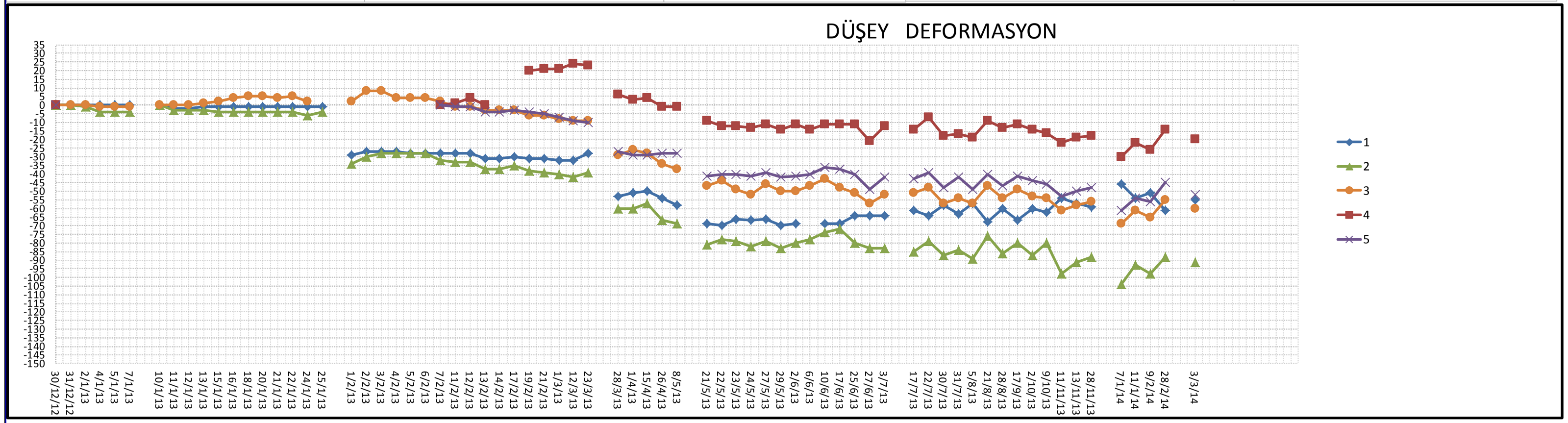
ÜSTYARI KAZI TARİHİ : 20.12.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 08.01.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 12.01.2013

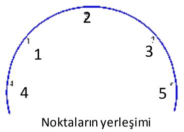
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 17.01.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 18.01.2013
İNVERT (3. KADEME) KAZI TARİHİ : 19.01.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 16. TUNEL ISTASYONU (Km. 2+045.20 DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-b**	**16.ÖLÇ. İSTASYONU**	**2 045.20**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

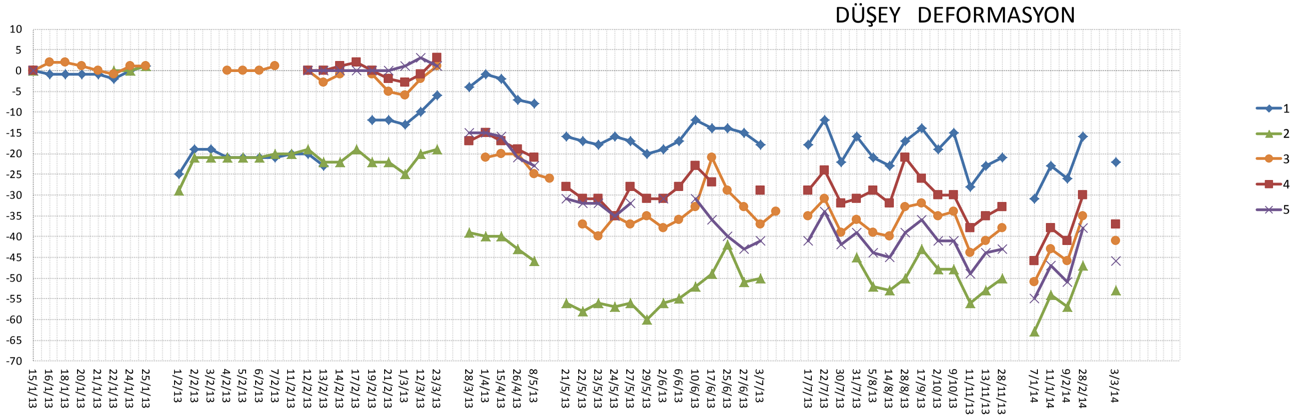
ÜSTYARI KAZI TARİHİ : 27.12.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 03.02.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 25.01.2013

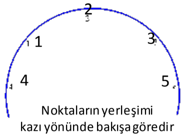
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 21.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 16.04.2013
İNVERT (3. KADEME) KAZI TARİHİ : 29.05.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 17. TUNEL ISTASYONU (Km. 2+028.50 DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-a**	**17.ÖLÇ. İSTASYONU**	**2 028.50**





Grafikte düşey ölçek mm'dir.

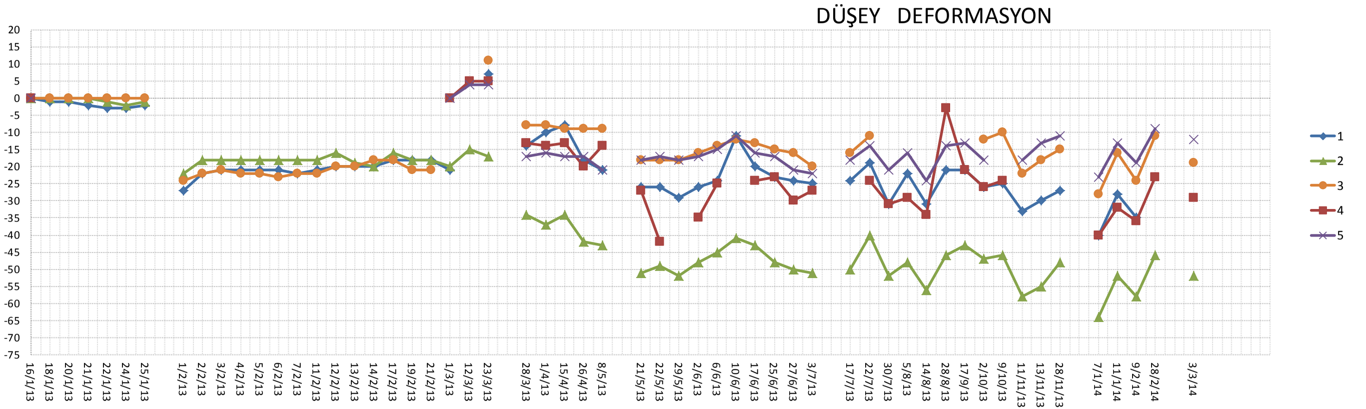
ÜSTYARI KAZI TARİHİ : 05.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 10.02.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 09.02.2013

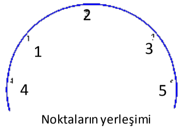
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 02.03.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 18. TUNEL ISTASYONU (Km. 2+015.30 DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B 3-a**	**18.ÖLÇ. İSTASYONU**	**2+015.30**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 11.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 16.02.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 23.02.2013

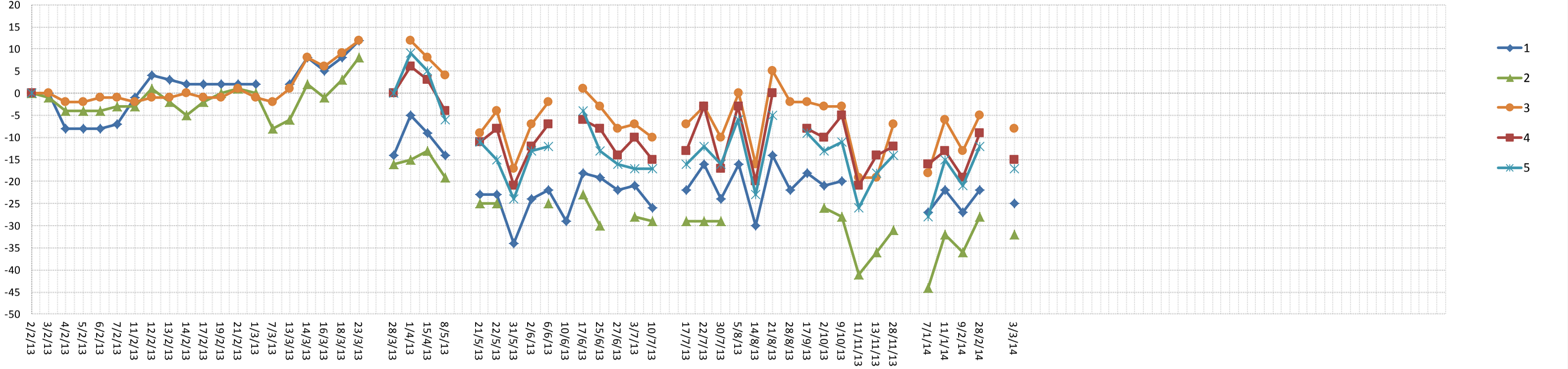
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 14.04.2013

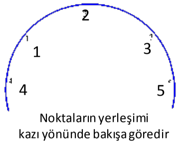
Altyarıların sağ/sol
yönleri projeye göredir.

YT2 19. TUNEL ISTASYONU (Km. 1+979.35) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**19.ÖLÇ. İSTASYONU**	**1 + 979.35**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

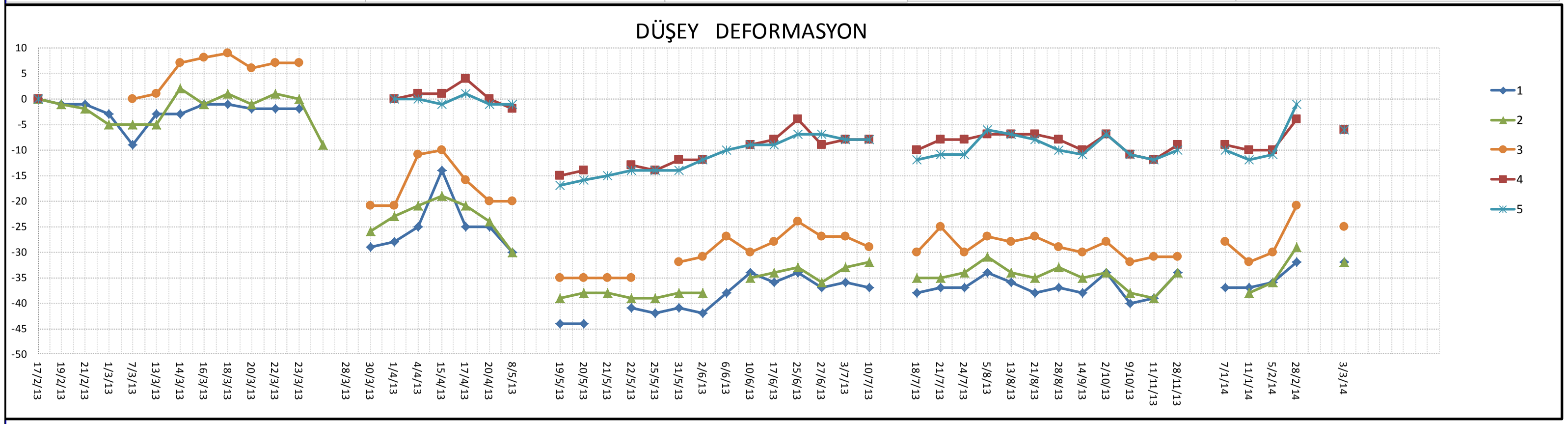
ÜSTYARI KAZI TARİHİ : 27.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 19.03.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 21.03.2013

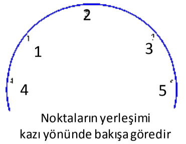
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 24.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 15.04.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 20. TUNEL ISTASYONU (Km. 1+939.40) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**20.ÖLÇ. İSTASYONU**	**1 + 939.40**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

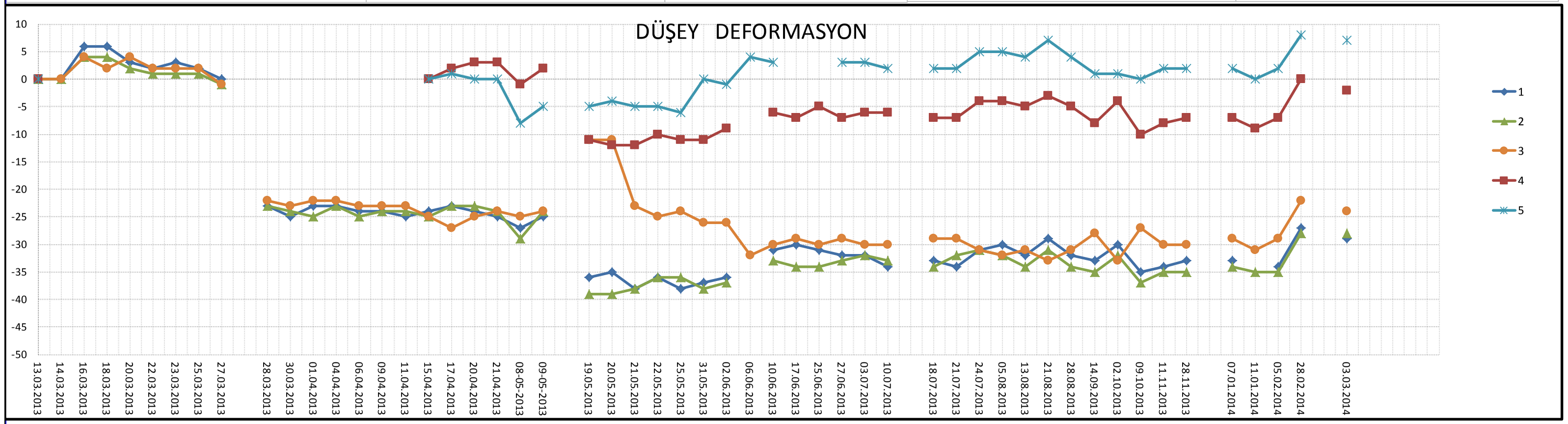
ÜSTYARI KAZI TARİHİ : 09.02.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 24.03.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 26.03.2013

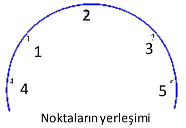
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 27.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 27.04.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 21. TUNEL ISTASYONU (Km. 1+913.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**21.ÖLÇ. İSTASYONU**	**1 + 913.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

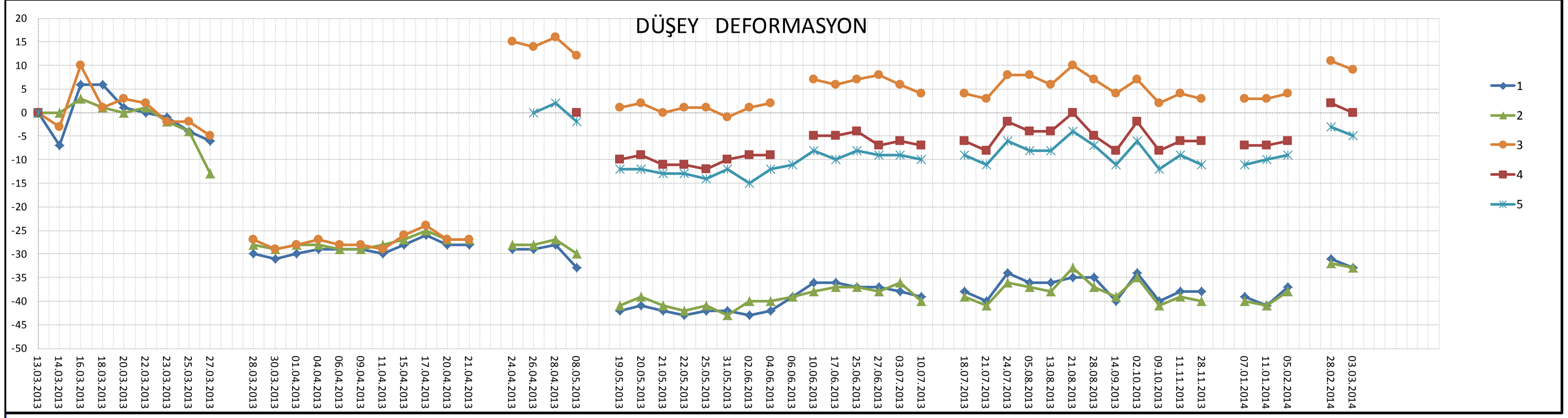
ÜSTYARI KAZI TARİHİ : 09.02.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 30.03.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 03.04.2013

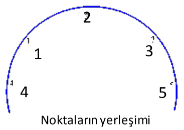
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 27.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 12.07.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 22. TUNEL ISTASYONU (Km. 1+880.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**22.ÖLÇ. İSTASYONU**	**1 + 880.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

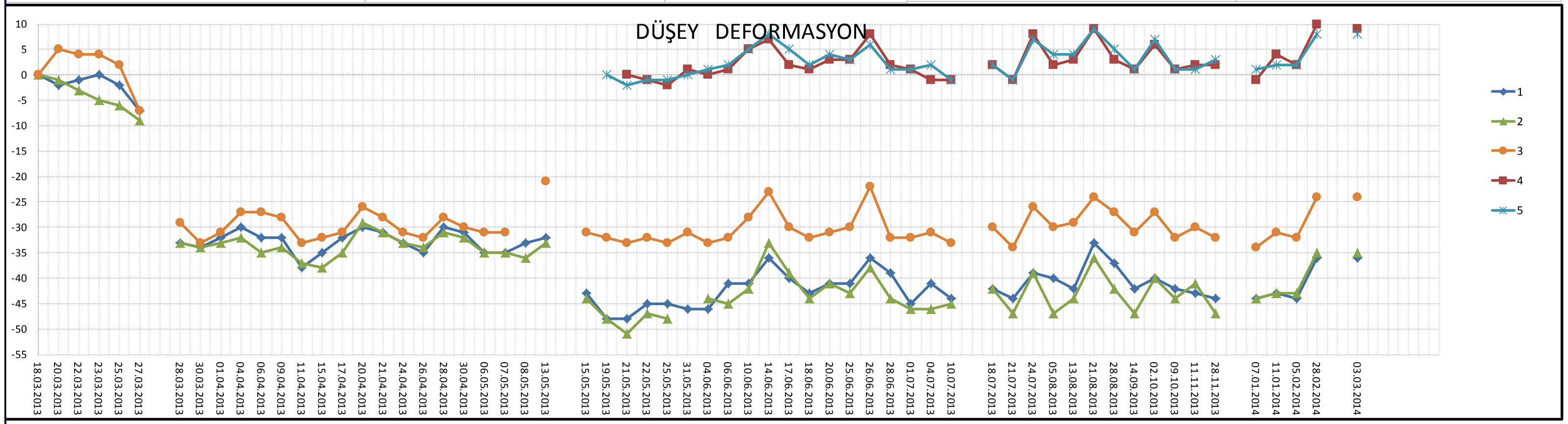
ÜSTYARI KAZI TARİHİ : 01.03.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 18.04.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 21.04.2013

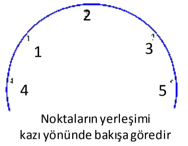
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 18.04.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 05.04.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 23. TUNEL ISTASYONU (Km. 1+837.15) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**23.ÖLÇ. İSTASYONU**	**1 + 837.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

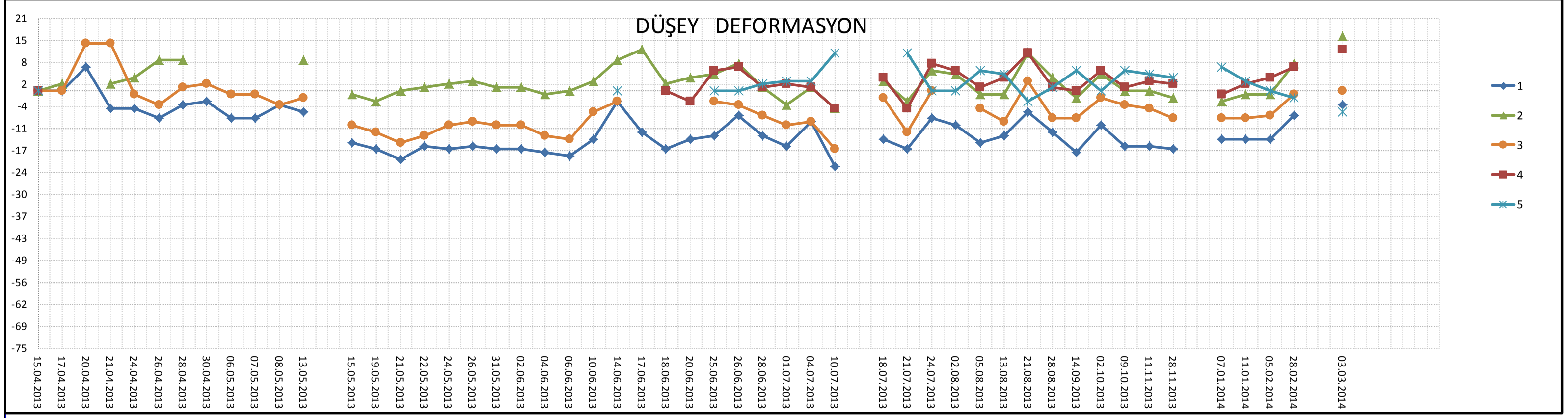
ÜSTYARI KAZI TARİHİ : 13.03.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 09.05.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 14.05.2013

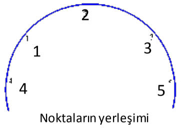
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 19.07.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 06.06.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT2 24. TUNEL ISTASYONU (Km. 1+800.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 2 YEŞİLDERE PORTAL**	**B - 2**	**24.ÖLÇ. İSTASYONU**	**1 +800.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

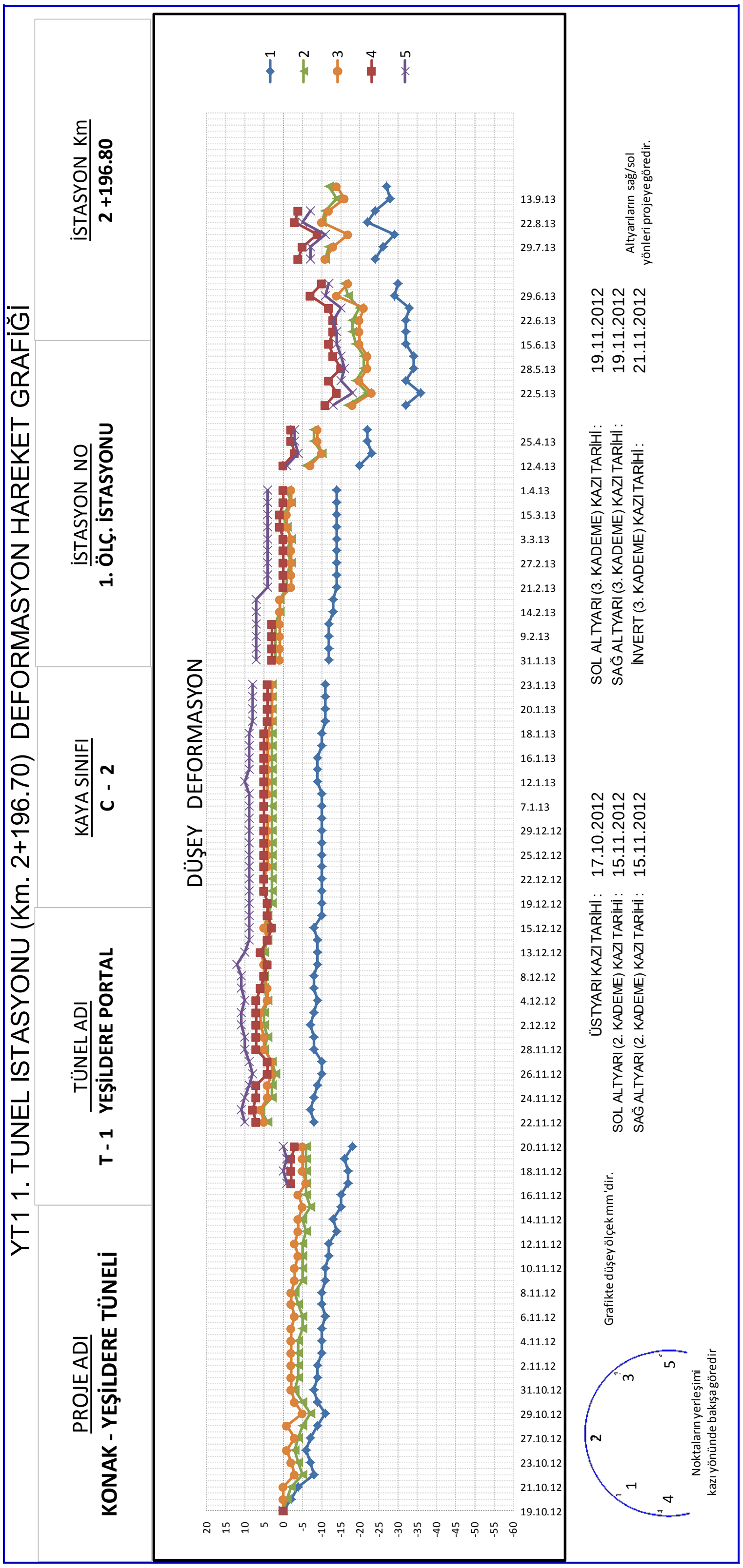
Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 02.04.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 09.06.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 15.06.2013

