ASSESSMENT OF CUT SLOPE STABILITY IN WESTERN BLACK SEA REGION (TURKEY)

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

BY

MERVE ÖZKÖSE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
GEOLOGICAL ENGINEERING

SEPTEMBER 2019

Approval of the thesis:

ASSESSMENT OF CUT SLOPE STABILITY IN WESTERN BLACK SEA REGION (TURKEY)

submitted by **MERVE ÖZKÖSE** in partial fulfillment of the requirements for the degree of **Master of Science in Geological Engineering Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** ________________

Prof. Dr. Erdin Bozkurt
Head of Department, **Geological Engineering** ________________

Prof. Dr. Tamer Topal
Supervisor, **Geological Engineering, METU** ________________

Examining Committee Members:

Prof. Dr. Erdal Çokça
Civil Engineering, METU ________________

Prof. Dr. Tamer Topal
Geological Engineering, METU ________________

Assoc. Prof. Dr. Mutluhan Akın
Geological Engineering, Nevşehir HBVU ________________

Assoc. Prof. Dr. Nejan Huvaj Sarıhan
Civil Engineering, METU ________________

Assist. Prof. Dr. Onur Pekcan
Civil Engineering, METU ________________

Date: 13.09.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Merve Özköse

Signature:

ABSTRACT

ASSESSMENT OF CUT SLOPE STABILITY IN WESTERN BLACK SEA REGION (TURKEY)

Özköse, Merve
Master of Science, Geological Engineering
Supervisor: Prof. Dr. Tamer Topal

September 2019, 298 pages

Cut slopes are intensely prone to weathering in the cause of excavation effects. Weathering effects can reduce strength of rocks and results in instabilities in the long run. By the reasons of rocks containing joints, fractures, faults, bedding planes and pore spaces, they are likely to be weathered because of wetting-drying cycles, climate changes, and chemical action of solutions absorbed. This study is mainly concerned with the slope stability analysis for sixteen permanent cut slopes that are composed of limestone, sandstone, marl and mudstone, having heights between 8 and 60 m, along the highways within the borders of Karabük, Zonguldak and Düzce province at Western Black Sea Region in Turkey. Stability analyses were conducted by considering weathering effects with the help of field works, laboratory tests and computer softwares. The purpose is to reveal instability possibilities occurring throughout the determined slopes, chances that the road cuts may move downslope, and the most vulnerable slopes. Within the scope of this thesis, literature researches, field studies, laboratory works, and stability analyses were conducted. Field studies were performed in order to investigate the rock types that were encountered at the studied road cuts. Field observations about weathering degree and excavation types of the road-cuts have been done to examine their effects on stability, geometry and geological characteristics of the studied cut slopes. Scan line surveys were carried out with the aim of obtaining discontinuity-related data of the road-cuts. As an in-situ test, Schmidt hammer rebound test was carried out in the field to assess the strength of the rock units. Laboratory tests as unit weight, point load and uniaxial compression strength (UCS) tests have been performed on the rock specimens that were taken during field works for determining strength parameters and investigating the differences in weathering degrees of the rocks with the tests of methylene blue and slake durability. Slope stability analyses of the road-cuts were performed in accordance with strength parameters values of the rocks as weathered and relatively fresh types. The analyses were performed by modeling surface of the cut slopes as weathered rock with the determined depths and modeling rest of the slope material as relatively fresh. In addition to the slope stability analyses, rockfall analyses were performed in order to investigate the rockfall risks of the studied cut slopes. Taking into account of the studies performed, instability risks were assessed and prevention about drainage channels were recommended as a remedial measure due to surficial failures of the cut slopes.

Keywords: Slope Stability, Cut Slope, Weathering, Western Black Sea Region, Turkey

ÖZ

BATI KARADENİZ BÖLGESİ'NDEKİ (TÜRKİYE) YOL YARMALARININ ŞEV STABİLİTESİNİN DEĞERLENDİRİLMESİ

Özköse, Merve
Yüksek Lisans, Jeoloji Mühendisliği
Tez Danışmanı: Prof. Dr. Tamer Topal

Eylül 2019, 298 sayfa

Yol yarmaları, kazı etkileri nedeniyle ayrışmaya karşı oldukça eğilimlidir. Ayrışma etkileri kayaçların dayanımını azaltabilir ve uzun vadede ise duraysızlığa yol açabilir. Eklemler, kırıklar, faylar, tabakalanma düzlemleri ve boşluk hacimleri içermelerinden dolayı kayaçlar, ıslanma-kuruma döngüsü, iklim değişiklikleri ve emilen çözeltilerin kimsayal etkileri nedeniyle ayrışmaya karşı duyarlıdırlar. Bu çalışma temel olarak, Türkiye'nin Batı Karadeniz Bölgesi, Karabük, Zonguldak ve Düzce illeri sınırları içerisinde yer alan, karayolları üzerinde bulunan, 8-60 m yüksekliğine sahip olan, kireçtaşı, kumtaşı, marn ve çamurtaşından oluşan, 16 adet yol yarmasının duraylılık analizleri ile ilgilidir. Duraylılık analizleri, ayrışma etkilerini dikkate alarak, arazi çalışmaları, laboratuvar deneyleri ve bilgisayar programları kullanılarak yapılmıştır. Amaç, belirlenen yol yarmalarındaki duraylılık olasılıklarını, olası şev aşağı hareketlerini ve duraysızlığa en eğilimli şevleri bulmaktır. Bu tez kapsamında, literatür araştırmaları, arazi çalışmaları, laboratuvar deneyleri, duraylılık analizleri yapılmıştır. Çalışılan yol yarmalarında karşılaşılan kayaç türlerinin özelliklerini belirlemek amacıyla arazi gözlemleri yapılmış, şev geometrileri, şevlerde karşılaşılan birimlerin litolojik özellikleri, şevlerde karşılan süreksizlere ait veriler, ayrışma dereceleri, ayrışma derinlikleri ve kazı yöntemleri, bu değişkenlerin duraylılık üzerindeki etkilerini gözlemek amacıyla belirlenmiştir. Şevlerde karşılaşılan kayaçların dayanımlarını belirlemek amacıyla, yerinde deney olarak Schmidt çekici deneyi yapılmıştır. Arazi çalışmaları sırasında toplanan kaya örnekleri üzerinde, dayanım parametlerini belirlemek amacıyla birim ağırlığı, nokta yükleme ve tek eksenli basma dayanımı deneyleri, kayaçların ayrışma dereceleri arasındaki farkları belirlemek amacıyla metilen mavisi ve suda dağılmaya karşı dayanıklılık deneyleri yapılmıştır. Yol yarmalarının şev duraylılık analizleri, ayrışmış ve taze kayaç tiplerinin dayanım değerleri göz önünde bulundurularak, şev yarmalarının yüzeyleri belirlenen ayrışma derinlikleri ile ayrışmış kayaç olarak nitelendirilip, şevlerin kalan kısımlarının ise taze kayaç olarak nitelendirilmesiyle yapılmıştır. Yapılan çalışmalar göz önünde bulundurularak duraysızlık riskleri incelenmiş ve yüzeysel yenilmelere önlem olarak yol yarmalarının önünde bulunan drenaj kanallarının periyodik olarak bakımı önerilmiştir.

Anahtar Kelimeler: Şev Stabilitesi, Yol Yarması, Ayrışma, Batı Karadeniz, Türkiye

To my Mother,

Ferahnaz ÖZKÖSE

ACKNOWLEDGEMENTS

I would like to express my special thanks to my supervisor Prof. Dr. Tamer Topal for his patience, valuable guidance, encouragement and continued advice throughout all process of this study. It is an honor for me to work with him.

I wish to thank my examining committee members, Prof. Dr. Erdal Çokça, Assoc. Prof. Dr. Mutluhan Akın, Assoc. Prof. Dr. Nejan Huvaj Sarıhan and Assist. Prof. Dr. Onur Pekcan for their valuable recommendations and criticism.

I would like to express my appreciation to Timur Ersöz for his invaluable technical guidance, help on laboratory and field works and his friendship.

I would like to thank Yavuz Kaya and Dr. Felat Dursun for their help on laboratory works and their whole-hearted companionship.

I am thankful to my friends İlker Şahin and İpek Kasım for their companionship on field works and my friends Tuğçe Tayfuner and Tuğba Öztürk for their sympathy and motivation.

I would like to thank my friend and my significant other Uraz Can Ertuğrul for his support during this thesis, his guidance and companionship at field works.

Finally, I would like to express my deepest gratitude to my family; my brother Metehan Özköse and my sister Başak Aker for their energy and encouragement and my lovely mother Ferahnaz Özköse for her belief and sympathy, and to my father Halis Özköse.

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CHAPTER 1

INTRODUCTION

1.1. Purpose of the Study

Road-cuts are intensely prone to weathering activities by the reason of their disturbed structure and topographical condition due to excavation. Weathering effect can reduce strength parameters of rocks and cause of failures in the long run. By the reason of rocks containing joints, micro to macro fractures, faults, bedding planes and pore spaces, they are likely to be weathered due to wetting-drying cycles, temperature changes, and chemical action of solutions absorbed. This study is mainly concerned with assessment of slope stability analysis of the selected road-cuts in Western Black Sea Region in Turkey by considering weathering effects. The analyses were performed by modeling surface of the road-cuts as weathered rock in the determined depths and considering rest of the slope material as relatively fresh.

Within the scope of this study, literature researches on regional geology, weathering effects on rock strength and methodology of slope stability analysis were carried out. Field observations about weathering degree and excavation types of the road-cuts have been done, geometry and geologic characteristics of the slopes have been determined. By sample collection at sixteen cut slopes, scan-line survey and in-situ tests data were gathered in the field. Laboratory tests have been performed on the rock samples that were taken during field works not only for determining strength parameters but also for investigating the differences in weathering degrees of the rocks with the tests of methylene blue and slake durability. Finally slope stability analysis of the road-cuts were performed in accordance with strength parameters values of rocks as weathered and relatively fresh.

1.2. Location of the Study Area

Locations of the road-cuts in the study area are within the borders of Karabük, Zonguldak and Düzce province in Turkey, along Ankara-Karabük D755, Karabük-Zonguldak D030, Zonguldak-Ankara D750, Ereğli-Akçakoca D010 and Düzce-Akçakoca D655 highways.

Their positions (shown as yellow mark in Figure 1.1) are between 18 km northeast of Eskipazar and 12 km southeast of Zonguldak centrum, and between 2 km southwest of Alaplı and 9 km southeast of Akçakoca.

Figure 1.1. Location map of the studied cut slopes

Coordinates of the road-cuts are listed in Table 1.1 in terms of Universal Transverse Mercator (UTM) as northing, easting and elevation. Entire cut slopes are located in the zone of 36T.

Table 1.1 *Northing, Easting Coordinates and Elevations of the studied road-cuts (Universal Transverse Mercator – Zone: 36T)*

Slope No.	Northing	Easting	Elevation (m)
MS-1	4585059	410411	389
MS-2.1	4581259	412773	246
MS-2.2	4581167	412220	248
MS-2.3	4581115	412676	250
MS-3	4568565	429449	73
MS-4	4561727	451137	152
MS-5	4556901	469821	299
MS-6	4547439	471819	421
MS-7.1	4558815	363033	26
MS-7.2	4558878	363026	15
MS-8.1	4538211	346847	450
MS-8.2	4538155	346826	451
MS-9	4543406	349457	244
MS-10	4543498	349152	267
MS-11	4543830	348780	227
MS-12	4544221	348829	207

Plan and related elevation profile view of the study area are given in Figure 1.2. Twelve of the studied cut slope elevations are higher than 200 m and the rest of them are lower than 200 m above sea level. Other four road-cuts are located in gentle topography.

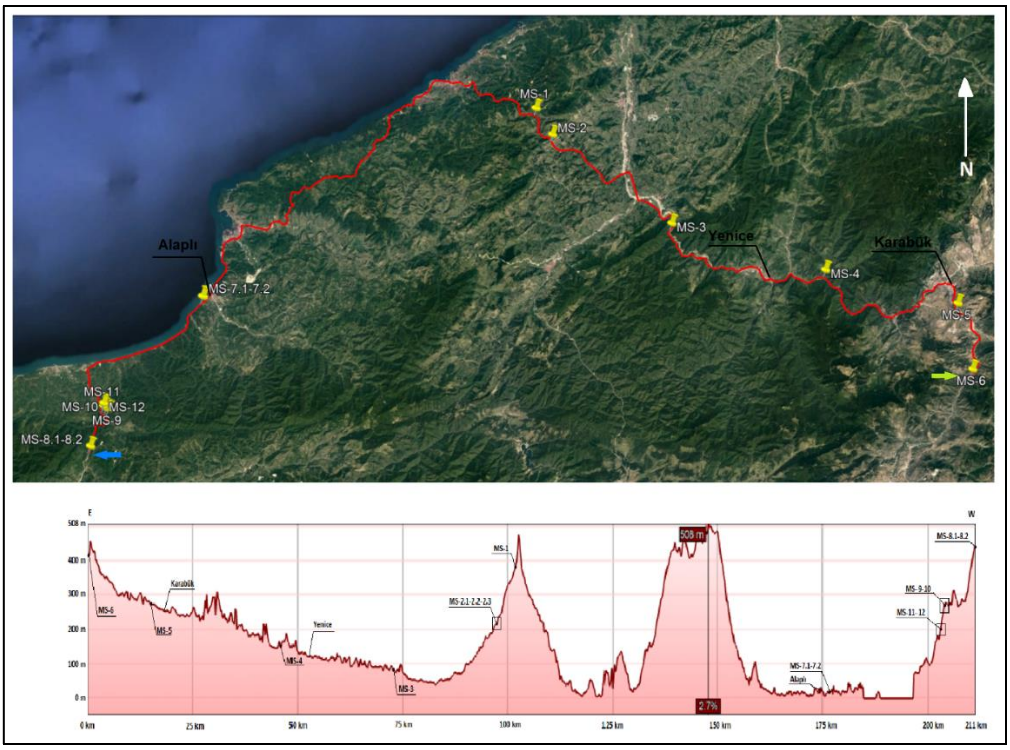


Figure 1.2. Plan view and elevation profile of the studied route

1.3. Climate and Vegetation of the Study Area

The studied cut slopes are located in Karabük, Zonguldak and Düzce province in Western Black Sea region where Black Sea region climate is effective. Black Sea region is the rainiest region in Turkey. The region is mostly rainy throughout the year. Generally, winters are cold, and summers are warm in the Black Sea Region. Forest vegetation is dominant in the whole area.

As reported by Turkish State Meteorological Service (MGM, 2018) data between the years of 1939-2018, average annual precipitation amount of Karabük province is 40.9 kg/m^2. Highest precipitation amount of Karabük is in May, and lowest is in August. Average annual temperature for Karabük is 13.4°C. Highest and lowest monthly temperatures are detected in July and January, respectively (Table 1.2). Average annual precipitation is 101.5 kg/m^2 in Zonguldak that is considerably higher than

Düzce and Karabük cities. Highest monthly precipitation is in December and lowest one is in May for Zonguldak city. Average annual temperature of Zonguldak is 13.6°C that is very similar to Karabük city. Maximum monthly temperature is observed in August and minimum one is in January in Zonguldak (Table 1.2). Average annual precipitation of Düzce is 69.0 kg/m^2. Highest precipitation is observed in December, lowest one is in July. Average annual temperature is 13.4°C for Düzce city which is same as Karabük city. Maximum temperature is observed in July and lowest is in January (Table 1.2). Zonguldak is very humid although Karabük and Düzce are semi-humid to humid.

Natural vegetation in the Black Sea region is forest. Vegetation is broad-leaved forests that shed leaves in winter in lower altitudes. As the altitude increases, vegetation changes and mixed-leaved forests are encountered. At the higher altitudes coniferous forests and Alpine meadows are encountered.

Table 1.2. *Meteorological data of Karabük, Zonguldak, Düzce (DMİ 2018) (Temperature data in C° and precipitation data in kg/m²)*

	Months											
KARABÜK (1965-2018)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Average Temperature	2.9	4.8	8.1	12.8	17.4	21.0	24.0	23.8	19.5	14.2	8.2	4.2
Average Max. Temperature	7.4	10.4	14.8	20.3	25.5	29.0	32.3	32.5	28.3	21.9	14.4	8.8
Average Min. Temperature	-0.5	0.4	2.7	6.8	10.7	13.8	16.5	16.4	12.7	8.7	3.7	0.9
Average Precipitation Amount	51.4	34.3	44.8	49.2	56.9	49.4	25.6	23.2	29.1	40.6	35.1	50.9
ZONGULDAK (1939-2018)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Average Temperature	6.1	6.2	7.4	11.2	15.4	19.6	21.9	21.9	18.7	15.1	11.6	8.3
Average Max. Temperature	9.2	9.5	10.9	14.9	18.8	23.0	25.1	25.3	22.4	18.6	15.2	11.5
Average Min. Temperature	3.4	3.4	4.5	8.0	12.1	15.8	18.0	18.2	15.4	12.2	8.8	5.6
Average Precipitation Amount	137.5	97.4	98.0	63.9	53.6	71.3	67.8	83.7	103.8	145.8	142.2	152.8
DÜZCE (1959-2018)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Average Temperature	3.8	5.3	7.9	12.4	16.7	20.6	22.6	22.4	18.8	14.3	9.6	5.8
Average Max. Temperature	8.1	10.2	13.6	18.9	23.3	27.1	29.0	29.1	25.9	20.7	15.5	10.1
Average Min. Temperature	0.4	1.3	3.5	7.2	11.2	14.6	16.8	16.9	13.3	9.7	5.2	2.3
Average Precipitation Amount	89.4	69.1	74.1	60.6	63.1	60.9	42.8	50.6	51.6	81.6	80.7	102.9

1.4. Methodology

The method of study comprises four parts in this thesis. Firstly, the priority has been given to literature survey that is about geology of study area and rock material properties. At the following part, studies have been performed in the field in order to make observations, gathering data on rock classification, rock properties, excavation types, weathering degrees of the slopes and collect samples from the selected cut slopes to use at laboratory works. In the third part of the study, in-situ tests and laboratory tests were conducted. Schmidt hammer tests as in-situ test which have been done at the field and laboratory tests such as point load test, uniaxial compressive strength test were performed to detect strength parameters of rocks. Besides, methylene blue and slake durability tests were performed to reveal durability of rocks against weathering. In the final part, 2D analysis of the cut slopes have been performed in order to examine their stability.

In the first part of the study, literature survey about geology of the study area was carried out as well as research about rock properties, decreasing of rock strength by the reason of weathering and excavation effects. Hencher and McNicholl (1995), Hack (1998), Topal and Sozmen (2003), Ersöz and Topal (2018a, b) stated that weathering has an impact on rock strength parameters. Not only weathering can decrease strength of rock materials but also excavation may decrease strength parameters of rocks depending upon its type. Besides geology of the study area comprising investigated road-cuts was surveyed.

In the second part of this study, field works such as field observations, gathering data for classification of rocks, rock properties, excavation types, weathering degrees have been performed. In addition to observations and gathering data, sample collection for laboratory tests and scan-line surveys were carried out in the field. By the help of scan-line surveys, discontinuity-related data were obtained. Excavation types and weathering degrees of the slopes were specified so as to examine their effects on stability of the road-cuts. In addition to all of these data, types of discontinuities, orientation, spacing, roughness, infill material type and width, persistence, aperture, wall strength, block sizes of fallen rocks were gathered. Furthermore, as an in-situ test Schmidt hammer rebound test was carried out in the field so as to assess uniaxial compressive strength of both weathered and relatively fresh rock samples. Rock mass strength parameters such as cohesion and internal friction angle were determined by the help of Geological Strength Index (GSI) (Hoek, 1994). In order to obtain GSI value, structure of the rock mass and surface conditions such as weathering, and roughness of rock mass were taken into consideration. After obtaining GSI values of rock mass, strength parameters were determined in the light of Hoek-Brown failure criterion (Hoek et al., 2002). Additionally, rock mass strength, weathering degree, condition of discontinuities such as spacing, persistence, aperture, roughness, infilling, and also groundwater condition were examined.

In the third part, in order to get rock strength parameters, unit weight, durability of rocks against weathering, laboratory tests were performed for relatively fresh and weathered rocks. Schmidt rebound hammer test as an in-situ test, point load and uniaxial compression strength (UCS) tests were carried out with the aim of getting rock strength parameters. Unit weight tests were performed by sample saturation and drying so as to find dry and saturated unit weight of both weathered and relatively fresh samples of rocks. In order to obtain information about durability of rocks, slake durability test was performed as 20 cycles for each cut slopes by simulating wetting and drying cycles. Besides, methylene blue test was performed to find cation exchange capacity of the rocks. The common purpose of these tests are getting information about the parameters of the rocks for better modelling of the studied cut slopes for their stability.

At the final part of the study, 2D analyses were carried out for each road-cut to check their stability conditions. The software application Dips 6.0 (Rocscience, 2013) was used for kinematic analysis for discontinuity-controlled failures with data gathered from the field. After applying kinematic analysis, by using strength properties of both weathered and relatively fresh rocks of the road-cuts, limit equilibrium analysis for discontinuity-controlled rocks were performed using the software applications RocPlane 2.0 (Rocscience, 2005), Swedge 4.0 (Rocscience 2004), RocTopple 1.0 (Rocscience, 2015). Likewise, limit equilibrium analyses for rock mass were carried out with the help of the software applications of Slide (6.0) (Rocscience, 2011) for the overall stability of the studied road-cuts. In addition to kinematic and limit equilibrium analysis, rockfall risks of the studied cut slopes were investigated with the help of RocFall 6.0 (Rocscience, 2016) software.

CHAPTER 2

LITERATURE REVIEW

2.1. Previous Studies about Geology

Firstly, literature survey about geology of the study area is carried out. From younger to older Çaycuma, Karabük, Akveren, Kilimli, Ulus and Çakraz are the formations where 16 different examined cut slopes are located on.

The Çaycuma formation is typically siliciclastic turbiditic deposits consisting of sandstone, siltstone, and claystone alternation and pyroclastic or volcanogenic deposits as agglomerate, tuff, tuffite that are located at the south of Devrek Basin (Siyako et al., 1980) and extends through northeast and southwest of the study area. In his study of landslide hazard assessment around Bolu region using Geographical Information Systems and remote sensing, Suzen (2002) stated that the Çaycuma formation is continuation of the cover units of the Bolu Massif and main lithologies of the formation are alternation of turbiditic sandstone and siltstone, marl with gypsum intercalations, mudstone, and calcareous mudstone. According to İsmailoğlu et al. (1999), the Çaycuma formation in the study area comprises mudstone, claystone, sandstone alternation that shows flysch characteristics. As stated by Yergök et al. (1987), the age of the Çaycuma formation is Middle-Lower Eocene. It is moderate to weak in strength as a whole, nonetheless layers of thin and medium bedded mudstones and claystones show weak and very weak strength. Generally, failures occur between these bedding planes that are weak and very weak in strength. Thus, circular and planar failures are generally observed in these units. As stated by İsmailoğlu et al. (1999), circular failures in this region mostly occurred in completely weathered parts of the rocks that show flysch character. Moreover, planar failures at the study area occurred after heavy rainfalls as sliding over saturated and weakened flysch deposits.

As reported by Saner et al. (1979) and Yergök et al. (1987), the Karabük formation consists of uncertainly layered gypsum fragmented marl, sandstone and marl alternation, carbonated sandstone and the age of the formation is Early-Late Eocene.

According to Akyol et al. (1974), the Akveren formation is composed of clayey limestone, marl, carbonated mudstone and calciturbite. In addition, Kaya et al. (1986) states that the formation contains tuff, sandstone, claystone. As stated by Ketin and Gümüş (1996), the age of the Akveren formation is Maastrichtian, by Gedik and Korkmaz (1984) the age is Maastrichtian-Paleocene, by Akman (1992) Campanian-Paleocene and by Tüysüz et al. (1997) the age of the formation is Maastrichtian. As reported by Koralay (2009), the Akveren formation consists of sandstone, sandy limestone and marl. In their study on Western Pontides and their geological evolution, Yiğitbaş et al. (1999) stated that the Akveren formation is a typical transgressive sequence resting on various older units. In addition, Kaya et al. (1986) clarified that the Akveren formation overlies Hatipler formation, and Ozer (1994) assessed the contact between these two formations and stated that they are gradational.

The Kilimli formation that is observed in the study area consists of silt and sandstone containing, uncertainly layered, soil like marl (Saner et al., 1980). The age of the formation is Lower Cretaceous (Siyako et al., 1980).

The Ulus formation that is observed at the study area of this thesis consists of turbiditic sandstone, marl, sandstone and shale alternation, locally conglomerates, claystone, siltstone, mudstone. As stated by Saner et al. (1979), Siyako et al. (1980), Aydın et al. (1987), and Yergök et al. (1987), the age of the Ulus formation is Early-Late Cretaceous.

The Çakraz formation is totally composed of terrestrial deposits (Tüysüz et al., 2004). The main lithologies of the formation are terrestrial sandstone and mudstone. At the lower portions of the Çakraz formation there can be seen conglomerates. At the upper portions, alternations of sandstone, mudstone, and claystone are observed. The age of the formation is Permian-Triassic (MTA, 2002d).

According to study about GIS-based landslide susceptibility mapping in Devrek (Zonguldak) by Yılmaz et al. (2012), landslides are generally observed in the Çaycuma formation around the study area. Based on this study, landslides occur as rotational and translational controlled by bedding planes occur. Besides, Yılmaz et al. (2012) state that lithology, slope properties, elevation, aspect and drainage density are the main factors of the slope failures and landslides occurrence.

2.2. Stability of Slopes, Weathering and Excavation

Disturbance of initial geometry and strength of the cut slopes may result in possible failures of slopes (Ersöz and Topal, 2018a). The load differentiations on cut slopes and shear strength differences can change the stability and safety factor of slopes with time (Duncan et al., 2014). Natural occurrences as water and seismic activity and also man-made factors can result in load variations (Highland and Bobrowsky, 2008). Besides; weathering effects are increasing based on disturbances, stress relief, load variations and natural apertures as discontinuities and faults (Ersöz and Topal, 2018a). Taking these reasons into account, assessment of slope stability is very critical for the safety of road cuts.

Weathering and excavation are the factors that can change the strength parameters of the disturbed material. Hack (1998) states that rocks mass ratings are diminished by the effects of excavation in some rock mass classification systems. Weathering with direct atmospheric chemical effects and stress application can disturb the materials (Price, 1995).

Decrease in shear strength and increase in shear stress are the two causes of instability of slopes (Duncan et al., 2014). One of the main causes of decreasing shear strength is weathering and one of the main causes of increasing shear stress is excavation. Thus, both weathering and excavation can result in decreasing of safety factor and stability problems due to shear strength decreasing and shear stress increasing.

Weathering and excavation can act upon a rock slope individually or it is possible that weathering is caused by the effect of excavation. As mentioned by Hack and Price (1997), due to stress relief after excavation, new cracks on rock slopes can be formed and existing discontinuities and planes of weaknesses can be enlarged. Hence, effect of weathering and excavation may result in losing strength of the rock materials and rock masses and decrease in stability of slopes.

There will be decrease in the stability of cut slopes due to disturbance of initial geometry, aperture widening of discontinuities as results of stress relief and excavation. In case delinquently designed cut slope encounter with changing stability, there will be possible failure of cut slope resulted in incidents (Ersöz and Topal, 2018a). In order to investigate stability of slopes, rock mass properties of cut slope are determined by the help of future excavation method and possible weathering degree (Hack et al., 2002). According to Tran et al. (2019), there should be provision for weathering based on completely weathered material values and residual soil before construction and excavation of cut slopes.

2.2.1. Slope Movement Classification

Slope movements may occur due to disturbance of slope material by weathering, excavation and seismic loads. Slope movements can be classified according to type of movement, type of material, failure area geometry, rate of movement, resulting deposits, causes of movement, state of activity, degree of displaced mass disruption, age, degree of development and relation of slide geometry to geologic structure

(Hungr et al., 2014). Table 2.1 shows the slope movement classification considering type of movement and type of material. Type of movement includes fall, topple, slides, and spreads, flows or slope deformation. Types of material considers whether failure material is rock, soil (debris or earth).

Table 2.1 *Slope Movement Classification (Hungr et al., 2014)*

Type of Movement	Rock	Soil
Fall	1. Rock/ice fall[a]	2. Boulder/debris/silt fall[a]
Topple	3. Rock block topple[a]	5. Gravel/sand/silt topple[a]
	4. Rock flexural topple	
Slide	6. Rock rotational slide	11. Clay/silt rotational slide
	7. Rock planar slide[a]	12. Clay/silt planar slide
	8. Rock wedge slide[a]	13. Gravel/sand/debris slide[a]
	9. Rock compound slide	14. Clay/silt compound slide
	10. Rock irregular slide[a]	
Spread	15. Rock slope spread	16. Sand/silt liquefaction spread[a]
		17. Sensitive clay spread[a]
Flow	18. Rock/ice avalanche[a]	19. Sand/silt/debris dry flow
		20. Sand/silt/debris flowslide[a]
		21. Sensitive clay flowslide[a]
		22. Debris flow[a]
		23. Mud flow[a]
		24. Debris flood
		25. Debris avalanche[a]
		26. Earthflow
		27. Peat flow
Slope deformation	28. Mountain slope deformation	30. Soil slope deformation
	29. Rock slope deformation	31. Soil creep
		32. Solifluction

[a] Movement types that usually reach extremely rapid velocities as defined by Cruden and Varnes (1996). The other landslide types are most often (but not always) extremely slow to very rapid

2.2.2. Types of Slope Failure in Rock

According to Craig (2004), slope failures are based on the interplay between two types of forces that are driving and resisting forces. Resisting forces deter downslope movement of slope material on the other hand driving forces affects slope stability negatively. Thus, slope failures occur when driving forces overcome resisting forces. The major cause of driving forces is gravity that affects not only the stability of natural but also excavated slopes. Planar, wedge, toppling and circular types of failures (Figure 2.1) are the rock slope failures categories based on discontinuities and orientation of slope (Hoek and Bray, 1981).