SOL ALTYARI (3. KADEME) KAZI TARİHİ : 10.07.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 18.07.2013

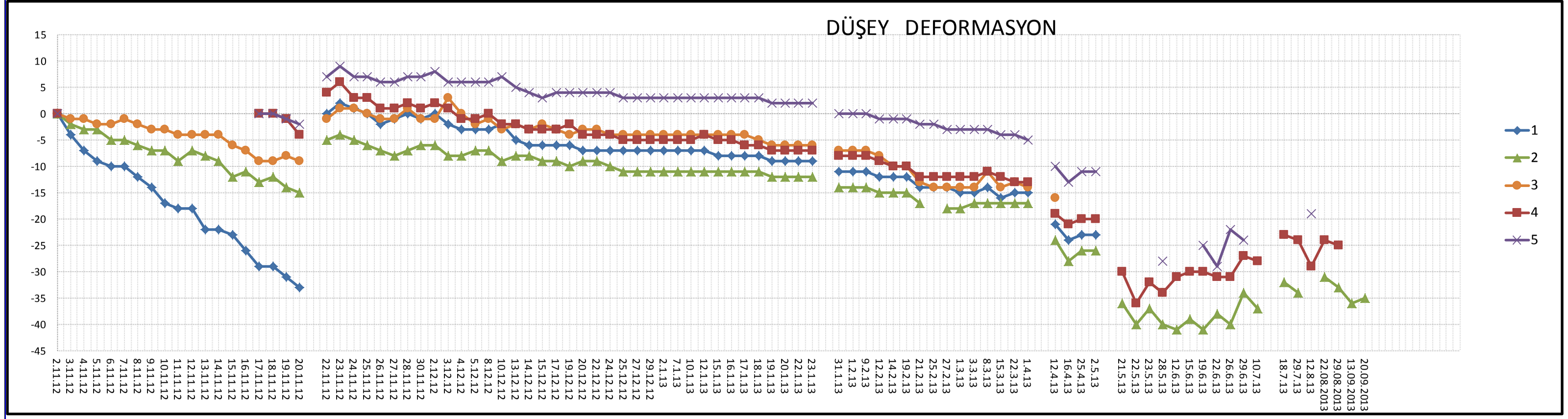
Altyarıların sağ/sol
yönleri projeye göredir.

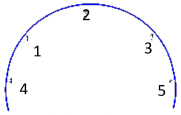
Figure F.24 to F.41: Tube-1 measured vertical displacement graphs at given kilometers



YT1 2. TUNEL ISTASYONU (Km. 2+186.09) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**C - 2**	**2.ÖLÇ. İSTASYONU**	**2 + 186.09**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

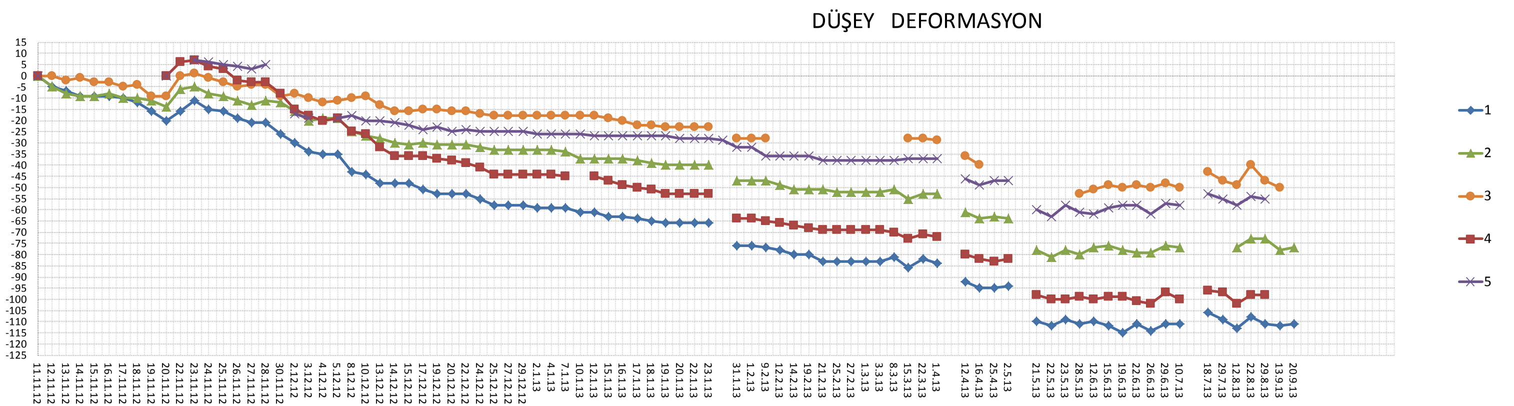
ÜSTYARI KAZI TARİHİ : 29.10.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 15.11.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 15.11.2012

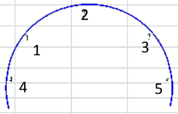
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 19.11.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 19.11.2012
İNVERT (3. KADEME) KAZI TARİHİ : 20.11.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 4. TUNEL ISTASYONU (Km. 2+163.66) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**4.ÖLÇ. İSTASYONU**	**2 + 163.66**





Noktaların yerleşimi
kazı yönünde bakışa göredir

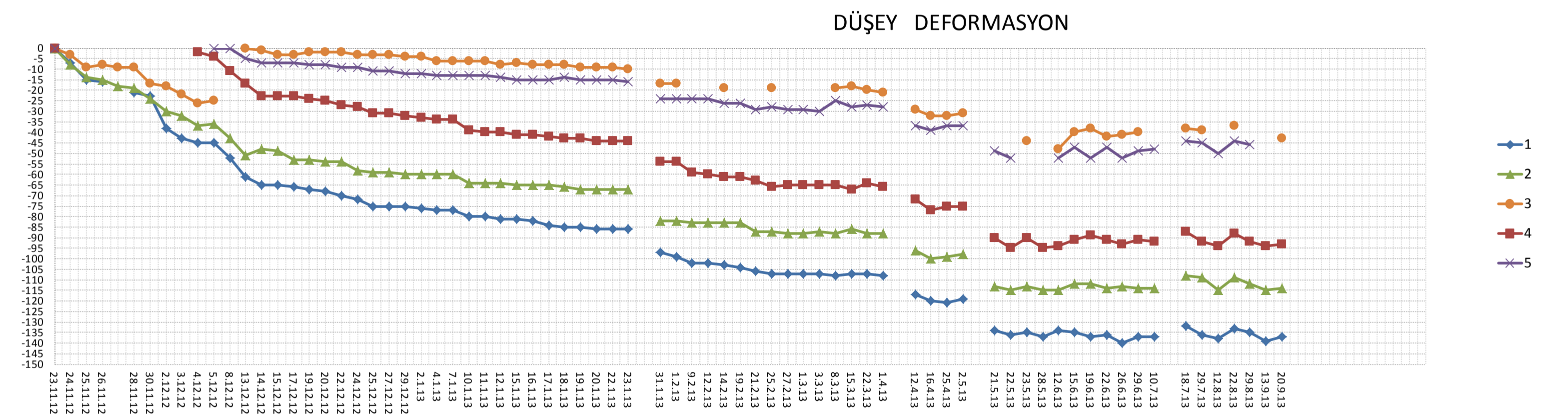
Grafikte düşey ölçek mm 'dir.

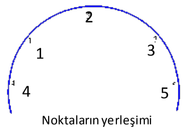
ÜSTYARI KAZI TARİHİ :	08.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ :	19.11.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ :	18.11.2012
SOL ALTYARI (3. KADEME) KAZI TARİHİ :	20.11.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ :	20.11.2012
İNVERT (3. KADEME) KAZI TARİHİ :	01.12.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 5. TUNEL ISTASYONU (Km. 2+153.35) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**5.ÖLÇ. İSTASYONU**	**2 + 153.35**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

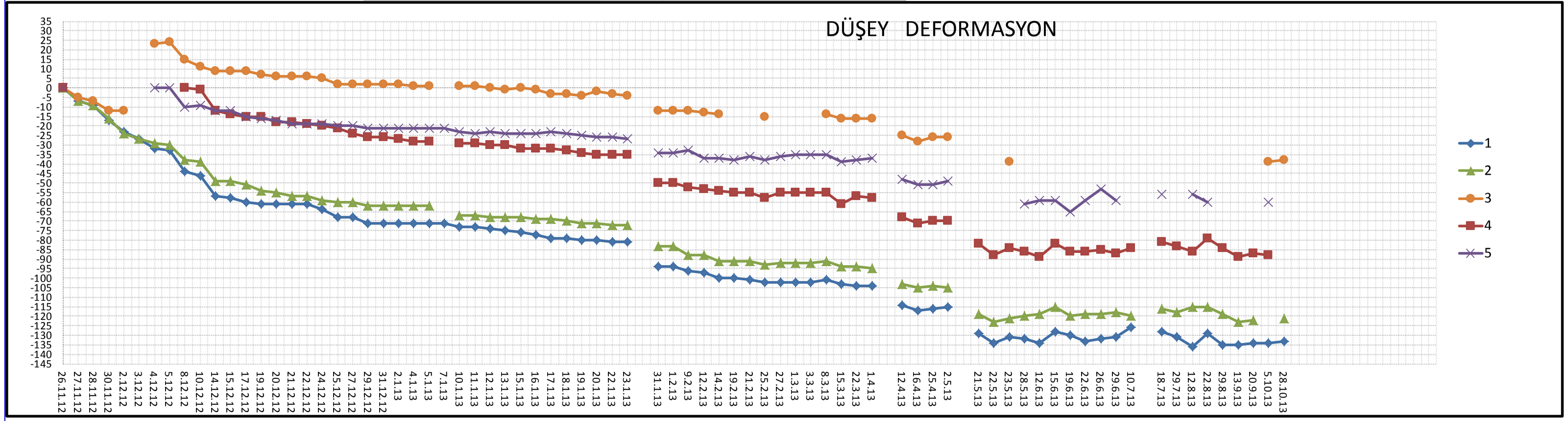
ÜSTYARI KAZI TARİHİ : 12.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 28.11.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 29.11.2012

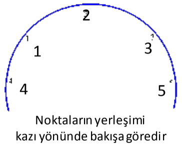
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 01.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 01.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 01.12.2012

Altyarıların sağ/sol
yönleri projeye göredir.

6. TUNEL ISTASYONU (Km. 2+146.75) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI **KONAK - YEŞİLDERE TÜNELİ**	TÜNEL ADI **T - 1 YEŞİLDERE PORTAL**	KAYA SINIFI **B 3-b**	İSTASYON NO **6.ÖLÇ. İSTASYONU**	İSTASYON Km **2 +146.75**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

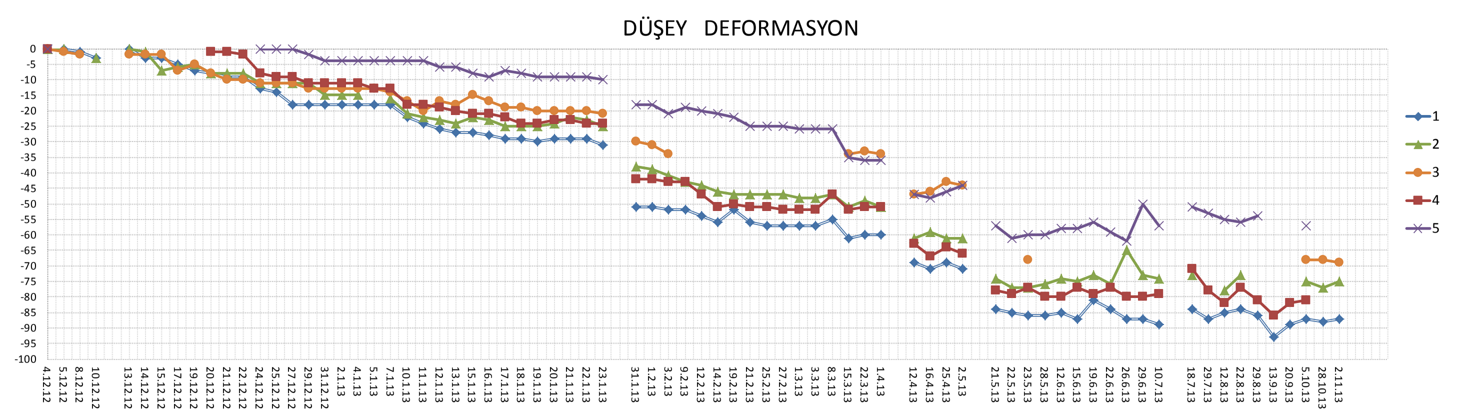
ÜSTYARI KAZI TARİHİ : 23.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 30.11.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 06.12.2012

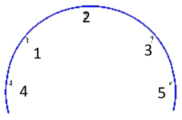
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 08.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 10.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 11.12.2012

Altyarıların sağ/sol yönleri projeye göredir.

YT1 7. TUNEL ISTASYONU (Km. 2+135.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**7.ÖLÇ. İSTASYONU**	**2 +135.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

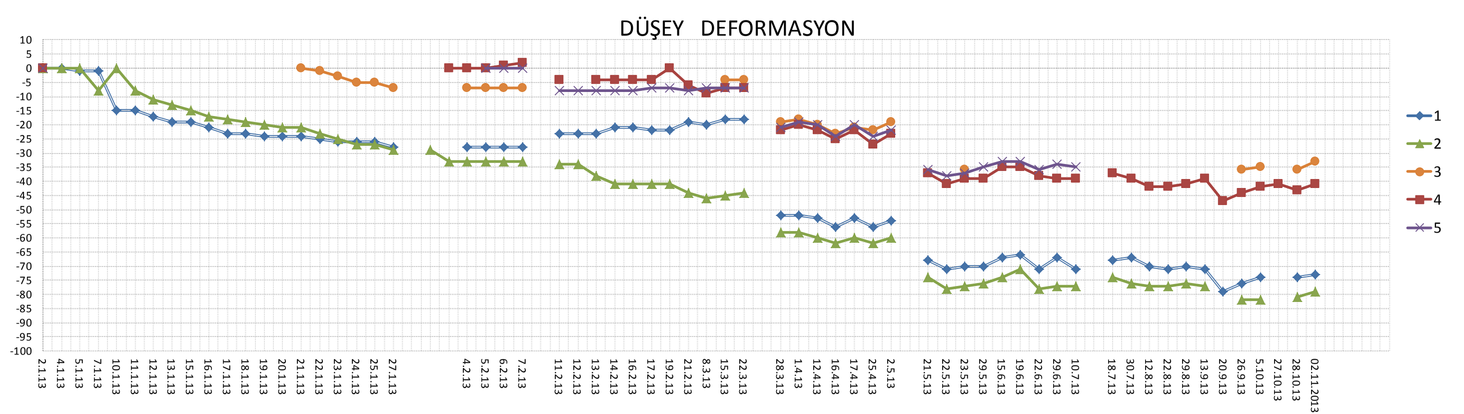
ÜSTYARI KAZI TARİHİ : 28.11.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 07.12.2012
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 07.12.2012

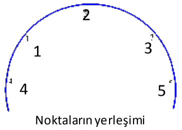
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 10.12.2012
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 10.12.2012
İNVERT (3. KADEME) KAZI TARİHİ : 11.12.2012

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 10. TUNEL ISTASYONU (Km. 2+100.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**10.ÖLÇ. İSTASYONU**	**2 +100.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 28.12.2012
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 26.01.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 25.01.2013

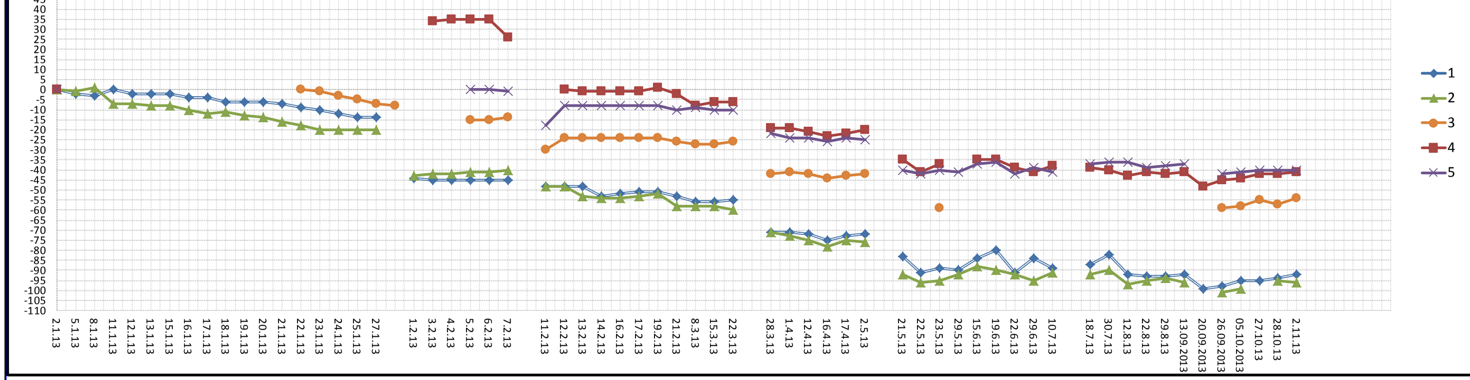
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 29.01.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 29.01.2013
İNVERT (3. KADEME) KAZI TARİHİ : 31.01.2013

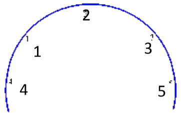
Altyarıların sağ/sol
yönleri projeye göredir.

YT1 111. TUNEL ISTASYONU (Km. 2+086.25) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**11.ÖLÇ. İSTASYONU**	**2+ 086.25**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 02.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 28.01.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 28.01.2013

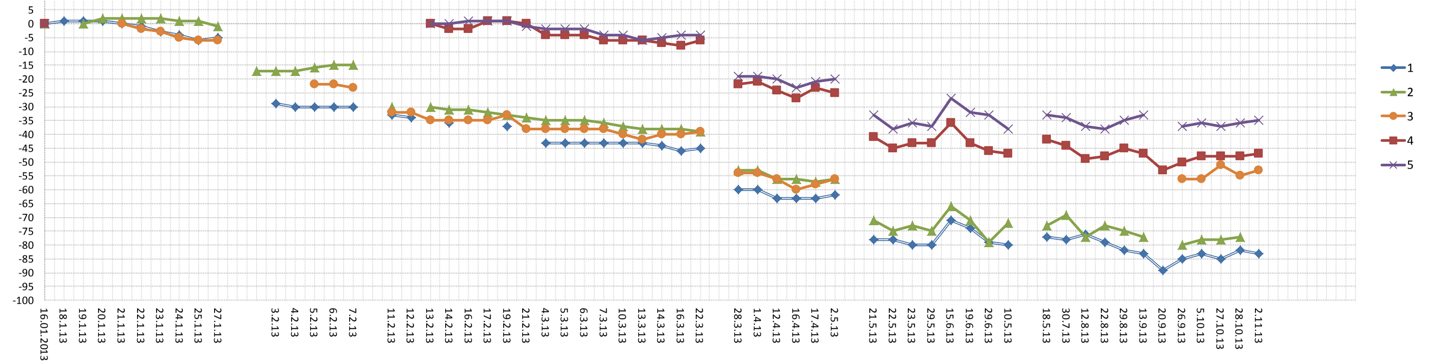
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 30.01.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 29.01.2013
İNVERT (3. KADEME) KAZI TARİHİ : 30.01.2013

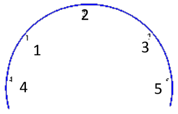
Altyarıların sağ/sol
yönleri projeye göredir.

YT1 12. TUNEL ISTASYONU (Km. 2+077.08) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**C 2**	**12.ÖLÇ. İSTASYONU**	**2+ 077.08**

DÜŞEY DEFORMASYON





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm'dir.