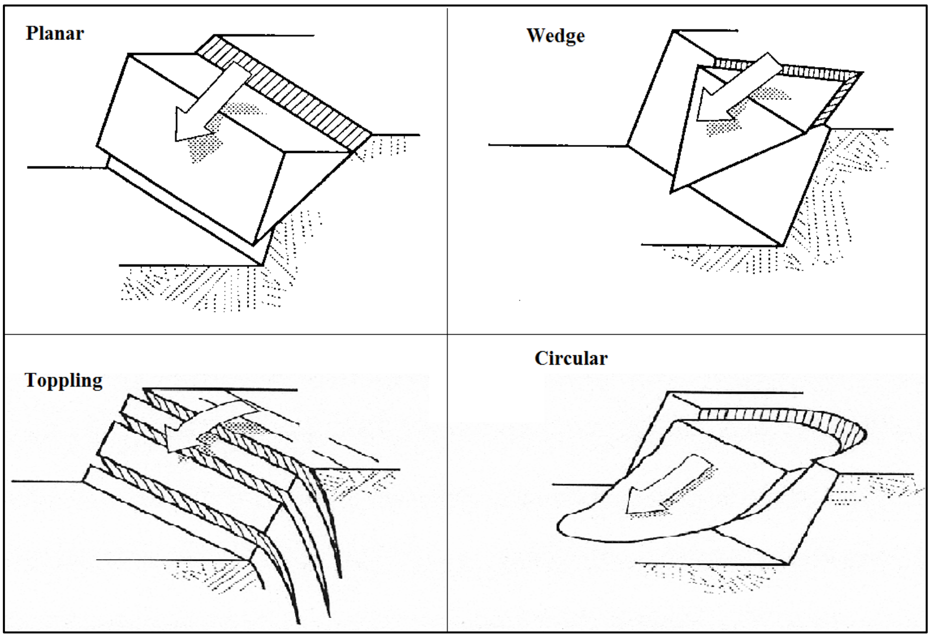


Figure 2.1 Failure Types of Rock Slopes (Hoek and Bray, 1981)

2.2.2.1. Planar Failure

Planar failure is a type of slope failure that occurs when the strike of structural discontinuity, such as joints, faults or bedding planes, is nearly parallel to the slope face. In addition, the potential discontinuity dips towards the slope with an angle smaller than slope face and greater than the friction angle of the slope (Kovari and Fritz, 1984; Tang et al., 2017). Tension cracks on the upper portion of the slopes are significant identifiers of planar failure. When shearing stresses becomes greater than resisting forces of the slopes, planar failure occurs and rock mass resting on the discontinuity surface slides down (Hocking, 1976; Hoek and Bray, 1981). Hoek and Bray (1981) clarified planar failure analysis just for slopes that have horizontal upper surface and vertical tension cracks. After Sharma (1995), the planar failure analysis accounted for inclined upper surfaces and tension cracks.

2.2.2.2. Wedge Failure

Wedge failure can occur due to two discontinuities that have a line of intersection dipping out of the slope face, and plunge of the intersection line must be steeper than the average friction angle of the two slide plane and gentler than the slope face dip (Hoek and Bray, 1981). A wedge failure mass slides through line of intersection, in other words slides on two planes or on one plane. If one of the wedge plane dip has more convenient orientation for sliding than line of intersection, sliding on single plane may occur.

2.2.2.3. Toppling Failure

Toppling failure can be distinguished by forward rotation of rock columns or a mass of soil out of a slope around an axis or a point lies below the gravity center of the displaced material. Toppling failure occurs due to gravity that exerted by upslope material weight from the displaced mass. Water and ice cracks in the slope mass and differential weathering, vibration, undercutting, excavation or stream erosion may cause toppling failure (Highland and Bobrowsky, 2008). According to Goodman (1989), thin bedded sediments, schists and slates that are steeply inclined into the face of slopes, can more easily come out with toppling failure.

2.2.2.4. Circular Failure

Circular failure, different than other failure types, occurs in highly weathered or highly jointed rocks with a very low intact strength (Hoek and Bray, 1981). Due to fractures being too many and closely spaced and randomly oriented, the least resistant path is automatically occurred in rock mass. When compared with the size of the slope, if individual particles in rock or soil mass are very small, circular failures may occur (Duncan et al., 2014).

2.2.3. Rock Strength

Rock material is polycrystalline solid or continuum that consists of natural mineral aggregates. Rock material properties are subject to constituent minerals' properties and their bonding type with each other. On the other part, rock mass is defined as a discontinuum that consists of rock material rendered by discontinuities (Deere and Miller, 1966).

Rock strength is the one of the most critical parameters considering the cut slope design process and it can be quantified by applying three stresses: compressive stress, tensile stress and shear stress. Compressive stress is application of two opposite forces on a rock specimen that causes specimen to deform to occupy a smaller volume. Correspondingly, compressive strength is the maximum compressive stress that the specimen under a gradually applied load can sustain without fracture. Shearing is result of equal and opposing forces acting along a plane of weakness that are fracture, fault or bedding plane inclined at an angle to the forces. For tensile strength, application of two forces are directed outwards in opposite action and it results in decreasing the volume of the specimen. In order to determine tensile strength of the rocks, direct pull, bending and Brazillian tests can be applied as laboratory tests. Besides, point load tests can be used indirectly to obtain tensile strength (Pariseu, 2012) and to obtain compressive strength with conversion (Gangopadhyay, 2013). With uniaxial compression test by taking cylindrical specimen of intact rock, uniaxial compressive strength can be determined (Hudson and Harrison, 2000). Determination of rock mass properties can be obtained by measuring or estimating directly or using both intact rock and discontinuity properties (Hudson and Harrison, 2000). According to Bieniawski (1989), several types of rock mass classifications can be done by considering intact rock and discontinuity data.

2.2.3.1. Shear Strength Parameters Used in Stability of Rock Slopes

According to Goodman (1989), for the cut slopes consisting of weak, soil-like rocks shear failure is very probable. As given below, shear strength of a material is represented by the help of Mohr-Coulomb equation.

$$\tau = c + \sigma \tan \Phi$$

where c=cohesion, σ=normal stress, and Φ=internal friction angle. Due to shearing off the most irregularities, the relationship above is applicable for high normal stress values as stated by Barton (1976).

Different from the first equation, for irregular rock surfaces, at low normal stress conditions, alternative equation is developed (Patton, 1966; Barton, 1976).

$$\tau = c + \sigma \tan (\Phi + i)$$

where i is the average deviation angle of particle displacements from the applied shear stress direction.

If the discontinuities of rocks are filled with weathered or decomposed materials or small rock fragments, shear strength will be lower than the rock mass itself. Because intact rock surfaces are not touching each other in this situation, and rock mass will have the properties of infill material (Indraratna et al., 2008).

Otherwise, in case of discontinuities being planar and unfilled, cohesion can be counted as zero as in the below equation (Barton, 1976).

$$\tau = \sigma \tan [\Phi + JRC \log (JCS/\sigma)]$$

where JRC is joint roughness coefficient, and JCS is joint wall compressive strength.

Duncan et al. (2014) has noted that the undisturbed peak strength is the strength of undisturbed test specimens from the field. The residual values can be acquired if undisturbed material is sheared and the peak value has been passed. This residual value can be used for back calculation, in case requirement of slope redesign (Skempton, 1985).

2.2.4. Weathering

In the literature many geologists have defined the issue of weathering differently from different perspectives. According to Dearman (1974) and Fookes et al. (1971), weathering is the alteration process of rock that occurs under the direct influence of hydrosphere and the atmosphere at or near the earth surface. Similarly, Ollier (1991) states that water and air are the effects of alteration and break down of rocks. Hack (1998) described weathering as chemical and physical change of rock mass and rock material under the effect of hydrosphere and atmosphere. Price (1995) defined weathering as ‘‘the irreversible response of soil and rock materials and masses to their natural or artificial exposure to the near-surface geomorphologic or engineering environment.’’

The controlling parameters of weathering in artificial slopes are classified into three categories which are internal, external and geotechnical (Huisman, 2006). Internal control parameters of weathering are soil or rock mass or material properties which are material composition, permeability and discontinuities. External control parameters of weathering are topography, climate and weathering related to environment. Geotechnical control parameters of weathering are slope height, slope angle, measures of drainage and excavation method. According to Fookes et al. (1971) and Hack (1998), physical and chemical weathering are two main processes of weathering.

Weathering both physical and chemical has an effect of degradation of undisturbed rock, size diminishing, strength decreasing of undisturbed rock blocks, turning of incoming fractures to mechanical discontinuities, shear strength decreasing of discontinuities, and mostly decomposing of the rock mass into soil (Tating et al., 2019). Product of weathering process in moderately or highly weathered rock masses can be soil materials in the discontinuity of rocks or residual soil or completely weathered rock mass (Fookes, 1997; Price et al., 2009; Hencher, 2015). All of the undisturbed rock can be altered into mostly clay minerals in residual soil and completely weathered material (Tran et al., 2019).

2.2.4.1. Weathering Types

Weathering is distinguished in two categories; physical (mechanical) weathering and chemical weathering. Generally, in most weathering processes, both physical and chemical weathering can be observed at the same time. Mechanical weathering occurs near earth surface. On the other hand, chemical weathering can have affect through the depths of tens or hundreds of meters below the earth surface (Price, 1995). According to Dearman (1974), less important weathering type is biological weathering which is a combination of disintegration and decomposition induced by bio-physical and bio-chemical agencies.

Physical (mechanical) weathering is fragmentation of rocks into small pieces without losing original properties. Result of this process is termed as disintegration of rock materials (Cabria, 2015). According to Fookes et al. (1988) and Hack (1998), physical weathering usually occurs due to temperature and pressure changes, wetting and drying, freeze and thaw cycles, shrinkage of minerals and differential expansion of rock mass. Besides, excavation with pressure release due to mass losing can be resulted in disintegration of rock material (Huisman et al., 2011).

Chemical weathering is another main process of weathering, formation of secondary minerals after decomposition of minerals (Hack, 1998). Chemical weathering often results in forming clay minerals, while some minerals survive and remain unchanged. Discoloration of the rock material demonstrates the early stages of chemical weathering (ANON, 1977). The process of chemical weathering occurs at wet and hot climatic regime with a high degree of probability (Saunders and Fookes, 1970). According to Tating et al. (2019), chemical weathering can be resulted in rock strength increasing in some instances, decreasing of mechanical discontinuities and increasing of shear strength by means of the reverse effect of cementation in specific grades of weathering process.

2.2.4.2. Classification of Weathering

Purpose of rock mass classification is "to provide short-hand descriptions for zones of rock of particular qualities to which can be assigned engineering characteristics within a single project" ANON (1995). Many researchers or standards (Moye, 1955; Dearman, 1976; Stapledon, 1976; ANON, 1977; BS5930, 1981) have commented on classification of weathering. Similarities can be seen on each classification systems, grades of weathering are characterized by discoloration, decomposition and disintegration grades. The general schemes of each classification are based on terms, descriptions and grades (or degree) representing fresh to residual soil by symbols of I to VI, respectively. The most commonly used weathering classification scheme is the BS5930:1981 (Table 2.2). In this classification, grade I is divided into IA and IB in order to show difference of rock material discoloration of faintly weathered rock against fresh rock.

Table 2.2 *Grades of Rock Mass Weathering/Alteration (BSI, 1981)*

Term	**Description**	**Grade**
Fresh	No visible sign of rock material weathering	IA
Faintly weathered	Discoloration on major discontinuity surfaces	IB
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker than in its fresh condition	II
Moderately weathered	Less than half of rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as core stones	III
Highly weathered	More than half of rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as core stones	IV
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure still largely intact	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported	VI

2.2.4.3. Weathering Effects on Strength of the Rocks

With the effect of weathering, intact rock and also discontinuities are influenced. In other words, whole rock mass is exposed to weathering effects (Hack, 1998). When cut slope materials undergo weathering processes and stress relief, degradation of engineering properties of rocks may take place (Huisman et al., 2011; Tating et al., 2013; Vlastelica et al., 2016; Ersoz and Topal, 2018b). Rock material quality decreases by weathering effects. Bonding of grains are disrupted hence micro fractures and new minerals are created (Gupta and Rao, 2000). Tensile strength, compressive strength, and to some extent elastic modulus are highly affected by weathering

(Heidari et al., 2013). During weathering, some index properties of rocks such as dry density, void ratio, clay content and sonic velocity may decrease whereas the others like water absorption and effective porosity may increase (Ceryan, 2007). After reaching certain weathering stage of the rocks, all these changes occur, and strength of the rock starts to decrease.

According to Hack and Price (1997), weathering modifies discontinuities, new cracks can be formed in intact rocks and already existing cracks can be opened after stress relief and discontinuity wall and infill materials are weakened by weathering. Huisman (2006) states that penetration depth of weathering is an important factor for discontinuities, the shear strength decreases when it passes the discontinuity roughness (Huisman, 2006).

2.2.4.4. Weathering in Engineering Time

Weathering degrees of natural slopes and their geotechnical characteristics, deterioration of soil or rock mass generally are considered on geologic scale, in time span as thousands of years (Utili, 2004). Weathering forces can affect rock durability and rock strength may decrease in ten years of engineering timescale (Fookes et al., 1988). The engineering time span for weathering is considered as tens of years in this study.

All engineering structures which involve natural materials are affected by time-related rock or soil degradation, but the most destructive effect is on man-made slopes. According to Huisman (2006), geotechnical properties of rocks can be seriously affected by degradation which decreases mass strength and results in decreasing of slope stability in engineering timescales. Oxidation-reduction and solution are the two important chemical weathering processes within the engineering timescale. Physical weathering and load imposing have the most disruptive effects for rock mass in engineering time (Fookes et al., 1988). Weathering process and slope material degradation induce erosion and decrease of slope stability in progress of time (Tran et al., 2019)

Primary reason for failure during the engineering lifetime of cut slopes is weathering of slope materials (Hencher and McNicholl, 1995; Hack and Price, 1997; Hack, 1998; Huisman et al., 2011; Tating et al., 2013; Viles, 2013; Hencher, 2015). Huisman (2006) stated that deterioration for the cut slopes may be very rapid or very slow, some road cuts may face with instability problems due to weathering during construction. On the other side, some road cuts may preserve their stability state throughout the centuries with no significant loss of stability.

2.2.4.5. Weathering Depth and Differential Weathering of Rock Masses

Weathering depths appeared at the slope surfaces can be determined within the intent of finding out mechanism of failure of the road cuts. The weathering depths of rock mass can be determined by field observations, visual estimations by taking into account of weathering descriptions of rocks. Additionally, in-situ test such as Schmidt hammer test can be used in determining weathering depths of rock mass. Starting from disturbed zone of rock mass, Schmidt hammer values increase and become stable where the depth of undisturbed zone begins. Surficial degradation that occurred at disturbed zones can be observed during field works and also in the analysis of slope stability. According to Ersöz and Topal (2018a and b), if weathering depth around 1-2 m is formed at the cut slopes, there may be threats for highways due to increasing of degradation and surface failure problems.

As stated by Ploessel (1982), differential weathering occurs due to differences in weathering resistance and susceptibility of varied rock types that result in different weathering depths of various rock types. The result of differential weathering is uneven surfaces of rock mass that is especially distinct in tilted sequences of sedimentary rocks (Byrne, 1963; Pipkin and Ploessel, 1973; Ploessel, 1973). Differential weathering can result in stability problems of cut slopes by the reason of faster deterioration of relatively weaker parts of the rock mass and weathering degrees vary between rock types (Sestanovic et al., 1994). Hereby, engineering structures can be seriously affected by differential weathering (Hoek et al., 1998; Arbanas et al., 2007). Differential weathering may result in undercutting of relatively stronger rocks. Stability of rocks may decrease with the undercutting effects, and rocks blocks tend to fail on certain geometries (Ersöz, 2017).

Differential weathering is very likely observable for flysch-type cut slopes. In the study area of this thesis, there are flysch-like deposits that are sedimentary rock alternations associated with orogenesis (Pettinga 1987). It can be observed that relatively stronger rocks in flysch type deposits are generally slightly weathered, however; weaker rocks are moderately or highly weathered. Due to heterogeneity and differential weathering of rock mass, tectonically disturbed flysch-like deposits are critical for rock slope stability (Hoek and Marinos, 2000; Marinos et al., 2004; Borgatti et al., 2006, Arbanas et al., 2008; Marinos et al., 2010; Arbanas et al., 2014; Marinos et al., 2015).

2.2.5. Excavation

Excavation of any type has an effect on diminishing rock mass strength because of stress relaxation by load decreasing on the rock. Expansion of the rock mass can occur after excavation which leads to increase in porosity and permeability because of decreasing contact strength among particles (Wetzel and Einsele, 1991). Due to effects of fracture creating, enlarging of existing discontinuities, turning incipient fractures into mechanical discontinuities, excavation method of cut slopes have a main effect on rock mass (Hack et al., 2003; Laubscher and Jakubec, 2001; Ersoz and Topal, 2018b). Excavation of cut slopes mostly make rock mass more susceptible to impacts of weathering by virtue of increasing the possibility of water, and air infiltration and percolation through the rock mass (Tran et al., 2019). Thus, this situation can cause instabilities of road-cuts.

As stated by Hack and Price (1997), effects of stress relief which are in interaction with weathering impacts and the stress relief effects after excavation of cut slopes cannot be differentiated from weathering impacts.

While using Geological Strength Index (GSI) (Hoek, 1994) for rock mass, it is important to consider disturbance/damage factor (D) for excavation of road-cuts. Disturbance/damage factor depends upon excavation types as blasting (good blasting/poor blasting), mechanical excavation, natural/handmade and varies from 0 for undisturbed rock mass to 1 for very disturbed rock mass (Hoek, 2002).

CHAPTER 3

GEOLOGY

3.1. Regional Geology

The study area of this thesis is located on Pontides tectonic unit that is one of the main tectonic unit of Turkey. Other two main units are the Anatolides-Taurides, and Arabian Platform (Ketin, 1966). Due to subduction zone that forms south of Pontides, the Pontides show characteristics of Laurussian continent and has a lot of similarities with Balkans and Caucasus tectonic units (Okay, 2008). Because of having different geological evolutions, Pontides are divided into three different sub-unit terranes called Sakarya, Istanbul and Strandja terranes (Okay, 2008). The study area is located nearly at the middle of the Istanbul terrane (Figure 3.1).

The study area is at fore-arc part of the Intra-Pontide suture zone which is the mark of Intra-Pontide Ocean. Ordovician to Carboniferous aged sedimentary units and Pan-African crystalline basement cover large part of the area as can be seen in Figure 3.1. According to Ustaömer et al. (2005), Pan-African crystalline basement is comprised of granitoids, amphibolites, gneisses, metavolcanic rocks and metaophiolite which are Precambrian (Cadomian) aged. These basement units are overlained by Ordovician-Carboniferous aged sedimentary units (Dean et al., 2000)

According to Göncüoğlu (2010), Visean aged Middle Devonian to Lowermost Carboniferous slope-type and flysch-type sediments conformably overlie the Paleozoic succession at the Istanbul terrane. In the Zonguldak area shelf-type carbonates, and non-marine, coal bearing Carboniferous units are formed The Middle Devonian and Early Carboniferous succession. In Istanbul terrane, Cretaceous flysch-type sediments generate the post-Triassic cover. The east-west trending clastics and carbonates with volcanic intercalations represent the Early Tertiary deposits in the Istanbul terrane.

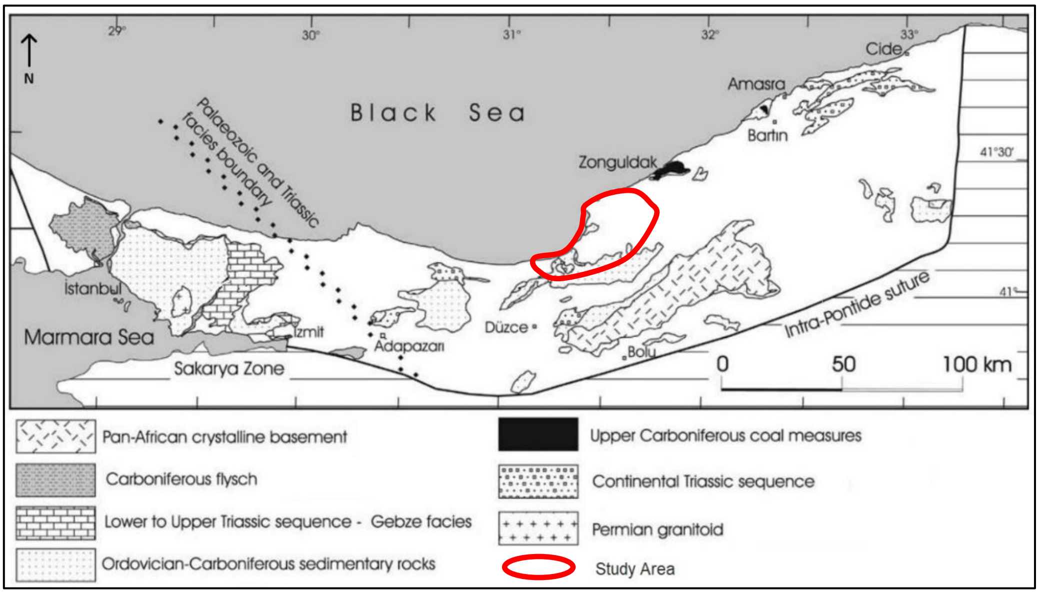


Figure 3.1. The map showing study area location in the Istanbul terrane (Modified from Okay (2008))

3.2. Site Geology

The geological maps were retrieved and modified from MTA 1/100 000 scaled geological maps (MTA, 2002a; MTA, 2002b; MTA, 2002c; MTA, 2002d) of Turkey (Figures 3.2 and 3.3). In accordance with studies on rock types in the field, 6 different geological formations are observed. They are Çaycuma, Karabük, Akveren, Kilimli, Ulus and Çakraz formations from younger to older at the study area.

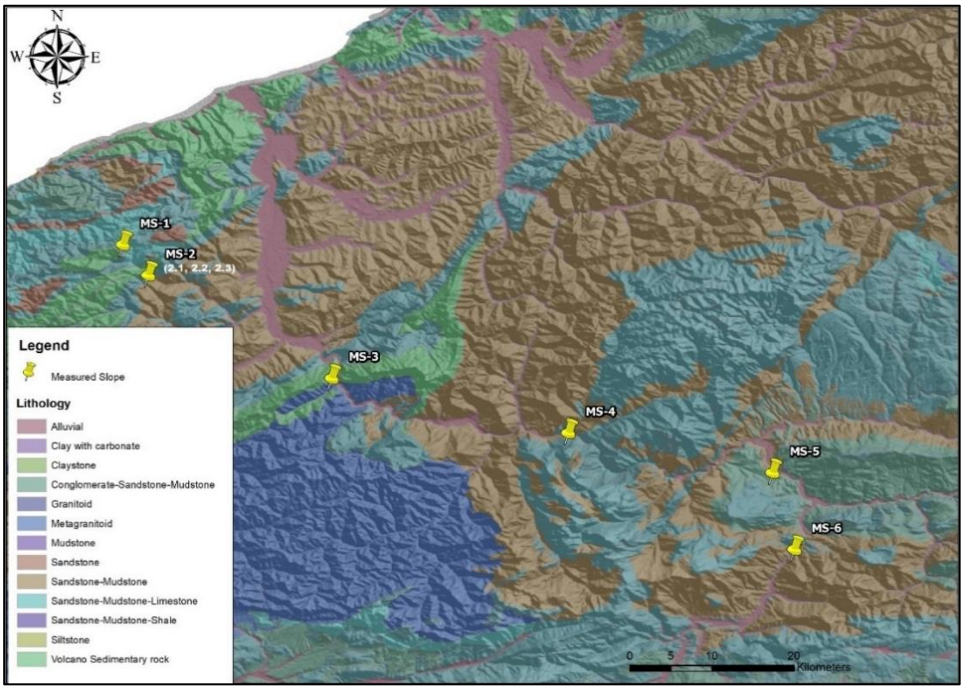


Figure 3.2. The map showing geologic units and studied road cuts between MS-1 and MS-6 (Modified from MTA (2002a; 2002b; 2002c; 2002d))

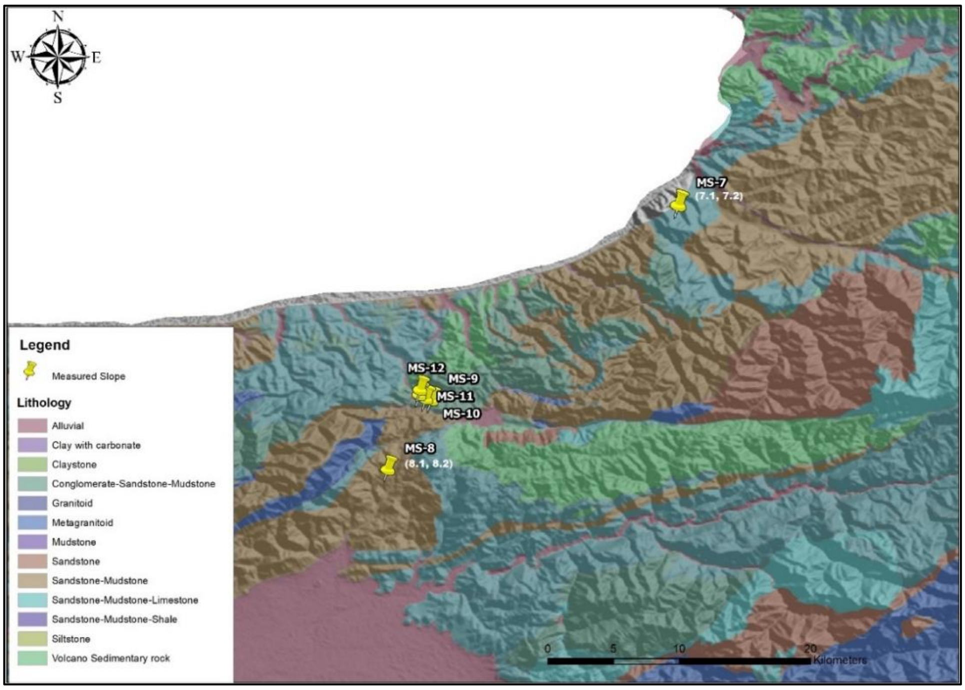


Figure 3.3. The map showing geologic units and studied road cuts between MS-7.1 and MS-12 (Modified from MTA (2002a; 2002b; 2002c; 2002d))

3.2.1. Çaycuma Formation

Çaycuma formation is extending through northeast and southwest of the study area and consists of typically siliciclastic turbiditic deposits consisting of sandstone, siltstone, and claystone alternation, and pyroclastic or volcanogenic deposits as agglomerate, tuff, tuffite that are located at the south of Devrek Basin (Siyako et al., 1980). Sandstones of the Çaycuma formation mostly contain carbonate cemented volcanic materials. According to İsmailoğlu et al. (1999) the Çaycuma formation is composed of mudstone, claystone, sandstone alternation that shows flysch characteristics and mapped by Akartuna (1953) as flysch. Suzen (2002) stated that the Çaycuma formation is continuation of the cover units of the Bolu Massif and main lithologies of the formation are alternation of turbiditic sandstone and siltstone, marl with gypsum intercalations, mudstone, and calcareous mudstone. The limestones and siltstones of the Çaycuma formation are described as fine to medium grained, gray and light greenish colored. On the other side, the sandstones are characterized by thin to medium bedded, light green and yellowish colored. Thickness of the Çaycuma formation is approximately 1200 meters and it overlays the Akveren formation which is observed in the study area (MTA, 2002a). The age of the formation is indicated to be Middle-Lower Eocene (Yergök et al., 1987)

The Çaycuma formation is observed in the study area at Stops MS-8.1 and MS-8.2 (Figure 3.3) as gray-brownish, slightly to moderately weathered sandstone.

3.2.2. Karabük Formation

Karabük formation can be observed near Karabük and Eflani region (Tüysüz et al., 2004). The formation consists of uncertainly layered greenish gray gypsum fragmented marl, sandstone and marl alternation, carbonated sandstone, mudstone and conglomerates. The sandstones of this formation are described as gray-green colored, carbonate cemented, round grained. Generally, this formation represents a complex of stream-delta that is shallowing and coarsening upwards. Marine-deltaic deposits and overlaying fluvial deposits are observed at west yet, red colored fluvial deposits are dominating at east. The thickness of this formation is approximately 350-400 meters; however, towards Eflani region the thickness increases and reaches up to 2000 meters (Tüysüz et al., 2004). The age of the Karabük formation is Early-Late Eocene as reported by Saner et al. (1979) and Yergök et al. (1987)

The Karabük formation is observed at Stop MS-5 (Figure 3.2) and according to field studies general rock type is determined as marl at the studied slope, which is highly weathered, gray colored, locally laminated and thick bedded.

3.2.3. Akveren Formation

Akveren formation comprised of clayey limestone, marl, carbonated mudstone and calciturbite (Akyol et al., 1974). As reported by Koralay (2009), the Akveren formation consists of sandstone, sandy limestone and marl. In addition, Kaya et al. (1986) states that the formation contains tuff, sandstone, claystone, clayey limestone, marl, calcareous mudstone as alternation. Limestone, sandstone, shale, calcarenite, and conglomerate can be considered as flysch deposits. At the bottom of the formation, sandy limestones are seen and to the upwards alternation of claystone-siltstone and clayey limestone-marl can be observed (MTA, 2002c). According to Akyol et al. (1974), the thickness of formation is approximately 400 meters around Cide-Kurucaşile. Besides, Akman (1992) stated that the thickness of this formation is approximately 600 meters near Doğaşı-Kayadiniçavuş. As stated by Ketin and Gümüş (1963) and Tüysüz et al. (1997), age of the Akveren formation is Maastrichtian, by Akman (1992), Campanian-Paleocene, and by Gedik and Korkmaz (1984) the age of unit is Maastrichtian-Paleocene.

The Akveren formation can be observed in the study area at Stops MS-2.1, MS-2.2, MS-2.3, MS-3, MS-7.1, and MS-7.2 (Figures 3.2 and 3.3) as slightly to highly weathered brown-greenish gray colored mudstone and white-greenish gray colored marl alternation and moderately weathered, white-yellowish colored limestone.

3.2.4. Kilimli Formation

Kilimli formation is observed at Kilimli in confined area and around Körpeoğlu region and in between Amasra and Cide in an extensive area (Yergök et al., 1987; Akman, 1992; Tüysüz et al., 1997). According to Saner et al. (1980), the Kilimli formation is composed of silt and sandstone containing uncertainly layered, soil like gray-greenish colored marl. Sand content increases towards upwards of the formation. As stated by Siyako et al. (1980), thickness of the formation is between 0 and 400 meters, and by Yergök et al. (1987) the thickness is maximum 700 meters. The Kilimli formation that is observed in the study area is Lower Cretaceous aged according to Siyako et al. (1980).

Dark gray colored mudstones and yellow colored limestones are moderately weathered in this formation which is observed only at Stop MS-1 in the study area (Figure 3.2).

3.2.5. Ulus Formation

Ulus formation is located at extensive area of Ulus basin from Sünnice at west and Azdavay at east (Tüysüz et al., 2004). The Ulus formation begins with the interlocation of turbiditic sandstone intercalations in the marl at the south of the Cide-Kuruşile line. As these contributions gradually increase, it becomes a thin-medium-thick layered homogeneous sandstone-shale intercalation. This formation starts with fan-like sediments at the bottom and passes into turbiditic sandstone-shale intercalations. These fan deposits are composed of light greenish-mottled conglomerates, sandstones and claystones which are approximately 50 meters thick.

The sections overlying this partly clastic sequence are dominated by sandstone intercalated claystone-siltstone stack or claystone-sandstone stack with higher claystone content. In the upper parts of the formation, it can be observed that the sandstone layers are thicker and more abundant. At the upper levels of the formation, there are red pelagic mudstones and radiolarian cherts towards Azdavay region. According to Tüysüz et al. (2000), a complex interfingered with volcanic rocks is observed at the eastern parts of the Ulus Basin. Thickness of the Ulus formation is not known certainly yet. Saner et al. (1979) mentioned that the thickness of the unit could be presumably 3000 meters. As stated by Saner et al. (1979), Siyako et al. (1980), Aydın et al. (1987), and Yergök et al. (1987), age of the Ulus formation is Early-Late Cretaceous.

The Ulus formation can be observed at MS-4, MS-6 (Figure 3.2) in the study area. The rock types are determined as highly weathered, dark gray colored marl, slightly to highly weathered dark gray colored mudstone and yellow-brownish slightly weathered sandstone.

3.2.6. Çakraz Formation

As reported by Tüysüz et al. (2004), Çakraz formation is totally composed of terrestrial deposits. Main lithologies of the formation are terrestrial sandstone and mudstone. At the lower portions of the Çakraz formation, conglomerates can be seen. The conglomerates that are located at the bottom of the formation are reddish, motley, round grained and poorly sorted. At the upper portions, alternations of sandstone, mudstone, and claystone are observed, however conglomerates can rarely be seen. The formation is easily recognized due to its characteristic reddish appearance while sandstones are white, and mudstones are greenish colored. Turning the color of the units to red towards the top, layers become more regular, gradual decreasing of the channel structures, rare occurrence of the symmetrical wave traces are the sign of the transition from the irregular braided stream sediments to the more regular meandering stream-flood plain sediments. The age of the formation is Permian-Triassic (MTA, 2002d).

The Çakraz formation can be observed at Stops MS-9, MS-10, MS-11, and MS-12 (Figure 3.3) in the study area. The main rock types are moderately weathered yellowish-light brown colored marl and moderately to highly weathered, yellowish /reddish/yellowish brown colored sandstone.

3.3. Tectonics and Seismicity

Due to the subduction of Neotethys, back arc structural components can be observed at the western parts of the investigation area. On the account of compressional regime, which started at Late Cretaceous continued until Middle Eocene, small scaled faults and NE-SW trending foldings are present at the western parts of the study area. Effects of the North Anatolian Fault can be observed as matching of small scaled faults and the main fault at the western part of the study area (MTA, 2002a).

Structural components which are observed at the eastern part of the investigation area occurred during and after Tertiary. At this part of the study area, structural components are E-W aligned. It is observed that the synclines in the basin are more prominent and the anticlines are narrower or narrowed by thrusts (MTA, 2002c). The movements of the folds, overturned positions and thrusts indicate the compressive forces existing in the N-S direction (Saner et al., 1980). Due to dominant N-W directional compression, the Ulus formation was pushed on the Tertiary sediments by an E-W directional thrust fault that is inclined towards south. Thus, Tertiary deposits were folded, toppled and imbricated to each other in the north direction. In the northern boundary of the Tertiary basin, the Tertiary rocks form a syncline overturned to the south due to the compression, especially around Karabük. After that, a NE-SW trending strike-slip fault occurred.

In the light of earthquake hazard map of Turkey of General Directorate of Disaster Affairs' (GDDA, 2018), the maximum horizontal ground acceleration (PGA) values of the studied road cuts are in the range of 0.217-0.401 g (Figure 3.4) (Table 3.1). 2 of the studied road cuts have PGA values that are equal or greater than 0.4 g and 6 of the road cuts have PGA values in between 0.3-0.4 g and 8 of the road cuts have PGA values in between 0.2-0.3 g.

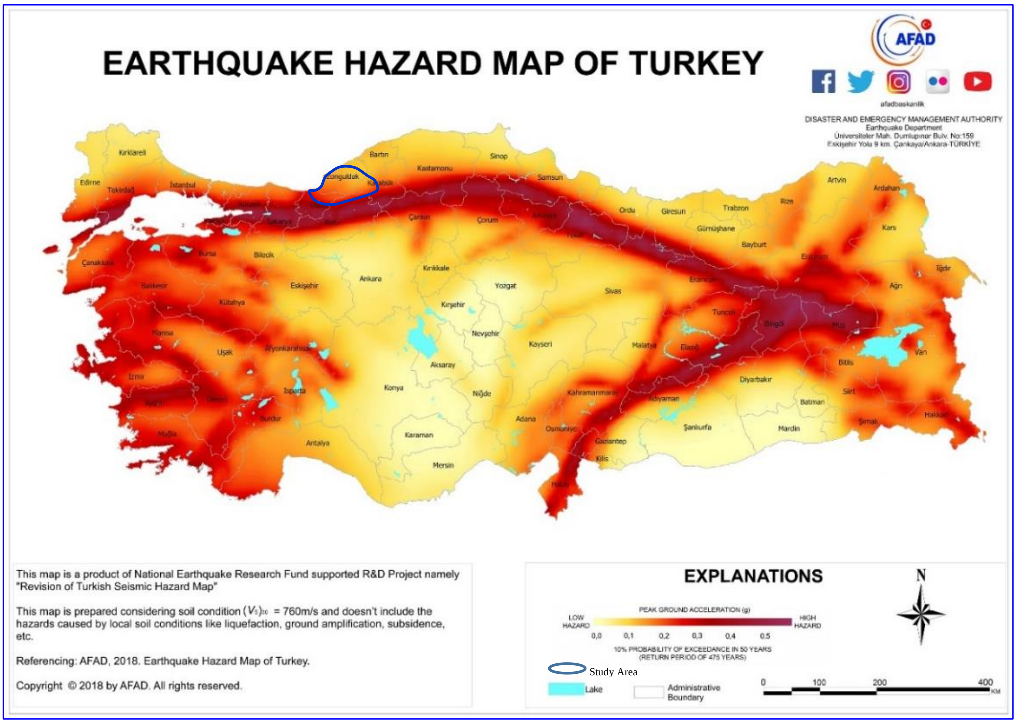


Figure 3.4. Earthquake zoning map of Turkey showing study area
(Modified from GDDA, 2018)

Table 3.1. *PGA values of the studied road cuts*

Road Cut	PGA (GDDA, 2018)	Road Cut	PGA (GDDA, 2018)
MS-1	0.217	**MS-7.1**	0.283
MS-2.1	0.217	**MS-7.2**	0.283
MS-2.2	0.217	**MS-8.1**	0.401
MS-2.3	0.217	**MS-8.2**	0.401
MS-3	0.221	**MS-9**	0.371
MS-4	0.277	**MS-10**	0.372
MS-5	0.322	**MS-11**	0.372
MS-6	0.399	**MS-12**	0.371

Peak ground acceleration (PGA) can be derived for specific locations by the help of deterministic approach of attenuation relationship. Acceleration values between periods of 0.01 and 10 seconds are determined from the attenuation relationship indicated by Idriss (2007) by the help of the formula below;

$$\ln [PGA(X)] = \alpha 1(X) + \alpha 2(X)M - [\beta 1(X) + \beta 2(X)M]*\ln (Rrup + 10) + \gamma(X)Rrup + \phi(X)F$$

The formula is chosen due to similarities between the fault types of the study area and the study of Idriss (2007). In the formula PGA(X) is peak ground acceleration in g's, $\alpha 1(X)$, $\alpha 2(X)$, $\beta 1(X)$, and $\beta 2(X)$ are regression parameters, M is moment magnitude, Rrup is the closest distance to rupture surface in km, $\gamma(X)$ is adjustment factor of distance, $\phi(X)$ faulting factor style, and F is source mechanism designator. Peak horizontal accelerations are implicitly derived from 0.01 second as introduced by Idriss (2007). Moment magnitude (M) is 7.4 for this study due to earthquake which has occurred in 1944 in Bolu-Gerede (Kondo et al., 2005). Closest distances to the rupture surfaces are given in Table 3.2. Source mechanism designator (F) has taken as 0 due to strike slip fault mechanism.

By the use of attenuation relationship (Idriss, 2007), peak ground acceleration values (PGA) are determined and shown in Table 3.2. The parameters used obtained from the regressions are presented in Table 3.3.

Table 3.2. *Distances of road-cuts to NAFZ and PGA values (Idriss, 2007)*

Road Cut	**Distance to fault-NAFZ (km)**	**PGA (Idriss, 2007 NGA)**	**Road Cut**	**Distance to fault-NAFZ (km)**	**PGA (Idriss, 2007 NGA)**
MS-1	71	0.116	MS-7.1	59	0.141
MS-2.1	67	0.124	MS-7.2	59	0.141
MS-2.2	67	0.124	MS-8.1	43	0.195
MS-2.3	67	0.124	MS-8.2	43	0.195
MS-3	51	0.164	MS-9	47	0.179
MS-4	41	0.205	MS-10	47	0.179
MS-5	32	0.256	MS-11	49	0.172
MS-6	22	0.363	MS-12	49	0.172

Table 3.3. *The parameters for Moment Magnitude greater than or equal to 6.75 (Idriss, 2007)*

T= 0,01 sec (i.e. PGA)						
α_1(T)	α_2(T)	β_1(T)	β_2(T)	γ(T)	ϕ(T)	SE**
5,632	-0,4104	2,9832	-0,2339	0,00047	0,12	0,46

In reference to these results, it can be said that by the reasons of considering specific fault types and distance between faults and each road cuts, PGA values that are derived from relationship of Idriss (2007) are expected to give more precise results in compassion with GDDA (2018).

CHAPTER 4

ENGINEERING GEOLOGICAL PROPERTIES OF ROCKS

16 road-cuts were investigated that are composed of different rock types. Starting from field works which are field observations, discontinuity survey and in-situ tests and besides laboratory tests, engineering geological properties of the studied road cuts were designated. In-situ and laboratory tests were performed on both weathered and fresh rocks that were collected during field works by the intent of designation of the material properties of each type. Sample collection were carried out manually in the field in order to perform laboratory tests. By the help of Schmidt rebound hardness test which is an in-situ test that were performed in the field (ISRM, 1981), relatively strong and weaker parts of the road-cuts were determined together with field observations for flysch deposits that were encountered at the great part of the study area. Almost at all studied road cuts, surficial degradation that is occurred as surficial failures at some road cuts resulting from weathering of the rock mass near the surface is seen. Differential weathering degrees and fractures of the rock mass result in surficial degradation that changes in depth. In addition to the tests that were related to analysis of slope stability, slake durability and methylene blue adsorption tests were performed by the intent of examining durability and clay content of the slope materials. Scanline surveys as field work of collecting discontinuity data, excavation method of each cut slope and weathering degree were used all together with intent to designate the properties of rock mass. For the cut slopes that are composed of the flysch deposits, rock mass properties were estimated by calculation with weighted percentages of each rock type.

4.1. Rock Material Properties

Rock material properties can be determined with the help of laboratory tests. In the studied 16 road-cuts, different rock types were observed such as limestone, sandstone, marl and mudstone. In situ and laboratory tests were conducted to designate rock material properties that were encountered in the study area.

4.1.1. Unit Weight and Effective Porosity

In accordance with ISRM (1981) effective porosity and unit weight that are directly associated with density, are determined by using method of saturation and buoyancy. Density is a critical factor in the analysis of slope stability for limit equilibrium methods. In order to get results of saturated unit weight of the rock samples that were collected from the study area, vacuum chamber was used.

Unit weights and effective porosities of the rock samples of each road-cuts for fresh and weathered rock types are shown in Table 4.1. Fresh marl specimens of Stop MS-2.3 could not be collected. Detailed porosity and unit weight results of all road-cuts are listed in Appendix A in detail.

Table 4.1. *Average porosity and unit weight values of rocks at studied cut slopes*

		Fresh			Weathered		
Road Cut	**Rock Type**	**Dry Unit Weight (kN/m3)**	**Saturated Unit Weight (kN/m3)**	**Porosity (%)**	**Dry Unit Weight (kN/m3)**	**Saturated Unit Weight (kN/m3)**	**Porosity (%)**
MS-1	Limestone	24.52	25.23	8.01	24.45	25.21	6.99
MS-2.1	Marl	24.28	25.11	8.50	24.21	24.87	6.74
MS-2.2	Marl	24.44	25.13	7.11	24.28	24.85	5.76
MS-2.3	Marl	21.65	23.64	20.28	-	-	-
MS-3	Marl	25.37	25.89	5.50	25.32	25.86	5.35
MS-4	Marl	25.76	26.15	5.11	25.53	26.03	3.97
MS-5	Marl	23.10	24.50	15.24	22.77	24.26	14.28
MS-6	Sandstone	24.31	25.55	12.66	24.17	25.24	10.92
	Mudstone	23.14	24.36	14.99	22.48	23.95	12.44
MS-7.1	Limestone	24.16	25.02	9.36	23.98	24.90	8.81
MS-7.2	Limestone	23.55	24.64	11.31	23.49	24.60	11.08
MS-8.1	Sandstone	25.17	25.70	7.36	24.62	25.34	5.41
MS-8.2	Sandstone	25.15	25.64	11.33	23.54	24.65	4.97
MS-9	Marl	20.78	22.32	20.70	20.20	22.23	15.76
	Sandstone	20.17	22.31	24.35	19.22	21.61	21.81
MS-10	Sandstone	21.95	23.25	15.24	21.65	23.14	13.30
MS-11	Sandstone	24.43	24.84	6.36	22.95	23.57	4.16
MS-12	Sandstone	19.44	21.72	28.04	18.12	20.87	23.23

4.1.2. Uniaxial Compressive Strength

Uniaxial compressive strength (UCS) test is one of the applied laboratory tests for this study in accordance with ISRM (1981), having the aim of making strength classification of rock materials that were gathered from studied road cuts. Uniaxial compressive strength is a rock material property which is one of the most essential factors for the stability of cut slopes. For limit equilibrium analysis and as well as for classifying the rock mass, UCS is directly used as an important strength parameter. A detailed intact rock strength scale that considers uniaxial compressive strength (UCS) tests is indicated in Table 4.2 (ANON, 1970). This rock strength classification system can be applied for all rock types. Table 4.3 demonstrates the average UCS values of both dry and saturated rock specimens from the selected cut slopes. The complete results of the UCS tests are attached in Appendix A in detail.

Table 4.2. *Intact rock strength scale considering UCS tests (ANON, 1970)*

Term	Strength (MPa)
Very weak	< 1.25
Weak	1.25 - 5
Moderately weak	5 – 12.5
Moderately strong	12.5 - 50
Strong	50 - 100
Very strong	100 - 200
Extremely strong	> 200

Table 4.3. *Average uniaxial compressive strength (UCS) values of both dry and saturated rock specimens from the selected cut slopes*

			UCS (MPa)	
Road Cut	**Rock Type**	**Sample Type**	**Dry**	**Saturated**
MS-1	Limestone	Fresh	-	39.42
MS-8.2	Sandstone	Fresh	28.04	23.97
MS-11	Sandstone	Weathered	19.43	15.58

In order to conduct UCS test in the laboratory for the studied cut slopes, more than 80 cubic rock specimens were arranged in the dimension of 50 mm^3. Before performing the test, nearly half of the cubic rock samples were eliminated by the reason of having cracks that could yield for wrong results. After elimination of unsuitable specimens, uniaxial compressive strength tests were conducted for 37 cubic rock specimens. By the reason of having heavily fractured and jointed structure and very weak to weak strength, uniaxial compressive strength test could not be applied for marl and mudstone. UCS tests could be applied only for limestone and sandstone cubic rock samples. The results of the UCS tests show that the tested limestone and sandstone rocks are moderately strong by using the intact rock strength scale (Tables 4.2 and 4.3).

4.1.3. Point Load Strength

With the purpose of determining the strength of rock materials, point load tests were conducted for the rock specimens that were gathered from the related studied cut slopes in accordance with the procedure of ISRM (1985). The test was carried out in the laboratory with manual point load device by loading hand pressure. Point load test results can be used indirectly to determine uniaxial compressive strength and uniaxial strength of the rocks (Bieniawski, 1975). It is possible to apply point load test on irregular samples (Topal, 2000). The specimens for point load test were arranged in accordance with the test procedure in desired sizes.

Sample sizes as width (W), and diameter or distance before the test (D) and for diameter or distance after the test (D’), and the failure load (P) were used to calculate the uncorrected point load strength (Is) with the help of the equation below;

$$Is = P \times (D')^2$$

After calculation of uncorrected point load strength (Is), corrected point load strength (Is(50)) can be calculated by the help of using factor of size correction (F) for irregular rock specimens. Related equations are shown below;

$$F = (D' / 50)^{0.45}$$

$$Is(50) = F \times Is$$

According to Topal (2000), in order to find the average Is (50) value (corrected point load strength) at least 10 valid tests should be carried out. The two for each lowest and the highest values are omitted, and the remaining values should be averaged. If sample number is less than 10, the highest and the lowest values are avoided, and average of the remaining values are counted.

The results of the point load tests are demonstrated in Table 4.4 as for fresh and weathered rock specimens in dry and saturated condition. Saturated conditions were generated with the use of vacuum chamber or with 1 day saturation. In this study fresh marl specimens could not be gathered from the field to apply point load test, due to its fractured structure and depth of the weathering zone that make impossible to reach the desired sized of the rock specimens. Apart from this, point load tests were performed on all other rock types as it should be with minimum 10 sample number.

In case of rock specimens being anisotropic, point load tests were carried out for both condition as normal (⊢) to the anisotropy plane and parallel (=) to the anisotropy plane. Both results for normal (⊢) and parallel (=) to the anisotropy planes are listed in Table 4.4 and the further detailed results of point load tests are shown in Appendix A.

Table 4.4. *Is(50) results for each cut slope.*

		Is(50) (MPa)				
		Fresh		Weathered		
Road Cut	**Rock Type**	**Dry**	**Saturated**	**Dry**	**Saturated**	
MS-1	Limestone	3.11	1.38	3.06	1.28	
MS-2.1	Marl	6.81	3.70	4.49	2.23	
MS-2.2	Marl	6.75	4.88	6.20	4.17	
MS-2.3	Marl	-	-	2.34	0.47	
MS-3	Marl	8.40	3.03	5.76	2.43	
MS-4	Marl	10.78	8.17	8.76	4.71	⊦
MS-4	Marl	3.33	3.04	2.22	1.80	=
MS-5	Marl	4.81	1.02	3.23	0.74	⊦
MS-5	Marl	1.35	0.10	0.68	0.07	=
MS-6	Mudstone	5.02	2.18	1.62	0.99	⊦
	Mudstone	2.29	0.86	1.04	0.37	=
	Sandstone	6.72	1.82	2.88	1.04	
MS-7.1	Limestone	8.23	3.05	6.23	2.30	
MS-7.2	Limestone	7.39	3.48	7.35	3.37	
MS-8.1	Sandstone	7.88	4.17	6.65	2.84	
MS-8.2	Sandstone	8.25	3.45	1.87	0.51	
MS-9	Marl	2.73	1.74	1.22	0.71	
	Sandstone	2.88	1.85	1.29	0.72	
MS-10	Sandstone	3.42	1.83	1.27	0.72	
MS-11	Sandstone	5.95	3.23	4.73	2.66	
MS-12	Sandstone	2.86	1.84	1.28	0.73	

As can be seen in the Table 4.4, point load strength of fresh specimens has higher values than weathered type of rock specimens. Likewise, point load strength indices of dry rock specimens are higher than saturated specimens.

K-values are appointed for the rocks in order to designate the uniaxial compressive strength (UCS) values by the correlation of UCS tests and point load test with the help of the below equation (Broch and Franklin, 1972; Bieniawski, 1975)

$$UCS = k * Is_{(50)}$$

However, uniaxial compressive strength test could not be applied for all rock types, in this study UCS tests was applied only for rock types of limestone and sandstone. K-value for limestone was determined as 18 and for sandstone k-value was determined as 10, in coherent with UCS test and point load tests. For the rock types of mudstone and marl, k-values are designated after literature survey. K-value is designated as 8 for marl according to Hawkins and Oliver (1986), and also for mudstone designated as 8 in accordance with the study of Azimian et al. (2013).

4.1.4. Schmidt Rebound Hardness

Schmidt rebound hammer test is conducted as an in-situ test for determining rock material hardness. For this study Schmidt rebound hardness test is applied in accordance with the procedure of ISRM (1981) with L-type Schmidt hammer.

According to the test procedure (ISRM, 1981), Schmidt rebound hammer test should be applied on the flat surfaces of the rock materials with no cracks around at least 6 cm. By holding the test hammer perpendicular to the surface of both fresh and weathered rock material, minimum 10 application should be performed. The measurements of Schmidt rebound hammer tests conducted for this study are listed in Table 4.5.

Table 4.5. *Schmidt hardness test values of the studied cut slopes*

Road Cut	Rock Type	Schmidt Value	
		Fresh	Weathered
MS-1	Limestone	36	20
	Mudstone	-	<10
MS-2.1	Marl	47	34
	Mudstone	-	<10
MS-2.2	Marl	41	39
	Mudstone	-	<10
MS-2.3	Marl	10	10
	Mudstone	<10	<10
MS-3	Marl	<10	<10
	Mudstone	<10	<10
MS-4	Marl	17	<10
	Mudstone	-	<10
MS-5	Marl	-	<10
MS-6	Sandstone	25	19
	Mudstone	<10	<10
MS-7.1	Limestone	39	27
MS-7.2	Limestone	51	20
MS-8.1	Sandstone	30	28
MS-8.2	Sandstone	40	31
MS-9	Marl	24	19
	Sandstone	32	<10
MS-10	Sandstone	46	31
MS-11	Sandstone	52	38
MS-12	Sandstone	24	17

The results of the Schmidt hammer tests are convertible to uniaxial compressive strength values. According to listed equations of different researchers (Table 4.6), conversions for different rock types were performed. For sandstone and limestone, equations of Deere and Miller (1966), O'Rourke (1989), Katz et al. (2000), Sachpazis (1990), Cargill and Shakoor (1990) and Yasar and Erdogan (2004), for marl equation of Gökçeoğlu (1996) and finally for mudstone equation of Kidybinski (1980) and Saptono et al. (2013) can be used for conversion of Schmidt rebound hardness values into uniaxial compressive strength (UCS).

Table 4.6. *Equations for the correlation of Schmidt hammer hardness and uniaxial compressive strength*

	Researcher	Equation
1	Deere and Miller (1966)	$\log \sigma_o(ult) = 0.00014\gamma N+3.16$
2	O'Rourke (1989)	$UCS = 702N-11040(psi)$
3	Katz et al., (2000)	$\ln (UCS) = 0.792 + 0.067N +/- 0.231$
4	Sachpazis (1990)	$N = 0.2329\ UCS+ 15.7244$
5	Cargill and Shakoor (1990)	$UCS = 4.3x10^2 (N\gamma) + 1.2$ (Sandstones)
		$UCS = 1.8x10^2 (N\gamma) + 2.9$ (Carbonates)
6	Gökçeoğlu (1996)	$UCS = 0.0001N^{3.2658}$
7	Yaşar and Erdoğan (2004)	$UCS = 4x10^{-6} N^{4.2917}$
8	Kidybinski (1980)	$UCS = 0.447exp^{(0.045(N+3.5))+\gamma}$
9	Saptono et al. (2013)	$UCS= 0.308\ N^{1.327}$

The converted Schmidt rebound hardness values into uniaxial compressive strength and the results of point load tests that were converted into UCS values considering related k-values are listed in Table 4.7. By taking into consideration of 9 different equations of different researchers, uniaxial strength values were calculated as can be seen in Table 4.7, and they are listed by equation numbers of Table 4.6. As can be seen in Table 4.7, converted UCS results from Schmidt hammer rebound tests mostly reveals exaggerated results regarding point load values (shown as PL). Mark of "*" is used for the negative results of converted UCS values that cannot be accepted.

Table 4.7. *Schmidt hammer rebound hardness values converted to UCS (MPa) in line with other studies*

				UCS (MPa)									
		Schmidt Value		1		2		3		4		5	
Road Cut	**Rock Type**	**Fresh**	**Weath.**	**F**	**W**	**F**	**W**	**F**	**W**	**F**	**W**	**F**	**W**
MS-1	Limestone	36	20	148.8	146.9	142.3	30.0	31.1	10.6	87.1	18.4	4.5	3.8
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-2.1	Marl	47	34	150.1	148.5	219.5	128.3	65.0	27.2	134.3	78.5	5.0	4.4
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-2.2	Marl	41	39	149.4	149.1	177.4	163.4	43.5	38.0	108.5	99.9	4.7	4.6
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	
MS-2.3	Marl	10	10	-	145.6	*	*	5.4	5.4	*	*	-	3.3
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	-	-
MS-3	Marl	<10	<10	-	-	-	-	-	-	-	-	-	-
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	-	-
MS-4	Marl	17	<10	146.6	-	8.9	-	8.7	-	5.5	-	3.7	-
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-5	Marl	-	<10	-	-	-	-	-	-	-	-	-	-
MS-6	Sandstone	25	19	147.5	146.7	65.1	23.0	14.9	9.9	39.8	14.1	3.9	3.2
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	-	-
MS-7.1	Limestone	39	27	149.1	147.6	163.4	79.1	38.0	17.0	99.9	48.4	4.6	4.1
MS-7.2	Limestone	51	20	150.4	146.8	247.6	30.0	85.0	10.6	151.5	18.4	5.1	3.8
MS-8.1	Sandstone	30	28	148.2	147.9	100.2	86.2	20.8	18.2	61.3	52.7	4.5	4.2
MS-8.2	Sandstone	40	31	149.4	148.1	170.4	107.2	40.7	22.2	104.2	65.6	5.6	4.4
MS-9	Marl	24	19	146.9	146.4	58.1	23.0	13.9	9.9	35.5	14.1	3.8	3.6
	Sandstone	32	<10	147.6	-	114.2	-	23.8	-	69.9	-	4.0	-
MS-10	Sandstone	46	31	149.4	147.8	212.5	107.2	60.8	22.2	130.0	65.6	5.6	4.1
MS-11	Sandstone	52	38	150.7	148.7	254.6	156.4	90.9	35.6	155.8	95.6	6.8	5.0
MS-12	Sandstone	24	17	146.8	146.0	58.1	8.9	13.9	8.7	35.5	5.5	3.2	2.6

Table 4.7. *Continued*

				UCS (MPa)									
		Schmidt Value		6		7		8		9		PL	
Road Cut	**Rock Type**	**Fresh**	**Weath.**	**F**	**W**	**F**	**W**	**F**	**W**	**F**	**W**	**F**	**W**
MS-1	Limestone	36	20	12.1	1.8	19.1	1.5	0.0	0.1	35.8	16.4	55.9	55.0
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-2.1	Marl	47	34	28.9	10.0	60.0	15.0	0.0	0.0	51.0	33.2	35.9	33.5
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-2.2	Marl	41	39	18.5	15.7	33.4	26.9	0.0	0.0	42.5	39.8	54.0	40.6
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-2.3	Marl	10	10	0.2	0.2	0.1	0.1	-	0.1	6.5	6.5	-	18.7
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	-	-
MS-3	Marl	<10	<10	-	-	-	-	-	-	-	-	67.2	46.0
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	-	-
MS-4	Marl	17	<10	1.0	-	0.8	-	0.1	-	13.2	-	24.3	17.8
	Mudstone	-	<10	-	-	-	-	-	-	-	-	-	-
MS-5	Marl	-	<10	-	-	-	-	-	-	-	-	24.7	13.0
MS-6	Sandstone	25	19	3.7	1.5	4.0	1.2	0.0	0.1	22.1	15.3	29.2	10.6
	Mudstone	<10	<10	-	-	-	-	-	-	-	-	60.5	19.9
MS-7.1	Limestone	39	27	15.7	4.7	26.9	5.6	0.0	0.0	39.8	24.4	148.2	86.2
MS-7.2	Limestone	51	20	37.7	1.8	85.2	1.5	0.0	0.1	56.8	16.4	133.1	132.4
MS-8.1	Sandstone	30	28	6.7	5.3	8.7	6.5	0.0	0.0	28.1	25.6	52.5	48.4
MS-8.2	Sandstone	40	31	17.1	7.4	30.0	10.1	0.0	0.0	41.2	29.3	55.0	18.7
MS-9	Marl	24	19	3.2	1.5	3.4	1.2	0.1	0.1	20.9	15.3	8.2	1.8
	Sandstone	32	<10	8.2	-	11.5	-	0.1	-	30.6	-	2.1	1.2
MS-10	Sandstone	46	31	26.9	7.4	54.7	10.1	0.0	0.0	49.5	29.3	28.5	12.7
MS-11	Sandstone	52	38	40.2	14.4	92.6	24.1	0.0	0.0	58.3	38.5	45.8	36.4
MS-12	Sandstone	24	17	3.2	1.0	3.4	0.8	0.1	0.1	20.9	13.2	7.3	5.6

By the help of the Schmidt hammer rebound test weathering depths of rock mass of the studied road cut were determined. Starting from disturbed zone of the rock mass, Schmidt hammer values increased and became stable where the depth of the undisturbed zone begins, thus; weathering degree of the rock mass were assigned.

4.1.5. Slake Durability Index

Durability is a term that indicates the weathering resistivity of the rocks and thus conserving initial size, shape and strength within time (Bell, 1993). As stated by to Topal and Doyuran (1997), it is possible to determine the durability of rocks with several ways such as wet-to-dry strength ratio, static durability index, rock durability index and slake durability index. In this study, slake durability test is conducted in compliance with the procedure of ISRM (1981) with the aim of assessing the durability of the studied rock types. According to the procedure slake durability test is applied as two wetting and drying cycles of each rock specimens that are nearly 500 g gathered from each studied cut slope, with drums rotation speed of 20 rpm and with 10 minutes test period. The index for two cycles is assessed as Id(2) by the help of the formula below;

$$Id(2) = (\ 2^{nd}C.W. / I.W.)x100$$

2^{nd} C.W. is weight of the sample after 2^{nd} cycle and I.W. is the initial weight of the sample before test. Remaining weights should be noted in order to calculate indices after each cycle. Remaining weight results after 1^{st} and 2^{nd} cycles can be categorized into degrees of durability as in the light of the classification system of Gamble (1971) (Table 4.8).

Table 4.8. *Slake durability classification (Gamble, 1971)*

Group Name	Id(1)	Id(2)
Very High Durability	>99	>98
High Durability	98-99	95-98
Medium High Durability	95-98	85-95
Medium Durability	85-95	60-85
Low Durability	60-85	30-60
Very Low Durability	<60	<30

The results of the slake durability tests are shown in Table 4.9. Detailed data of the tests are attached in Appendix A. “Type” data which were indicated in Table 4.9 is determined in keeping with ASTM D4644-87 (1998) by observing decomposition of the specimens.

Slake durability of the tested specimens are classified into the durability groups according to Gamble (1971) by considering Id(2) values, that are ranging between low durability to very high durability. It can be said that nearly half of the rock specimens have very high durability by considering two wetting-drying cycles. In detail; 47 % of the rock specimens can be classified in the group of very high durability, 26 % in high durability, 12 % in medium high durability, 9 % in medium durability, and 6 % in low durability.

The aim of the slake durability test is assessing the resistivity against weakening and dispersion of rock specimens with applied two wetting-drying cycles (ISRM, 1981). However, in order to get more precise results that would be consistent with the field observations, slake durability tests were performed as twenty cycles of wetting-drying in this study, thus; indices up to Id(20) were calculated. A graph showing the influence of the number of slaking cycles on slake-durability as slaking durability % retained versus number of slaking cycles is given in Figure 4.1. As can be seen in Figure 4.1, there is decrease in durability of some rock specimens that can be associated with different weathering degrees of the rocks due to porosity increasing, small scaled fractures and decreasing of the rock mass strength.