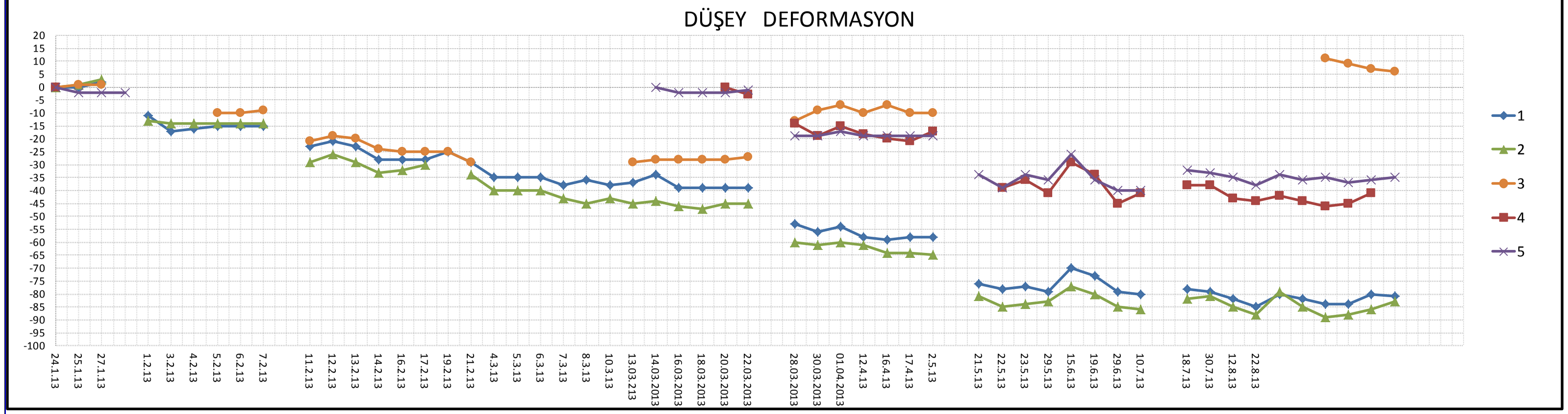
ÜSTYARI KAZI TARİHİ : 06.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 10.02.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 09.02.2013

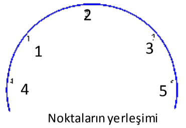
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 28.02.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 27.02.2013
İNVERT (3. KADEME) KAZI TARİHİ : 10.05.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 13. TUNEL ISTASYONU (Km. 2+058.18) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**13. ÖLÇ. İSTASYONU**	**2 +058.18**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

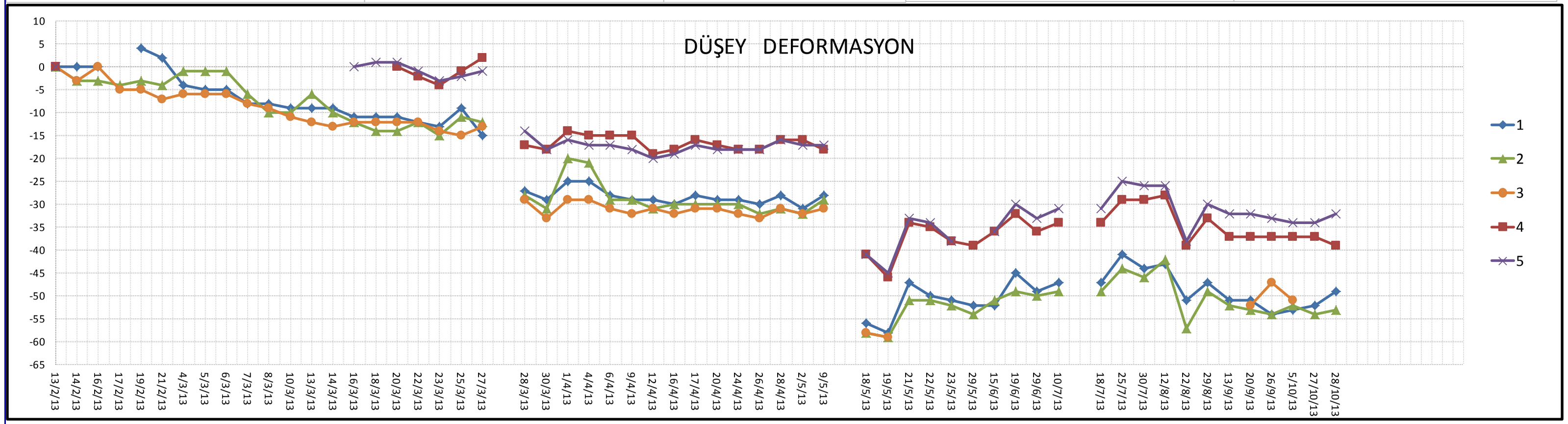
ÜSTYARI KAZI TARİHİ : 21.01.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 26.02.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 25.02.2013

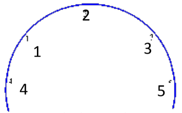
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 05.02.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 02.05.2013
İNVERT (3. KADEME) KAZI TARİHİ : 12.05.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 14. TUNEL ISTASYONU (Km. 2+040.10) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3-b**	**14. ÖLÇ. İSTASYONU**	**2 +040.10**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

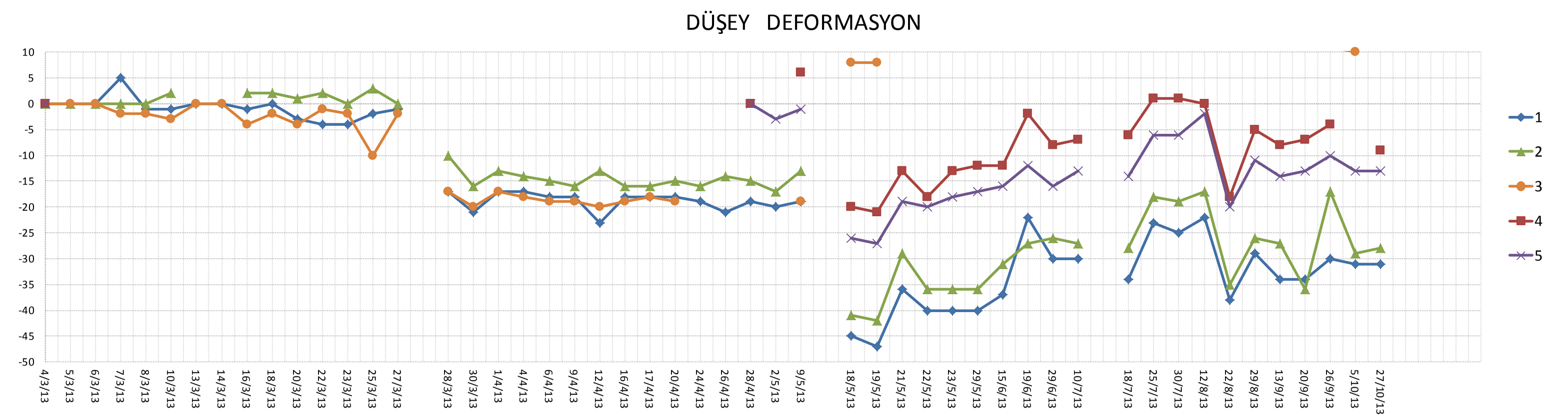
ÜSTYARI KAZI TARİHİ : 05.02.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 08.03.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 07.03.2013

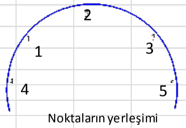
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 01.05.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 30.03.2013
İNVERT (3. KADEME) KAZI TARİHİ : 13.05.2013

Altyarıların sağ/sol yönleri projeye göredir.

YT1 15. TUNEL ISTASYONU (Km. 2+007.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 2**	**15. ÖLÇ. İSTASYONU**	**2 +007.00**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

ÜSTYARI KAZI TARİHİ : 28.02.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 23.04.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 21.04.2013

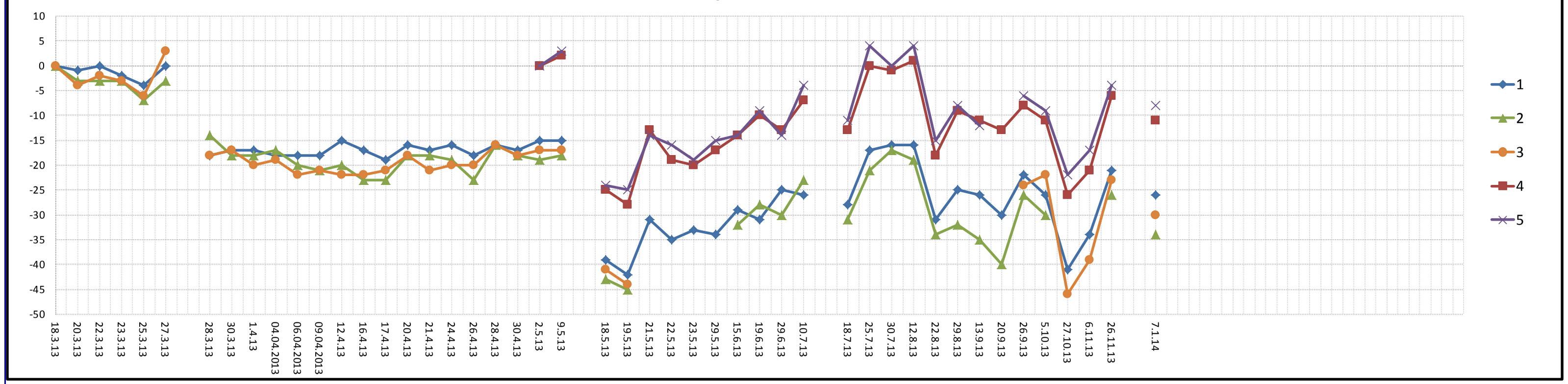
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 03.05.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 04.05.2013

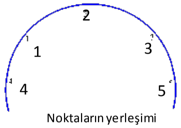
Altyarıların sağ/sol
yönleri projeye göredir.

YT1 16. TUNEL ISTASYONU (Km. 1+980.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 2**	**16. ÖLÇ. İSTASYONU**	**1 980.00**

DÜŞEY DEFORMASYON





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

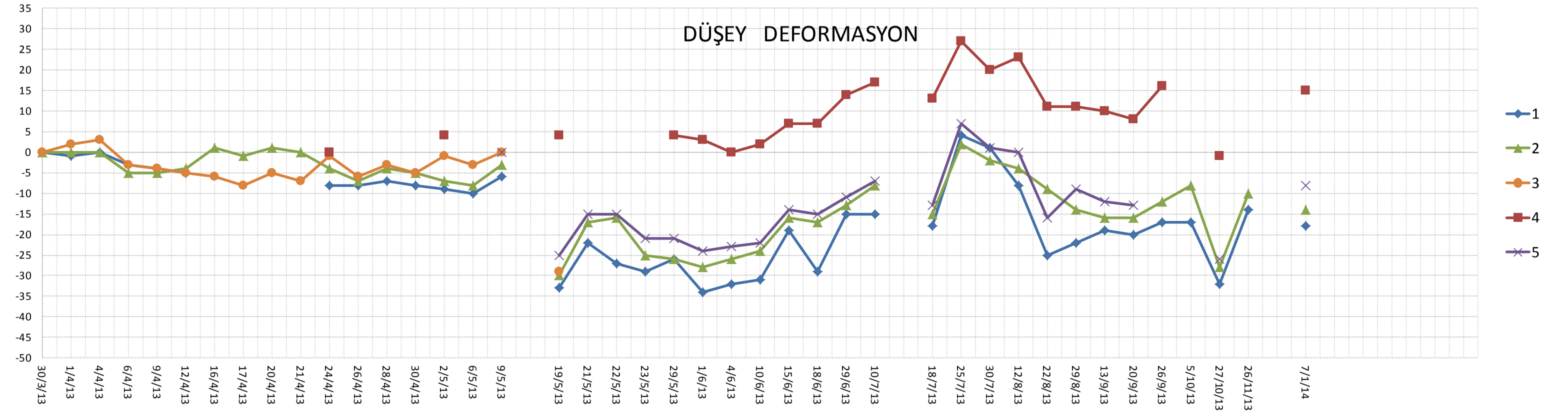
ÜSTYARI KAZI TARİHİ : 14.03.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 25.04.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 28.03.2013

SOL ALTYARI (3. KADEME) KAZI TARİHİ : 08.05.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 10.05.2013

Altyarıların sağ/sol yönleri projeye göredir.

YT1 17. TUNEL ISTASYONU (Km. 1+958.00) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 2**	**17. ÖLÇ. İSTASYONU**	**1 958.00**



Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

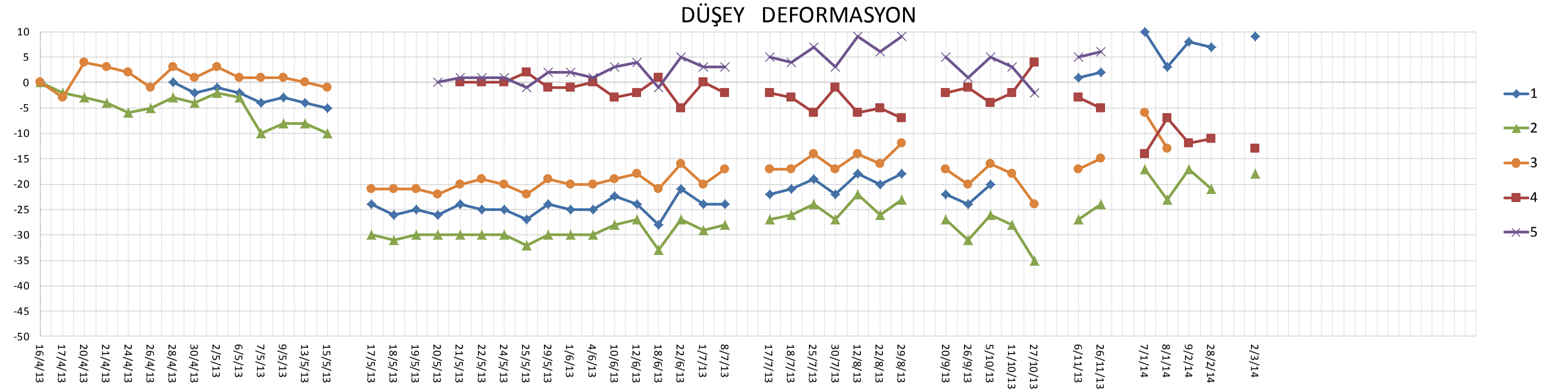
ÜSTYARI KAZI TARİHİ : 23.03.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 19.04.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 20.04.2013

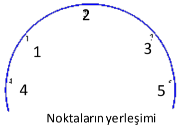
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.05.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 19.05.2013

Altyarıların sağ/sol yönleri projeye göredir.

YT1 17. TUNEL ISTASYONU (Km. 1+935.090) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 2**	**18. ÖLÇ. İSTASYONU**	**1 935.090**





Noktaların yerleşimi
kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

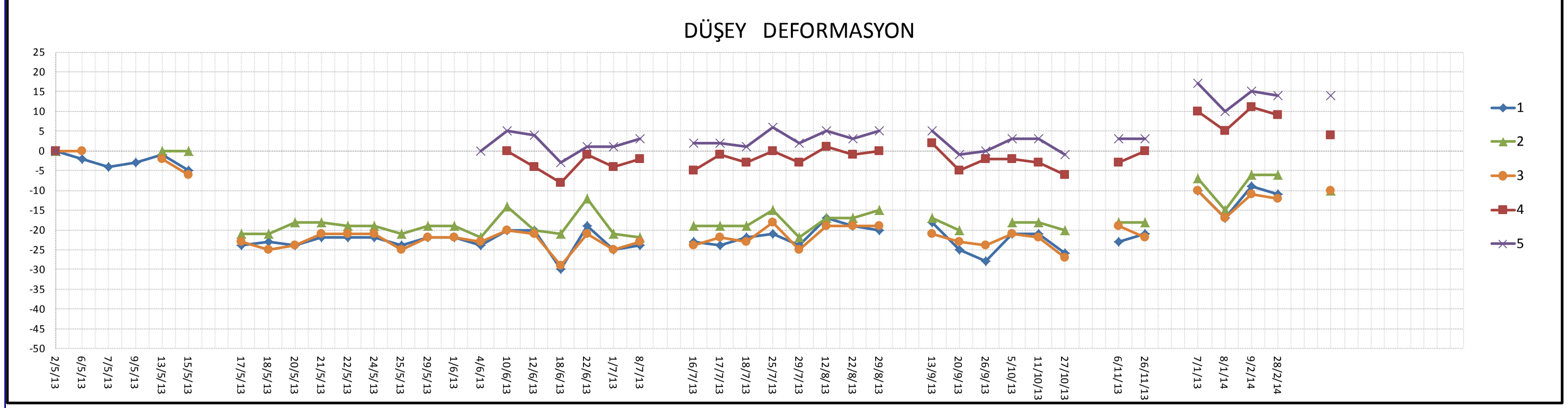
ÜSTYARI KAZI TARİHİ : 02.04.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 09.05.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 19.05.2013

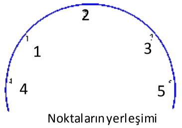
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 16.06.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 17.06.2013

Altyarıların sağ/sol
yönleri projeye göredir.

YT1 19. TUNEL ISTASYONU (Km. 1+886.010) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3a**	**19. ÖLÇ. İSTASYONU**	**1 886.010**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

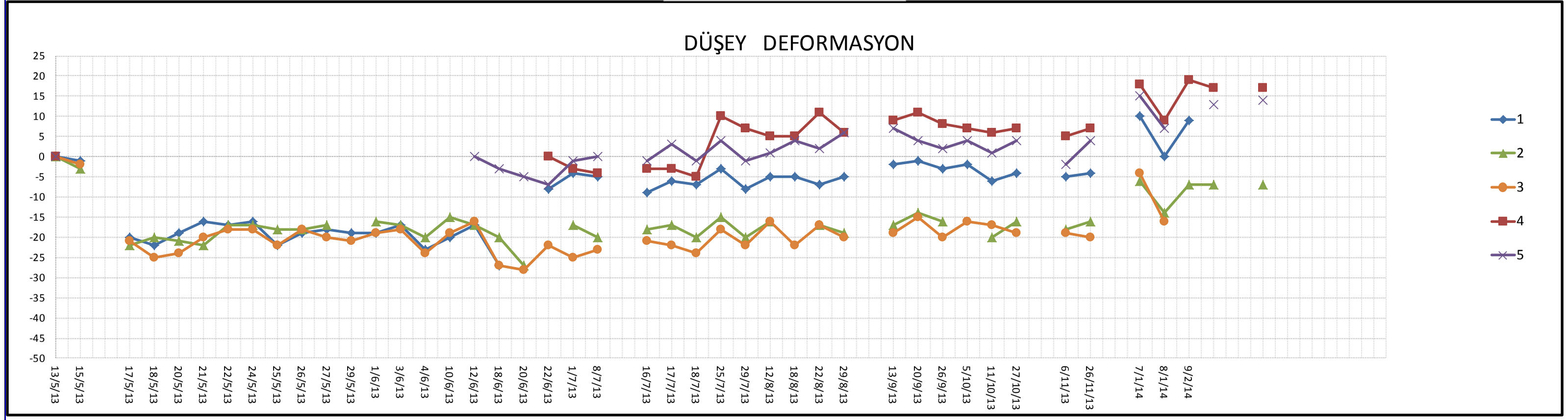
ÜSTYARI KAZI TARİHİ : 26.04.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 30.05.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 30.05.2013

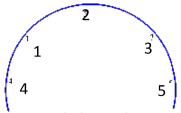
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 17.06.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 13.06.2013

Altyarıların sağ/sol yönleri projeye göredir.

YT1 20. TUNEL ISTASYONU (Km. 1+853.430) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3a**	**20. ÖLÇ. İSTASYONU**	**1 853.430**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

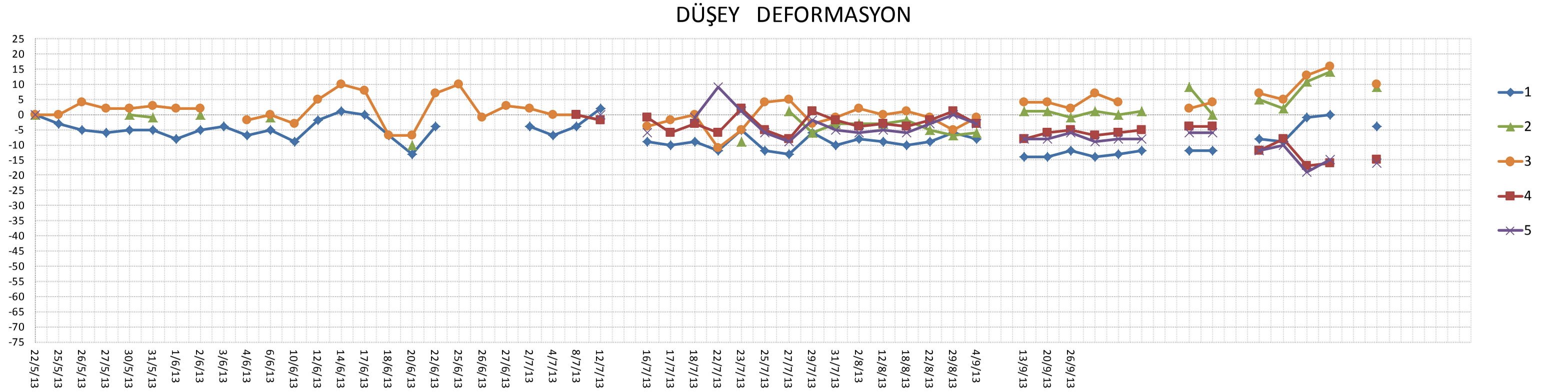
ÜSTYARI KAZI TARİHİ : 08.05.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 09.06.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 13.06.2013

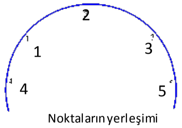
SOL ALTYARI (3. KADEME) KAZI TARİHİ : 02.08.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 26.07.2013

Altyarıların sağ/sol yönleri projeye göredir.

YT1 21. TUNEL ISTASYONU (Km. 1+823.130) DEFORMASYON HAREKET GRAFİĞİ

PROJE ADI	TÜNEL ADI	KAYA SINIFI	İSTASYON NO	İSTASYON Km
KONAK - YEŞİLDERE TÜNELİ	**T - 1 YEŞİLDERE PORTAL**	**B 3a**	**21. ÖLÇ. İSTASYONU**	**1 823.130**





Noktaların yerleşimi kazı yönünde bakışa göredir

Grafikte düşey ölçek mm 'dir.

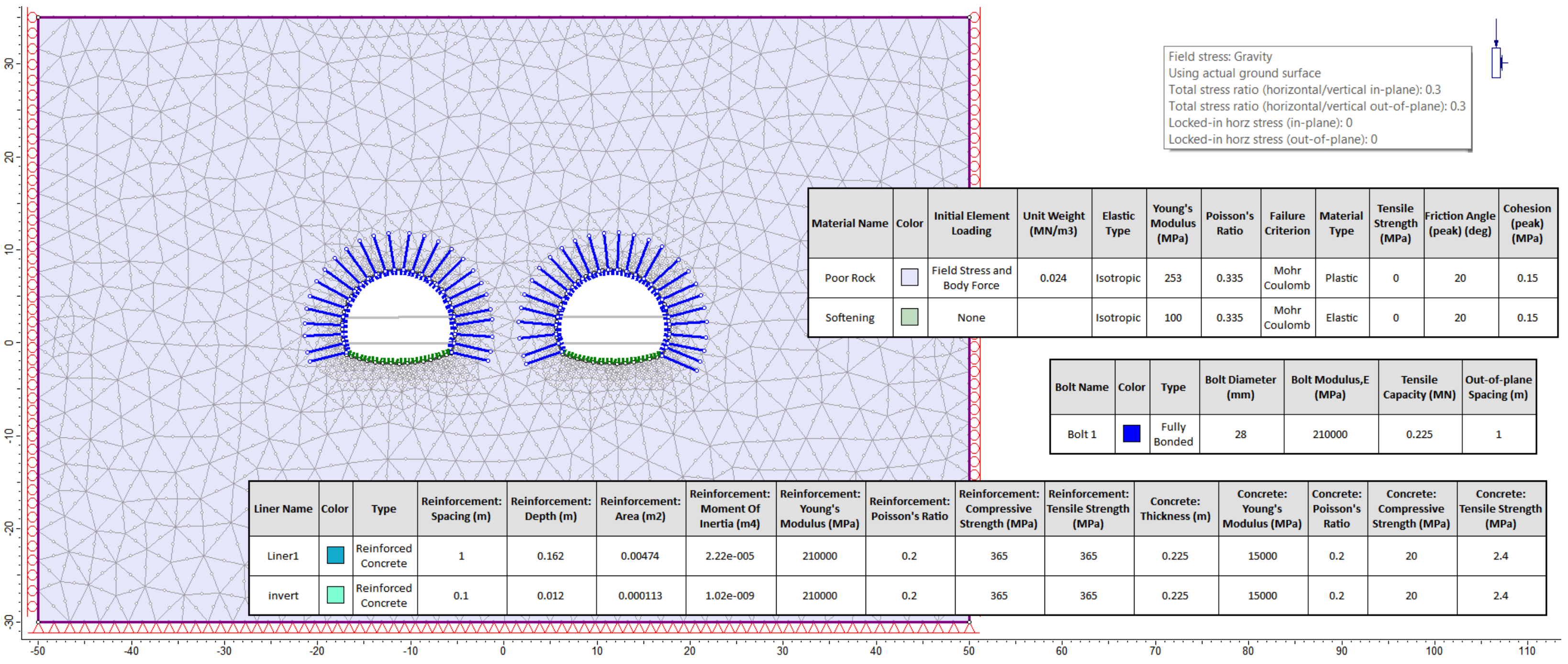
ÜSTYARI KAZI TARİHİ : 22.05.2013
SOL ALTYARI (2. KADEME) KAZI TARİHİ : 03.07.2013
SAĞ ALTYARI (2. KADEME) KAZI TARİHİ : 04.07.2013

SOL ALTYARI (3. KADEME) KAZI TARİHİ : 20.07.2013
SAĞ ALTYARI (3. KADEME) KAZI TARİHİ : 31.10.2013

Altyarıların sağ/sol yönleri projeye göredir.

APPENDIX-G: FINITE ELMENT ANAYSES RESULTS

The vertical displacement and support capacity plots are presented in APPENDIX-G.