Table 4.9. *Results of the slake durability tests of the tested samples.*

Slope	C	Rock Type	Id(1)	Id(2)	Id(20)	Type	Durability
MS-1	F	Limestone	98.30	97.64	89.76	Type I	High
	W		98.64	97.84	88.38	Type II	High
MS-2.1	F	Marl	99.58	99.37	96.79	Type I	Very High
	W		99.43	99.20	95.98	Type I	Very High
MS-2.2	F	Marl	99.63	99.51	97.69	Type I	Very High
	W		99.56	99.37	97.60	Type I	Very High
MS-2.3	W	Marl	97.69	95.81	74.45	Type II	High
MS-3	F	Marl	99.56	99.25	96.05	Type I	Very High
	W		99.24	98.91	92.77	Type I	Very High
MS-4	F	Marl	99.16	98.84	95.11	Type I	Very High
	W		99.08	98.67	94.75	Type II	Very High
MS-5	F	Marl	97.04	94.72	77.47	Type II	Medium High
	W		95.07	91.82	69.55	Type II	Medium High
MS-6	F	Sandstone	98.45	97.59	89.88	Type I	High
	W		97.82	96.66	86.04	Type II	High
	W	Mudstone	98.56	97.73	90.00	Type II	High
MS-7.1	F	Limestone	99.44	99.24	96.62	Type I	Very High
	W		98.95	98.47	93.69	Type I	Very High
MS-7.2	F	Limestone	99.44	99.16	96.00	Type I	Very High
	W		99.20	98.87	95.10	Type I	Very High
MS-8.1	F	Sandstone	99.21	98.73	94.33	Type I	Very High
	W		98.75	98.10	92.33	Type I	Very High
MS-8.2	F	Sandstone	99.23	98.76	94.79	Type I	Very High
	W		91.30	85.57	41.55	Type II	Medium
MS-9	F	Marl	95.12	91.18	78.07	Type II	Medium High
	W		81.37	69.49	8.57	Type III	Medium
	F	Sandstone	65.88	52.05	10.96	Type III	Low
	W		73.84	58.73	8.08	Type III	Low
MS-10	F	Sandstone	98.94	98.37	92.64	Type I	High
	W		98.47	97.36	84.99	Type II	High
MS-11	F	Sandstone	99.09	98.53	93.98	Type I	Very High
	W		98.51	97.87	92.99	Type I	High
MS-12	F	Sandstone	95.92	92.35	53.35	Type II	Medium High
	W		91.03	84.71	41.68	Type III	Medium

*C: Condition of the rock, F: Fresh, W: Weathered

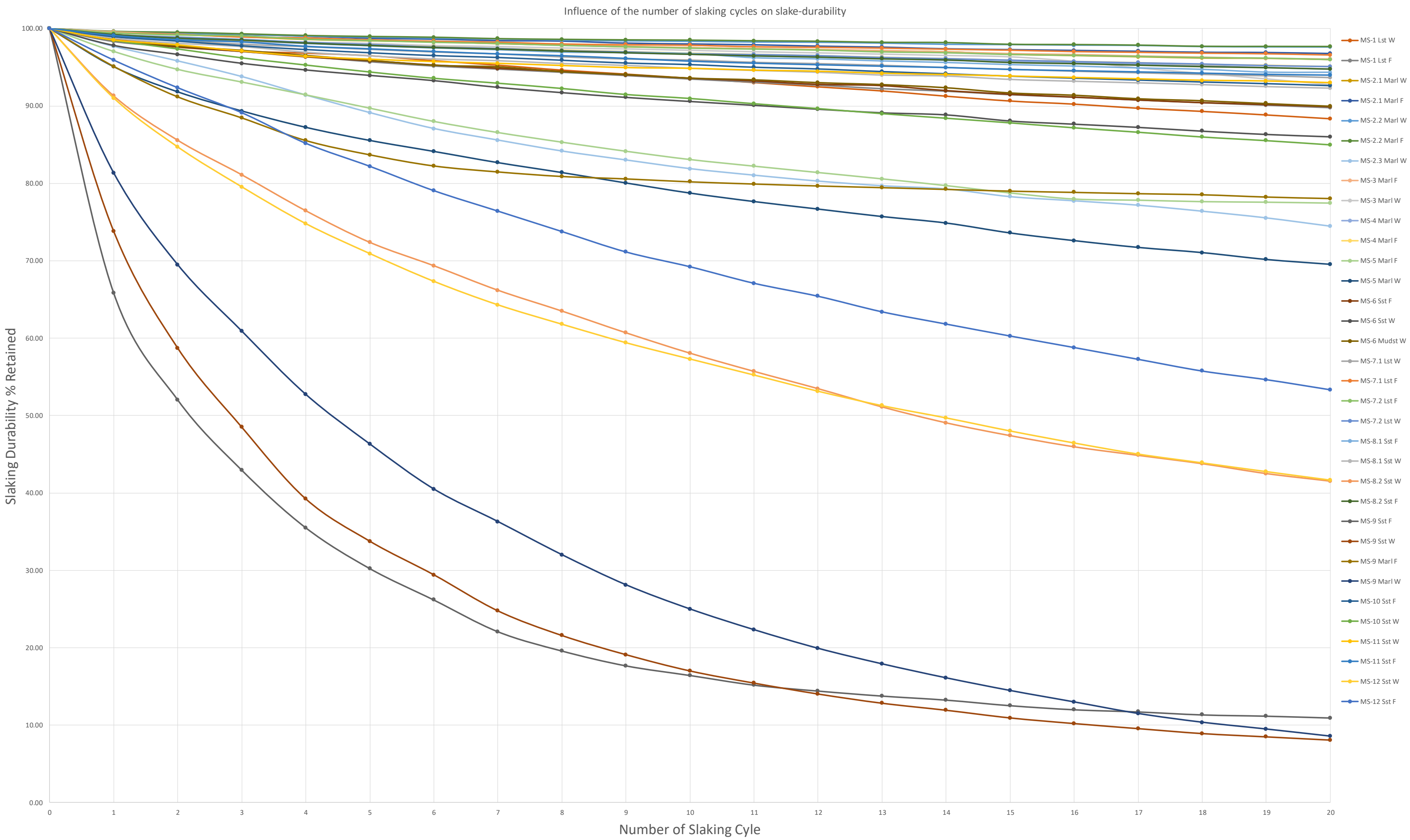


Figure 4.1. Influence of the number of slaking cycles on slake-durability of the tested samples.

4.1.6. Methylene Blue Adsorption

Methylene blue adsorption (MBA) test is applied as a laboratory test in accordance with the test procedure of AFNOR (1980) for this study with the aim of assessing clay content of rocks. The logic behind the test is on condition that high values of methylene adsorption points towards high swelling activity. In spite of this, lower values of absorption mostly indicates low swelling activities (Topal, 1996).

One of the two methods of methylene blue adsorption test namely the spot method is carried out for this study due to its being more practicable and timesaving in contrast with turbidimetric method as stated by Topal (1996). In order to apply the method used being simplified titration technique, specific amount of methylene blue concentration is instilled in mixture of ground sample and purified water. While adding methylene blue solution into ground rock sample and water mixture, the methylene blue is added to the surface of clay minerals by expelling the (+) ions of clay minerals. When all (+) ions of the clay minerals are replaced with methylene blue ions, maximum value of adsorption is reached. Cation exchange capacity (C.E.C.) and methylene blue adsorption (MBA) of the specimens are calculated with the adsorbed methylene blue solution amount.

Methylene blue adsorption test results are listed in Table 4.10 as MBA in g/100g and CEC in meq/100g for each studied cut slope, for both weathered and fresh rock specimens. The photos of methylene blue adsorption test are attached in Appendix A.

Table 4.10. *Methylene blue adsorption test results of the rocks specimens*

Stop No.	Rock Type	Condition	MBA g/100g	C.E.C. meq/100g	Stop No.	Rock Type	Condition	MBA g/100g	C.E.C. meq/100g
MS-1	Limestone	Fresh	0.93	2.1	**MS-6**	Sandstone	Fresh	1.60	3.6
		Weathered	0.93	2.1			Weathered	2.27	5.1
	Mudstone	Weathered	1.20	2.7		Mudstone	Weathered	2.00	4.5
MS-2.1	Marl	Fresh	1.73	3.9	**MS-7.1**	Limestone	Fresh	1.07	2.4
		Weathered	2.00	4.5			Weathered	1.07	2.4
	Mudstone	Weathered	3.20	7.2	**MS-7.2**	Limestone	Fresh	0.80	1.8
MS-2.2	Marl	Fresh	0.93	2.1			Weathered	0.93	2.1
		Weathered	1.20	2.7	**MS-8.1**	Sandstone	Fresh	0.93	2.1
	Mudstone	Weathered	3.60	8.1			Weathered	1.20	2.7
MS-2.3	Marl	Weathered	3.60	8.1	**MS-8.2**	Sandstone	Fresh	1.07	2.4
	Mudstone	Weathered	3.47	7.8			Weathered	1.73	3.9
MS-3	Marl	Fresh	1.33	3	**MS-9**	Sandstone	Fresh	0.93	2.1
		Weathered	1.60	3.6			Weathered	0.93	2.1
	Mudstone	Weathered	2.93	6.6		Marl	Fresh	0.67	1.5
MS-4	Marl	Fresh	0.67	1.5			Weathered	0.93	2.1
		Weathered	0.80	1.8	**MS-10**	Sandstone	Fresh	0.67	1.5
	Mudstone	Weathered	1.73	3.9			Weathered	0.67	1.5
MS-5	Marl	Fresh	1.60	3.6	**MS-11**	Sandstone	Fresh	0.67	1.5
		Weathered	1.73	3.9			Weathered	0.67	1.5
					MS-12	Sandstone	Fresh	0.67	1.5
							Weathered	1.07	2.4

4.2. Rock Mass Properties

Rock mass is different from rock material by referring discontinuities and weathering manner (Singh and Goel, 2011). Rock mass properties are lithological features of the rock mass that can be observed and measured in the field including discontinuities as faults, fractures and joints.

For this study, detailed scan line surveys were conducted in the field in order to examine rock mass properties that are discontinuity features, weathering condition and excavation condition of each studied road cut. Data collection tables showing details of scan line surveys are given in Appendix B and a representative data collection table were given in Table 4.11. In the scope of the scan line survey, orientation and condition of discontinuities that are roughness, infill material, persistence and aperture are examined in the field. Orientation and condition of discontinuities are important factors for failure mechanisms of road-cuts. Roughness of the discontinuities was designated in the light of the procedure of ISRM (1978), while determining roughness characteristics of the discontinuities in the field, a hand-sized profilometer was used. Additionally, infill of the discontinuities was designated by considering the material type and thickness. Weathering condition and method of excavation are two of the factors that are critical for rock materials. They can change the strength parameters of the disturbed material. For this study, weathering condition for each road cut and each rock type was assessed in the field. Differential weathering concept were considered for the rock types that are encountered in this study, especially for flysch type deposits. Method of excavation is another important factor for rock mass properties, as D factor affects the features of rock mass in accordance with the failure criterion of Hoek and Brown (1980).

Table 4.11. *A representative data collection table for the cut slope MS-1*

DATA COLLECTION TABLE						
Stope No.	**MS-1**	**Coordinates**	**X:**	410411	**Y:**	4585059

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa (Mudstone)	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa (Limestone)	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows

Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered	1.00
Crushed intact rock	0.62		Slightly	0.95
Lithology			Moderately	0.90
Mudstone : 30 %, dark Gray, 10-15 cm thick			Highly	0.62
Limestone : 70 %, yellow-light yellow, 1.5 m thick			Completely	0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Strike (degrees)	110	Stable	1	**Rockfall**	Large Limestone Blocks
Dip (degrees)	80 S	Small problem	2	"Landslide Site" signboard near the slope	
Slope height (m)	25	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)		150	30	90	155	160
Dip (degrees)		10 W	64 SE	72 S	12 W	15 W
Spacing (DS) (cm)		Lst: 90cm, Mdst: 60cm	5cm	20cm	12cm	10cm
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Smooth Planar	Rough Planar	Smooth Planar	Smooth Planar
Infill M.	Clay material / CaCO3, 2mm-1mm	2 mm	1 mm	2 mm	2 mm	1 mm
Persistence	consistent with spacing and bedding planes					
Aperture	1 mm - 2 mm - 5 mm - 8 mm	2 mm	4mm	5mm	8 mm	1mm
Wall Strength	Lst Weathered : 20 SC, Lst Fresh : 36 SC,	Bedding Plane : 36 SC,		Mudst.<10 SC		

Sample Bag #	240 LST F, 240 LST W	**UCS**	+	**Photo.**	#1:joint, #2: bedding plane	

4.3. Characterization of Studied Road-cuts

In order to fulfil this study, 16 permanent road-cuts were examined comprehensively by considering their geometrical characteristics, lithological properties, strength and discontinuity features, type of excavations and weathering conditions. In the field it is observed that the excavation method used for 15 of the road-cuts is mechanical excavation and for 1 road-cut, the excavation method is conventional blasting. The age of the studied cut slopes are approximately 10 years. The heights of the studied road cuts, which are in the range of 8 to 60 meters, are listed in Table 4.12. The slope angles are given in Table 4.13, which are in the range of 30 to 80°. The encountered rock types of the studied road cuts are limestone, sandstone, marl and mudstone as can be seen in Table 4.14.

Table 4.12. *Height of the studied road cuts*

Road Cut	Slope Height (m)	Road Cut	Slope Height (m)
MS-1	25	**MS-7.1**	35
MS-2.1	10	**MS-7.2**	8
MS-2.2	15	**MS-8.1**	8
MS-2.3	20	**MS-8.2**	10
MS-3	15	**MS-9**	8
MS-4	50	**MS-10**	60
MS-5	15	**MS-11**	40
MS-6	25	**MS-12**	15

Table 4.13. *Slope angles of the studied road cuts*

Road Cut	Slope Angle (°)	Road Cut	Slope Angle (°)
MS-1	80	**MS-7.1**	66
MS-2.1	55	**MS-7.2**	64
MS-2.2	50	**MS-8.1**	30
MS-2.3	52	**MS-8.2**	30
MS-3	60	**MS-9**	65
MS-4	60	**MS-10**	45
MS-5	50	**MS-11**	40
MS-6	60	**MS-12**	50

Table 4.14. *Rock types encountered at the studied road cuts*

Road Cut	**Rock Type**	**Road Cut**	**Rock Type**
MS-1	Limestone	**MS-5**	Marl
	Mudstone	**MS-6**	Sandstone
MS-2.1	Marl		Mudstone
	Mudstone	**MS-7.1**	Limestone
MS-2.2	Marl	**MS-7.2**	Limestone
	Mudstone	**MS-8.1**	Sandstone
MS-2.3	Marl	**MS-8.2**	Sandstone
	Mudstone	**MS-9**	Marl
MS-3	Marl		Sandstone
	Mudstone	**MS-10**	Sandstone
MS-4	Marl	**MS-11**	Sandstone
	Mudstone	**MS-12**	Sandstone

The point load tests were performed on both dry and saturated samples. For slope stability analysis, saturated test results were taken into consideration for the point load tests results as well as unit weight and uniaxial compressive strength values. Rock strength and unit weight of the flysch type deposits were determined by taking weighted average values of the lithologies according to field observation on percentage estimation of units as in the study of Marinos and Hoek (2001).

Specimens for the mudstone could not be gathered from the cut slopes of MS-1, MS-2.1, MS-2.2, MS-2.3, MS-3, and MS-4 in required sizes for determining unit weight and uniaxial compressive strength due to having high degree of fractured nature. Sufficient sizes of the mudstone samples could only be obtained from the cut slope MS-6 thus, for the mudstones of MS-1, MS-2.1, MS-2.2, MS-2.3, MS-3, and MS-4 uniaxial compressive strength and unit weight values of MS-6 is used.

Likewise, because of the highly fractured structure of the marl required sized specimens could not be obtained from the cut slopes of MS-2.2 and MS-2.3. The marl specimens in proper sizes for unit weight and uniaxial compressive strength could be gathered from Stop MS-2.1, MS-4, MS-5 and MS-9. The uniaxial compressive strength value of the marl of Stop MS-2.1 is used for the marl of MS-2.2 and MS-2.3. Also, unit weight value of Stop MS-2.1 is used for the unit weight value of Stop MS-2.3 due to being very close to each other and having the same lithological characteristics.

In the field, scan line surveys and field observations were carried out for the studied cut slopes in order to obtain information on discontinuity features that would be utilized to estimate rock mass properties. In addition to the scan line surveys, field observations about weathering were done with the aim of gathering data about condition and degree of weathering. It is observed that in most of the studied cut slopes surficial losses of rock materials occurred due to rock material weathering starting from the slope surface.

By the help of the laboratory tests which were performed on the rock specimens obtained from the study area, unit weight, uniaxial compressive strength, slake durability index and cation exchange capacity were determined. In order to conduct limit equilibrium analysis, cohesion value is accepted as “0” for being on the safe side as creating cohesionless part that will result in surficial instabilities.

4.3.1. Stop MS-1

Description

Location of the cut slope MS-1 is nearly 12 km southeast of Zonguldak centrum in the Kilimli formation. The height of MS-1 is approximately 25 m and measured dip of the cut slope is 80°. Cut slope MS-1 is composed of limestone-mudstone alternation that is 70 % of yellow-light yellow, nearly 1 to 1.5 m thick fine-medium grained limestone and 30 % of dark gray 10 to 15 cm thick, fine grained mudstone (Figure 4.2). Large limestone blocks were encountered above the wall, however, none of them was observed at road level. Besides, there was “Landslide Site” caution signboard near the slope. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.2. View of the road-cut at MS-1

Unit Weight and Strength

Unit weight results of the cut slope MS-1 are demonstrated in Table 4.15. Unit weight values that are belonging to saturated rock specimens are used for the stability analyses. In order to achieve the resultant value, weighted average of the limestone from this cut slope and the mudstone from the cut slope MS-6 are considered because specimens for the mudstone could not be gathered from the cut slopes of MS-1 in required sizes for determining the unit weight. The resultant value for fresh rock material is 24.97 kN/m^3 and the resultant value for weathered rock material is 24.83 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-1 are shown in Table 4.15. Saturated uniaxial compressive strength values of the limestone and mudstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. Specimens for the mudstone could not be gathered from the cut slopes of MS-1 in required sizes for the point load tests due to having high degree of fractured structure thus point load test results of MS-6 is used. The k value is in coherent with UCS test results for the limestone of the cut slope MS-1 and that is 18. However, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for the mudstone is impossibility of gathering proper specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 19 MPa by taking weighted average considering saturated, relatively fresh rock mass value.

Table 4.15. *UCS and unit weight values of the specimens at MS-1*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-1	**Limestone**	**UCS (MPa)**	55.92	24.77	55.00	23.04
		Unit Weight (kN/m^3)	24.52	25.23	24.45	25.21
MS-6	**Mudstone**	**UCS (MPa)**	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)	23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-1 are designated as 10/240, 64/120 and 72/180 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.3. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.4. It can be said that persistence of the discontinuities is mostly consistent with spacing and bedding planes. 1 mm, 2 mm, 5 mm and 8 mm apertures were encountered, and the infill material of the discontinuities are generally clay and calcium carbonate that are 1 to 2 mm in thickness.

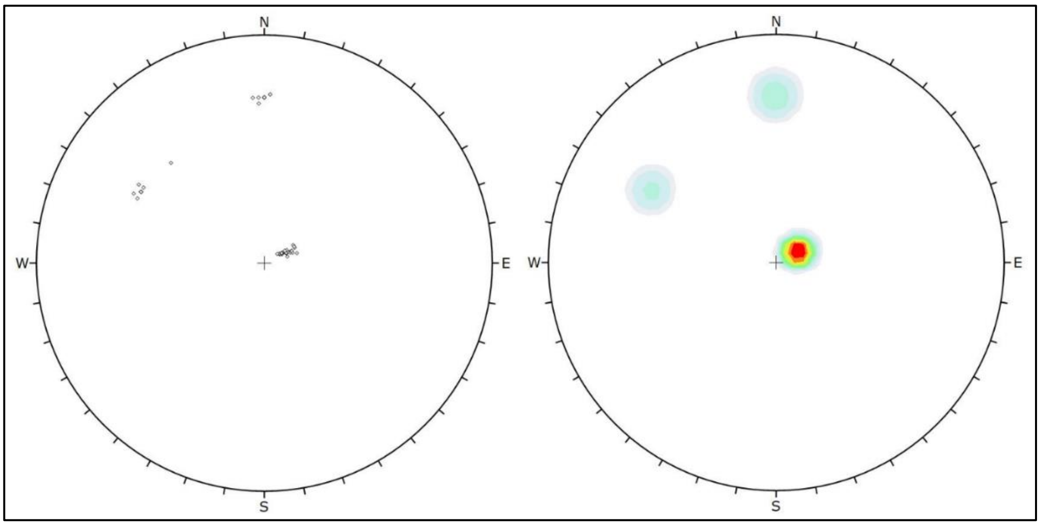


Figure 4.3. Pole plot and contour plot of the discontinuities at road cut MS-1

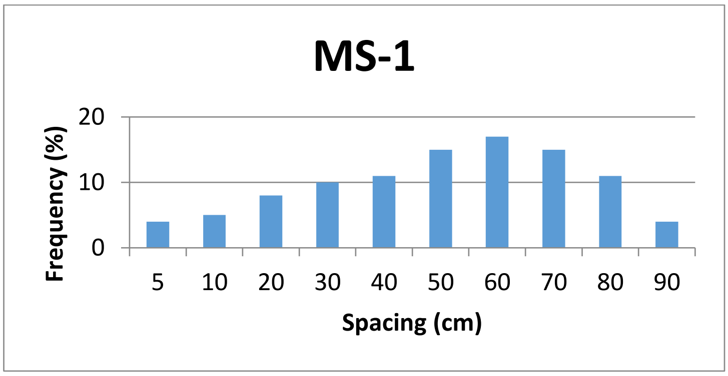


Figure 4.4. Spacing versus frequency histogram for the discontinuities at road-cut MS-1

Weathering and Clay Content Features

According to the field observations, both limestone and mudstone of the cut slope MS-1 are generally identified as moderately weathered. Locally, there are surficial degradation and staining through fractures mostly in the thick limestone beds. Besides, the mudstone layers are prone to weathering due to their fragmented nature but regarding the field observations, they are moderately weathered. Weathering depth of the cut slope is designated as 25 cm in thickness.

Slake durability test results demonstrate that the limestone of the cut slope MS-1 is highly durable both for fresh and weathered rock types (Table 4.16). The difference in Id(20) values for fresh and weathered limestone specimens are resulted from degrees of degradation. Specimens of the mudstone could not be gathered for the slake durability tests because of their fragile nature. For all samples, the methylene blue test results for the fresh and weathered limestones are identical. Weathered specimens of the limestone and the mudstone shows that the mudstones have higher weathering degrees than the limestone, considering MBA and CEC results. Fresh mudstone specimens to apply methylene blue and slake durability tests could not be collected from the field due to its deep weathering zone and fragile nature.

Table 4.16. *Slake durability and methylene blue test results of the specimens at MS-1*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-1	Limestone	97.64	89.76	0.93	2.10	97.84	88.38	0.93	2.10
	Mudstone	-	-	-	-	-	-	1.20	2.70

4.3.2. Stop MS-2.1

Description

The cut slope MS-2.1 is located at nearly 16 km southeast of Zonguldak centrum in the Akveren formation. MS-2.1 is approximately 10 m in height and dip of the cut slope is measured as 55°. The cut slope is comprised of marl-mudstone alternation that is 80 % of white-light colored, nearly 10 to 20 cm thick bedded, fine-grained marl and 20 % of brown-greenish 5 cm thick bedded, fine grained mudstone (Figure 4.5). As field observation, the cut slope MS-2.1 is totally stable however, surficial degradation and surficial failures are encountered and resulted in ravelling of very small sized specimens into the drainage channel in front of the cut slope. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.5. View of the road-cut at MS-2.1

Unit Weight and Strength

Unit weight values of the cut slope MS-2.1 are shown in Table 4.17. In order to obtain saturated unit weight values of the rock specimens for the stability analysis, weighted average of the marl from the cut slope MS-2.1 and the mudstone from the cut slope MS-6 are considered due to lacking of the mudstone specimens from the cut slopes of MS-2.1 in required sizes for determining the unit weight. The unit weight of fresh rock material is 24.96 kN/m^3 and the unit weight for weathered rock material is 24.68 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-2.1 are listed in Table 4.17. Saturated uniaxial compressive strength values of the marl and mudstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. Specimens for the mudstone could not be gathered from the cut slopes of MS-2.1 in required sizes for the point load tests due to having fractured structure, and point load test results of the marl of MS-6 is used. The k value for the marl of the cut slope MS-2.1 is determined by the literature survey (Azimian et al., 2013), as 8. In addition, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). UCS value of the rock mass that is used for the stability analysis is determined as 25 MPa by taking weighted average considering saturated, relatively fresh rock mass values.

Table 4.17. *UCS and unit weight values of the specimens at MS-2.1*

			Fresh		**Weathered**	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-2.1	**Marl**	**UCS (MPa)**	54.46	29.58	35.94	17.87
		Unit Weight (kN/m^3)	24.28	25.11	24.21	24.87
MS-6	**Mudstone**	**UCS (MPa)**	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)	23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent 3 sets of discontinuities of the cut slope MS-2.1 are designated as 75/225, 35/180 and 90/125 in dip/dip direction. The pole plot and the contour plot of the discontinuities at road cut MS-2.1 are demonstrated in Figure 4.6. Discontinuity spacing histogram of frequency of the discontinuities at the road cut is given in Figure 4.7. It can be said that persistence of the discontinuities is mostly consistent with spacing however, bedding planes are more persistent. Mostly 1 to 2 mm apertures were encountered, and the infill material of the discontinuities is generally clay that are 1 to 2 mm in thickness. High degree of jointing in the rocks implies small sized blocks, which match with the already fallen marl and mudstone fragments.

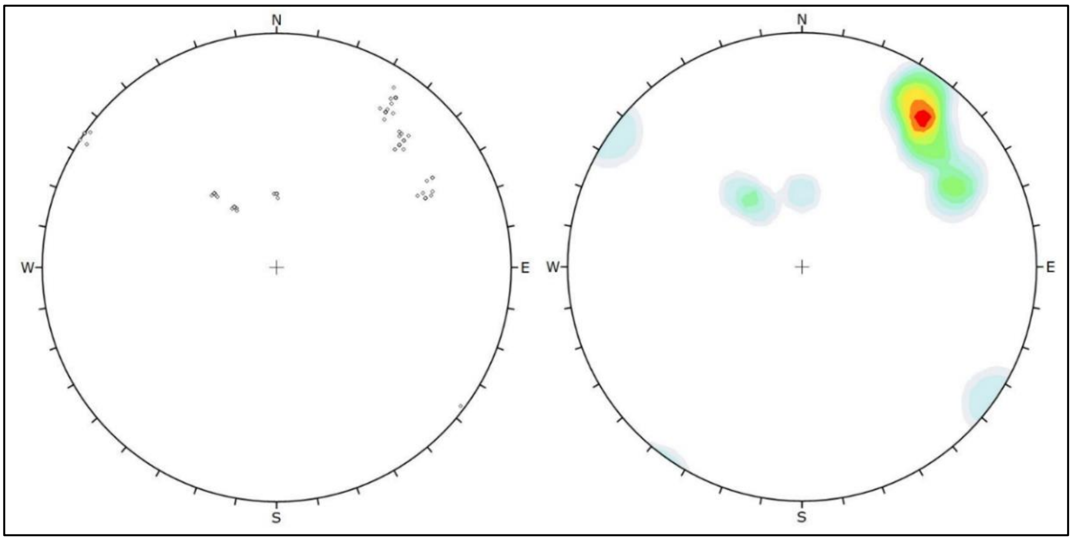


Figure 4.6. Pole plot and contour plot of the discontinuities at road cut MS-2.1

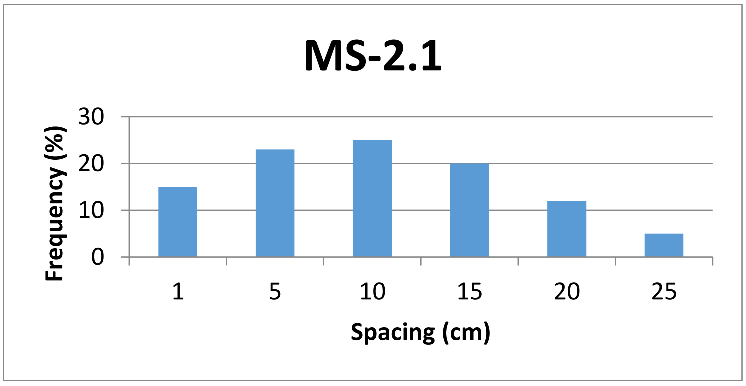


Figure 4.7. Spacing versus frequency histogram for the discontinuities at road-cut MS-2.1

Weathering and Clay Content Features

Based on the field observations, the marl of the cut slope MS-2.1 is generally identified as slightly weathered and mudstones are generally identified as moderately weathered. Generally, there are surficial degradation through fractures of the whole cut slope. The marl and mudstone layers are prone to weathering due to their fragmented nature. Weathering depth of the cut slope is designated as 35 cm in thickness.

Slake durability test results demonstrate that the marl of the cut slope MS-2.1 has very high durability both for fresh and weathered rock types (Table 4.18). Id(20) values for fresh and weathered marl specimens are very close to each other. In addition to these, methylene blue test results for fresh and weathered marl are low. By comparing the weathered marl and mudstone specimen results, it can be said that the mudstone has higher weathering degree than the marl.

Table 4.18. *Slake durability and methylene blue test results of the specimens at MS-2.1*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-2.1	Marl	99.37	96.79	1.73	3.90	99.20	95.98	2.00	4.50
	Mudstone	-	-	-	-	-	-	3.20	7.20

4.3.3. Stop MS-2.2

Description

Location of the cut slope MS-2.2 is nearly 16 km southeast of Zonguldak centrum, close to the cut slope MS-2.1 and in the Akveren formation. The height of MS-2.2 is approximately 15 m and measured dip of the cut slope is 50°. The cut slope is composed of marl-mudstone alternation that is 75 % of white-light gray colored, nearly 15 to 20 cm thick bedded, fine-medium grained marl and 25 % of gray-dark gray-greenish 5 to 6 cm thick bedded, fine grained mudstone (Figure 4.8). As field observation the cut slope MS-2.2 is totally stable yet, there were rarely surficial failures and rockfalls of small sized specimens into the drainage channel in front of the cut slope. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.8. View of the road-cut at MS-2.2

Unit Weight and Strength

Unit weight results of the cut slope MS-2.2 are demonstrated in Table 4.19. Unit weight values that are belonging to the saturated rock specimens are used in the analyses. In order to achieve the resultant unit weight value, weighted average of the marl from this cut slope and the mudstone from the cut slope MS-6 are considered because specimens for the mudstone could not be gathered from the cut slopes of MS-2.2 in required sizes for determining the unit weight. The resultant value for fresh rock material is 24.94 kN/m^3 and the resultant value for weathered rock material is 24.62 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-2.2 are shown in Table 4.19. Saturated uniaxial compressive strength values of the marl and mudstone are used in the stability analysis and calculated by considering the related k values designated from the literature survey. Specimens for the mudstone could not be gathered from the cut slopes of MS-2.2 in required sizes for the point load tests due to having high degree of fractured structure, thus point load test results of the mudstone of MS-6 is used. The k value obtained from the literature survey as for the marl of the cut slope MS-2.2 (Azimian et al., 2013) and that is 8. In addition to this, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for the marl and mudstone is impossibility of gathering sufficient sized specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 24 MPa by taking weighted average considering relatively fresh rock mass value.

Table 4.19. *UCS and unit weight values of the specimens at MS-2.2*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-2.1&2	**Marl**	**UCS (MPa)**	54.46	29.58	35.94	17.87
		Unit Weight (kN/m^3)	24.44	25.13	24.28	24.85
MS-6	**Mudstone**	**UCS (MPa)**	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)	23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent 5 sets of discontinuities of the cut slope MS-2.2 are designated as 40/320, 80/220, 50/040, 70/180 and 45/140 as in dip/dip direction. The scattered results of discontinuities at road cut MS-2.2 are demonstrated in pole and contour diagrams as shown in Figure 4.9. A histogram of discontinuity spacing frequency of the road cut is given in Figure 4.10. It can be said that the joints are mostly bed confined and persistence of the discontinuities are mostly consistent with spacing, and bedding planes are more persistent. 2 to 4 mm apertures were encountered, and the infill material of the discontinuities is generally clay materials that is lower than 5 mm in thickness.

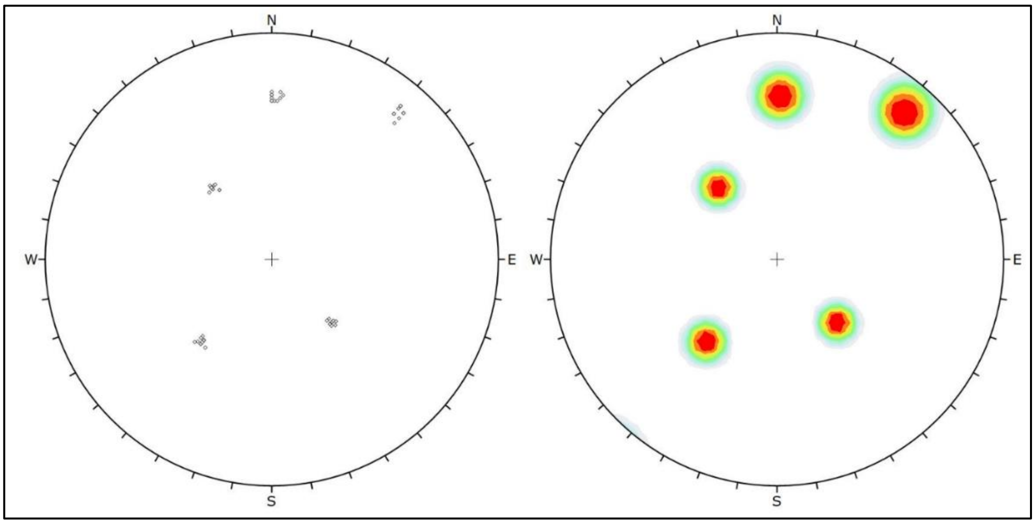


Figure 4.9. Pole plot and contour plot of the discontinuities at road cut MS-2.2

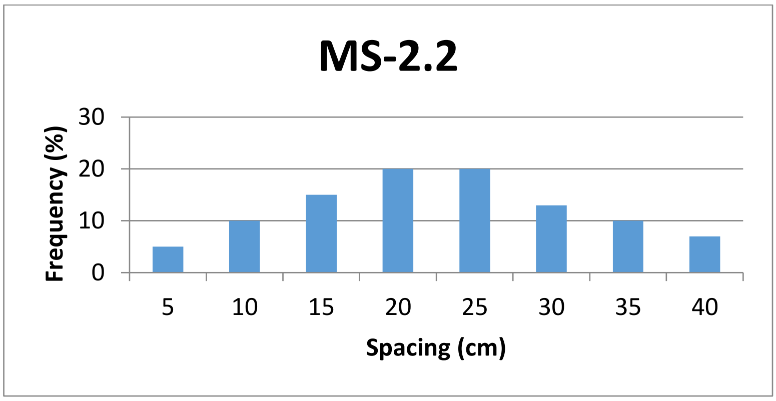


Figure 4.10. Spacing versus frequency histogram for the discontinuities at road-cut MS-2.2

Weathering and Clay Content Features

According to the field observations, the marl of the cut slope MS-2.2 is generally identified as slightly weathered and the mudstones are generally identified as moderately weathered. Generally, there are surficial degradation through fractures of the cut slope. Weathering depth of the cut slope is designated as 30 cm in thickness.

Slake durability test results demonstrate that the marl of the cut slope MS-2.2 has very high durability both for fresh and weathered rock types (Table 4.20). Id(20) values for fresh and weathered marl specimens are very close to each other. In addition to these, methylene blue test results for fresh and weathered marl are quite low. Taking into account of the weathered marl and the mudstone values of MBA and CEC, it can be said that the mudstones are prone to weathering much more in comparison with the marl.

Table 4.20. *Slake durability and methylene blue test results of the specimens at MS-2.2*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-2.2	Marl	99.51	97.69	0.93	2.10	99.37	97.60	1.20	2.70
	Mudstone	-	-	-	-	-	-	3.60	8.10

4.3.4. Stop MS-2.3

Description

Location of the cut slope MS-2.3 is nearly 16 km southeast of Zonguldak centrum, close to the cut slopes MS-2.1 and MS-2.2 in the Akveren formation. The height of MS-2.3 is approximately 20 m and measured dip of the cut slope is 52°. Cut slope MS-2.3 is composed of marl-mudstone alternation that is 70 % of white-light yellow, nearly 5 to 10 cm thick fine grained, thin bedded marl and 30 % of white-reddish approximately 1 cm thick, fine grained mudstone (Figure 4.11). Surficial degradation and surficial failures are encountered and resulted in rockfalls of very small sized specimens into the drainage channel in front of the cut slope into a large extent. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

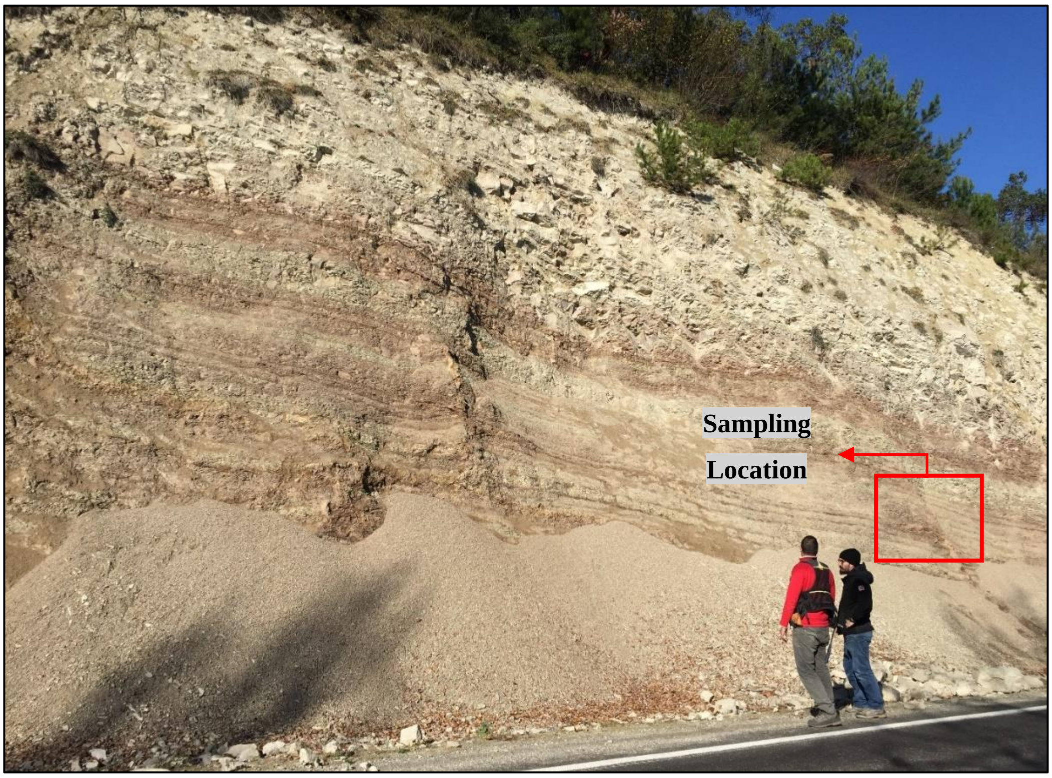


Figure 4.11. View of the road-cut at MS-2.3

Unit Weight and Strength

Unit weight results of the cut slope MS-2.3 are demonstrated in Table 4.21. Unit weight values that are belonging to saturated rock specimens are used in the analyses. In order to achieve the resultant unit weight value, weighted average of the marl from MS-2.1 and the mudstone from the cut slope MS-6 are considered because specimens for the marl and mudstone could not be gathered from the cut slopes of MS-2.3 in required sizes for determining the unit weight. The resultant value for fresh rock material is 24.89 kN/m^3 and the resultant value for weathered rock material is 24.59 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-2.3 are shown in Table 4.21. Saturated uniaxial compressive strength values of the marl and mudstone are used in the stability analysis and calculated by considering the related k values designated from the literature survey. Specimens for the marl and mudstone could not be gathered from the cut slopes of MS-2.3 in required sizes for the point load tests due to having intensely fractured structure, thus the point load test results of MS-2.1 is used for the marl and the point load test results of MS-6 is used for the mudstone. The k value obtained from the literature survey as for the marl of cut slope MS-2.3 (Azimian et al., 2013) and that is 8. In addition to this, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for marl and mudstone is impossibility of gathering sufficient sized specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 23 MPa by taking weighted average considering relatively fresh rock mass value.

Table 4.21. *UCS and unit weight values of the specimens at MS-2.3*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-2.1	**Marl**	**UCS (MPa)**	54.46	29.58	35.94	17.87
		Unit Weight (kN/m^3)	24.28	25.11	24.21	24.87
MS-6	**Mudstone**	**UCS (MPa)**	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)	23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-2.3 are designated as 40/320, 80/210, 40/180, 45/020 and 75/330 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.12. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.13. It can be said that persistence of the discontinuities is mostly consistent with spacing and bedding planes. 1 mm to 2 mm apertures were encountered, and the infill material of the discontinuities are generally clay that are mostly 2 mm in thickness. High degree of jointing in the rocks implies small sized blocks, which match with the already fallen marl and mudstone fragments.

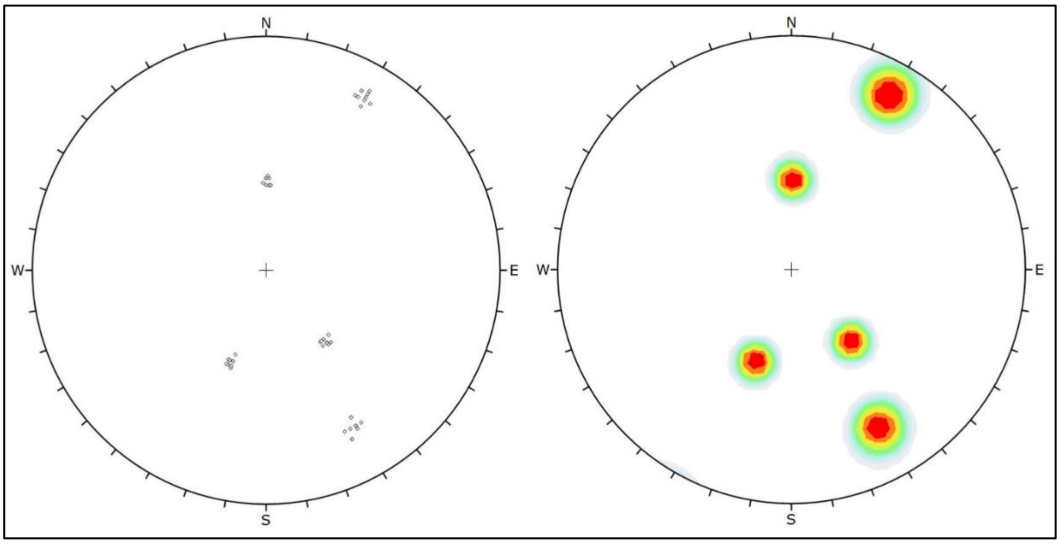


Figure 4.12. Pole plot and contour plot of the discontinuities at road cut MS-2.3

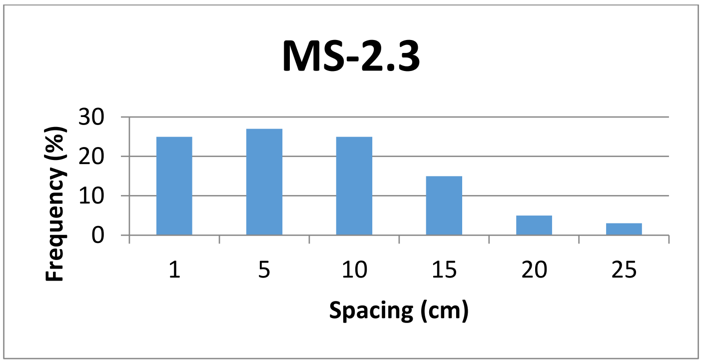


Figure 4.13. Spacing versus frequency histogram for the discontinuities at road-cut MS-2.3

Weathering and Clay Content Features

According to the field observations, both marl and mudstone of the cut slope MS-2.3 is generally identified as highly weathered. Generally, there are surficial degradation through fractures of the whole cut slope. The marl and mudstone layers are prone to weathering due to their fragmented nature. Weathering depth of the cut slope is designated as 40 cm in thickness.

Rock specimens in required sizes of fresh and weathered rock type of the mudstone and the fresh marl could not collected for the slake durability tests. Thus, slake durability test was performed only for the weathered marl of MS-2.3. The result demonstrate that the weathered marl of the cut slope MS-2.1 has high durability (Table 4.22). Likewise, methylene blue test could only be conducted for the weathered samples of marl. The methylene blue test results for the weathered marl and the weathered mudstone are quite close to each other.

Table 4.22. *Slake durability and methylene blue test results of the specimens at MS-2.3*

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-2.3	Marl	-	-	-	-	95.81	74.45	3.60	8.10
	Mudstone	-	-	-	-	-	-	3.47	7.80

4.3.5. Stop MS-3

Description

Location of the cut slope MS-3 is nearly 37 km southeast of Zonguldak centrum in the Akveren formation. The height of MS-3 is approximately 15 m and measured dip of the cut slope is 60°. Cut slope MS-3 is composed of marl-mudstone alternation that is 90 % of light greenish-gray, nearly 2 to 4 cm thick fine-grained marl and 10 % of light brownish 1 to 2 cm thick, fine grained locally oxidized mudstone (Figure 4.14). As field observation cut slope MS-3 is totally stable however, surficial degradation and surficial failures are encountered and resulted in rockfalls of 1 cm, 5 cm and 10 cm rock specimens into the drainage channel in front of the cut slope. Excavation method for the cut slope is mechanical excavation, thus disturbance factor (D) can be taken as 0.7.

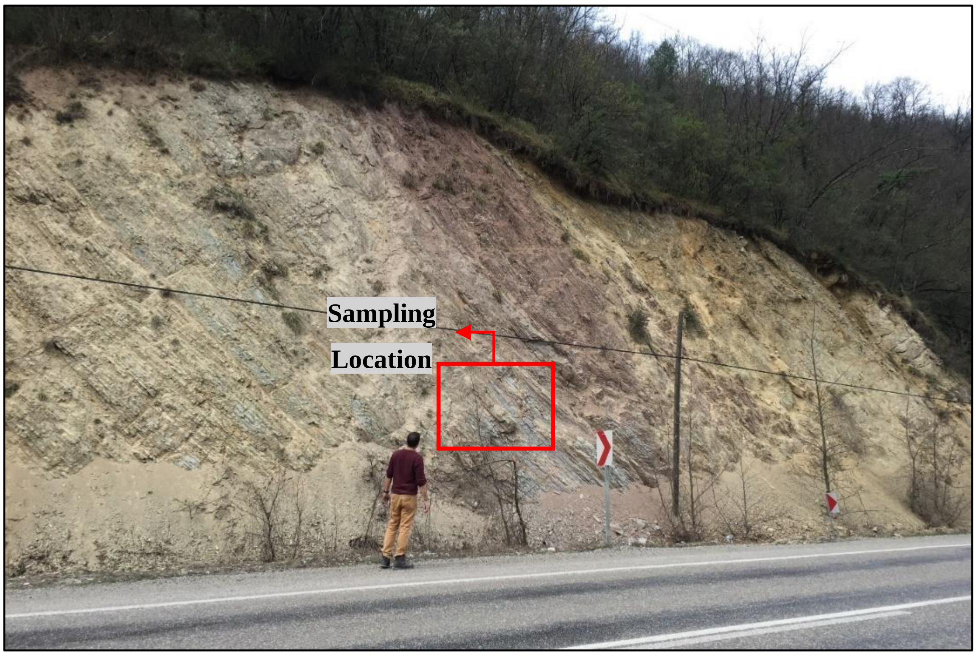


Figure 4.14. View of the road-cut at MS-3

Unit Weight and Strength

Unit weight results of the cut slope MS-3 are demonstrated in Table 4.23. Unit weight values that are belonging to saturated rock specimens are used in the analyses. In order to achieve the resultant value, weighted average of the marl from this cut slope and the mudstone from the cut slope MS-6 are considered because specimens for the mudstone could not be gathered from the cut slopes of MS-3 in required sizes for determining the unit weight. The resultant value for fresh rock material is 25.74 kN/m^3 and the resultant value for weathered rock material is 25.67 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-3 are shown in Table 4.23. Saturated uniaxial compressive strength values of the marl and mudstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. Specimens for the mudstone could not be gathered from the cut slopes of MS-3 in required sizes for the point load tests due to having high degree of fractured structure and point load test results of MS-6 is used. The k value is designated from the literature for the marl of cut slope MS-3 (Azimian et al., 2013) and that is 8. However, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for the mudstone and marl is impossibility of collecting sufficient sized specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 23 MPa by taking weighted average considering relatively fresh rock mass value.

Table 4.23. *UCS and unit weight values of the specimens at MS-3*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-3	**Marl**	**UCS (MPa)**	67.19	24.25	46.04	19.47
		Unit Weight (kN/m^3)	25.37	25.89	25.32	25.86
MS-6	**Mudstone**	**UCS (MPa)**	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)	23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-3 are designated as 60/010, 80/040, 32/160 and 72/180 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.15. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.16. 1 to 2 mm apertures were encountered, and the infill material of the discontinuities are generally clay that are 1 to 2 mm in thickness.

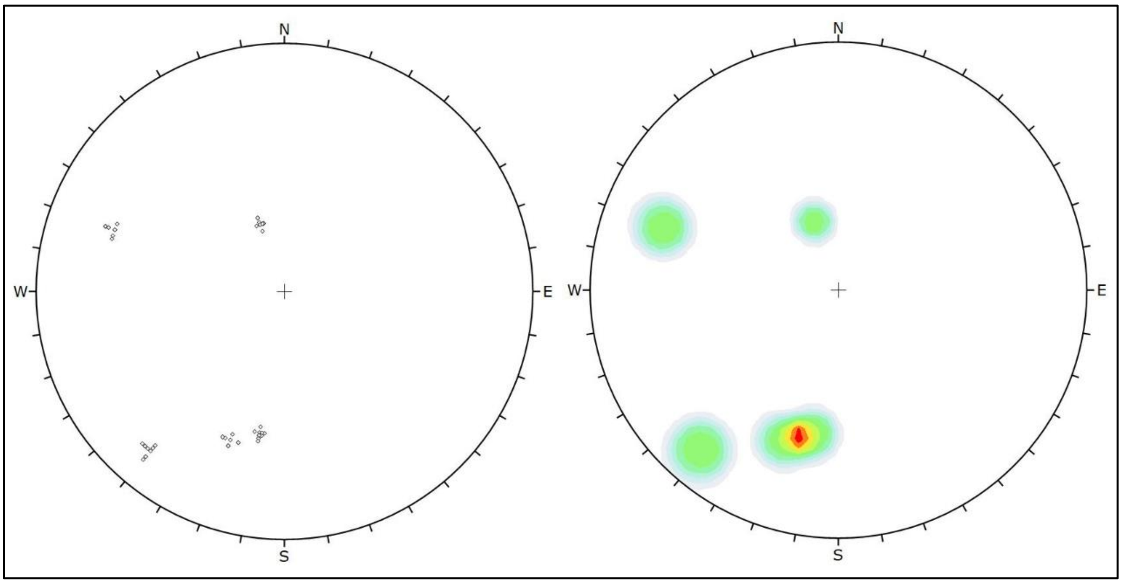


Figure 4.15. Pole plot and contour plot of the discontinuities at road cut MS-3

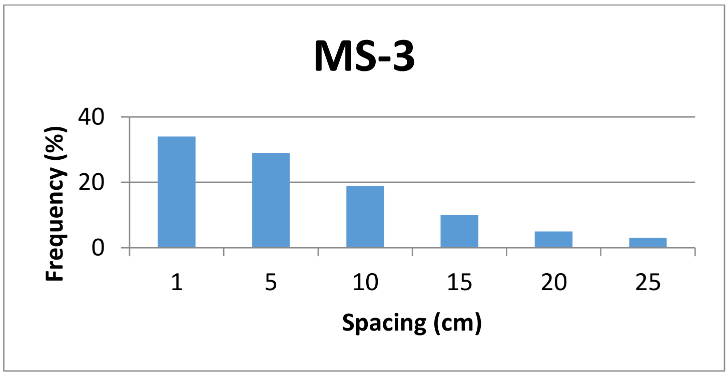


Figure 4.16. Spacing versus frequency histogram for the discontinuities at road-cut MS-3

Weathering and Clay Content Features

According to the field observations, both marl and mudstone of the cut slope MS-3 is generally identified as highly weathered. Generally, there are surficial degradation and staining through fractures. Besides, the mudstone layers are prone to weathering much more due to their fragmented nature. Weathering depth of the cut slope is designated as 30 cm in thickness.

Rock specimens in required sizes of fresh and weathered rock type of the mudstone could not collected for the slake durability tests. Thus, slake durability test was performed only for the marl specimens of MS-3. Slake durability test results demonstrate that the marl of the cut slope MS-3 has very highly durability both for fresh and weathered rock types (Table 4.24). The difference in Id(20) values for fresh and weathered marl specimens are resulted from degrees of degradation. For all that, the methylene blue test results for the weathered marl and mudstone show that the mudstone have higher degree of weathering than the marl.

Table 4.24. *Slake durability and methylene blue test results of the specimens at MS-3*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-3	Marl	99.25	96.05	1.33	3.00	98.91	92.77	1.60	3.60
	Mudstone	-	-	-	-	-	-	2.93	6.60

4.3.6. Stop MS-4

Description

Location of the cut slope MS-4 is nearly 17 km west of Karabük centrum in the Ulus formation. Total height of MS-4 is approximately 50 m with 2 benches and measured dip of the cut slope is 60°. Cut slope MS-4 is composed of marl-mudstone alternation that is 50 % of gray-dark gray, nearly 10-20 cm thick fine-medium grained marl and 50 % of dark gray 10 to 50 cm thick, fine-medium grained mudstone (Figure 4.17 and 4.18). There were wire mesh through almost whole cut slope in order to prevent rockfalls onto the road as a precaution. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.17. View of the road-cut at MS-4

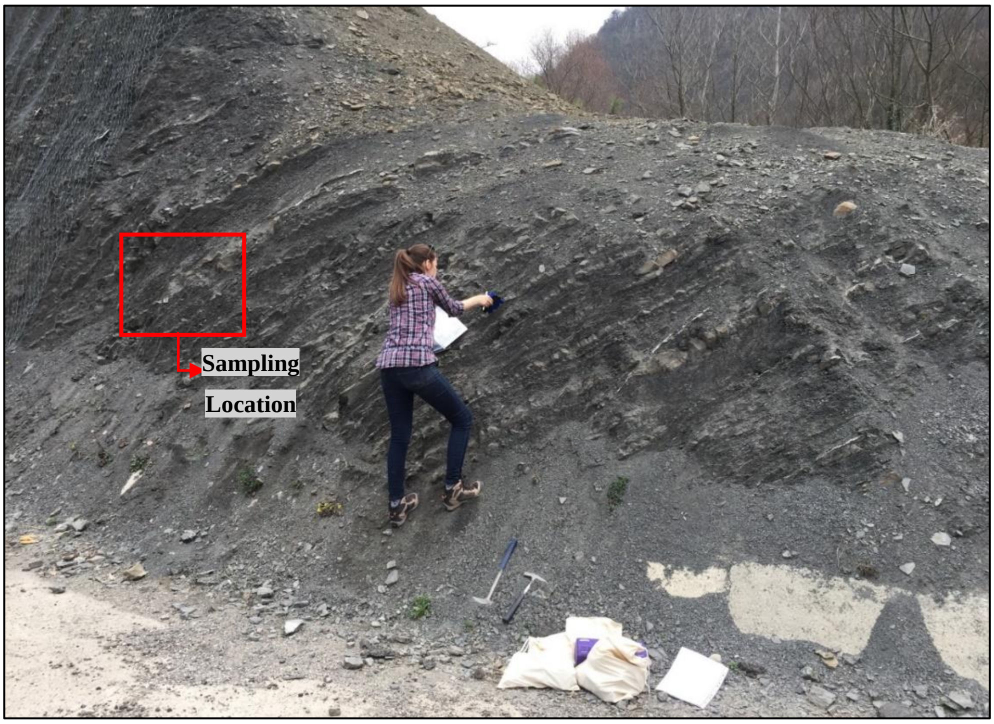


Figure 4.18. View of the road-cut at MS-4

Unit Weight and Strength

Unit weight results of the cut slope MS-4 are demonstrated in Table 4.25. Unit weight values that are belonging to saturated rock specimens are used in the analyses. In order to achieve the resultant value, weighted average of the marl from this cut slope and the mudstone from the cut slope MS-6 are considered because specimens for the mudstone could not be gathered from the cut slopes of MS-4 in required sizes for determining the unit weight. The resultant value for fresh rock material is 25.25 kN/m^3 and the resultant value for weathered rock material is 24.99 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-4 are shown in Table 4.25. Saturated uniaxial compressive strength values of the marl are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The point load tests are performed both parallel and normal to the anisotropy planes for the marl. The values that are normal to the anisotropy plane are used for the cut slope MS-4 taking into account of the potential failure direction.

Specimens for the mudstone could not be collected from the cut slopes of MS-4 in required sizes for the point load tests due to having high degree of fractured structure thus the point load test results of MS-6 is used. The k value is designated from the literature for the marl of cut slope MS-4 (Azimian et al., 2013) and that is 8. Likewise, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for the mudstone is impossibility of gathering sufficient sized specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 36 MPa by taking weighted average considering saturated, relatively fresh rock mass value.

Table 4.25. *UCS and unit weight values of the specimens at MS-4*

				Fresh		Weathered	
Stop	**Rock Type**	**Test**		**Dry**	**Saturated**	**Dry**	**Saturated**
MS-4	**Marl**	**UCS (MPa)**	⊦	86.21	65.40	70.11	37.70
			=	26.65	24.35	17.77	14.38
		Unit Weight (kN/m^3)		25.76	26.15	25.53	26.03
MS-6	**Mudstone**	**UCS (MPa)**		18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)		23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-4 are designated as 60/130, 60/220 and 60/200 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.19. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.20. It can be said that persistence of the discontinuities are mostly consistent with spacing and bedding planes. 1 mm to 2 mm and locally 5 cm to 10 cm apertures were encountered, and the infill material of the discontinuities are generally 2 mm thick clay and 0.5 to 1 cm calcite. High degree of jointing in the rocks implies small sized blocks, which match with the already fallen marl fragments.

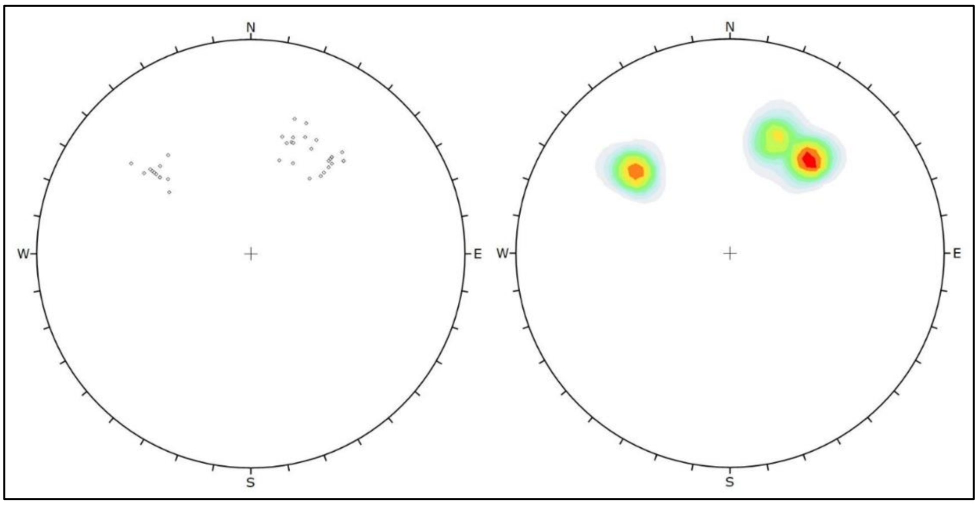


Figure 4.19. Pole plot and contour plot of the discontinuities at road cut MS-4

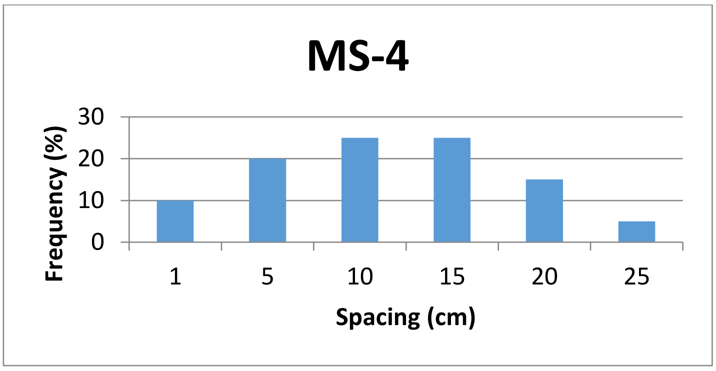


Figure 4.20. Spacing versus frequency histogram for the discontinuities at road-cut MS-4

Weathering and Clay Content Features

According to the field observations, both marl and mudstone of the cut slope MS-4 is generally identified as highly weathered. Differential weathering is observed at the road cut as mudstone layers are much more prone to weathering due to their fragmented nature. Weathering depth of the cut slope is designated as 35 cm in thickness.

Rock specimens in required sizes of fresh and weathered rock type of the mudstone could not be collected for the slake durability tests. Thus, the slake durability test was performed only for the marl specimens of MS-4. Slake durability test results demonstrate that the marl of the cut slope MS-4 has very highly durability both for fresh and weathered rock types (Table 4.26). Id(20) values for fresh and weathered marl specimens very close to each other. In addition, methylene blue test results for the weathered marl and mudstone shows that the mudstone of the cut slope MS-4 have higher degree of weathering than the marl.