Field stress: Gravity
Using actual ground surface
Total stress ratio (horizontal/vertical in-plane): 0.3
Total stress ratio (horizontal/vertical out-of-plane): 0.3
Locked-in horz stress (in-plane): 0
Locked-in horz stress (out-of-plane): 0

Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Tensile Strength (MPa)	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
Poor Rock	▢	Field Stress and Body Force	0.024	Isotropic	253	0.335	Mohr Coulomb	Plastic	0	20	0.15
Softening	🟩	None		Isotropic	100	0.335	Mohr Coulomb	Elastic	0	20	0.15

Bolt Name	Color	Type	Bolt Diameter (mm)	Bolt Modulus,E (MPa)	Tensile Capacity (MN)	Out-of-plane Spacing (m)
Bolt 1	🟦	Fully Bonded	28	210000	0.225	1

Liner Name	Color	Type	Reinforcement: Spacing (m)	Reinforcement: Depth (m)	Reinforcement: Area (m2)	Reinforcement: Moment Of Inertia (m4)	Reinforcement: Young's Modulus (MPa)	Reinforcement: Poisson's Ratio	Reinforcement: Compressive Strength (MPa)	Reinforcement: Tensile Strength (MPa)	Concrete: Thickness (m)	Concrete: Young's Modulus (MPa)	Concrete: Poisson's Ratio	Concrete: Compressive Strength (MPa)	Concrete: Tensile Strength (MPa)
Liner1	🟦	Reinforced Concrete	1	0.162	0.00474	2.22e-005	210000	0.2	365	365	0.225	15000	0.2	20	2.4
invert	🟩	Reinforced Concrete	0.1	0.012	0.000113	1.02e-009	210000	0.2	365	365	0.225	15000	0.2	20	2.4

Figure G.1: Mesh and material properties of section T-Px

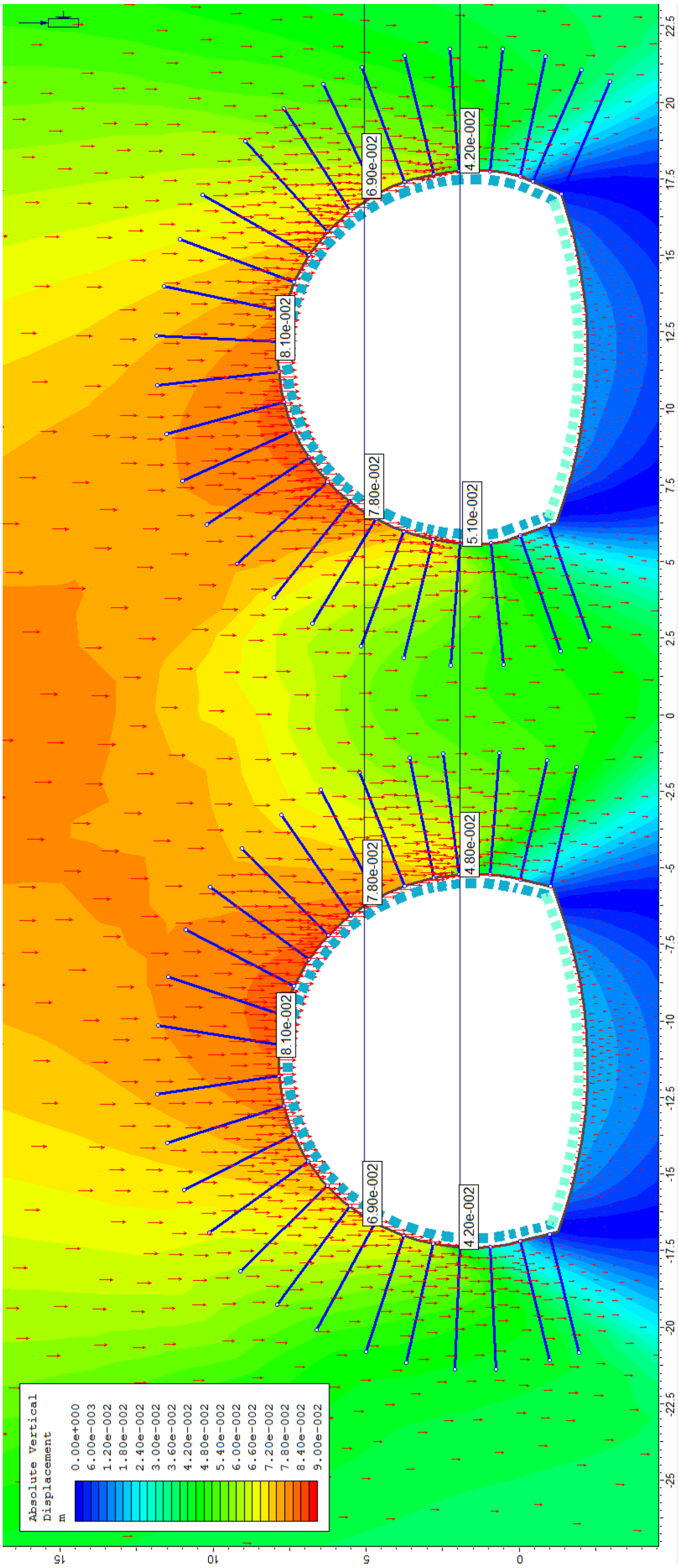


Figure G.2: Total vertical displacement of section T-Px

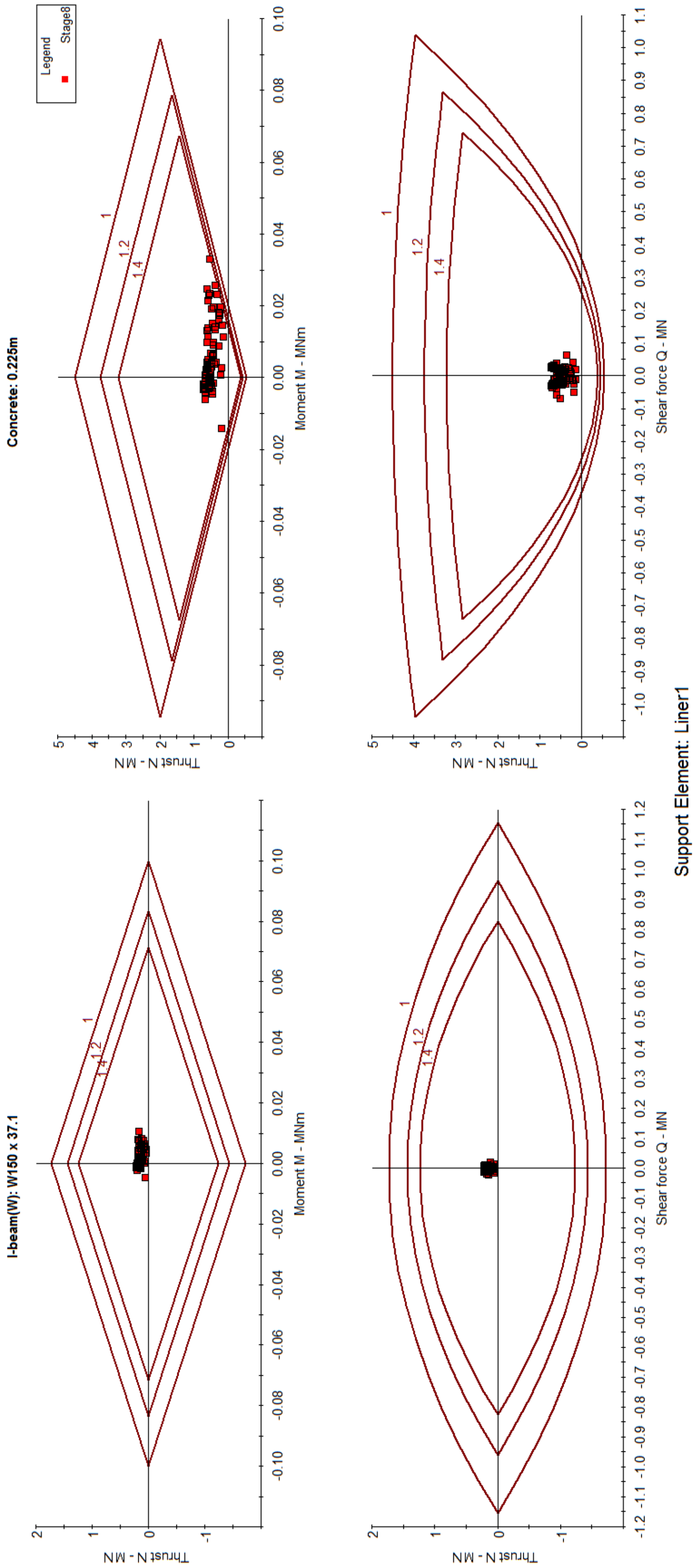


Figure G.3: Support capacity plots of section T-Px (Liner-1)

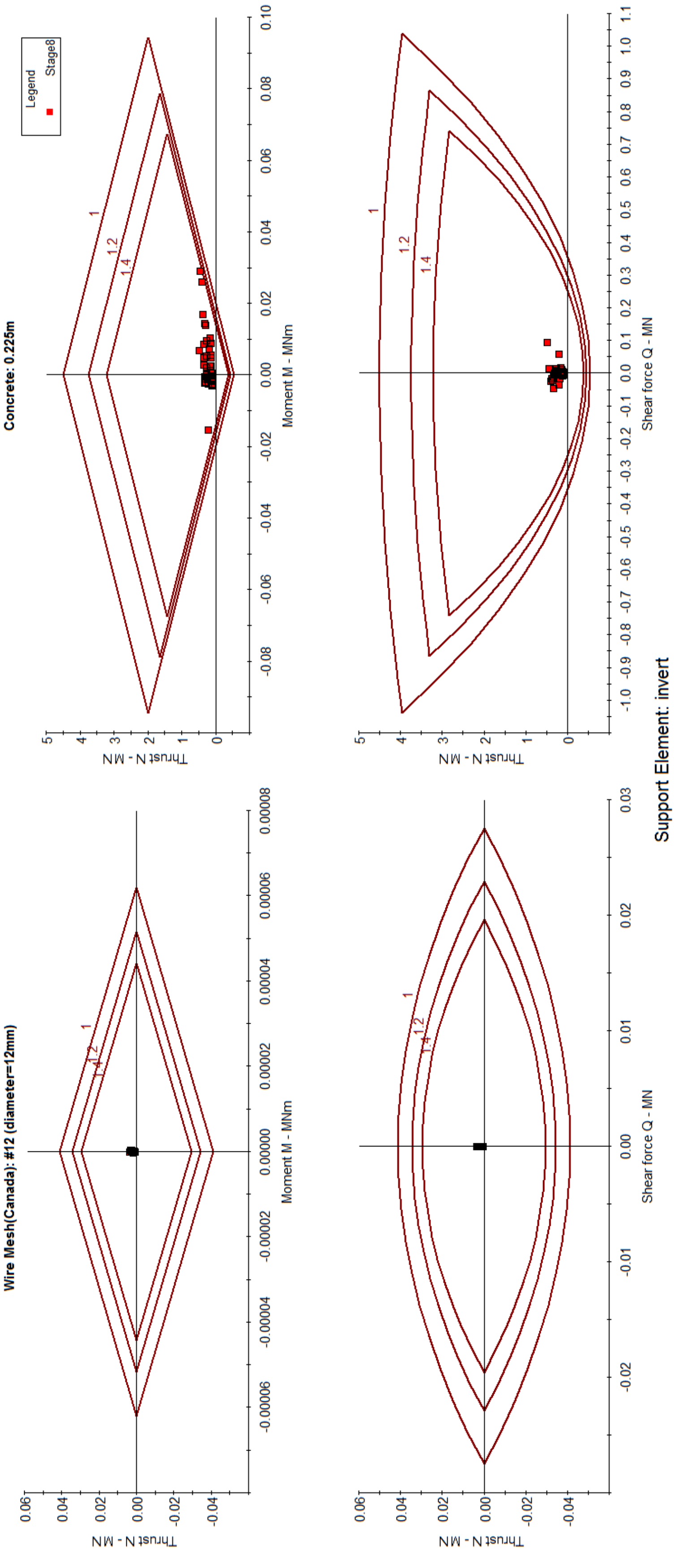


Figure G.4: Support capacity plots of section T-Px (Invert)

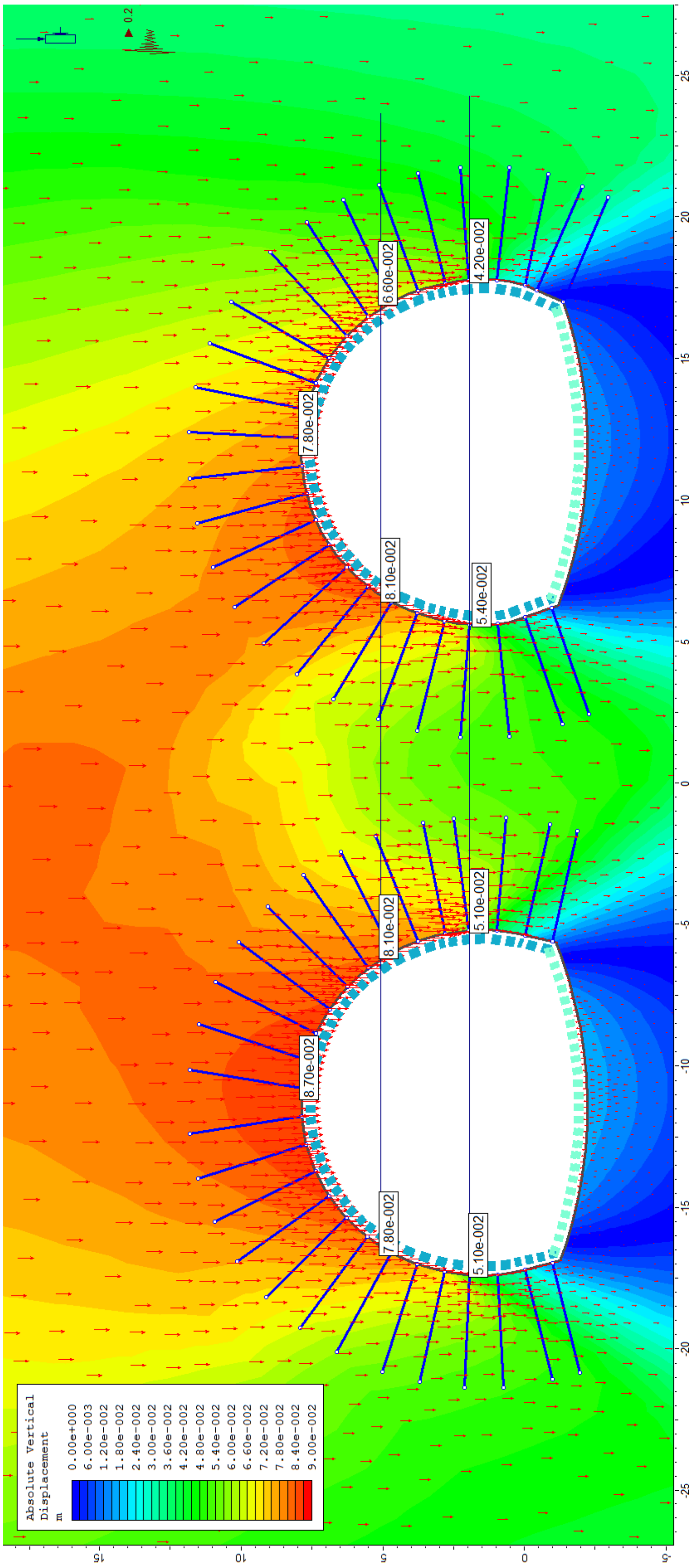
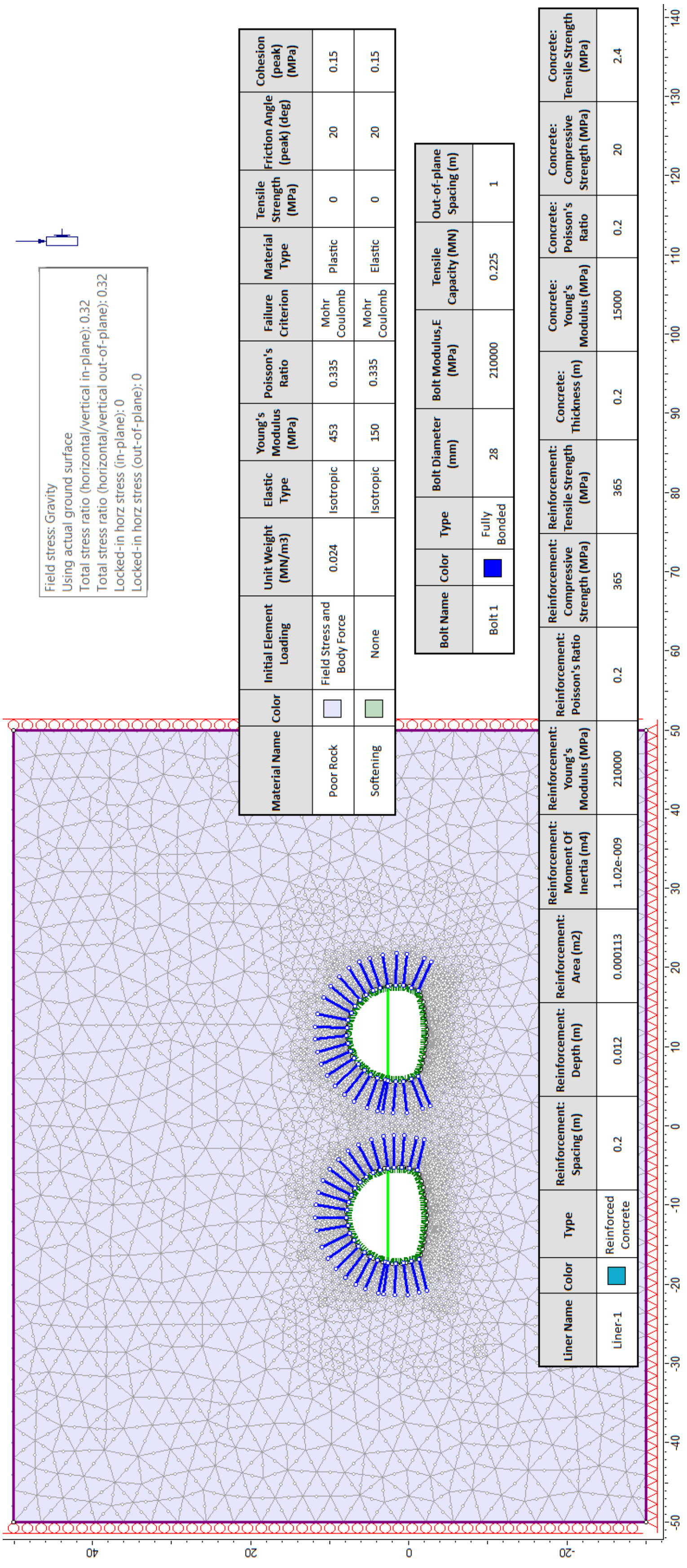


Figure G.5: Total vertical displacement of section T-Px under the seismic load



Field stress: Gravity
Using actual ground surface
Total stress ratio (horizontal/vertical in-plane): 0.32
Total stress ratio (horizontal/vertical out-of-plane): 0.32
Locked-in horz stress (in-plane): 0
Locked-in horz stress (out-of-plane): 0

Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Tensile Strength (MPa)	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
Poor Rock	☐	Field Stress and Body Force	0.024	Isotropic	453	0.335	Mohr Coulomb	Plastic	0	20	0.15
Softening	🟩	None		Isotropic	150	0.335	Mohr Coulomb	Elastic	0	20	0.15

Bolt Name	Color	Type	Bolt Diameter (mm)	Bolt Modulus,E (MPa)	Tensile Capacity (MN)	Out-of-plane Spacing (m)
Bolt 1	🟦	Fully Bonded	28	210000	0.225	1

Liner Name	Color	Type	Reinforcement: Spacing (m)	Reinforcement: Depth (m)	Reinforcement: Area (m2)	Reinforcement: Moment Of Inertia (m4)	Reinforcement: Young's Modulus (MPa)	Reinforcement: Poisson's Ratio	Reinforcement: Compressive Strength (MPa)	Reinforcement: Tensile Strength (MPa)	Concrete: Thickness (m)	Concrete: Young's Modulus (MPa)	Concrete: Poisson's Ratio	Concrete: Compressive Strength (MPa)	Concrete: Tensile Strength (MPa)
Liner-1	🟦	Reinforced Concrete	0.2	0.012	0.000113	1.02e-009	210000	0.2	365	365	0.2	15000	0.2	20	2.4