Table 4.26. *Slake durability and methylene blue test results of the specimens at MS-4*

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-4	Marl	98.84	95.11	0.67	1.50	98.67	94.75	0.80	1.80
	Mudstone	-	-	-	-	-	-	1.73	3.90

4.3.7. Stop MS-5

Description

Location of the cut slope MS-5 is nearly 4 km south of Karabük centrum in the Karabük formation. The height of MS-5 is approximately 15 m and measured dip of the cut slope is 50°. The cut slope is composed of marl that shows differential weathering between the layers. The marl of the cut slope MS-5 is gray, locally laminated, rarely 10-20 cm thick bedded (Figure 4.21). As field observation the cut slope MS-5 is totally stable, however; surficial degradation and surficial failures are encountered and resulted in rockfalls of 1 cm, 5 cm and rarely 10 cm rock specimens on the wall and into the drainage channel in front of the cut slope. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.21. View of the road-cut at MS-5

Unit Weight and Strength

Unit weight results of the cut slope MS-5 are demonstrated in Table 4.27. The unit weight value for fresh rock material is 24.50 kN/m^3 and the resultant value for relatively fresh rock material is 24.26 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-5 are shown in Table 4.27. Saturated uniaxial compressive strength values of the marl are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. However, k value for the marl is obtained from the literature survey as 8 (Azimian et al., 2013). The reason of lacking the UCS test for the marl is impossibility of gathering sufficient sized specimens to apply the test. The point load tests are performed both parallel and normal to the anisotropy planes for the marl. The values that are normal to the anisotropy plane are used for the cut slope MS-4 taking into account of potential failure direction. UCS value of the rock mass that is used for the stability analysis is determined as 8 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.27. *UCS and unit weight values of the specimens at MS-5*

				Fresh		Weathered	
Stop	**Rock Type**	**Test**		**Dry**	**Saturated**	**Dry**	**Saturated**
MS-5	**Marl**	**UCS (MPa)**	⊦	38.47	8.15	25.83	5.89
			=	10.83	0.81	5.42	0.52
		Unit Weight (kN/m^3)		23.10	24.50	22.77	24.26

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-5 are designated as 20/265 and 85/350 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.22. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure

4.23. It can be said that persistence of the discontinuities are mostly consistent with spacing and bedding planes. Approximately 2 mm thick apertures were encountered, and the infill material of the discontinuities are generally clay minerals 2 mm in thickness.

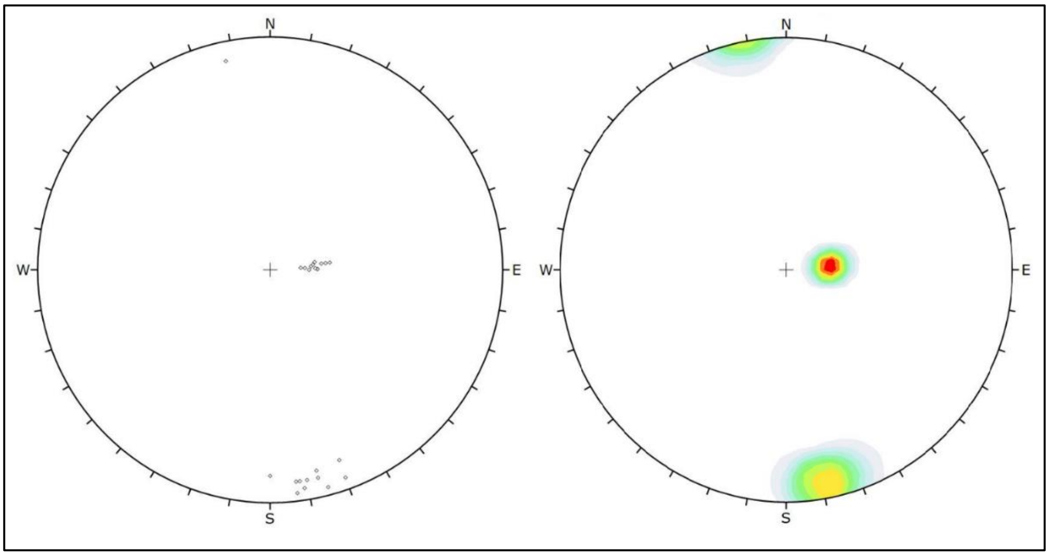


Figure 4.22. Pole plot and contour plot of the discontinuities at road cut MS-5

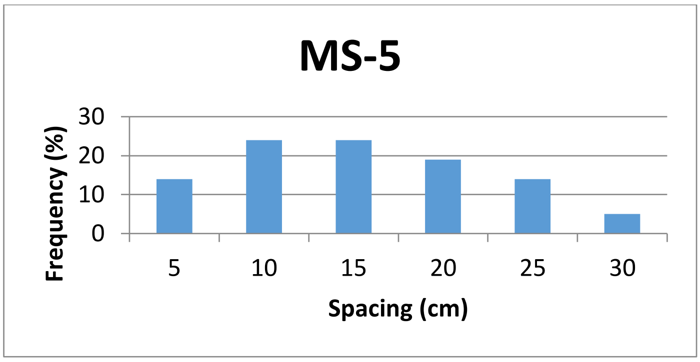


Figure 4.23. Spacing versus frequency histogram for the discontinuities at road-cut MS-5

Weathering and Clay Content Features

According to the field observations, the marl of the cut slope MS-5 is generally identified as highly weathered. Surficial degradation and staining through fractures are observed. The marl layers are prone to weathering due to their fragmented nature, differential weathering is observed at the cut slope. Weathering depth of the cut slope is designated as 30 cm in thickness.

Slake durability test results demonstrate that the marl of the cut slope MS-5 has medium high durability both for fresh and weathered rock types (Table 4.28). The difference in Id(20) values for fresh and weathered limestone specimens are resulted from degrees of degradation. In addition, methylene blue test results for fresh and weathered rock types are close to each other.

Table 4.28. *Slake durability and methylene blue test results of the specimens at MS-5*

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-5	Marl	94.72	77.47	1.60	3.60	91.82	69.55	1.73	3.90

4.3.8. Stop MS-6

Description

Location of the cut slope MS-6 is nearly 13 km south of Karabük centrum in the Ulus formation. The height of MS-6 is approximately 25 m and measured dip of the cut slope is 60°. Cut slope MS-6 is composed of sandstone-mudstone alternation that is 60 % of yellow-brownish, nearly 50-100 cm thick fine-medium grained sandstone and 40 % of grayish nearly 10 cm thick, fine grained mudstone (Figure 4.24). As a field observation, the cut slope MS-6 is stable however, surficial degradation and surficial failures are encountered and resulted in rockfalls of 10 cm, 20 cm and rarely 30 cm rock specimens into the drainage channel in front of the cut slope. Excavation method for the cut slope is mechanical excavation, thus disturbance factor (D) can be taken as 0.7.

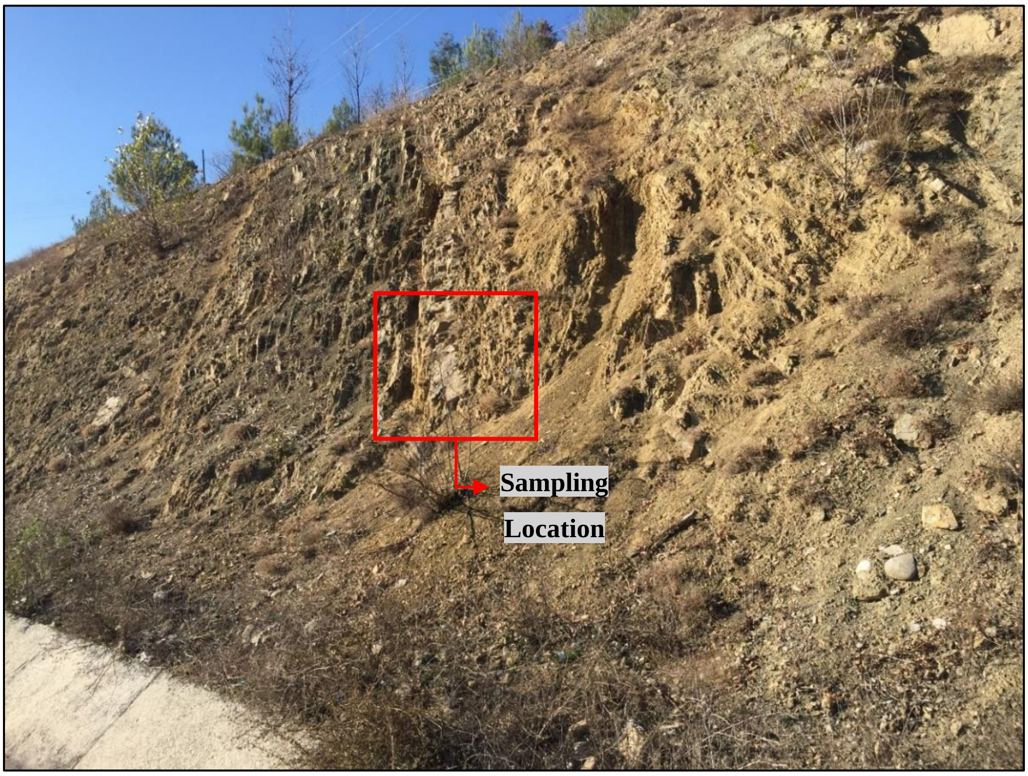


Figure 4.24. View of the road-cut at MS-6

Unit Weight and Strength

Unit weight results of the cut slope MS-6 are demonstrated in Table 4.29. In order to achieve the resultant value, weighted average of the sandstone and the mudstone from this cut slope are considered. The resultant value for fresh rock material is 25.08 kN/m^3 and the resultant value for weathered rock material is 24.72 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-6 are shown in Table 4.29. Saturated uniaxial compressive strength values of the limestone and mudstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the cut slope MS-6 and that is 10. However, k value for the mudstone is obtained from the literature survey as 8 (Hawkins and Oliver, 1986). The reason of lacking the UCS test for the mudstone is impossibility of gathering sufficient sized specimens to apply the test. The point load tests are performed both parallel and normal to the anisotropy planes for the mudstone. The values that are parallel to the anisotropy plane are used for the cut slope MS-6 taking into account of potential failure direction. UCS value of the rock mass that is used for the stability analysis is determined as 14 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.29. *UCS and unit weight values of the specimens at MS-6*

				Fresh		Weathered	
Stop	**Rock Type**	**Test**		**Dry**	**Saturated**	**Dry**	**Saturated**
MS-6	**Sandstone**	**UCS (MPa)**		67.25	18.23	28.78	10.44
		Unit Weight (kN/m^3)		24.31	25.55	24.17	25.24
MS-6	**Mudstone**	**UCS (MPa)**	⊦	40.15	17.47	12.96	7.89
			=	18.33	6.86	8.29	2.94
		Unit Weight (kN/m^3)		23.14	24.36	22.48	23.95

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-6 are designated as 70/160 and 40/070 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.25. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.26. It can be said that persistence of the discontinuities is mostly consistent with spacing and bedding planes. 2 mm, 3 mm and 4 mm apertures were encountered, and the infill material of the discontinuities are calcite that are 2 to 4 mm in thickness.

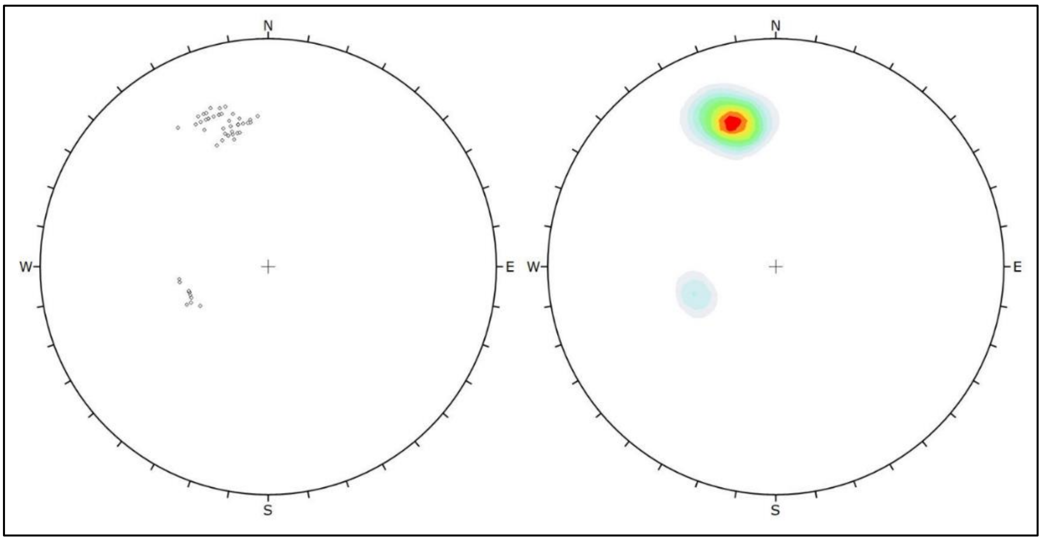


Figure 4.25. Pole plot and contour plot of the discontinuities at road cut MS-6

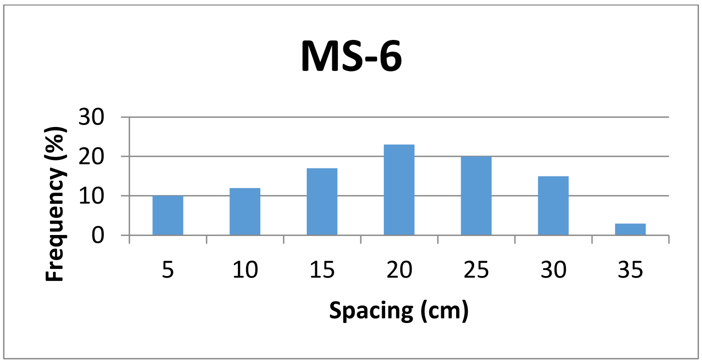


Figure 4.26. Spacing versus frequency histogram for the discontinuities at road-cut MS-6

Weathering and Clay Content Features

According to the field observations, both the sandstone and the mudstone of the cut slope MS-6 is generally identified as slightly weathered. There are surficial degradation and staining through fractures. Besides, the mudstone layers are much more prone to weathering due to their fragmented nature thus differential weathering is observed. Weathering depth of the cut slope is designated as 35 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-6 is highly durable both for fresh and weathered rock types (Table 4.30). Id(2) value of weathered mudstone shows high durability (Table 4.30). The difference in Id(20) values for fresh and weathered sandstone specimens are resulted from degrees of degradation. Due to highly fractured nature and deep weathering zone fresh specimens for the mudstone could not be collected to conduct slake durability test and methylene blue adsorption test. None the less, the methylene blue test results for fresh and weathered sandstone show some differences because of differential weathering.

Table 4.30. *Slake durability and methylene blue test results of the specimens at MS-6*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-6	Sandstone	97.59	89.88	1.60	3.60	96.66	86.04	2.27	5.10
	Mudstone	-	-	-	-	97.73	90.00	2.00	4.50

4.3.9. Stop MS-7.1

Description

Location of the cut slope MS-7.1 is nearly 13 km southwest of Ereğli county town in the Akveren formation. The height of MS-7.1 is approximately 35 m and measured dip of the cut slope is 66°. The cut slope is composed of limestone that is white-rarely yellowish-brownish colored, nearly 10-15 cm thick bedded, fine-medium grained (Figure 4.27). Limestone blocks that were 5 to 10 cm and maximum 20 cm were encountered above the wall however none of them was observed below the wall. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.27. View of the road-cut at MS-7.1

Unit Weight and Strength

Unit weight results of the cut slope MS-7.1 are demonstrated in Table 4.31. The unit weight value for fresh rock material is 25.02 kN/m^3 and the resultant value for weathered rock material is 24.90 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-7.1 are shown in Table 4.31. Saturated uniaxial compressive strength values of the limestone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the limestone of cut slope MS-7.1 and that is 18. UCS value of the rock mass that is used for the stability analysis is determined as 55 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.31. *UCS and unit weight values of the specimens at MS-7.1*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-7.1	**Limestone**	**UCS (MPa)**	148.15*	54.96	112.12*	41.32
		Unit Weight (kN/m^3)	24.16	25.02	23.98	24.90

**The UCS values of dry limestone samples are too high that were not used in the analysis.*

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-7.1 are designated as 22/260, 65/240, 70/330 and 65/060 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.28. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.29. It can be said that persistence of the discontinuities are mostly consistent with spacing and bedding planes. 1 mm to 8 mm apertures were encountered, and the infill material of the discontinuities are generally clay that are 2 mm to 4 mm in thickness.

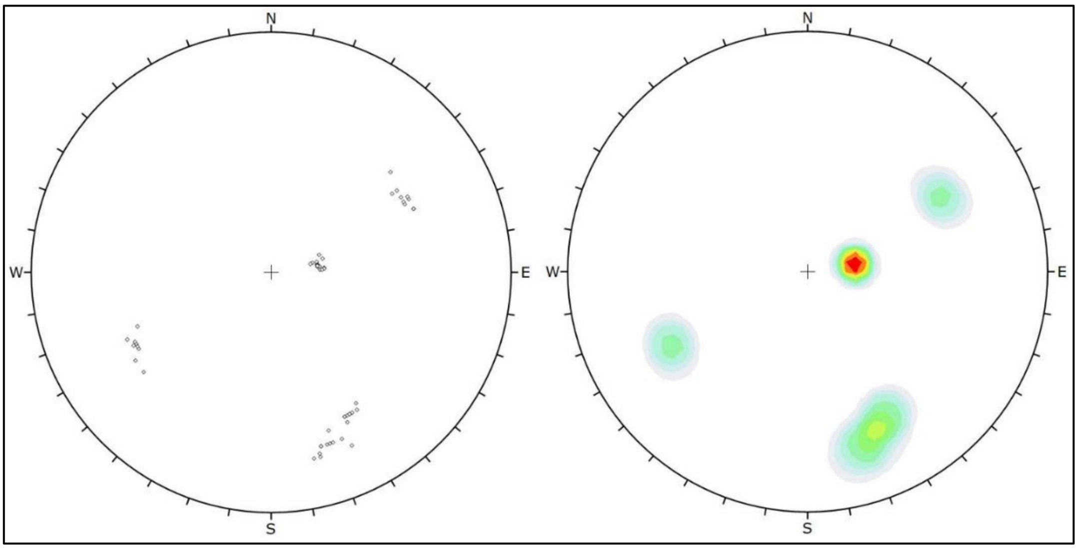


Figure 4.28. Pole plot and contour plot of the discontinuities at road cut MS-7.1

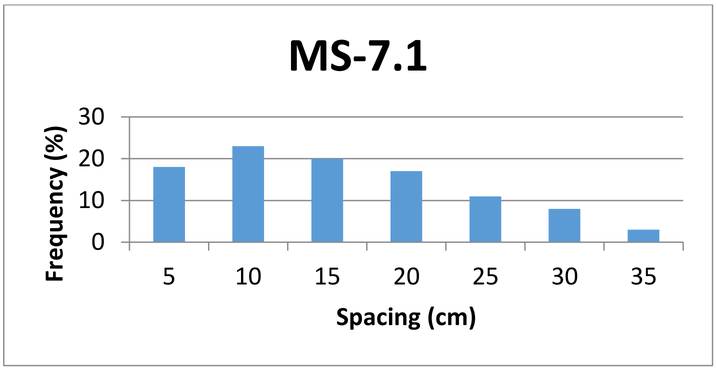


Figure 4.29. Spacing versus frequency histogram for the discontinuities at road-cut MS-7.1

Weathering and Clay Content Features

According to the field observations, the limestone of the cut slope MS-7.1 is generally identified as slightly weathered. Locally, there are surficial degradation and staining through fractures in the limestone beds. Differential weathering observed at the cut slope between the limestone layers. Weathering depth of the cut slope is designated as 25 cm in thickness.

Slake durability test results demonstrate that the limestone of the cut slope MS-7.1 has very high durability both for fresh and weathered rock types (Table 4.32). The difference in Id(20) values for fresh and weathered limestone specimens are resulted from degrees of degradation. In spite of this, methylene blue test results for fresh and weathered rock types are identical.

Table 4.32. *Slake durability and methylene blue test results of the specimens at MS-7.1*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-7.1	Limestone	99.24	96.62	1.07	2.40	98.47	93.69	1.07	2.40

4.3.10. Stop MS-7.2

Description

Location of the cut slope MS-7.2 is nearly 13 km southwest of Ereğli county town in the Akveren formation, opposite of the cut slope MS-7.1, across the road. The height of MS-7.2 is approximately 8 m and measured dip of the cut slope is 64°. Cut slope MS-7.2 is composed of limestone that is white-rarely yellowish-brownish colored, nearly 10-15 cm thick bedded, fine-medium grained (Figure 4.30). Limestone blocks that were 5 to 10 cm were encountered above the wall however none of them was observed below the wall. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.30. View of the road-cut at MS-7.2

Unit Weight and Strength

Unit weight results of the cut slope MS-7.2 are demonstrated in Table 4.33. The unit weight value for fresh rock material is 24.64 kN/m^3 and the resultant value for weathered rock material is 24.60 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-7.2 are shown in Table 4.33. Saturated uniaxial compressive strength values of the limestone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the limestone of the cut slope MS-7.2 and that is 18. UCS value of the rock mass that is used for the stability analysis is determined as 63 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.33. *UCS and unit weight values of the specimens at MS-7.2*

			Fresh		**Weathered**	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-7.2	**Limestone**	**UCS (MPa)**	133.06*	62.63	132.38*	60.63
		Unit Weight (kN/m^3)	23.55	24.64	23.49	24.60

**The UCS values of dry limestone samples are too high that were not used in the analysis.*

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-7.2 are designated as 25/260, 70/340, and 65/070 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.31. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.32. It can be said that persistence of the discontinuities are mostly consistent with spacing and bedding planes. 2 mm to 4 mm apertures were encountered, and the infill material of the discontinuities are generally clay that are 2 mm to 4 mm in thickness.

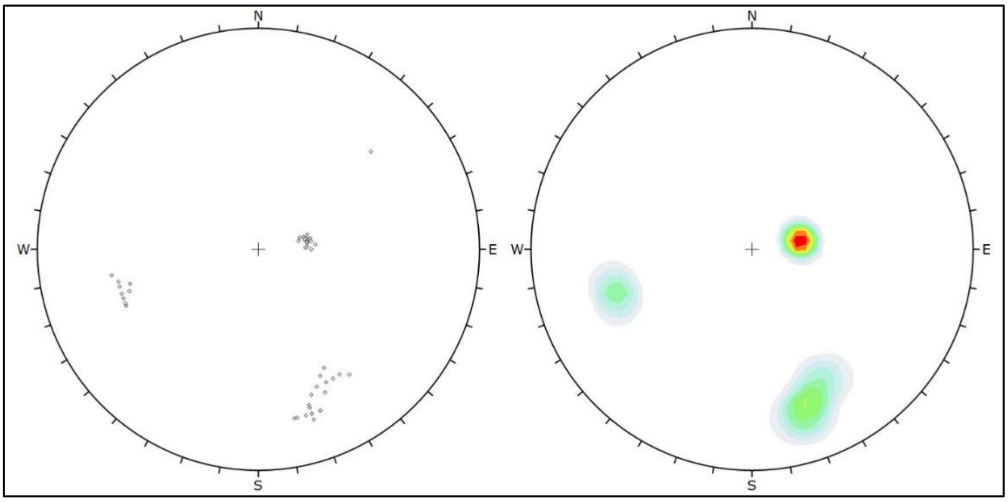


Figure 4.31. Pole plot and contour plot of the discontinuities at road cut MS-7.2

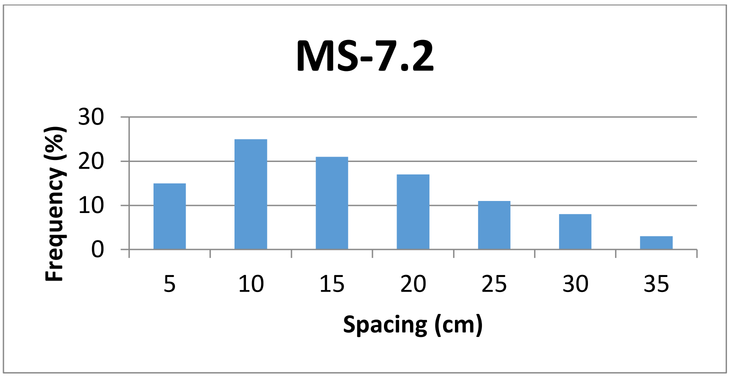


Figure 4.32. Spacing versus frequency histogram for the discontinuities at road-cut MS-7.2

Weathering and Clay Content Features

According to the field observations, the limestone of the cut slope MS-7.2 is generally identified as slightly weathered. Locally, there are surficial degradation and staining through fractures in the limestone beds. Differential weathering observed at the cut slope between the limestone layers. Weathering depth of the cut slope is designated as 25 cm in thickness.

Slake durability test results demonstrate that the limestone of the cut slope MS-7.2 has very high durability both for fresh and weathered rock types (Table 4.34). Id(20) values for fresh and weathered limestone specimens are very close to each other. Nonetheless, methylene blue test results for fresh and weathered rock types are close to each other and shows that weathering effect on the limestone is quite low.

Table 4.34. *Slake durability and methylene blue test results of the specimens at MS-7.2*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-7.2	Limestone	99.16	96.00	0.80	1.80	98.87	95.10	0.93	2.10

4.3.11. Stop MS-8.1

Description

Location of the cut slope MS-8.1 is nearly 13 km southeast of Akçakoca county town in the Çaycuma formation. The height of MS-8.1 is approximately 8 m and measured dip of the cut slope is 30°. The cut slope is composed of sandstone that is gray and brownish in color, nearly 4 to 15 cm thick fine-medium grained (Figure 4.33). As field observation the cut slope MS-8.1 is stable however, surficial degradation and surficial failures and resulted in rockfalls of 4-5 cm blocks on the retaining wall and rarely the drainage channel in front of the cut slope. Surface staining is observed as color changes into gray and weathered surface color changes into brown. Excavation method for the cut slope is mechanical excavation, thus disturbance factor (D) can be taken as 0.7.

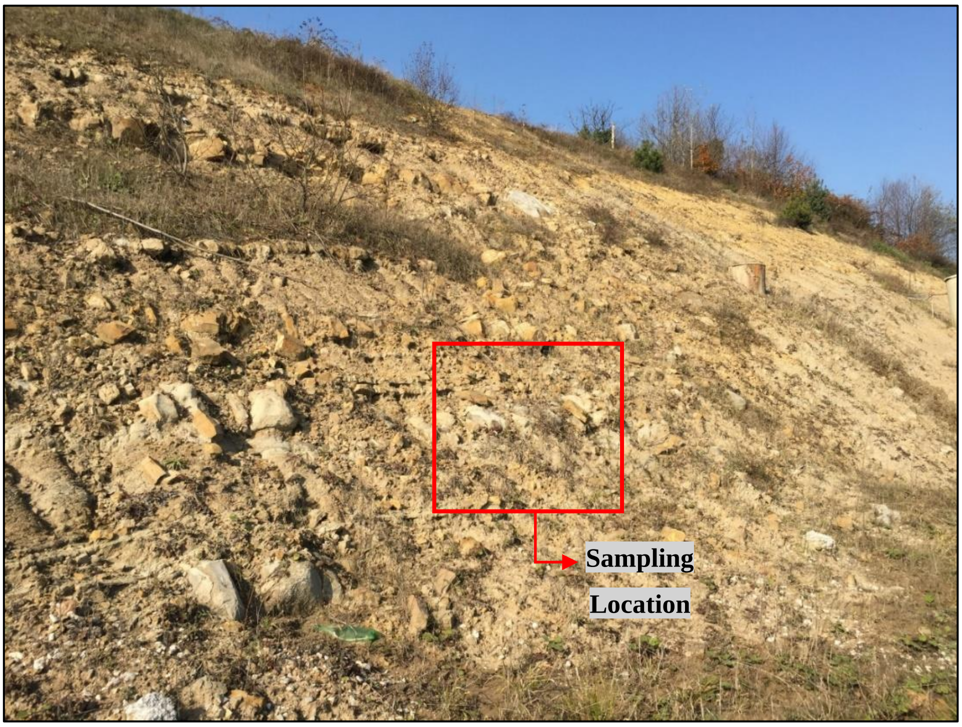


Figure 4.33. View of the road-cut at MS-8.1

Unit Weight and Strength

Unit weight results of the cut slope MS-8.1 are demonstrated in Table 4.35. The unit weight value for fresh rock material is 25.70 kN/m^3 and the resultant value for weathered rock material is 25.34 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-8.1 are shown in Table 4.35. Saturated uniaxial compressive strength values of the sandstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-8.1 and that is 10. UCS value of the rock mass that is used for the stability analysis is determined as 42 MPa by taking weighted average considering weathered rock mass value.

Table 4.35. *UCS and unit weight values of the specimens at MS-8.1*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-8.1	**Sandstone**	**UCS (MPa)**	78.82	41.71	66.52	28.39
		Unit Weight (kN/m^3)	25.17	25.70	24.62	25.34

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-8.1 are designated as 40/330, 60/125, 65/040 and 65/000 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.34. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.35. It can be said that persistence of the discontinuities are mostly consistent with spacing and bedding planes are more consistent. 1 mm, 2 mm and 5 mm apertures were encountered, and the infill material of the discontinuities are generally clayey sand and sandy clay that are 1 to 4 mm in thickness.

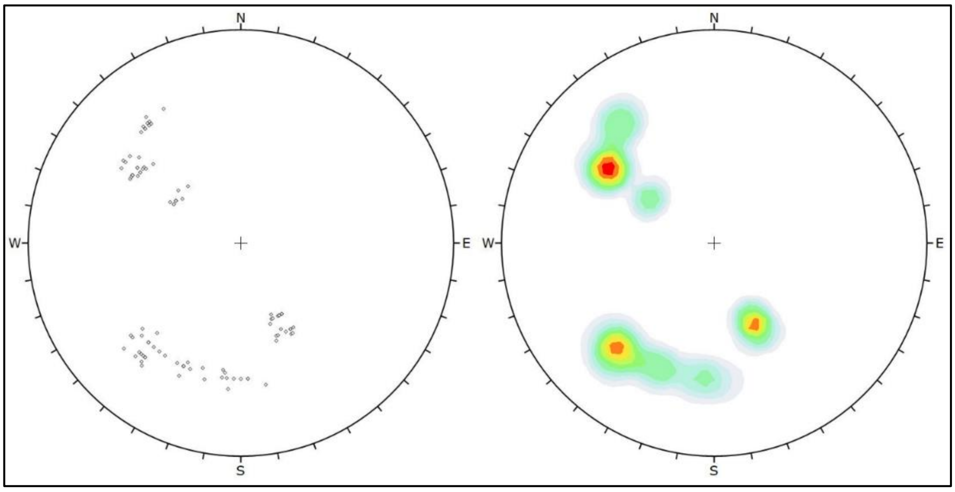


Figure 4.34. Pole plot and contour plot of the discontinuities at road cut MS-8.1

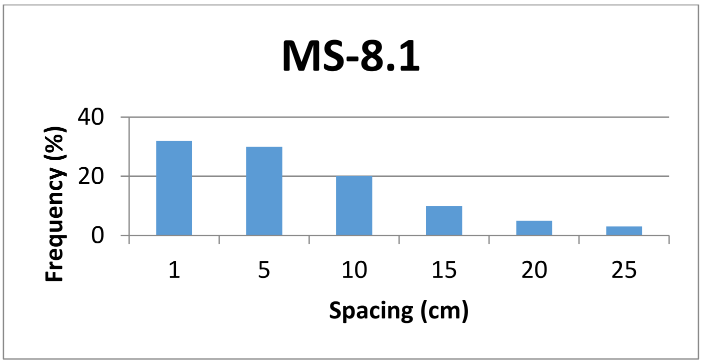


Figure 4.35. Spacing versus frequency histogram for the discontinuities at road-cut MS-8.1

Weathering and Clay Content Features

According to the field observations, the sandstone of the cut slope MS-8.1 is generally identified as moderately weathered. There are surficial degradation and staining through fractures. The sandstone layers are prone to weathering due to their fragmented nature. Weathering depth of the cut slope is designated as 30 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-8.1 has very high durability both for fresh and weathered rock types (Table 4.36). The slight difference in Id(20) values for fresh and weathered sandstone specimens are resulted from degrees of degradation. In addition, the methylene blue test results for the fresh and weathered rock types are given in Table 4.36.

Table 4.36. *Slake durability and methylene blue test results of the specimens at MS-8.1*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-8.1	Sandstone	98.73	94.33	0.93	2.10	98.10	92.33	1.20	2.70

4.3.12. Stop MS-8.2

Description

Location of the cut slope MS-8.2 is nearly 13 km southeast of Akçakoca county town, adjacent to the cut slope MS-8.1 and in the Çaycuma formation. The height of MS-8.2 is approximately 10 m and measured dip of the cut slope is 30°. Cut slope MS-8.2 is composed of sandstone that is gray and brownish in color, nearly 4 to 15 cm thick fine-medium grained (Figure 4.36). As a field observation, the cut slope MS-8.2 is stable however, surficial degradation and surficial failures and resulted in rockfalls of 4-5 cm blocks on the retaining wall and rarely the drainage channel in front of the cut slope. Surface retaining is observed as color changes into gray and weathered surface color changes into brown. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.36. View of the road-cut at MS-8.2

Unit Weight and Strength

Unit weight results of the cut slope MS-8.2 are demonstrated in Table 4.37. The unit weight value for fresh rock material is 25.65 kN/m^3 and the resultant value for weathered rock material is 24.64 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-8.2 are shown in Table 4.37. Saturated uniaxial compressive strength values of the sandstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-8.2 and that is 10. UCS value of the rock mass that is used for the stability analysis is determined as 34 MPa by taking weighted average considering weathered rock mass value.

Table 4.37. *UCS and unit weight values of the specimens at MS-8.2*

			Fresh		**Weathered**	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-8.2	**Sandstone**	**UCS (MPa)**	82.46	34.48	18.75	5.11
		Unit Weight (kN/m^3)	25.15	24.65	23.54	25.64

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-8.2 are designated as 30/000, 90/090, 65/160 and 70/185 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.37. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.38. It can be said that persistence of the discontinuities is mostly consistent with spacing and bedding planes are more consistent. 5 mm to 10 mm apertures were encountered, and the infill material of the discontinuities are generally clayey sand and sandy clay that are 3 to 8 mm in thickness.

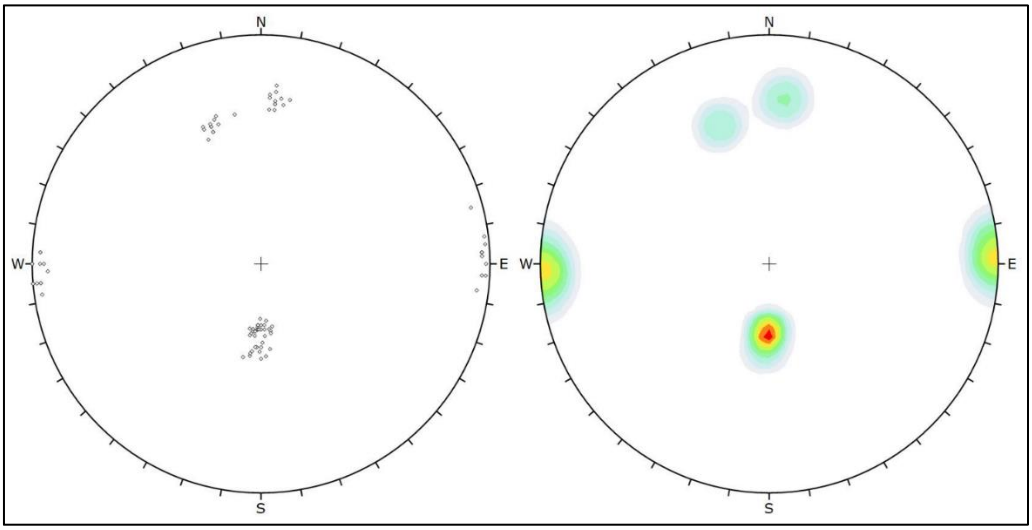


Figure 4.37. Pole plot and contour plot of the discontinuities at road cut MS-8.2

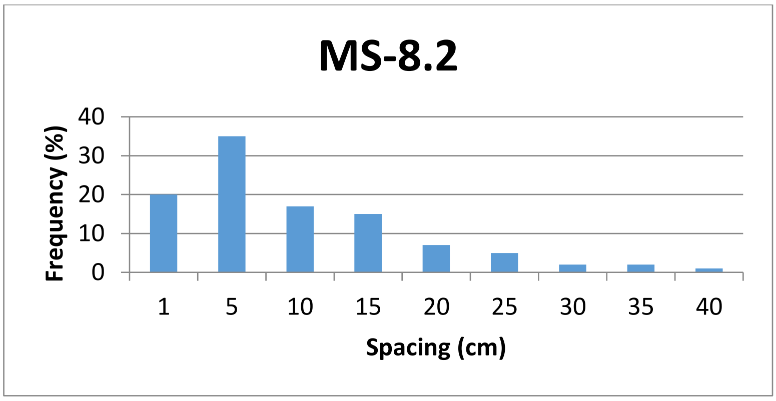


Figure 4.38. Spacing versus frequency histogram for the discontinuities at road-cut MS-8.2

Weathering and Clay Content Features

According to the field observations, the sandstone of the cut slope MS-8.2 is generally identified as slightly to moderately weathered. There are surficial degradation and staining through fractures. The sandstone layers are prone to weathering due to their fragmented nature. Weathering depth of the cut slope is designated as 30 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-8.2 has very high durability for fresh rock type, however; for weathered rock types the sandstone has medium high durability (Table 4.38). The difference in Id(20) values for fresh and weathered sandstone specimens are very high and it may be resulted from degrees of degradation. The methylene blue test results for fresh and weathered rock types are given in Table 4.38.

Table 4.38. Slake durability and methylene blue test results of the specimens at MS-8.2

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-8.2	Sandstone	98.76	94.79	1.07	2.40	85.57	41.55	1.73	3.90

4.3.13. Stop MS-9

Description

Location of the cut slope MS-9 is nearly 10 km southeast of Akçakoca county town in the Çakraz formation. The height of MS-9 is approximately 8 m and measured dip of the cut slope is 65°. The cut slope is composed of sandstone-marl alternation that is 65 % of yellowish white, nearly 2 cm thick fine-grained sandstone and 35 % of yellowish-light brown, nearly to 1 cm thick, fine grained marl (Figure 4.39). Surficial degradation and surficial failures are encountered and 4 to 5 cm block sized rockfalls are observed. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

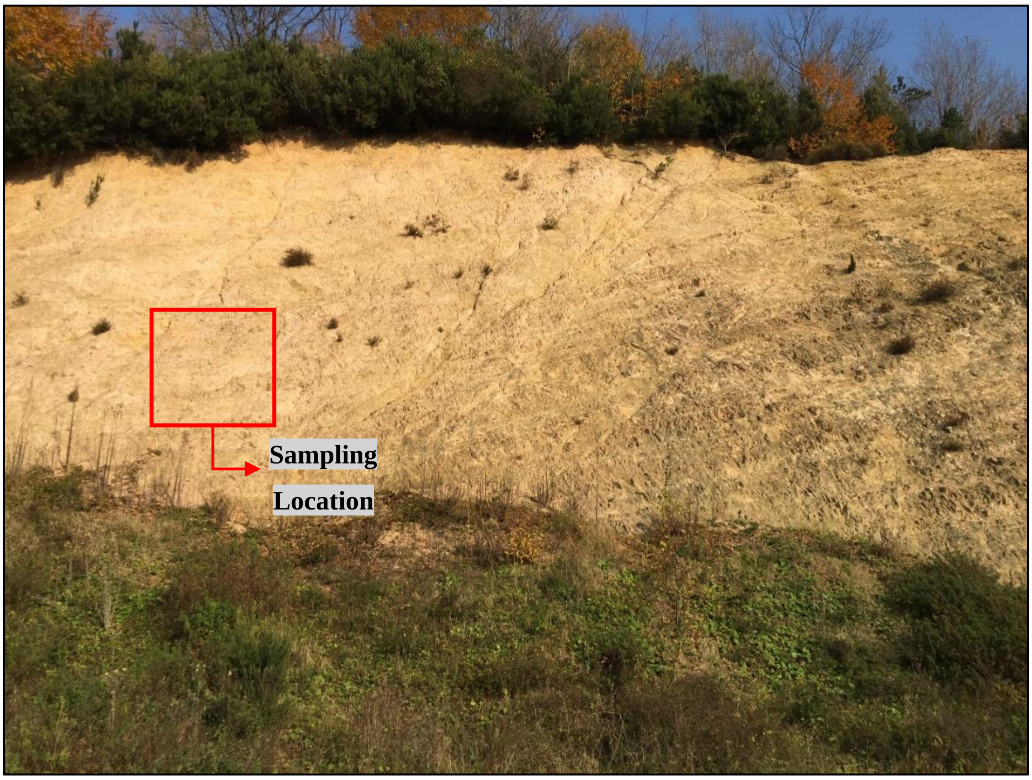


Figure 4.39. View of the road-cut at MS-9

Unit Weight and Strength

Unit weight results of the cut slope MS-9 are demonstrated in Table 4.39. In order to achieve the resultant value, weighted average of the sandstone and the marl from this cut slope are considered. The resultant value for fresh rock material is 22.31 kN/m^3 and the resultant value for weathered rock material is 21.83 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-9 are shown in Table 4.39. Saturated uniaxial compressive strength values of the sandstone and the marl are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-9 and that is 10. However, k value for the marl is obtained from the literature survey as 8 (Azimian et al., 2013). The reason of lacking the UCS test for the marl is impossibility of gathering sufficient sized specimens to apply the test. UCS value of the rock mass that is used for the stability analysis is determined as 17 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.39. *UCS and unit weight values of the specimens at MS-9*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-9	**Sandstone**	**UCS (MPa)**	28.81	18.47	12.90	7.25
		Unit Weight (kN/m^3)	20.17	22.31	19.22	21.61
MS-9	**Marl**	**UCS (MPa)**	21.83	13.94	9.78	5.65
		Unit Weight (kN/m^3)	20.78	22.32	20.20	22.23

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-9 are designated as 40/030, 60/040, 70/100 and 85/060 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.40. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.41. It can be said that persistence of the discontinuities are mostly consistent with spacing, and bedding planes are more consistent. 1 mm to 5 mm apertures were encountered, and the infill material of the discontinuities are generally silt, clayey sand-sandy clay that are 1 to 4 mm in thickness. High degree of jointing in the rocks implies small sized blocks, which match with the already fallen marl fragments.

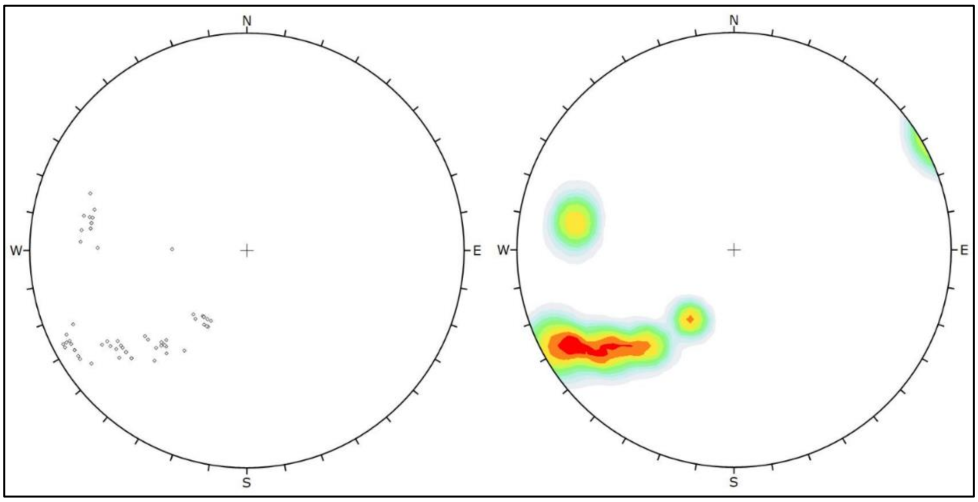


Figure 4.40. Pole plot and contour plot of the discontinuities at road cut MS-9

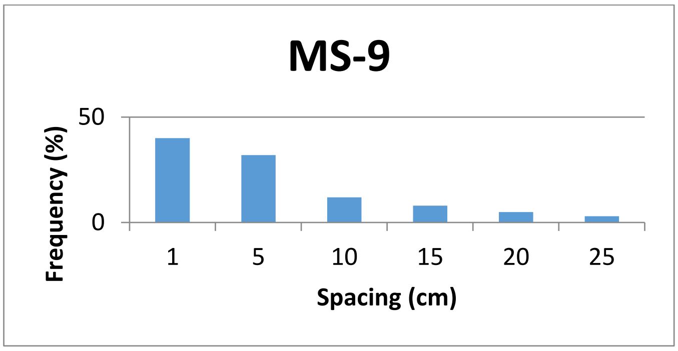


Figure 4.41. Spacing versus frequency histogram for the discontinuities at road-cut MS-9

Weathering and Clay Content Features

According to the field observations, both sandstone and the marl of the cut slope MS-9 is generally identified as moderately weathered. Locally, there are surficial degradation and staining through fractures. Weathering depth of the cut slope is designated as 30 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-9 has low durability both for fresh and weathered rock types. In addition, Id(2) value of the marl of the cut slope MS-9 has medium high durability for fresh rock type, and the marl specimens show medium durability for weathered rock types (Table 4.40). The difference in Id(20) values for fresh and weathered sandstone specimens are resulted from degrees of degradation. Besides, the difference between Id(20) values of fresh and weathered marl is very high. In spite of this, the methylene blue test results for fresh and weathered sandstone are identical. The methylene blue and the slake durability results of the marl and sandstone indicates that the marl are prone to weathering much more as against the sandstone of the cut slope MS-9.

Table 4.40. *Slake durability and methylene blue test results of the specimens at MS-9*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-9	Sandstone	52.05	10.96	0.93	2.10	58.73	8.08	0.93	2.10
	Marl	91.18	78.07	0.67	1.50	69.49	8.57	0.93	2.10

4.3.14. Stop MS-10

Description

Location of the cut slope MS-10 is nearly 10 km southeast of Akçakoca county town in the Çakraz formation. Total height of MS-10 is approximately 60 m with 2 benches and measured dip of the cut slope is 45°. Cut slope MS-10 is composed of sandstone that is volcanogenic in character with andesite fragments, brown-yellowish colored, medium (Figure 4.42). Large sandstone blocks were encountered that are mostly 5 to 10 cm and maximum 30 cm sized. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.42. View of the road-cut at MS-10

Unit Weight and Strength

Unit weight results of the cut slope MS-10 are demonstrated in Table 4.41. The unit weight value for fresh rock material is 23.25 kN/m^3 and the resultant value for weathered rock material is 23.14 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-10 are shown in Table 4.41. Saturated uniaxial compressive strength values of the sandstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-10 and that is 10. UCS value of the rock mass that is used for the stability analysis is determined as 18 MPa by taking weighted average considering relatively fresh, saturated rock mass value.

Table 4.41. *UCS and unit weight values of the specimens at MS-10*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-10	**Sandstone**	**UCS (MPa)**	34.16	18.34	12.72	7.24
		Unit Weight (kN/m^3)	21.95	23.25	21.65	23.14

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-10 are designated as 70/230, 70/175 and 70/260 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.43. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.44. 1 mm, 2 mm and 3 mm apertures were encountered, and there was generally no infill material of the discontinuities.

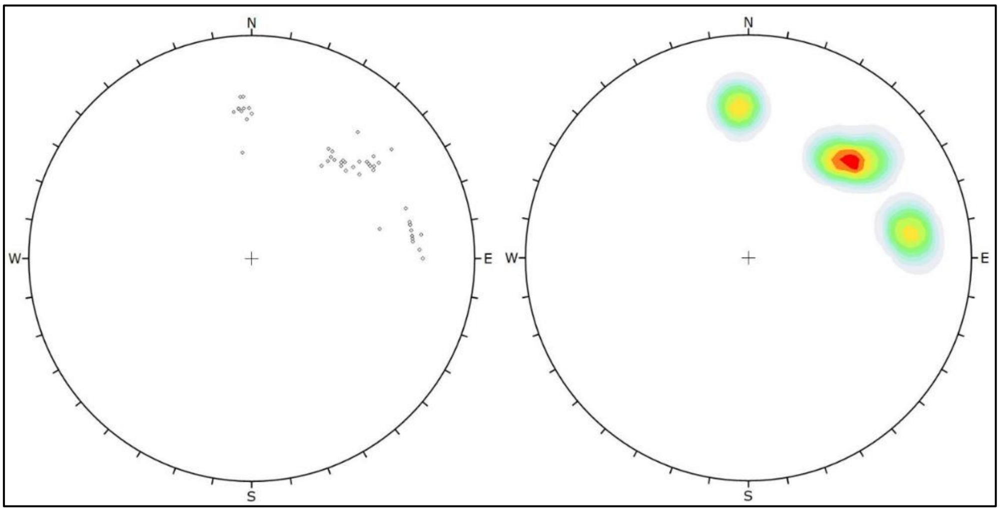


Figure 4.43. Pole plot and contour plot of the discontinuities at road cut MS-10

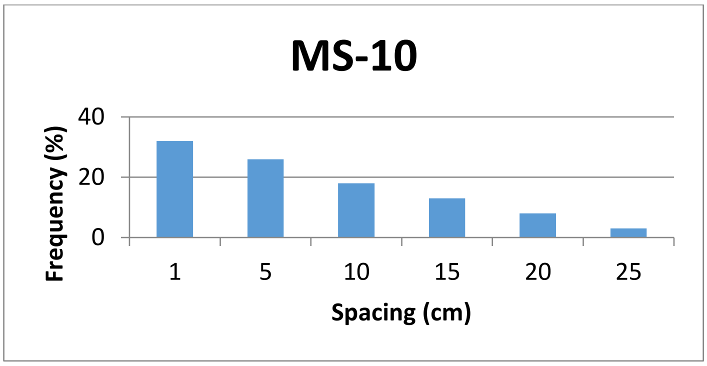


Figure 4.44. Spacing versus frequency histogram for the discontinuities at road-cut MS-10

Weathering and Clay Content Features

According to the field observations, the sandstone of the cut slope MS-10 is generally identified as moderately weathered. Locally, there are surficial degradation and staining through fractures. Weathering depth of the cut slope is designated as 25 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-10 has very high durability and the weathered sandstone has high durability (Table 4.42). The difference in Id(20) values for fresh and weathered sandstone specimens are resulted from degrees of degradation. For all that, the methylene blue test results for fresh and weathered rock types are identical and quite low.

Table 4.42. *Slake durability and methylene blue test results of the specimens at MS-10*

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-10	Sandstone	98.37	92.64	0.67	1.50	97.36	84.99	0.67	1.50

4.3.15. Stop MS-11

Description

Location of the cut slope MS-11 is nearly 9 km southeast of Akçakoca county town in the Çakraz formation. The height of MS-11 is approximately 40 m and measured dip of the cut slope is 40°. The cut slope is composed of sandstone that is reddish brown-yellowish brown medium grained (Figure 4.45). Large sandstone blocks were encountered that were mostly 10 cm, 50 cm to 70 cm sized. Unlike other road-cuts, the excavation method is conventional blasting therefore disturbance factor (D) for this road cut is 1.

Figure 4.45. View of the road-cut at MS-11

Unit Weight and Strength

Unit weight results of the cut slope MS-11 are demonstrated in Table 43. The resultant value for fresh rock material is 24.84 kN/m^3 and the resultant value for weathered rock material is 23.57 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-11 are shown in Table 4.43. Saturated uniaxial compressive strength values of the sandstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-11 and that is 10. UCS value of the rock mass that is used for the stability analysis is determined as 32 MPa by taking weighted average considering relatively fresh rock mass value.

Table 4.43. *UCS and unit weight values of the specimens at MS-11*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-11	**Sandstone**	**UCS (MPa)**	59.49	32.30	47.29	26.61
		Unit Weight (kN/m^3)	24.43	24.84	22.95	23.57

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-11 are designated as 60/185 and 90/080 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.46. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.47. 1 mm, 2 mm and 3 mm apertures were encountered, and there was no infill material of the discontinuities.

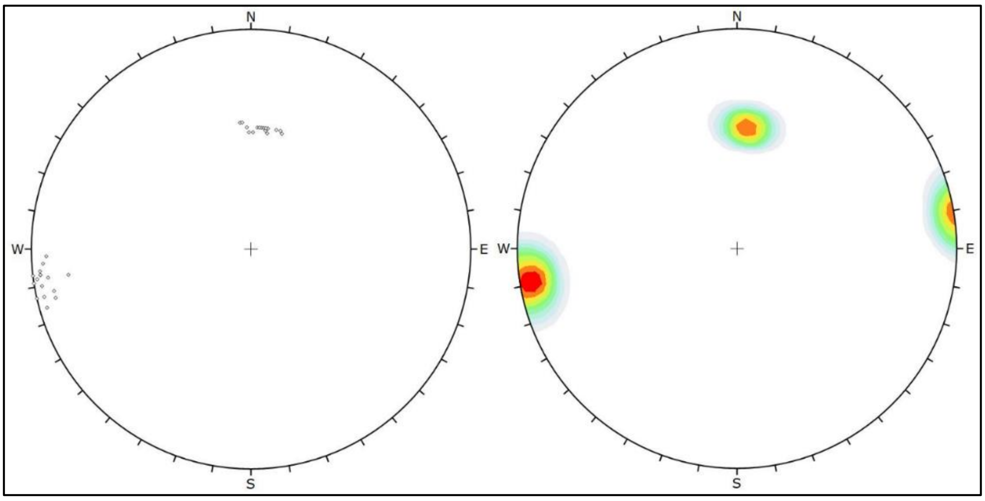


Figure 4.46. Pole plot and contour plot of the discontinuities at road cut MS-11

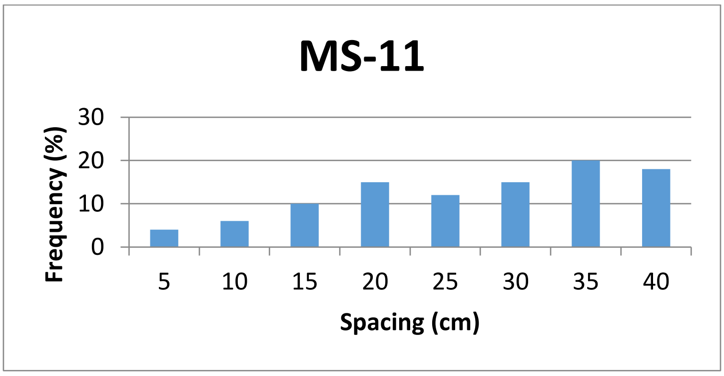


Figure 4.47. Spacing versus frequency histogram for the discontinuities at road-cut MS-11

Weathering and Clay Content Features

According to the field observations, the sandstone of the cut slope MS-11 is generally identified as moderately weathered. Locally, there are surficial degradation and staining through fractures. Weathering depth of the cut slope is designated as 25 cm in thickness.

Slake durability test results demonstrate that the sandstone of the cut slope MS-11 has very high durability for both fresh and weathered rock types (Table 4.44). The difference in Id(20) values for fresh and weathered sandstone specimens are quite low.

For all that, methylene blue test results for fresh and weathered rock types are identical.

Table 4.44. *Slake durability and methylene blue test results of the specimens at MS-11*

		Fresh				Weathered			
Stop	Rock Type	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)	Slake Durability (Id2)	Slake Durability (Id20)	MBA (gr/100 g)	CEC (meq/ 100 g)
MS-11	Sandstone	98.53	93.98	0.67	1.50	97.87	92.99	0.67	1.50

4.3.16. Stop MS-12

Description

Location of the cut slope MS-12 is nearly 8 km southeast of Akçakoca county town in the Çakraz formation. The height of MS-12 is approximately 15 m and measured dip of the cut slope is 50°. Cut slope MS-12 is composed of sandstone that is brownish-yellowish colored and fine grained (Figure 4.48). Surficial degradation and surficial failures are encountered and also 3 to 5 cm block sized rockfalls are observed. Excavation method for the cut slope is mechanical excavation, therefore disturbance factor (D) can be taken as 0.7.

Figure 4.48. View of the road-cut at MS-12

Unit Weight and Strength

Unit weight results of the cut slope MS-12 are demonstrated in Table 4.45. The unit weight value for fresh rock material is 21.72 kN/m^3 and the resultant value for weathered rock material is 20.87 kN/m^3.

Uniaxial compressive strength (UCS) values of the cut slope MS-12 are shown in Table 4.45. Saturated uniaxial compressive strength values of the sandstone are used in the stability analysis and calculated by considering the related k values obtained by the help of the point load tests. The k value is in coherent with UCS test results for the sandstone of the cut slope MS-12 and that is 10. UCS value of the rock mass that is used for the stability analysis is determined as 18 MPa by taking weighted average considering saturated, relatively fresh rock mass value.

Table 4.45. *UCS and unit weight values of the specimens at MS-12*

			Fresh		Weathered	
Stop	**Rock Type**	**Test**	**Dry**	**Saturated**	**Dry**	**Saturated**
MS-12	**Sandstone**	**UCS (MPa)**	28.64	18.37	12.84	7.25
		Unit Weight (kN/m^3)	19.44	21.72	18.12	20.87

Properties of Discontinuities

The most frequent sets of discontinuities of the cut slope MS-12 are designated as 55/280, 90/000, 7/340, 60/015 and 60/350 in dip/dip direction. The scattered results of discontinuities are demonstrated in pole and contour diagrams as shown in Figure 4.49. A histogram of discontinuity spacing frequency of the discontinuities at the road cut is given in Figure 4.50. It can be said that persistence of the discontinuities is mostly consistent with spacing and bedding planes. 1 mm, 2 mm to 8 mm apertures were encountered, and the infill material of the discontinuities are generally clay that are 2 to 4 mm in thickness. High degree of jointing in the rocks implies small sized blocks, which match with the already fallen sandstone fragments.

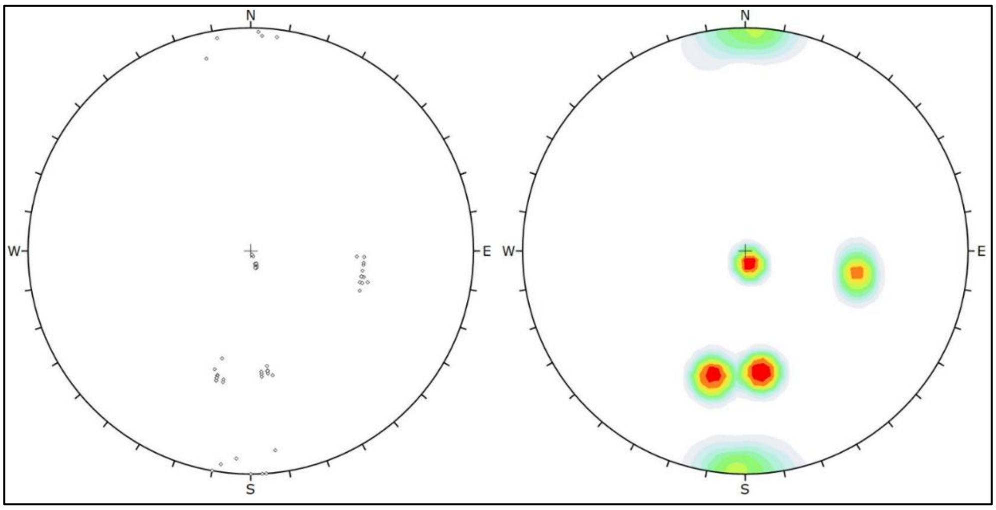


Figure 4.49. Pole plot and contour plot of the discontinuities at road cut MS-12

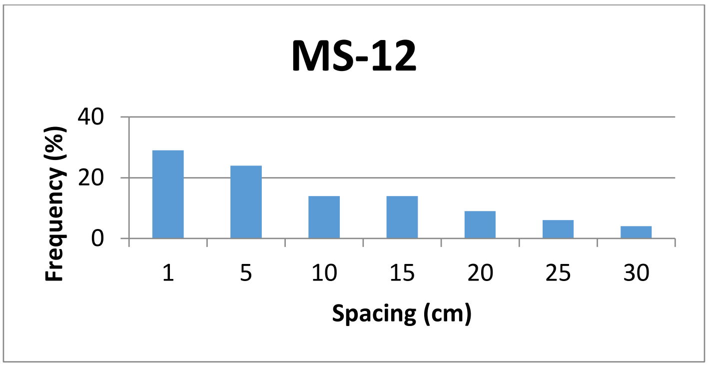


Figure 4.50. Spacing versus frequency histogram for the discontinuities at road-cut MS-12

Weathering and Clay Content Features

According to the field observations, the sandstone of the cut slope MS-12 is generally identified as highly weathered. There are surficial degradation and staining through fractures. Weathering depth of the cut slope is designated as 35 cm in thickness.

Slake durability test results demonstrate that the sandstone has medium to high durability both for fresh and weathered rock types (Table 4.46). The difference in Id(20) values for fresh and weathered limestone specimens are resulted from degrees of degradation. Methylene blue test results for fresh and weathered rock types are given in Table 4.46.

Table 4.46. *Slake durability and methylene blue test results of the specimens at MS-12*

		Fresh				Weathered			
Stop	**Rock Type**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**	**Slake Durability (Id2)**	**Slake Durability (Id20)**	**MBA (gr/100 g)**	**CEC (meq/ 100 g)**
MS-12	Sandstone	92.35	53.35	0.67	1.50	84.71	41.68	1.07	2.40

CHAPTER 5

SLOPE STABILITY AND ROCKFALL ANALYSES

In order to check the stability conditions of each studied road-cut, 2D slope stability analysis were conducted using various software applications. Kinematic analysis for discontinuity-controlled failures by the help of the data collected from the field, limit equilibrium analysis for discontinuity-controlled rocks by using strength properties of both weathered and relatively fresh rocks of the road-cuts were performed. In a similar manner, limit equilibrium analyses for rock mass were conducted for the overall stability of the studied road-cuts. In addition to kinematic and limit equilibrium analysis, rockfall risks of the studied cut slopes were assessed.

5.1. Kinematic Analyses for the Road-cuts

In order to conduct the kinematic analysis for discontinuity-controlled failures of the road-cuts, Dips 6.0 software (Rocscience, 2013) was used with scan-line survey data collected from the field. By applying the analysis, failure forms of the road-cuts were designated namely; planar, toppling and wedge. The results of the kinematic analysis are given in Table 5.1 as percentages of critical discontinuities for each slope.