Figure G.6: Mesh and material properties of section T-50x

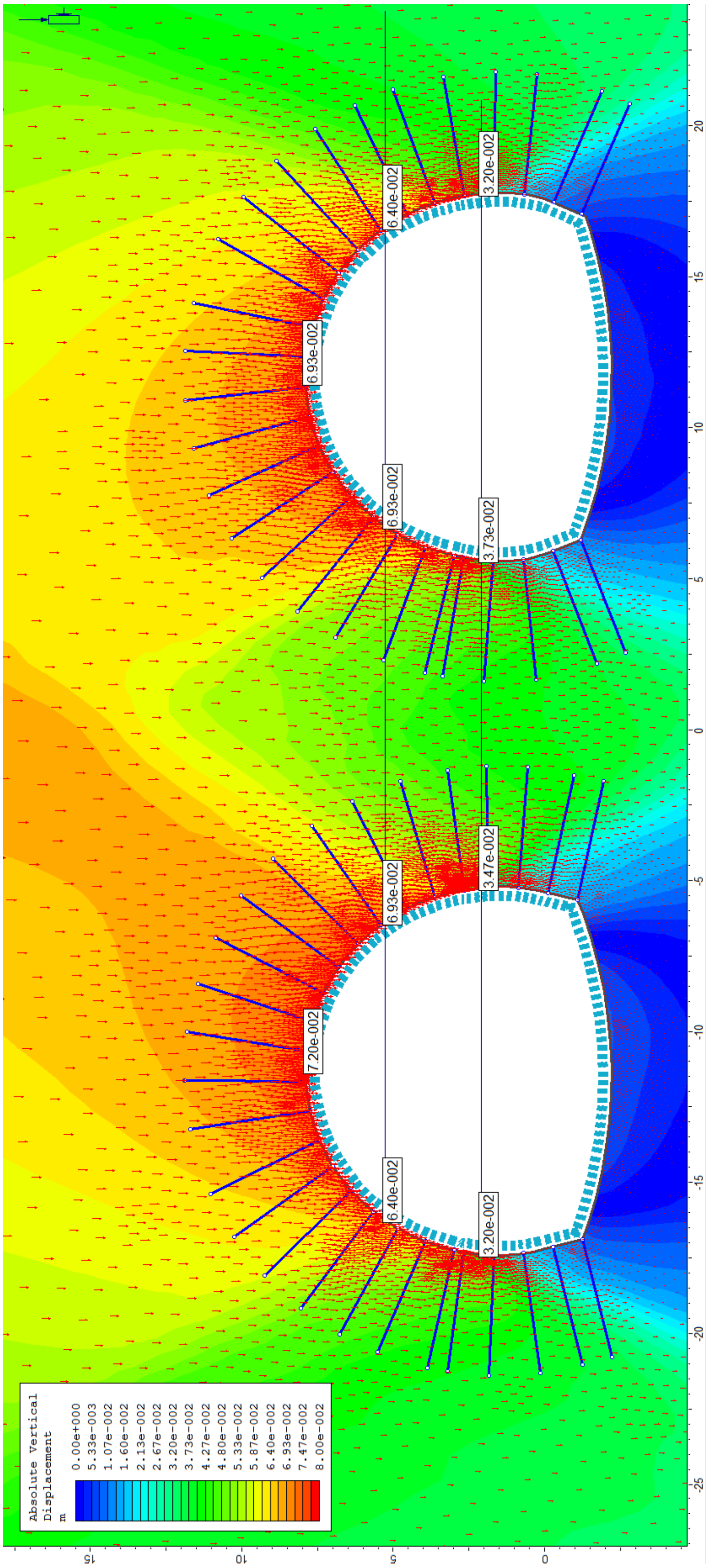


Figure G.7: Total vertical displacement of section T-50x

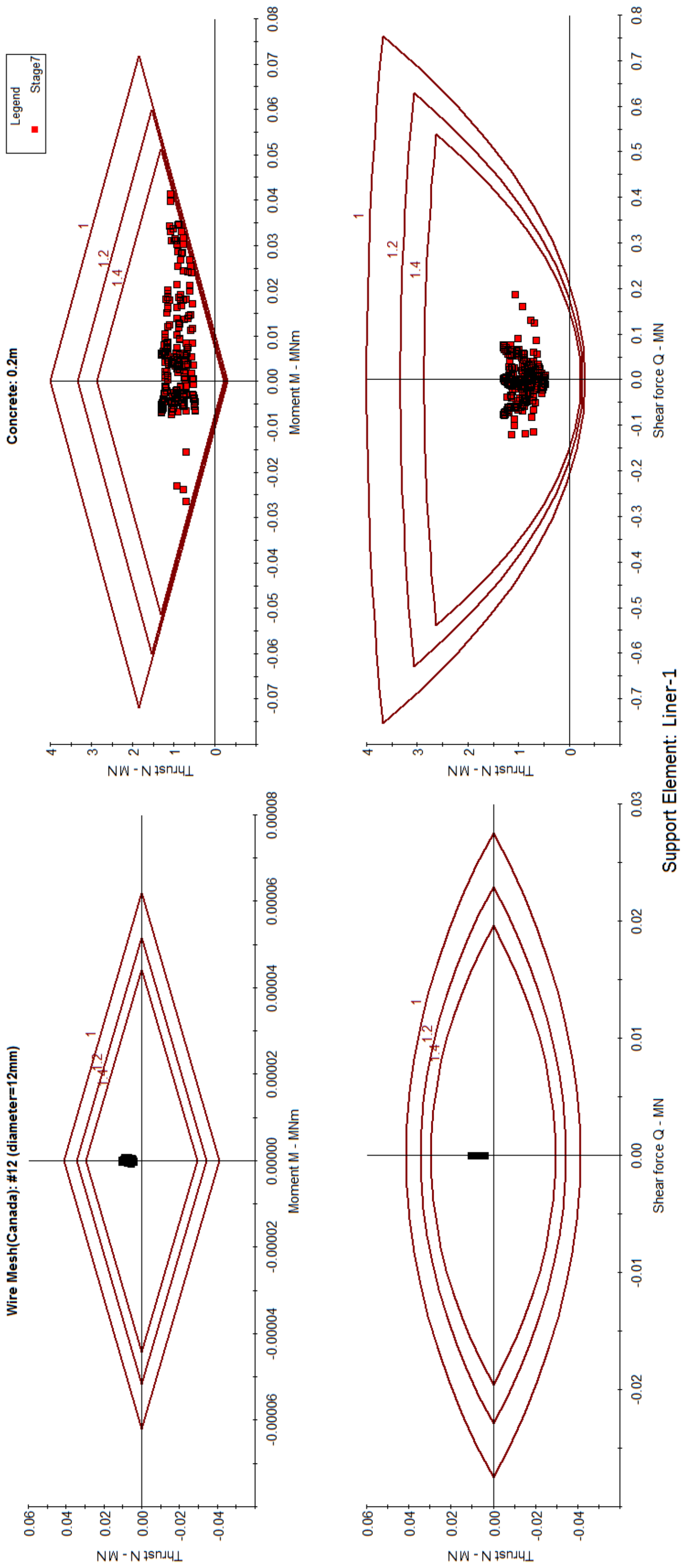


Figure G.8: Support capacity plots of section T-50x (Liner-1)

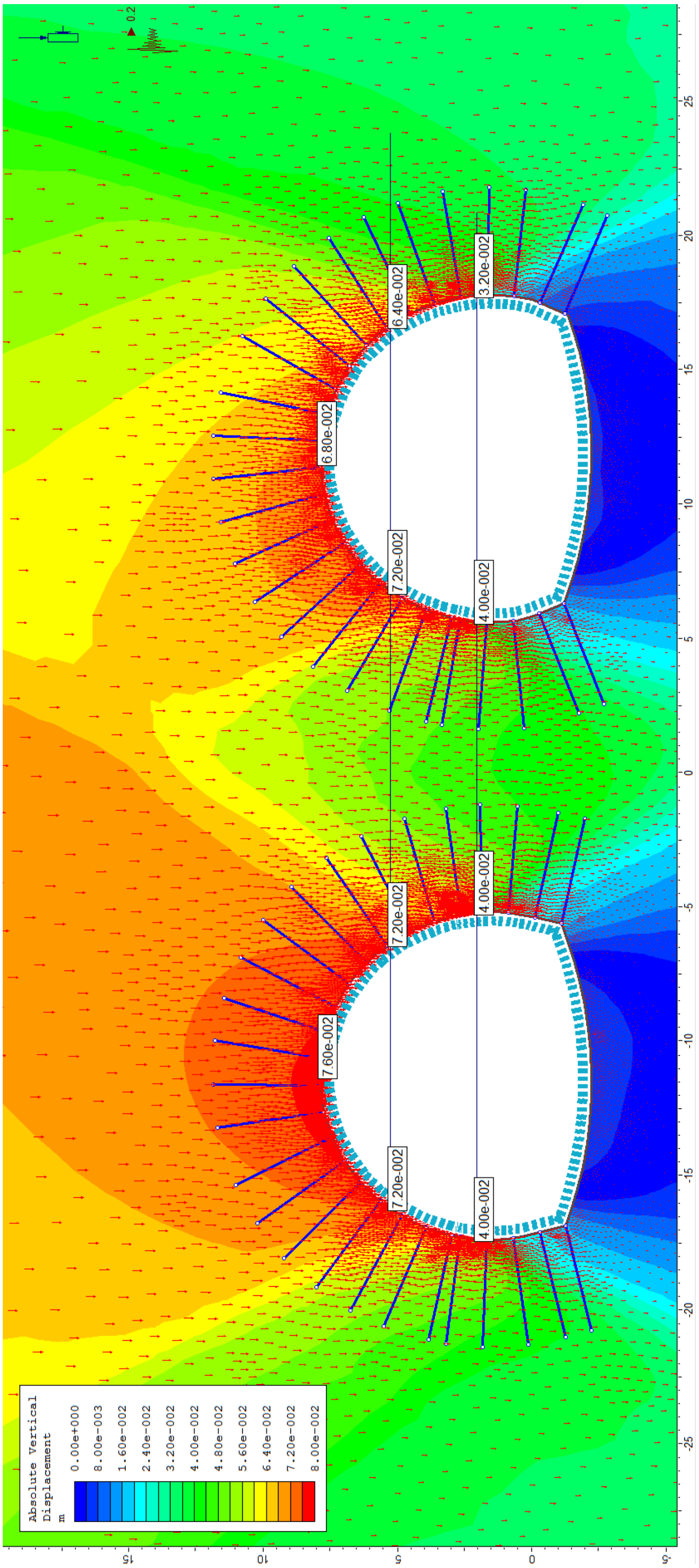
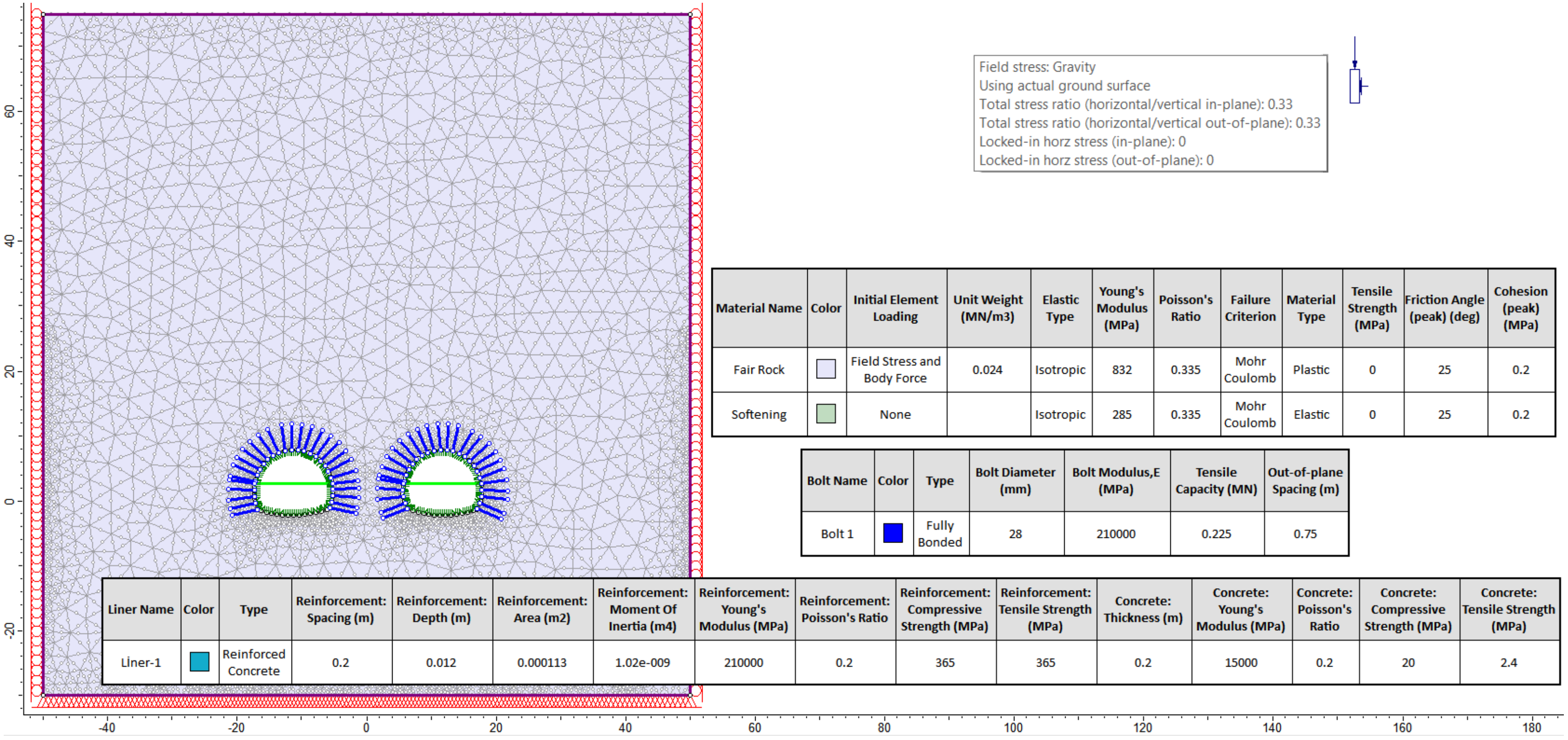


Figure G.9: Total vertical displacement of section T-50x under the seismic load



Field stress: Gravity
Using actual ground surface
Total stress ratio (horizontal/vertical in-plane): 0.33
Total stress ratio (horizontal/vertical out-of-plane): 0.33
Locked-in horz stress (in-plane): 0
Locked-in horz stress (out-of-plane): 0

Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Tensile Strength (MPa)	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
Fair Rock	☐	Field Stress and Body Force	0.024	Isotropic	832	0.335	Mohr Coulomb	Plastic	0	25	0.2
Softening	🟩	None		Isotropic	285	0.335	Mohr Coulomb	Elastic	0	25	0.2

Bolt Name	Color	Type	Bolt Diameter (mm)	Bolt Modulus,E (MPa)	Tensile Capacity (MN)	Out-of-plane Spacing (m)
Bolt 1	🟦	Fully Bonded	28	210000	0.225	0.75

Liner Name	Color	Type	Reinforcement: Spacing (m)	Reinforcement: Depth (m)	Reinforcement: Area (m2)	Reinforcement: Moment Of Inertia (m4)	Reinforcement: Young's Modulus (MPa)	Reinforcement: Poisson's Ratio	Reinforcement: Compressive Strength (MPa)	Reinforcement: Tensile Strength (MPa)	Concrete: Thickness (m)	Concrete: Young's Modulus (MPa)	Concrete: Poisson's Ratio	Concrete: Compressive Strength (MPa)	Concrete: Tensile Strength (MPa)
Liner-1	🟦	Reinforced Concrete	0.2	0.012	0.000113	1.02e-009	210000	0.2	365	365	0.2	15000	0.2	20	2.4

Figure G.10: Mesh and material properties of section T-75x

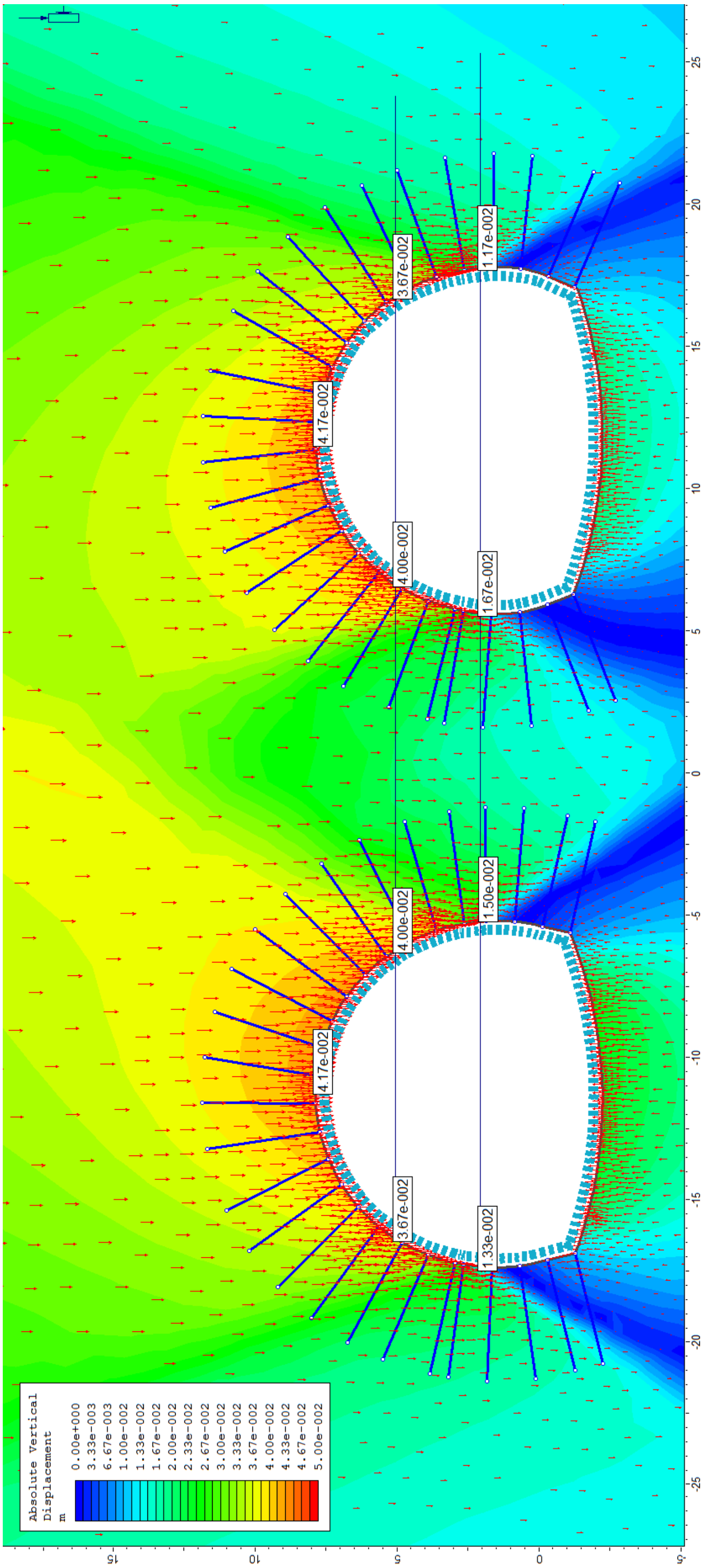


Figure G.11: Total vertical displacement of section T-75x

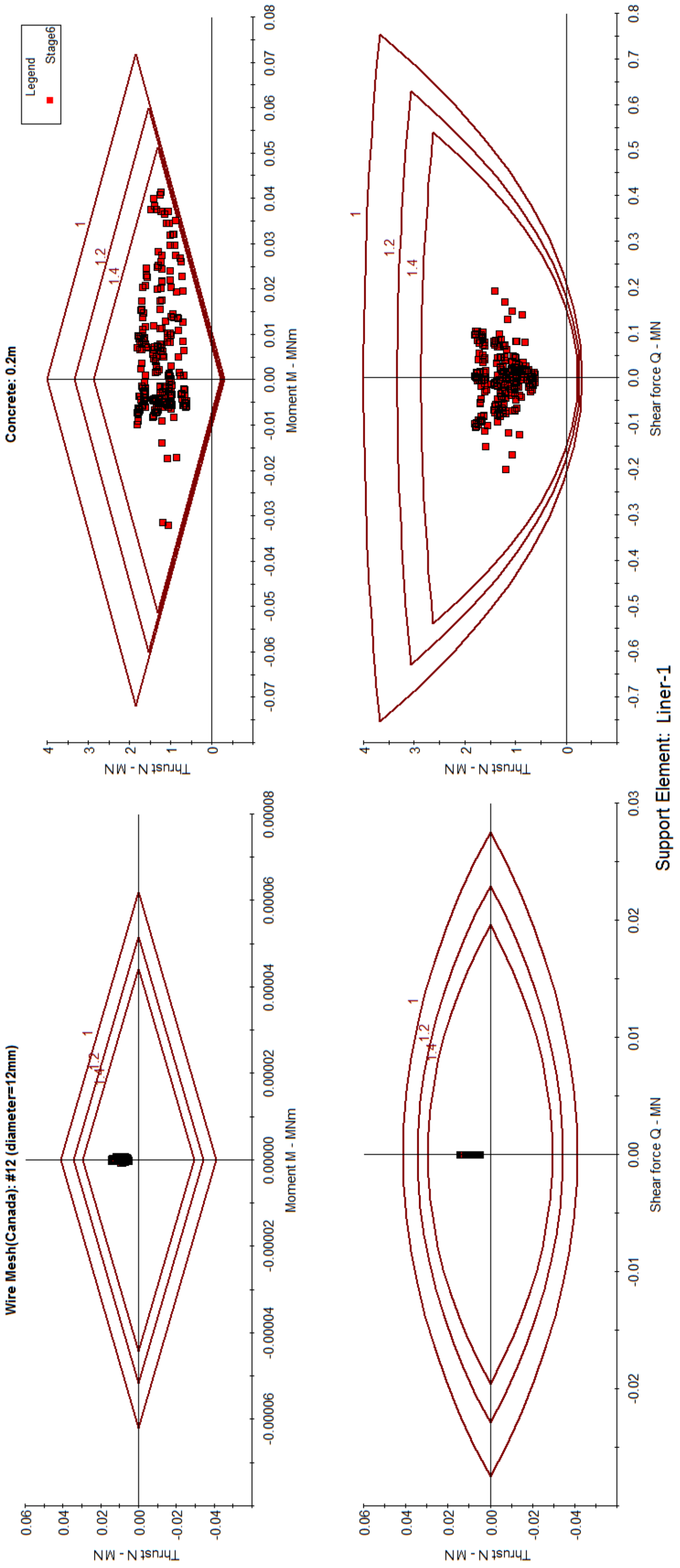


Figure G.12: Support capacity plots of section T-75x (Liner-1)

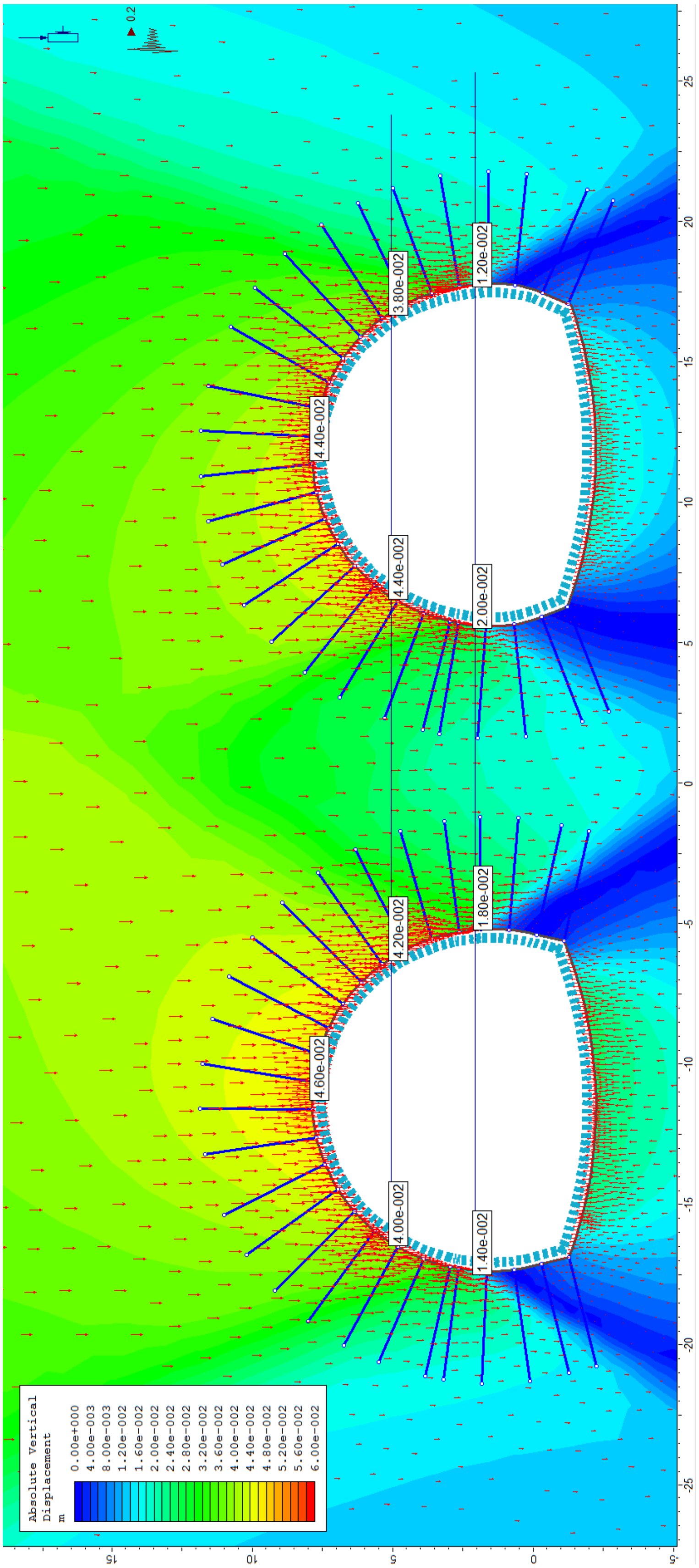
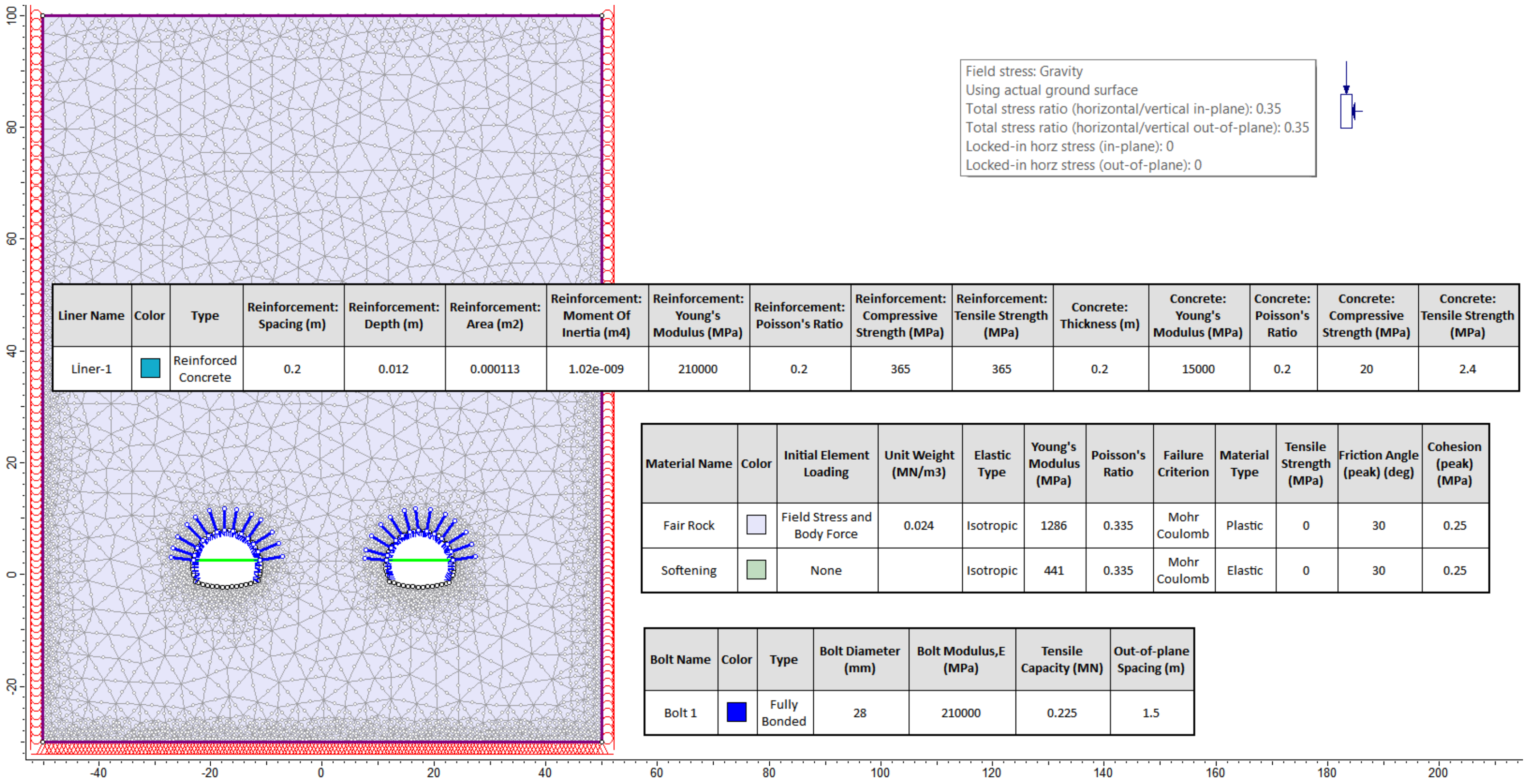


Figure G.13: Total vertical displacement of section T-75x under the seismic load



Field stress: Gravity
Using actual ground surface
Total stress ratio (horizontal/vertical in-plane): 0.35
Total stress ratio (horizontal/vertical out-of-plane): 0.35
Locked-in horz stress (in-plane): 0
Locked-in horz stress (out-of-plane): 0

Liner Name	Color	Type	Reinforcement: Spacing (m)	Reinforcement: Depth (m)	Reinforcement: Area (m2)	Reinforcement: Moment Of Inertia (m4)	Reinforcement: Young's Modulus (MPa)	Reinforcement: Poisson's Ratio	Reinforcement: Compressive Strength (MPa)	Reinforcement: Tensile Strength (MPa)	Concrete: Thickness (m)	Concrete: Young's Modulus (MPa)	Concrete: Poisson's Ratio	Concrete: Compressive Strength (MPa)	Concrete: Tensile Strength (MPa)
Liner-1	🟦	Reinforced Concrete	0.2	0.012	0.000113	1.02e-009	210000	0.2	365	365	0.2	15000	0.2	20	2.4

Material Name	Color	Initial Element Loading	Unit Weight (MN/m3)	Elastic Type	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Tensile Strength (MPa)	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
Fair Rock	⬜	Field Stress and Body Force	0.024	Isotropic	1286	0.335	Mohr Coulomb	Plastic	0	30	0.25
Softening	🟩	None		Isotropic	441	0.335	Mohr Coulomb	Elastic	0	30	0.25

Bolt Name	Color	Type	Bolt Diameter (mm)	Bolt Modulus,E (MPa)	Tensile Capacity (MN)	Out-of-plane Spacing (m)
Bolt 1	🟦	Fully Bonded	28	210000	0.225	1.5

Figure G.14: Mesh and material properties of section T-100x

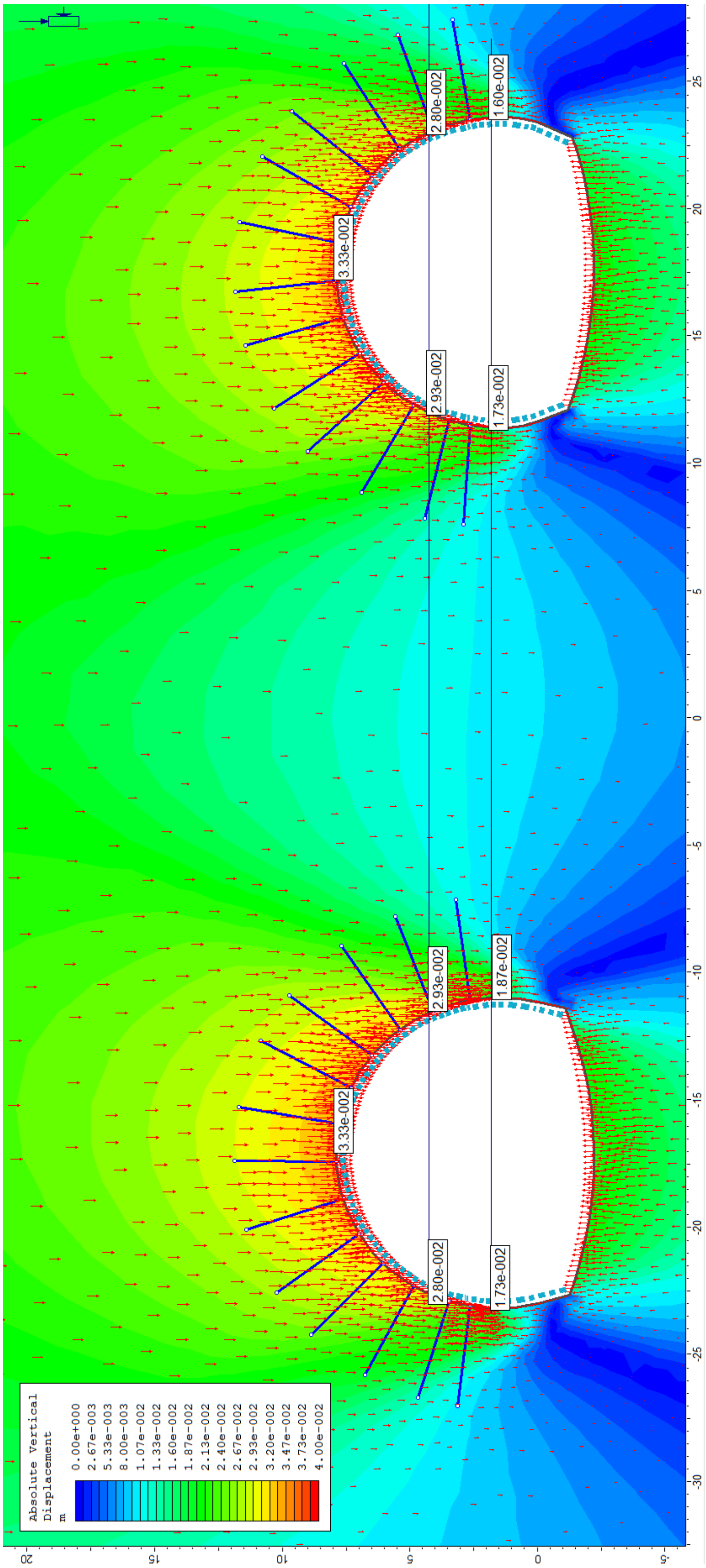


Figure G.15: Total vertical displacement of section T-100x

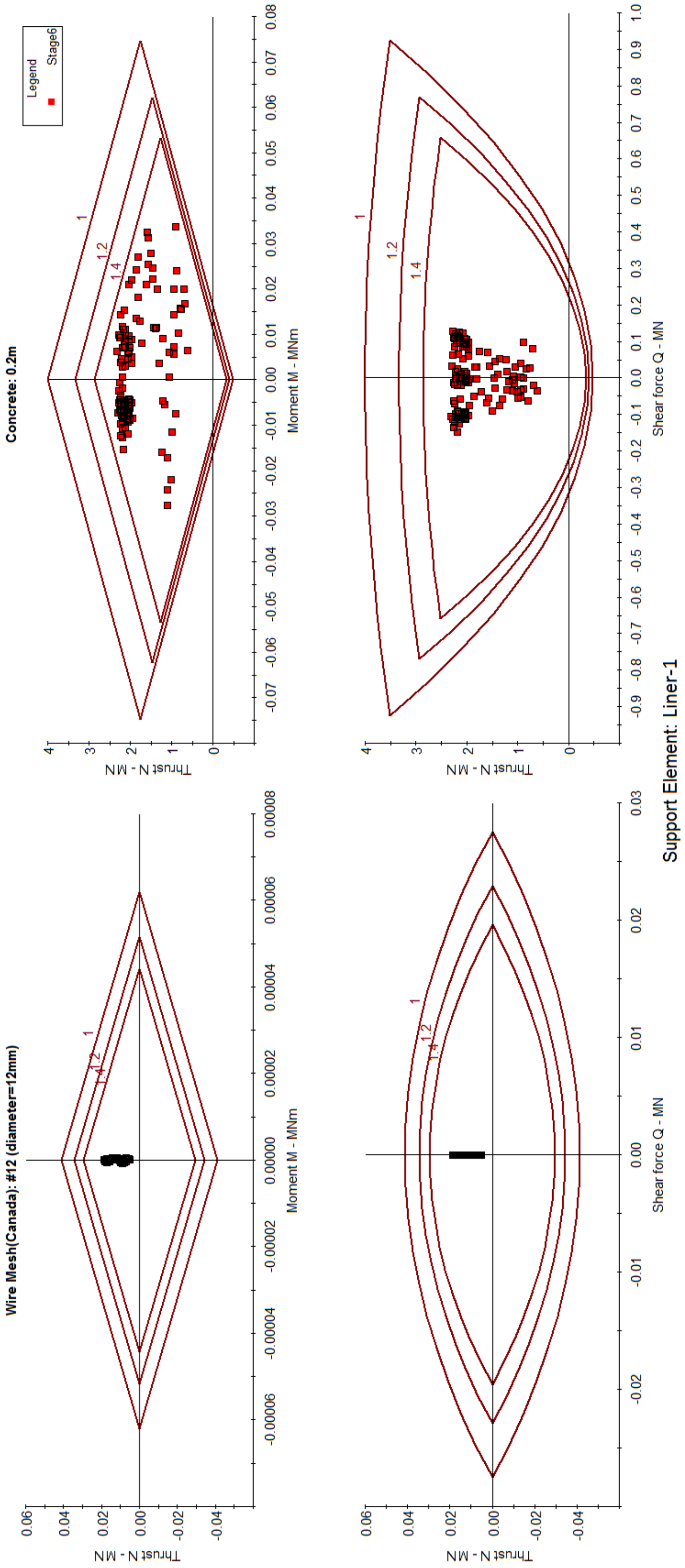


Figure G.16: Support capacity plots of section T-100x (Liner-1)

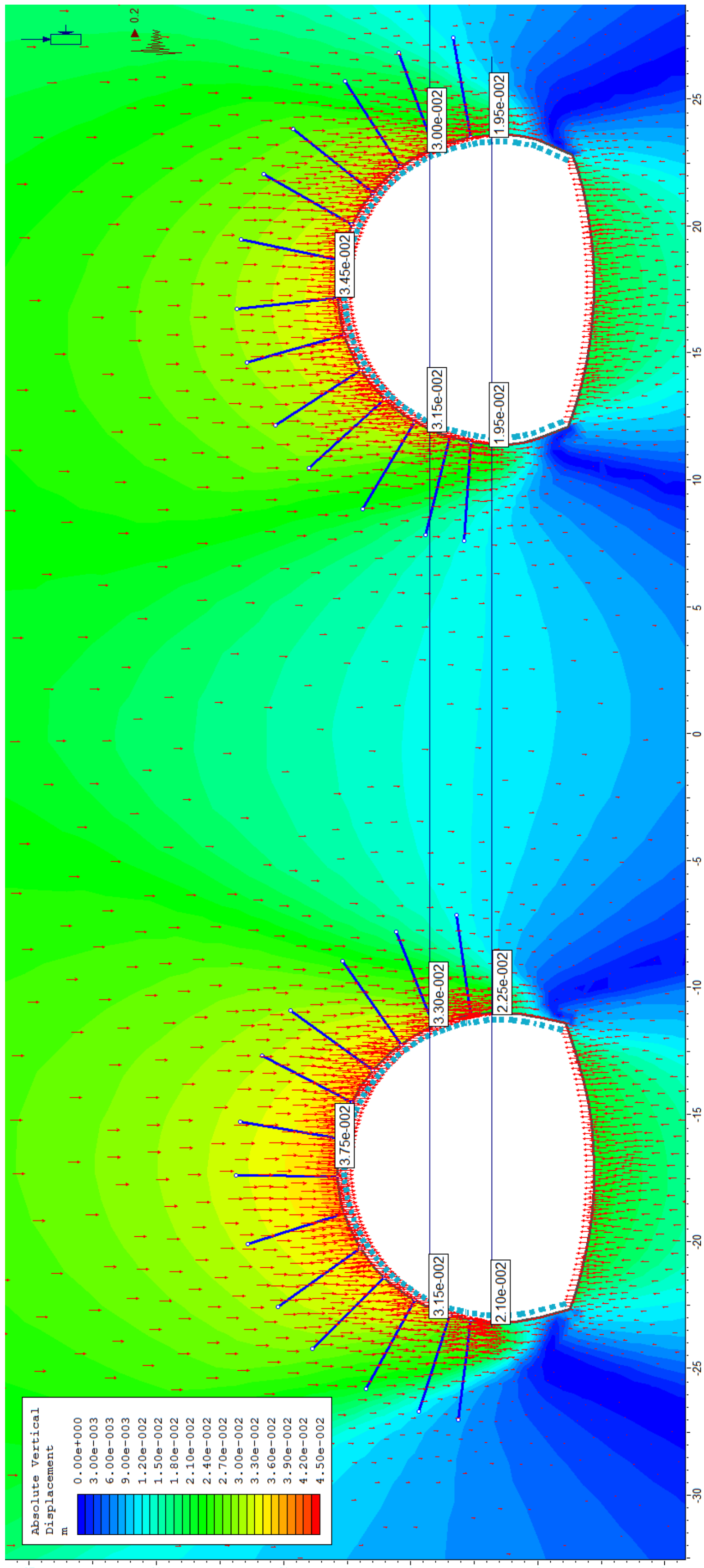
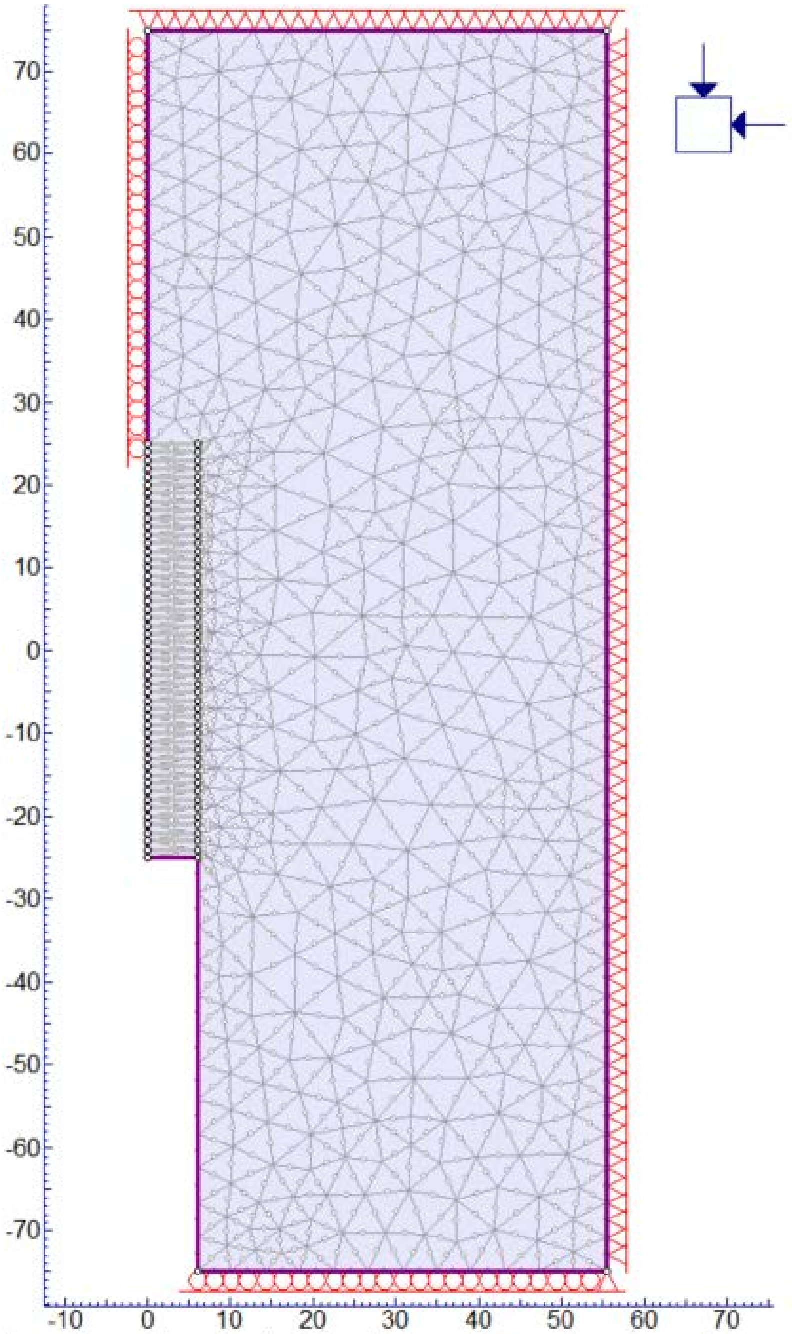


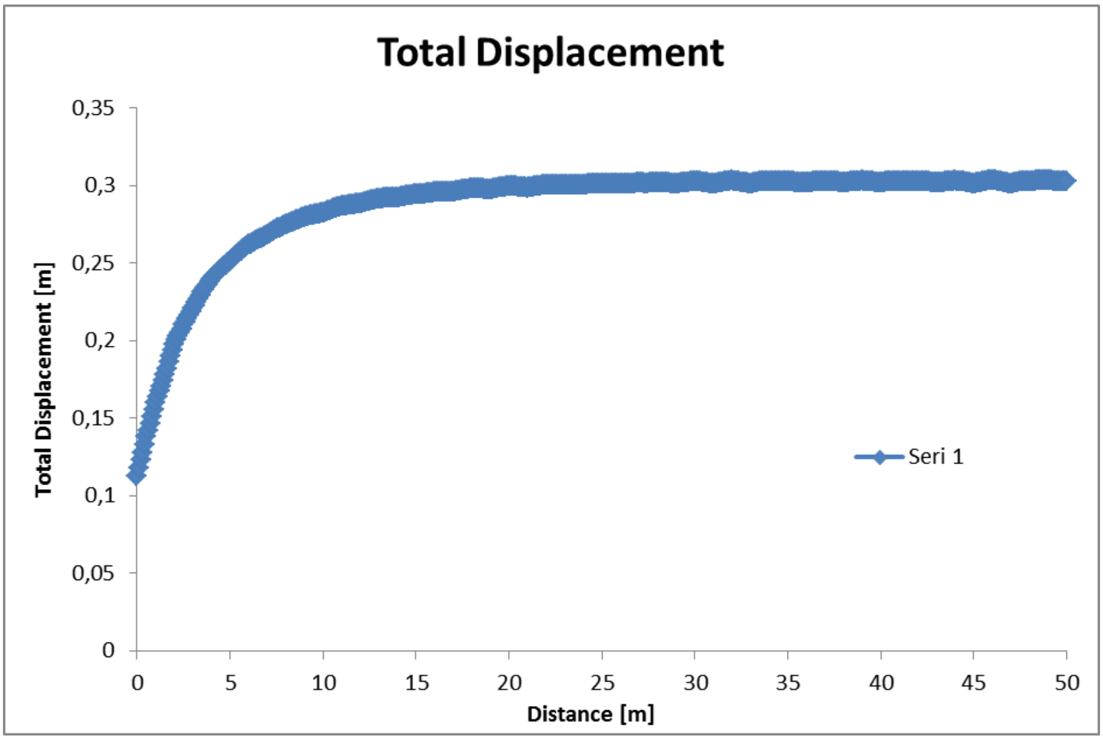
Figure G.17: Total vertical displacement of section T-100x under the seismic load

APPENDIX-H: AXISMMETRICAL MODELLING RESULTS

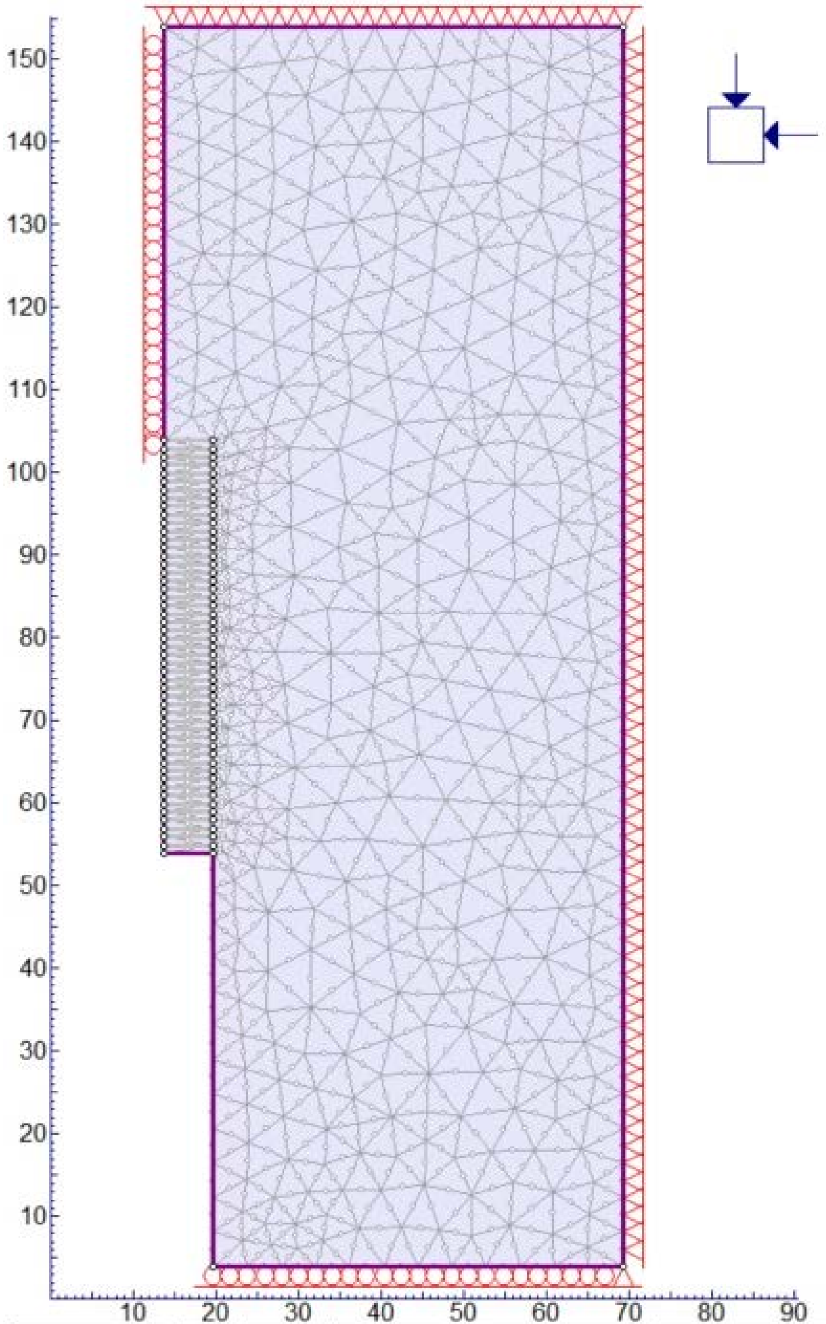
The axisymmetric modeling results and the reduction amount of the deformation modulus in all excavation sections are presented in APPENDIX-H.



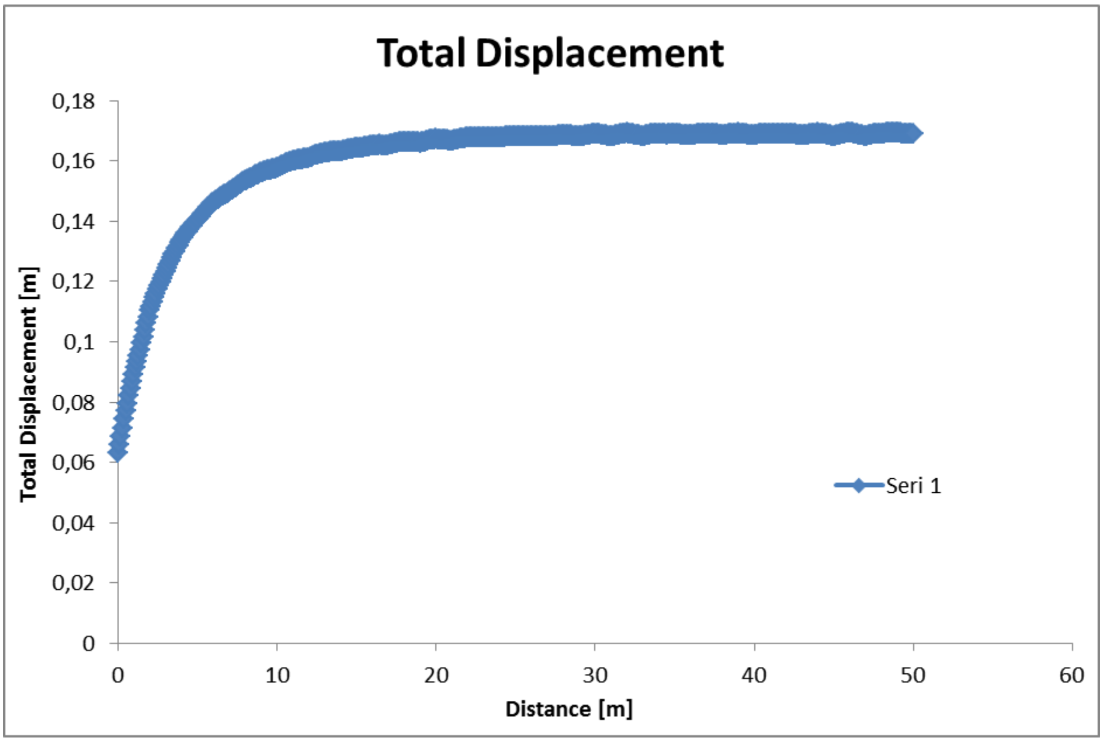
Material Name	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
T-Px	253	0.335	Mohr Coulomb	Elastic	20	0.15



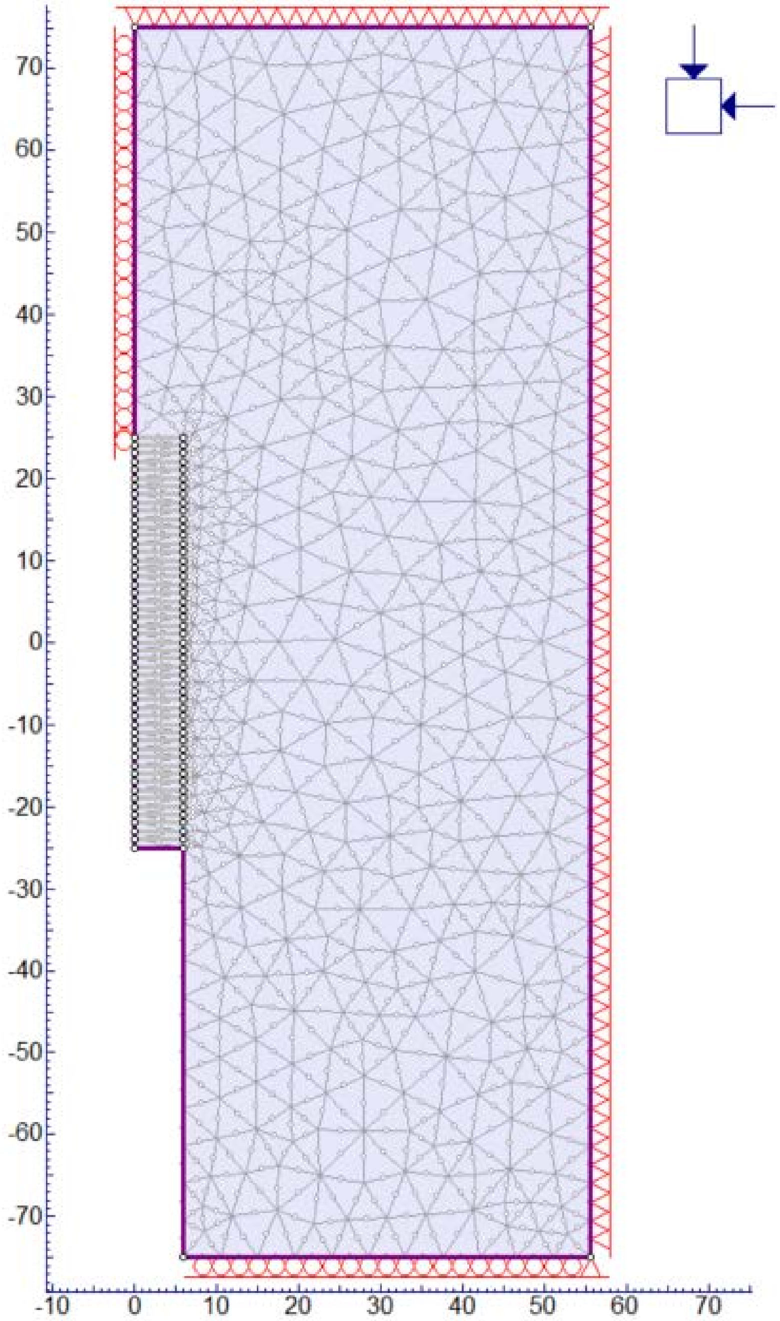
Distance to Excavation Face	Cumulative Displacement	Softening Ratio	Rock Mass Deformation Modulus	
			in-situ	induced
m	m	%	MPa	MPa
0	0,11287	37,3%	**253**	158,6
0,5	0,13796	45,6%		137,6
1	0,15990	52,9%		119,3
1,5	0,17819	58,9%		104,0
2	0,19777	65,4%		87,6
2,5	0,21002	69,4%		77,3
50	0,30250	100,0%		0,0



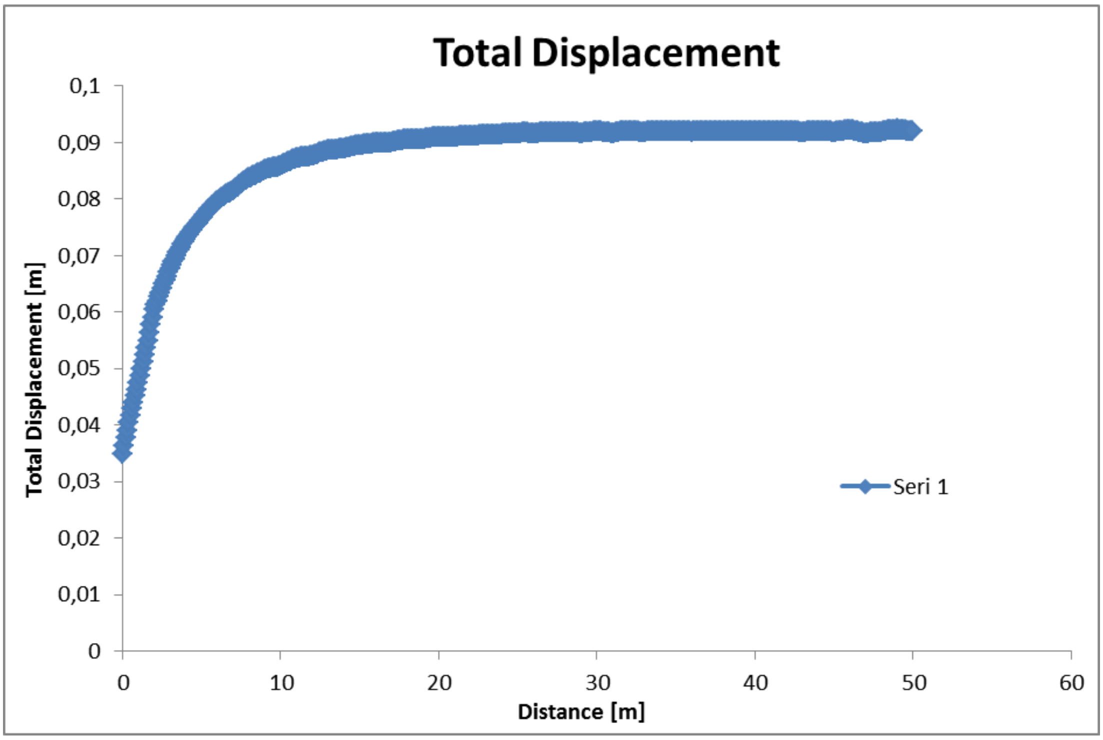
Material Name	Color	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
T-50x	☐	453	0.335	Mohr Coulomb	Elastic	20	0.15



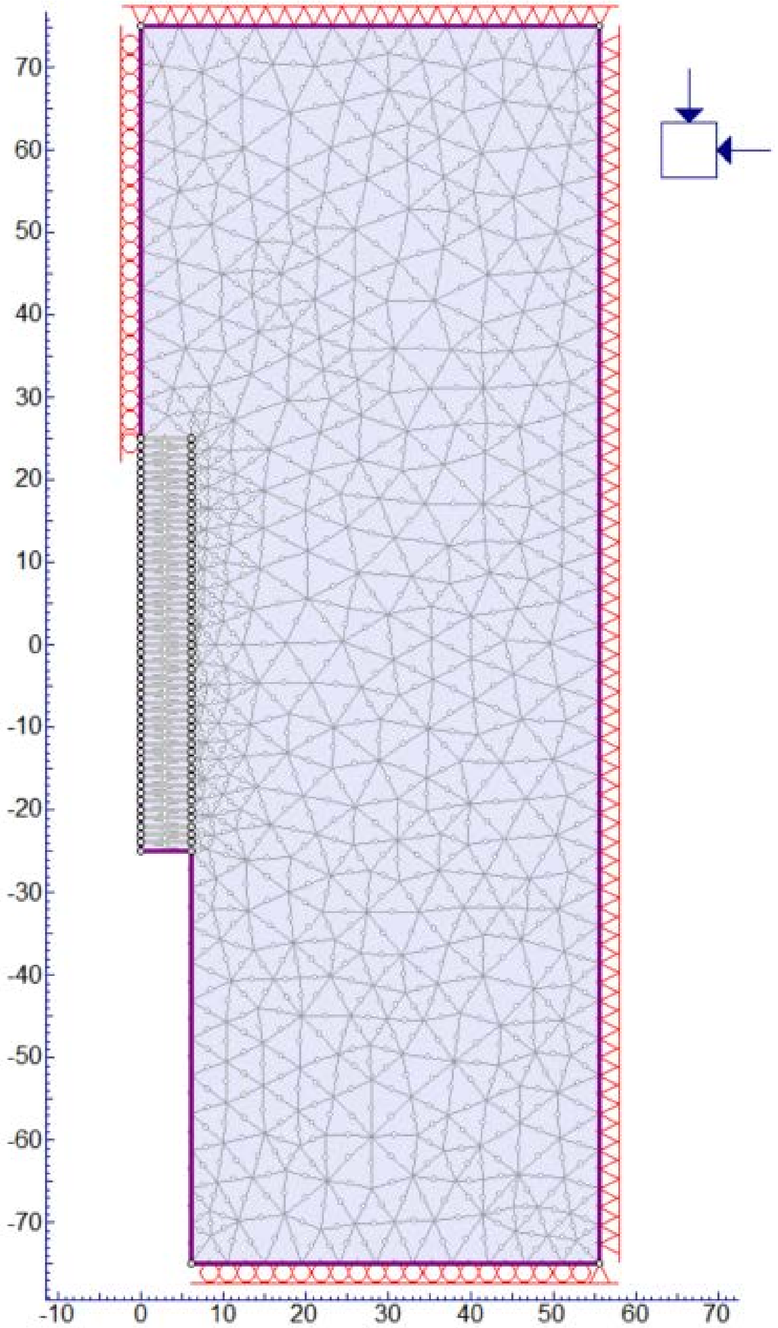
Distance to Excavation Face	**Total Displacement**	**Softening Ratio**	**Deformation Modulus**	
			in-situ	induced
m	m	%	MPa	MPa
0	0,06304	37,3%	**453**	284,0
0,5	0,07705	45,6%		246,4
1	0,08931	52,9%		213,5
1,5	0,09952	58,9%		186,2
2	0,11045	65,4%		156,8
2,5	0,11731	69,4%		138,5
50	0,16894	100,0%		0,0



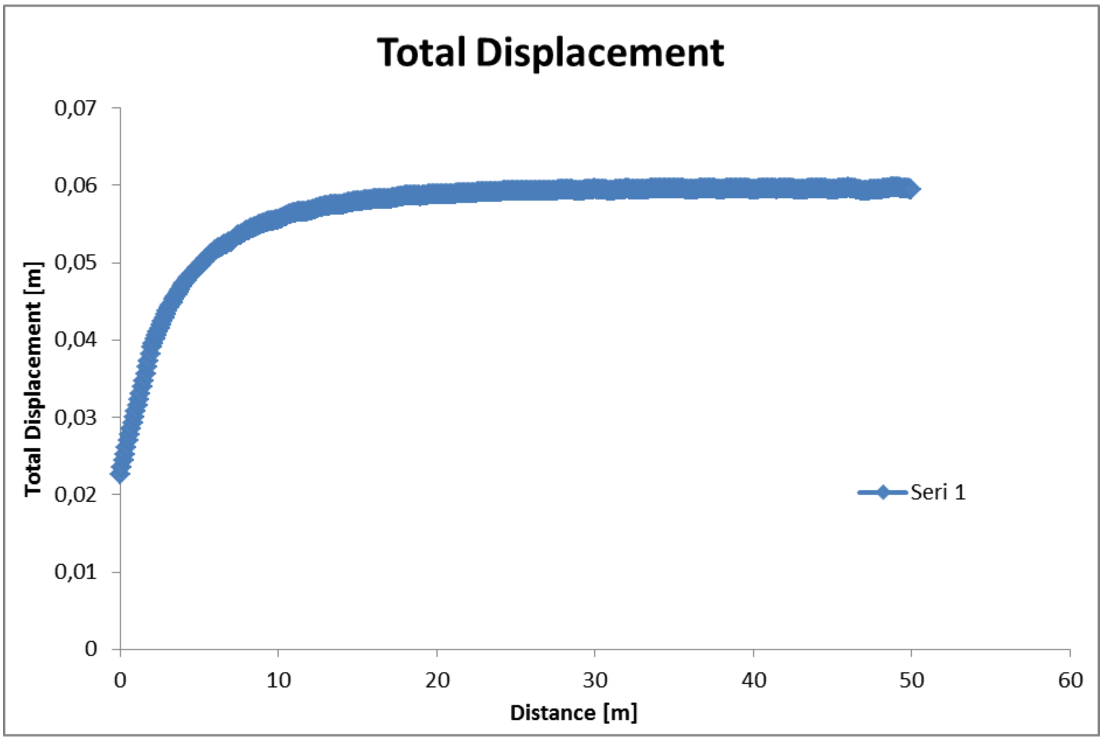
Material Name	Color	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
T-75x	□	832	0.335	Mohr Coulomb	Elastic	25	0.2



Distance to Excavation Face	Total Displacement	Softening Ratio	Deformation Modulus	
			in-situ	induced
m	m	%	MPa	MPa
0	0,03492	38,0%	**832**	516,0
0,5	0,04178	45,4%		454,0
1	0,04746	51,6%		402,6
1,5	0,05359	58,3%		347,1
2	0,06043	65,7%		285,3
2,5	0,06420	69,8%		251,2
50	0,09196	100,0%		0,0



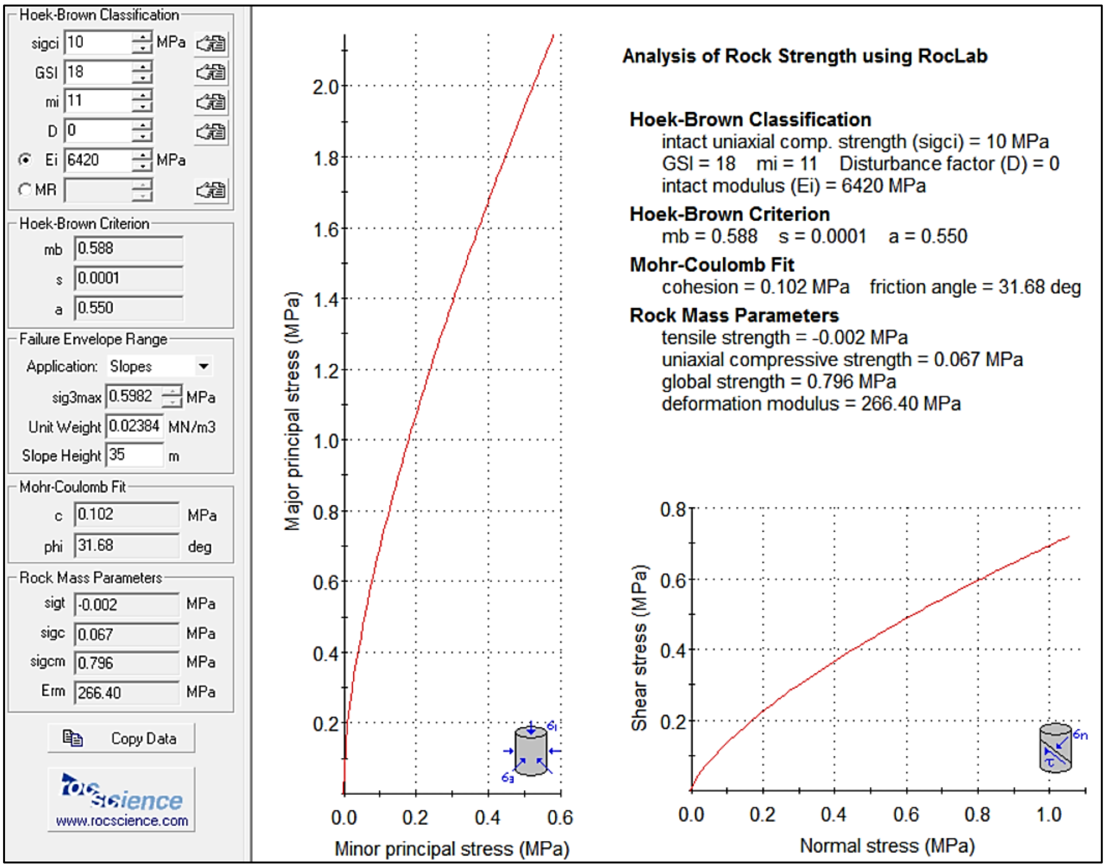
Material Name	Color	Young's Modulus (MPa)	Poisson's Ratio	Failure Criterion	Material Type	Friction Angle (peak) (deg)	Cohesion (peak) (MPa)
T-100x	□	1286	0.335	Mohr Coulomb	Elastic	30	0.25



Distance to Excavation Face	Total Displacement	Softening Ratio	Deformation Modulus	
			in-situ	induced
m	m	%	MPa	MPa
0	0,02259	38,0%	**1 286**	797,6
0,5	0,02703	45,4%		701,7
1	0,03070	51,6%		622,3
1,5	0,03467	58,3%		536,6
2	0,03910	65,7%		440,9
2,5	0,04153	69,8%		388,3
50	0,05950	100,0%		0,0

APPENDIX-I: ROCLAB SOFTWARE RESULTS AND COMPARISON OF RMR & GSI

RocLab software outputs are given in APPENDIX-I.



Hoek-Brown Classification
sigci 10 MPa
GSI 18
mi 11
D 0
● Ei 6420 MPa
○ MR

Hoek-Brown Criterion
mb 0.588
s 0.0001
a 0.550

Failure Envelope Range
Application: Slopes
sig3max 0.5982 MPa
Unit Weight 0.02384 MN/m3
Slope Height 35 m

Mohr-Coulomb Fit
c 0.102 MPa
phi 31.68 deg

Rock Mass Parameters
sigt -0.002 MPa
sigc 0.067 MPa
sigcm 0.796 MPa
Erm 266.40 MPa

Analysis of Rock Strength using RocLab

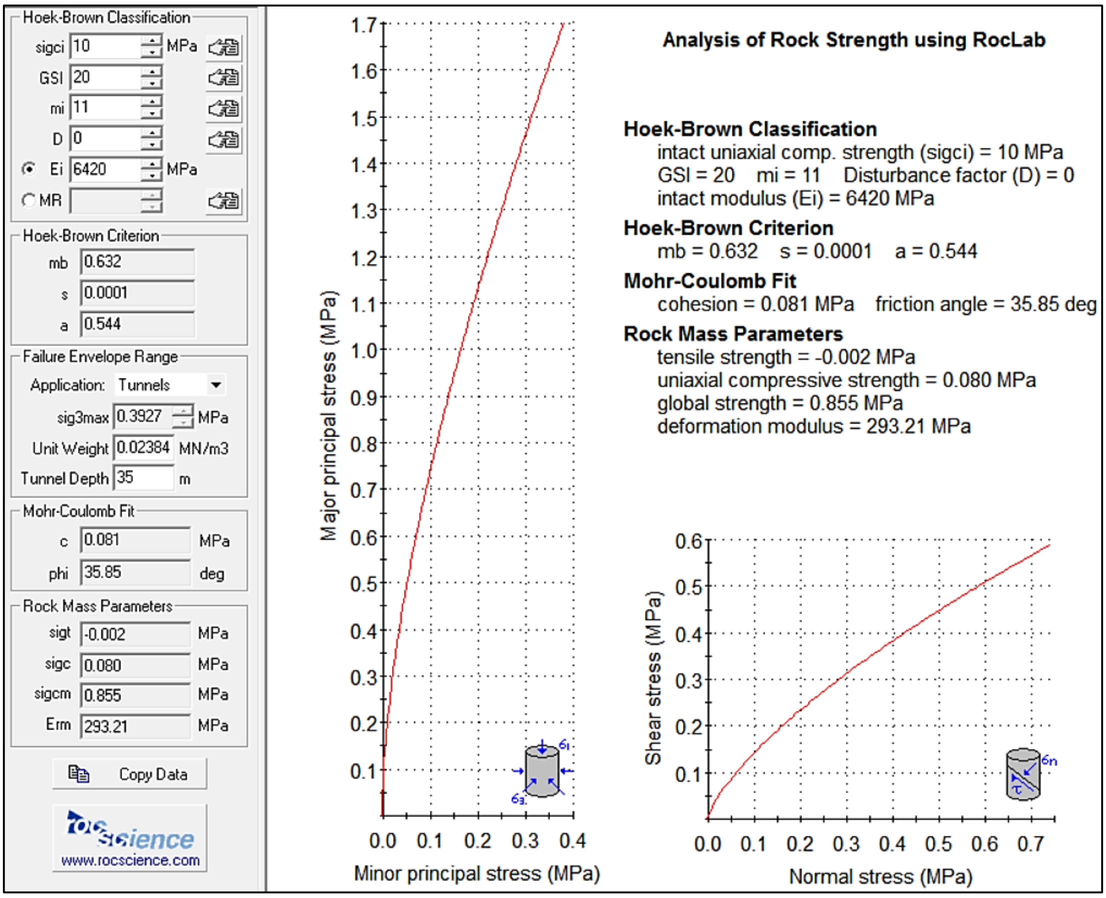
Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 10 MPa
GSI = 18 mi = 11 Disturbance factor (D) = 0
intact modulus (Ei) = 6420 MPa

Hoek-Brown Criterion
mb = 0.588 s = 0.0001 a = 0.550

Mohr-Coulomb Fit
cohesion = 0.102 MPa friction angle = 31.68 deg

Rock Mass Parameters
tensile strength = -0.002 MPa
uniaxial compressive strength = 0.067 MPa
global strength = 0.796 MPa
deformation modulus = 266.40 MPa

Figure I.1: GSI value of exit portal open cuts (Hoek, 2013), shear strength parameters and deformation modulus (Hoek et. al., 2006) (mi value taken from the average of sandstone, claystone and tuff units mi values)



Hoek-Brown Classification
sigci 10 MPa
GSI 20
mi 11
D 0
● Ei 6420 MPa
○ MR

Hoek-Brown Criterion
mb 0.632
s 0.0001
a 0.544

Failure Envelope Range
Application: Tunnels
sig3max 0.3927 MPa
Unit Weight 0.02384 MN/m3
Tunnel Depth 35 m

Mohr-Coulomb Fit
c 0.081 MPa
phi 35.85 deg

Rock Mass Parameters
sigt -0.002 MPa
sigc 0.080 MPa
sigcm 0.855 MPa
Erm 293.21 MPa

Analysis of Rock Strength using RocLab

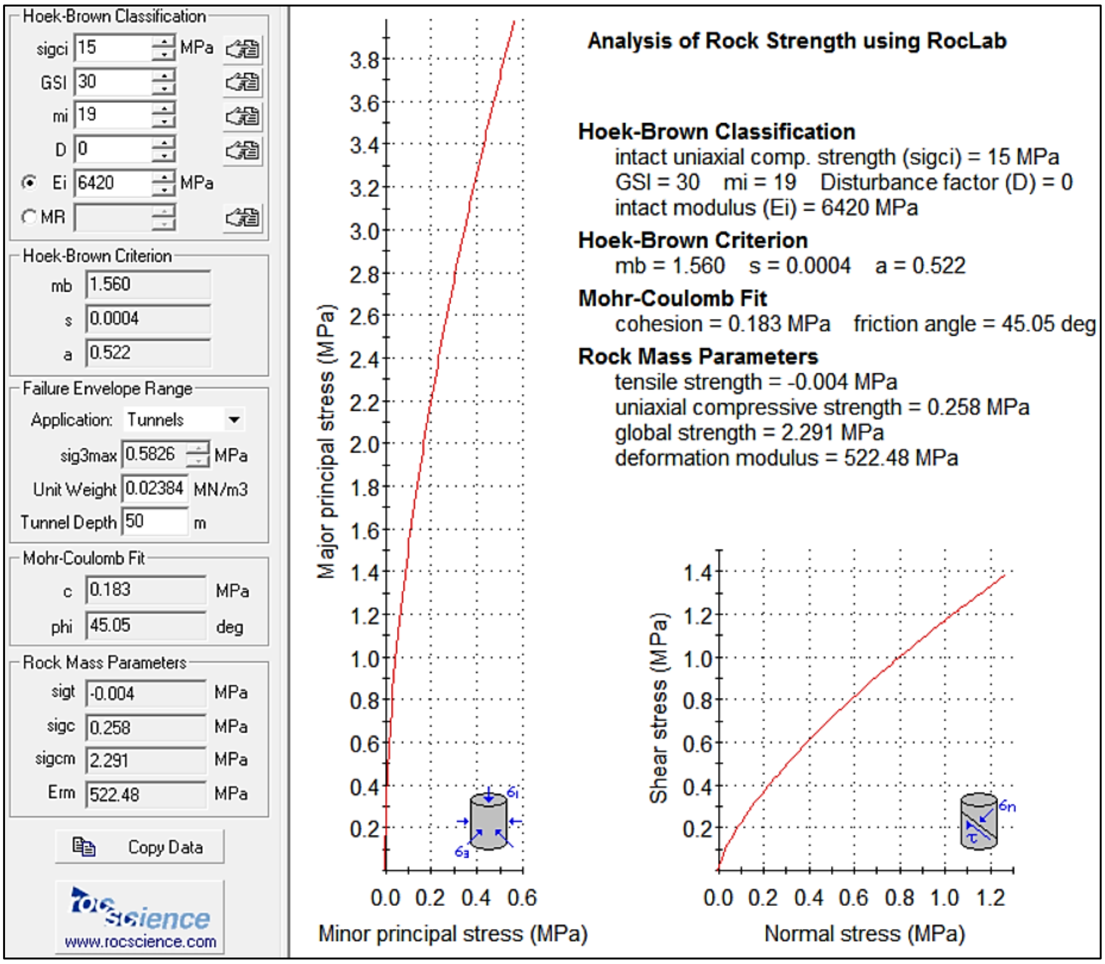
Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 10 MPa
GSI = 20 mi = 11 Disturbance factor (D) = 0
intact modulus (Ei) = 6420 MPa

Hoek-Brown Criterion
mb = 0.632 s = 0.0001 a = 0.544

Mohr-Coulomb Fit
cohesion = 0.081 MPa friction angle = 35.85 deg

Rock Mass Parameters
tensile strength = -0.002 MPa
uniaxial compressive strength = 0.080 MPa
global strength = 0.855 MPa
deformation modulus = 293.21 MPa

Figure I.2: GSI value of T-Px section (Hoek, 2013), shear strength parameters and deformation modulus (Hoek et. al., 2006) (mi value taken from the average of sandstone, claystone and tuff units mi values)


Hoek-Brown Classification
sigci 15 MPa
GSI 30
mi 19
D 0
● Ei 6420 MPa
○ MR

Hoek-Brown Criterion
mb 1.560
s 0.0004
a 0.522

Failure Envelope Range
Application: Tunnels
sig3max 0.5826 MPa
Unit Weight 0.02384 MN/m3
Tunnel Depth 50 m

Mohr-Coulomb Fit
c 0.183 MPa
phi 45.05 deg

Rock Mass Parameters
sigt -0.004 MPa
sigc 0.258 MPa
sigcm 2.291 MPa
Erm 522.48 MPa

Analysis of Rock Strength using RocLab

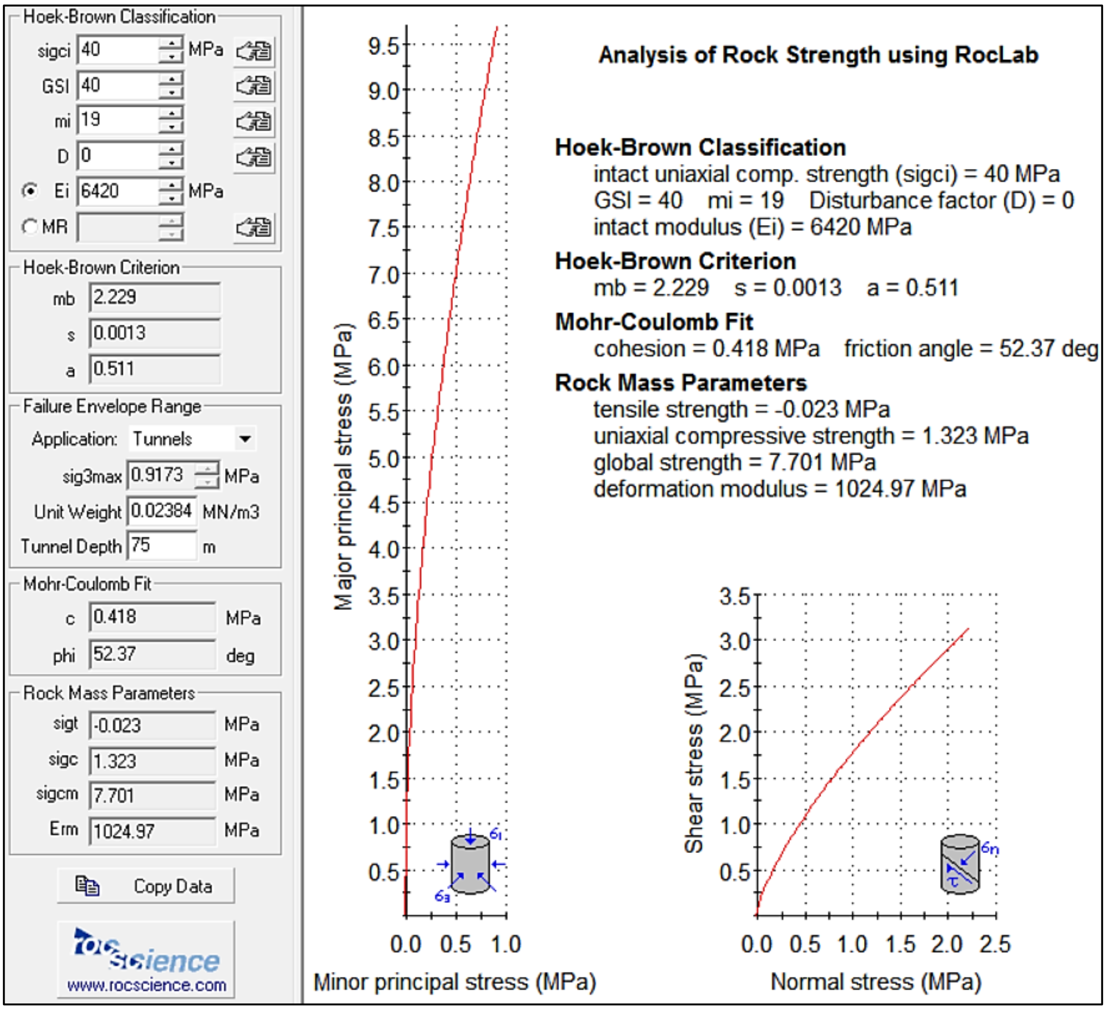
Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 15 MPa
GSI = 30 mi = 19 Disturbance factor (D) = 0
intact modulus (Ei) = 6420 MPa

Hoek-Brown Criterion
mb = 1.560 s = 0.0004 a = 0.522

Mohr-Coulomb Fit
cohesion = 0.183 MPa friction angle = 45.05 deg

Rock Mass Parameters
tensile strength = -0.004 MPa
uniaxial compressive strength = 0.258 MPa
global strength = 2.291 MPa
deformation modulus = 522.48 MPa

Figure I.3: GSI value of T-50x section (Hoek, 2013), shear strength parameters and deformation modulus (Hoek et. al., 2006) (mi value taken from the average of andesite and tuff units mi values)



Hoek-Brown Classification

sigci 40 MPa

GSI 40

mi 19

D 0

● Ei 6420 MPa

○ MR

Hoek-Brown Criterion

mb 2.229

s 0.0013

a 0.511

Failure Envelope Range

Application: Tunnels

sig3max 0.9173 MPa

Unit Weight 0.02384 MN/m3

Tunnel Depth 75 m

Mohr-Coulomb Fit

c 0.418 MPa

phi 52.37 deg

Rock Mass Parameters

sigt -0.023 MPa

sigc 1.323 MPa

sigcm 7.701 MPa

Erm 1024.97 MPa

Analysis of Rock Strength using RocLab

Hoek-Brown Classification

intact uniaxial comp. strength (sigci) = 40 MPa

GSI = 40   mi = 19   Disturbance factor (D) = 0

intact modulus (Ei) = 6420 MPa

Hoek-Brown Criterion

mb = 2.229   s = 0.0013   a = 0.511

Mohr-Coulomb Fit

cohesion = 0.418 MPa   friction angle = 52.37 deg

Rock Mass Parameters

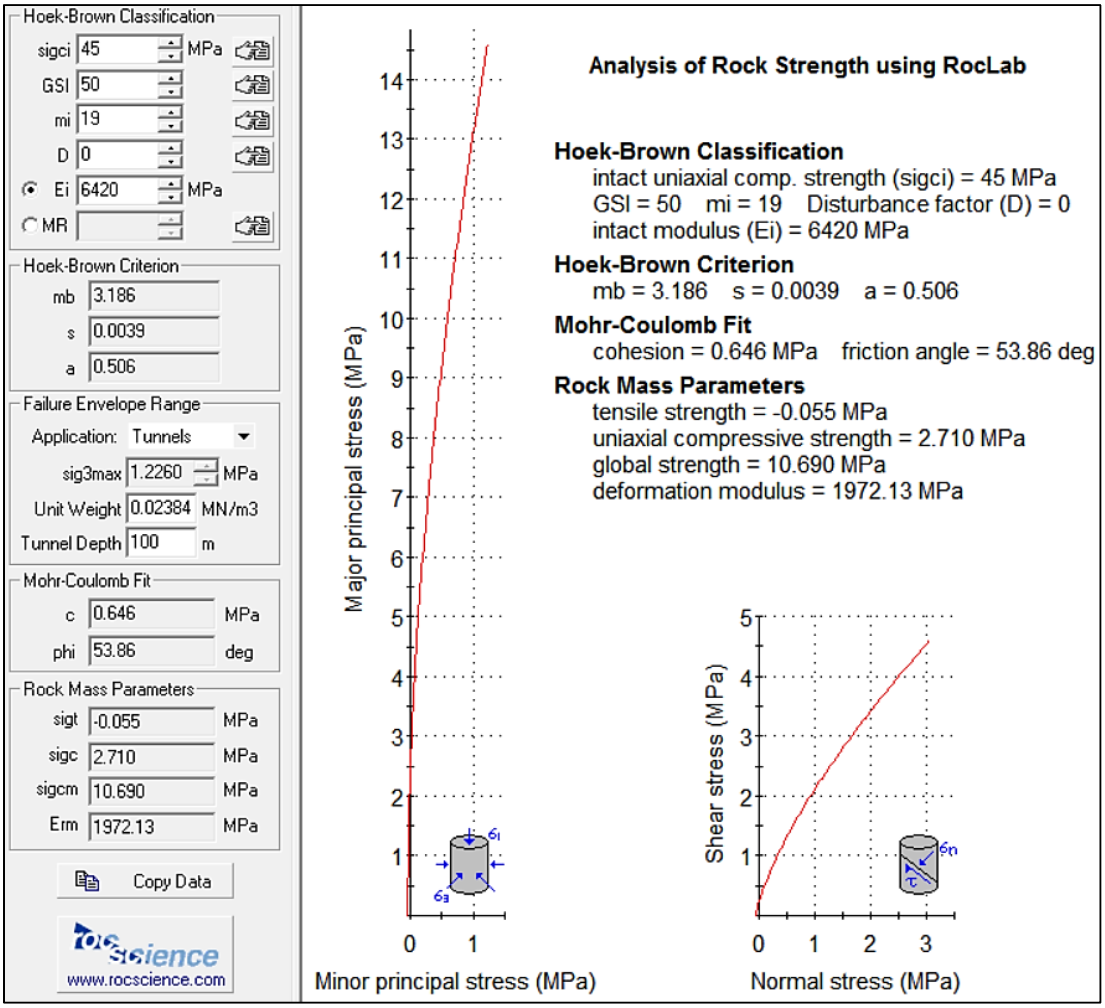
tensile strength = -0.023 MPa

uniaxial compressive strength = 1.323 MPa

global strength = 7.701 MPa

deformation modulus = 1024.97 MPa

Figure I.4: GSI value of T-75x section (Hoek, 2013), shear strength parameters and deformation modulus (Hoek et. al., 2006) (mi value taken from the average of andesite and tuff units mi values)



Hoek-Brown Classification

sigci 45 MPa

GSI 50

mi 19

D 0

● Ei 6420 MPa

○ MR

Hoek-Brown Criterion

mb 3.186

s 0.0039

a 0.506

Failure Envelope Range

Application: Tunnels

sig3max 1.2260 MPa

Unit Weight 0.02384 MN/m3

Tunnel Depth 100 m

Mohr-Coulomb Fit

c 0.646 MPa

phi 53.86 deg

Rock Mass Parameters

sigt -0.055 MPa

sigc 2.710 MPa

sigcm 10.690 MPa

Erm 1972.13 MPa

Analysis of Rock Strength using RocLab

Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 45 MPa
GSI = 50 mi = 19 Disturbance factor (D) = 0
intact modulus (Ei) = 6420 MPa

Hoek-Brown Criterion
mb = 3.186 s = 0.0039 a = 0.506

Mohr-Coulomb Fit
cohesion = 0.646 MPa friction angle = 53.86 deg

Rock Mass Parameters
tensile strength = -0.055 MPa
uniaxial compressive strength = 2.710 MPa
global strength = 10.690 MPa
deformation modulus = 1972.13 MPa

Figure I.5: GSI value of T-100x section (Hoek, 2013), shear strength parameters and deformation modulus (Hoek et. al., 2006) (mi value taken from the average of andesite and tuff units mi values)

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
RMR	23.0	33.5	46.5	57.0
Max. Overburden (m)	35	50	75	100
c (MPa)	0.15	0.15	0.2	0.25
Φ (°)	20	20	25	30

Geotechnical Section	T-Px	T-50x	T-75x	T-100x
GSI	20 (18.0)	30 (28.5)	40 (41.5)	50 (52.0)
Max. Overburden (m)	35	50	75	100
c (MPa)	0.081	0.183	0.418	0.646
Φ (°)	35.85	45.05	52.37	53.86

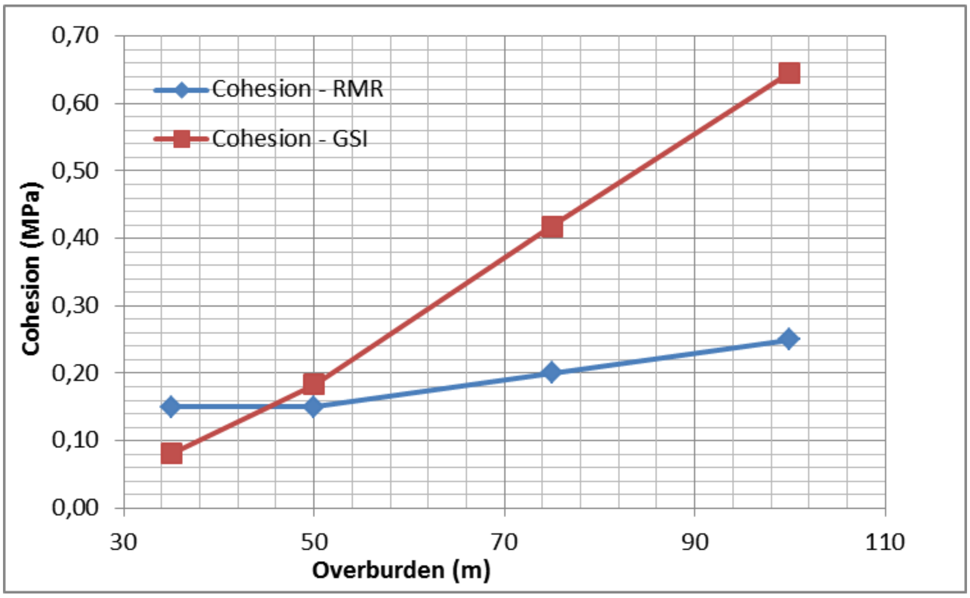


Figure I.6: Comparison of cohesions suggested by RMR and GSI classifications for the critical sections

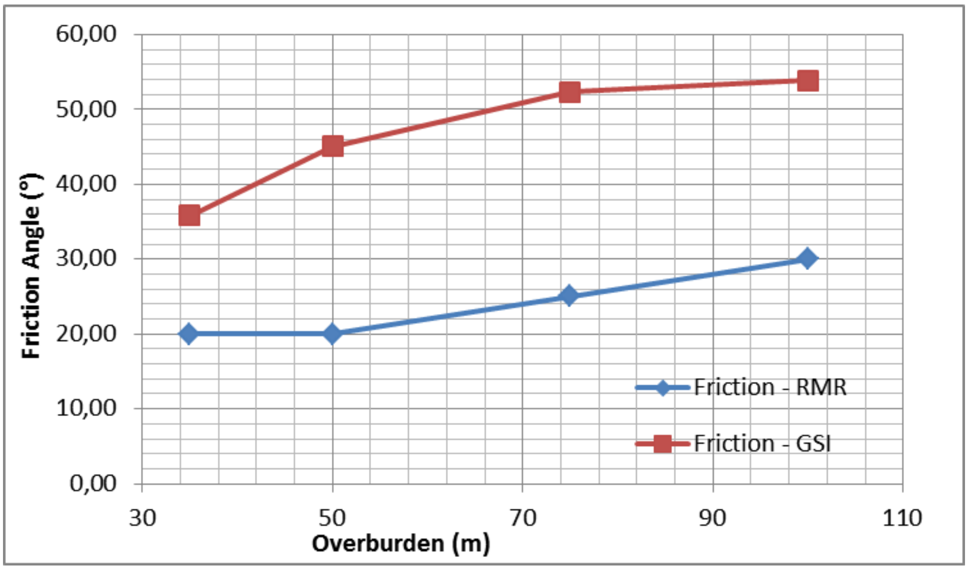


Figure I.7: Comparison of friction angles suggested by RMR and GSI classifications for the critical sections

APPENDIX-J: DESCRIPTIONS OF LIMIT EQULIBRIUM METHODS FOR SLOPE STABILITY ANALYSIS

Pockoski and Duncan (2000) summarized the components of limit equilibrium for comparing the methods sufficiency and the summary table is given in APPENDIX-J.

Descriptions of Methods of Analysis
Pockoski and Duncan (2000)

Method	Overall Moment Equilibrium	Individual Slice Moment Equilibrium	Horizontal Force Equilibrium	Vertical Force Equilibrium	Assumptions	Comments
Swedish Circle	Yes	No	No	No	Circular Slip Surface	Only for ϕ=0
Ordinary Method of Slices (Fellenius 1927)	Yes	No	No	No	Circular Slip Surface Side Forces Parallel to Base	Conservative Very inaccurate for high pore water pressures
Bishop's Modified Method (Bishop 1955)	Yes	No	No	Yes	Circular Slip Surfaces Side Forces Horizontal	Very inaccurate for high pore water pressures
Morgenstern and Price's Method (Morganstern and Price 1965)	Yes	Yes	Yes	Yes	Slip surface of any shape Pattern of Side Force Orientations	Much engineering time required to vary side force assumptions.
Spencer's Method (Spencer 1967)	Yes	Yes	Yes	Yes	Slip surface of any shape Side Forces Parallel	Simplest Method
Corps of Engineers Modified Swedish (1970)	No	No	Yes	Yes	Slip surface of any shape Side Forces Parallel to Slope	High factor of safety
Lowe & Karafiath (1960)	No	No	Yes	Yes	Slip surface of any shape Side Force Orientations Average of Slope and Slip Surface	Best side force assumption
Janbu Simplified (Janbu 1954)	No	No	Yes	Yes	Slip surface of any shape Side Forces Horizontal	Low Factor of Safety
GLE - General Limit Equlibrium	Yes	Yes	Yes	Yes	Slip surface of any shape Pattern of Side Force Orientations	Much engineering time required to vary side force assumptions.
GoldNail Method* (Golder)	Yes	*	Yes	Yes	Slip surface of any shape Normal Stress Distribution	Toe circles only
SNAIL Method (CALTRANS)	No	No	Yes	Yes	Slip surface of any shape Two or three wedges, with side force angle = ϕ	Limited shapes of slip surfaces