Table 5.1. *Results of the kinematic analysis of the studied cut slopes*

	Critical Discontinuities (%)		
Stop No.	**Planar**	**Toppling**	**Wedge**
MS-1	3.3	0.0	21.9
MS-2.1	26.4	0.0	49.8
MS-2.2	0.0	0.0	36.2
MS-2.3	0.0	12.0	10.7
MS-3	0.0	0.0	35.0
MS-4	0.0	33.3	5.9
MS-5	0.0	0.0	3.6
MS-6	0.0	0.0	43.3
MS-7.1	0.0	0.0	17.9
MS-7.2	0.0	0.0	0.9
MS-8.1	0.0	0.0	0.5
MS-8.2	0.0	0.0	0.1
MS-9	0.0	43.3	0.0
MS-10	0.0	0.0	7.6
MS-11	0.0	0.0	2.2
MS-12	0.0	0.0	7.0

While performing kinematic analysis in Dips 6.0 software (Rocscience, 2013), equal angle projection, lower hemisphere and Fischer contour distribution were chosen as stereonet options.

For Barton-Bandis failure criterion, an empirical relationship to model the shear strength of the discontinuities was considered for this study, in order to obtain shear strength parameters of the discontinuities at road-cuts. The criterion is relating the shear strength to the normal stress as shown in the equation below:

$$\tau = \sigma_n \tan\left[\phi_r + JRC \log_{10}\left(\frac{JCS}{\sigma_n}\right)\right]$$

where JRC represents the joint roughness coefficient, and JCS is for the joint wall compressive strength (Barton, 1973, 1976) and Φr is for the residual friction angle of surface of failure according to Barton and Choubey (1977) and can be derived from the equation:

$$\phi_r = (\phi_b - 20) + 20(r / R)$$

where Φ_b is the basic friction angle of surface of failure and r is the Schmidt hammer rebound value derived from weathered fracture surfaces and R is the Schmidt hammer rebound value derived from fresh surfaces.

For joint roughness coefficient (JRC), scale correction was made in accordance with the relationship of Barton and Bandis (1982) given below:

$$JRC_n = JRC_o \left(\frac{L_n}{L_o} \right)^{-0.02 JRC_o}$$

where L_0 represent the 100 mm profile-meter length and L_n refer to in situ block sizes.

Similarly, for joint wall compressive strength (JCS), scale correction was made according to the relationship of Barton and Bandis (1982) given below:

$$JCS_n = JCS_o \left(\frac{L_n}{L_o} \right)^{-0.03 JRC_o}$$

where L_0 represent the 100 mm profile-meter length and L_n refer to in situ block sizes.

JRC values were designated by matching of discontinuity surfaces profiles obtained with the help of hand profile-meter at the field with standard profiles of Barton and Choubey (1977) (Figure 5.1).

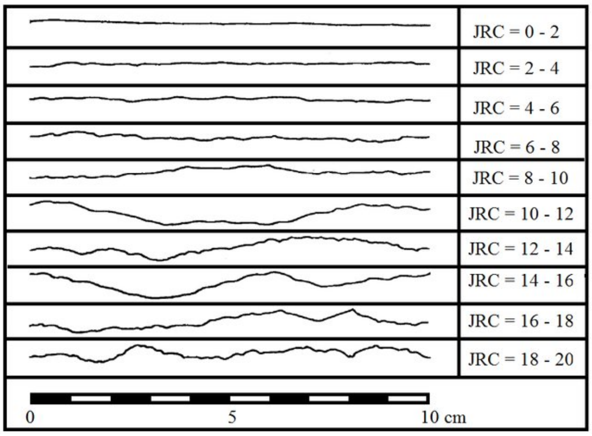


Figure 5.1. Roughness profiles and related JRC ranges (Barton and Choubey, 1977)

Kinematical analyses were conducted by considering internal friction angle obtained from shear box test results (basic friction angle (Φ_b) value) of the study by Ersöz and Topal (2018b), because the studied areas are very close to each other and consisting of the same lithologies with similar rock types.

The shear strength parameters of the rock mass as cohesion (c) and internal friction angle (Φ) were designated by considering the height and saturated unit weight for each road-cut (Figure 5.2).

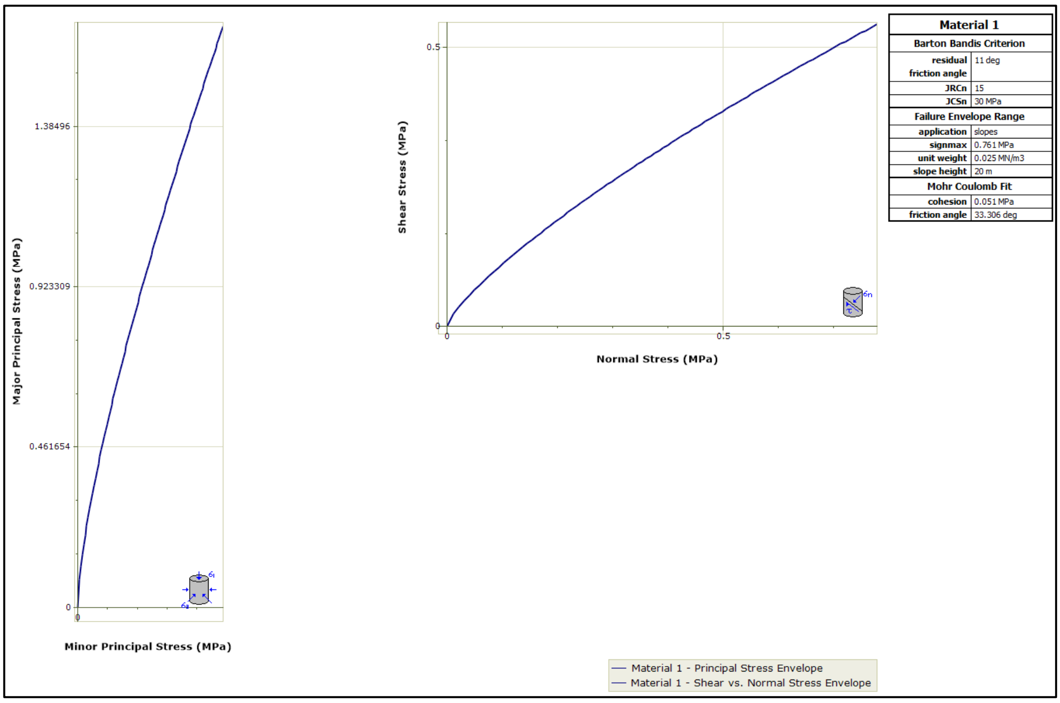


Figure 5.2 The shear strength values of the representative cut slope MS-1 (RocData, 2014)

The kinematic anaylses show that wedge failure possibility is likely at the cut slopes MS-1, MS-2.1, MS-2.2, MS-2.3, MS-3, MS-6, MS-7.1, MS-10 and MS-12. Planar sliding is critical for the cut slopes MS-1 and MS-2.1. Finally, toppling failure possibility is observed at the road-cuts MS-2.3 and MS-4. Further analysis of limit equilibrium for the discontinuity-controlled rocks were conducted by taking into consideration of these results (Figure 5.3-5.18).

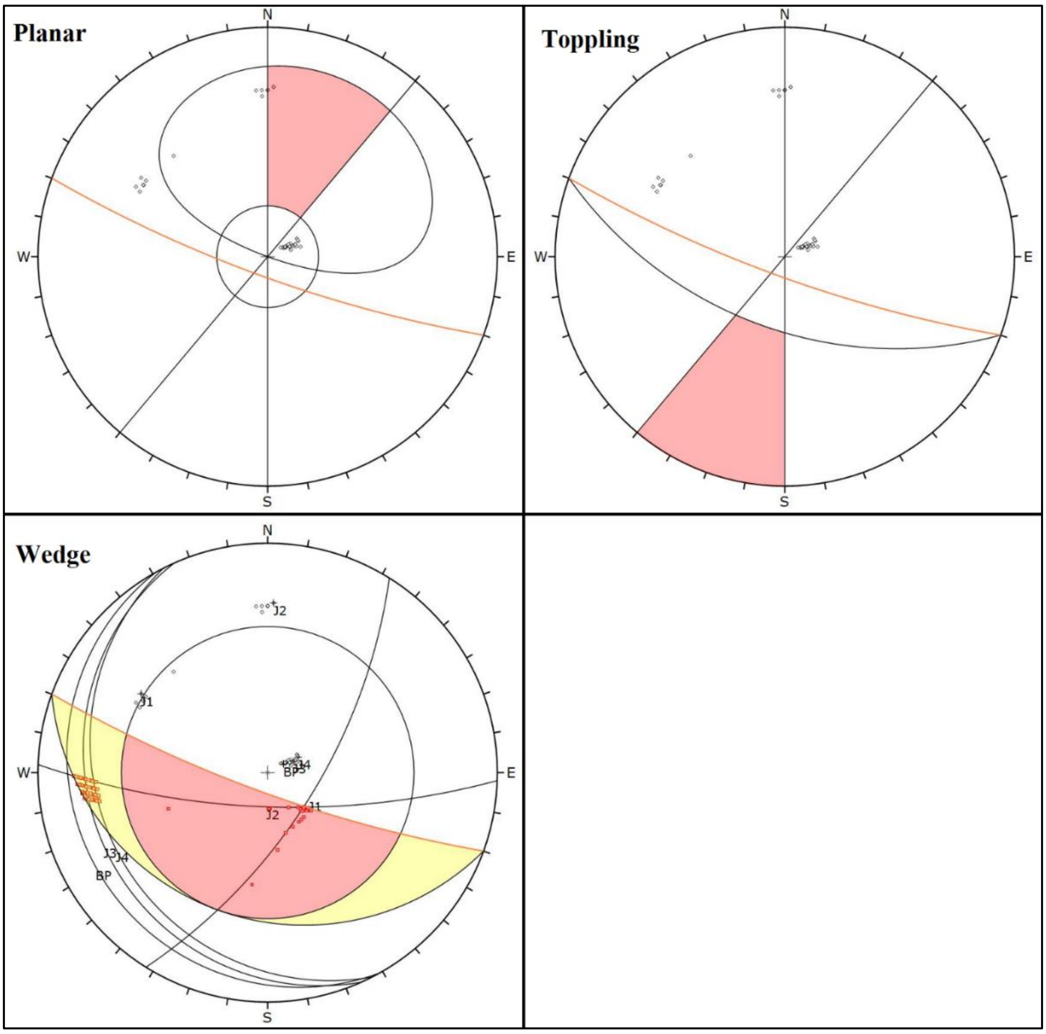


Figure 5.3. Kinematic analyses of MS-1

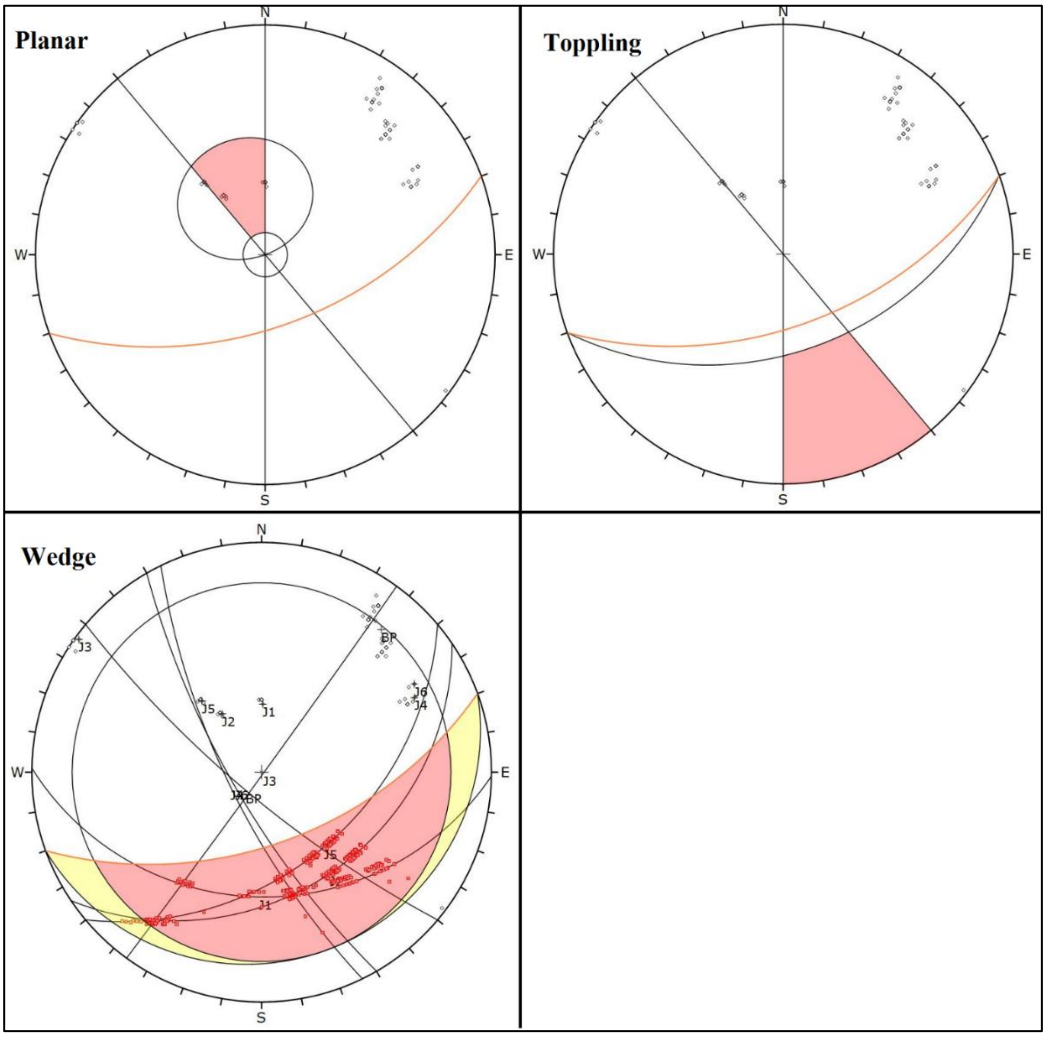


Figure 5.4. Kinematic analyses of MS-2.1

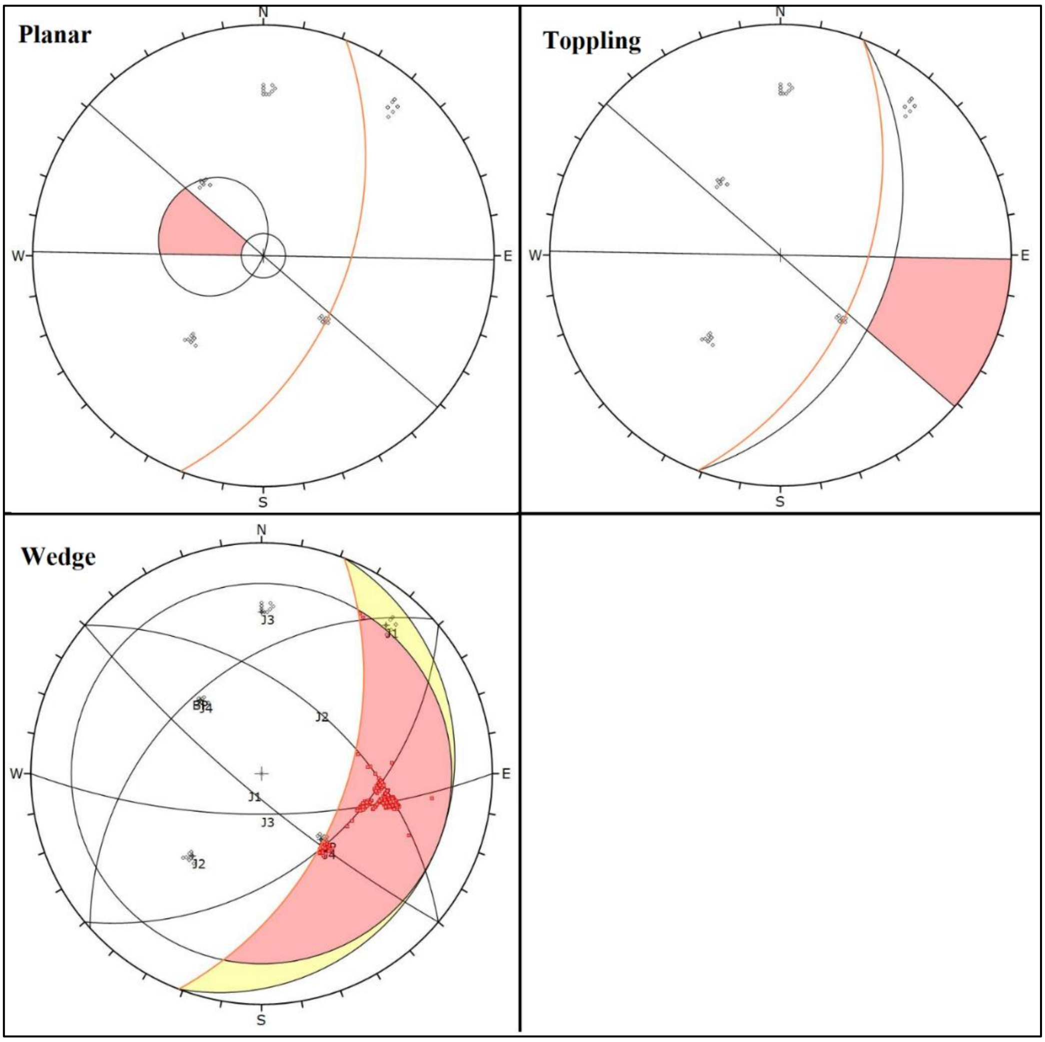


Figure 5.5. Kinematic analyses of MS-2.2

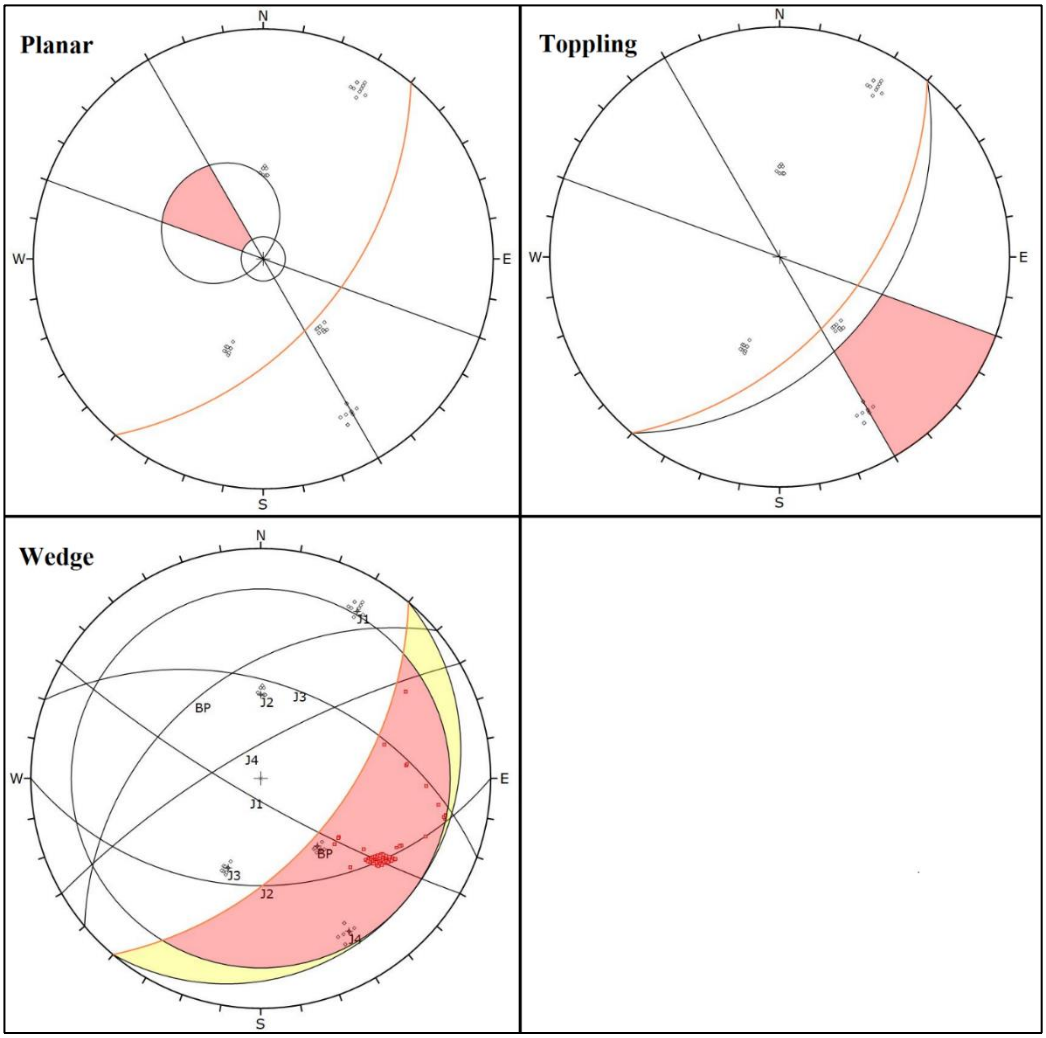


Figure 5.6. Kinematic analyses of MS-2.3

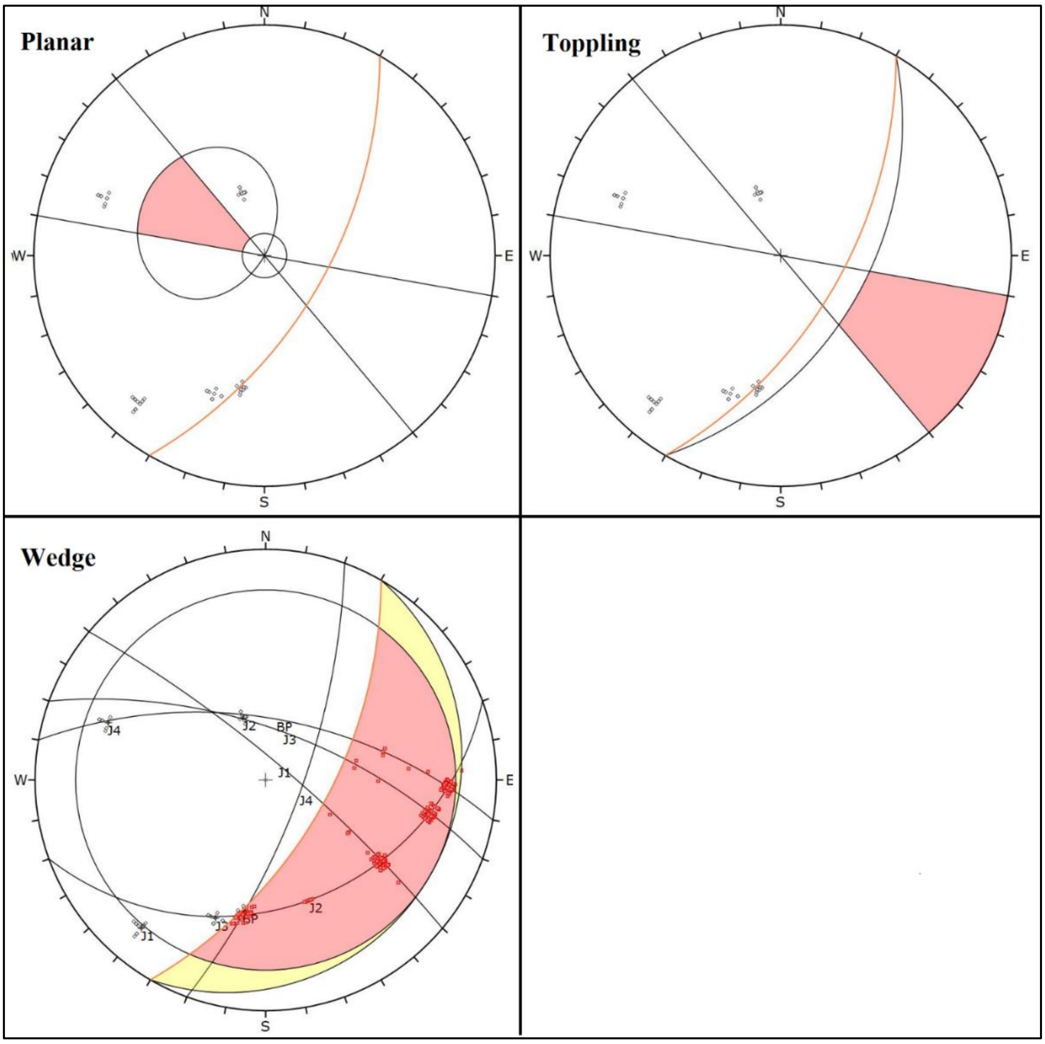


Figure 5.7. Kinematic analyses of MS-3

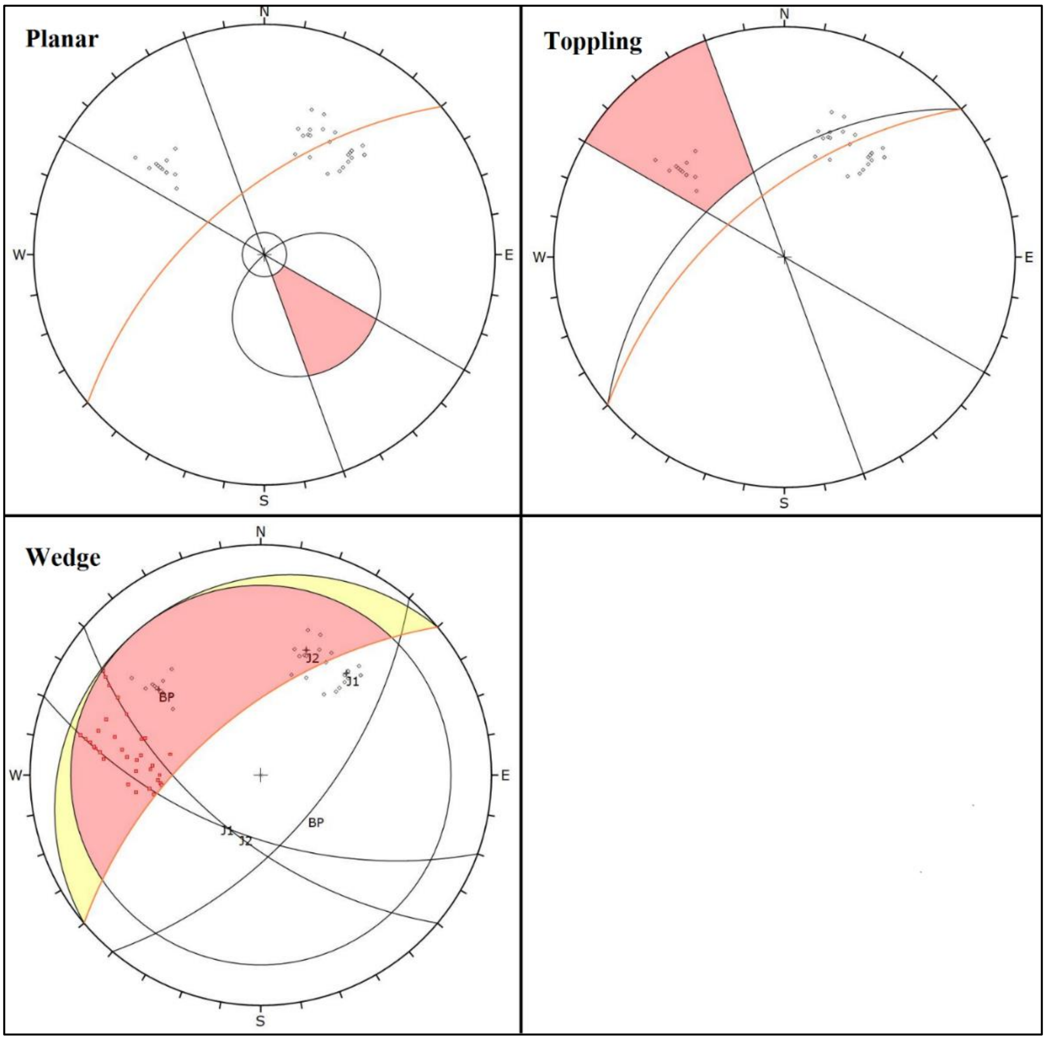


Figure 5.8. Kinematic analyses of MS-4

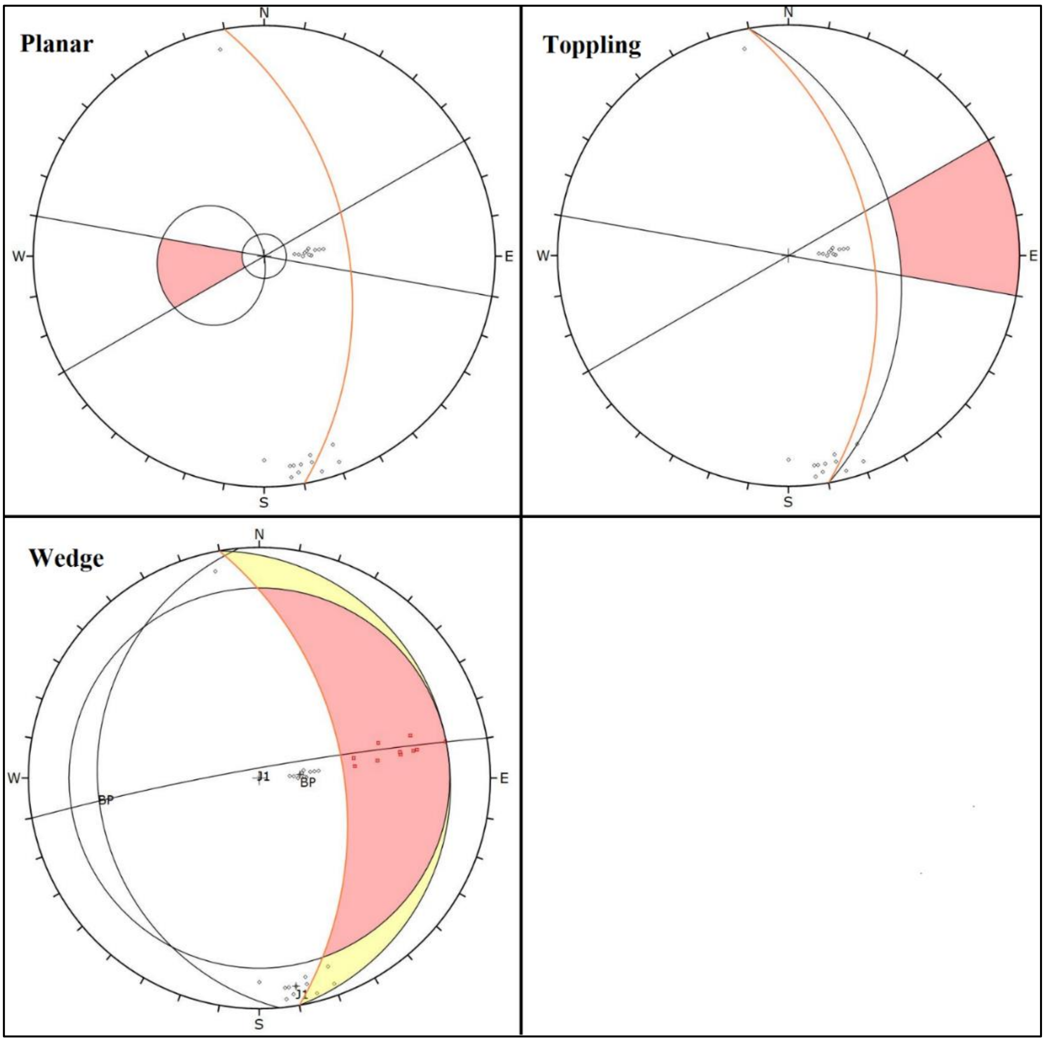


Figure 5.9. Kinematic analyses of MS-5

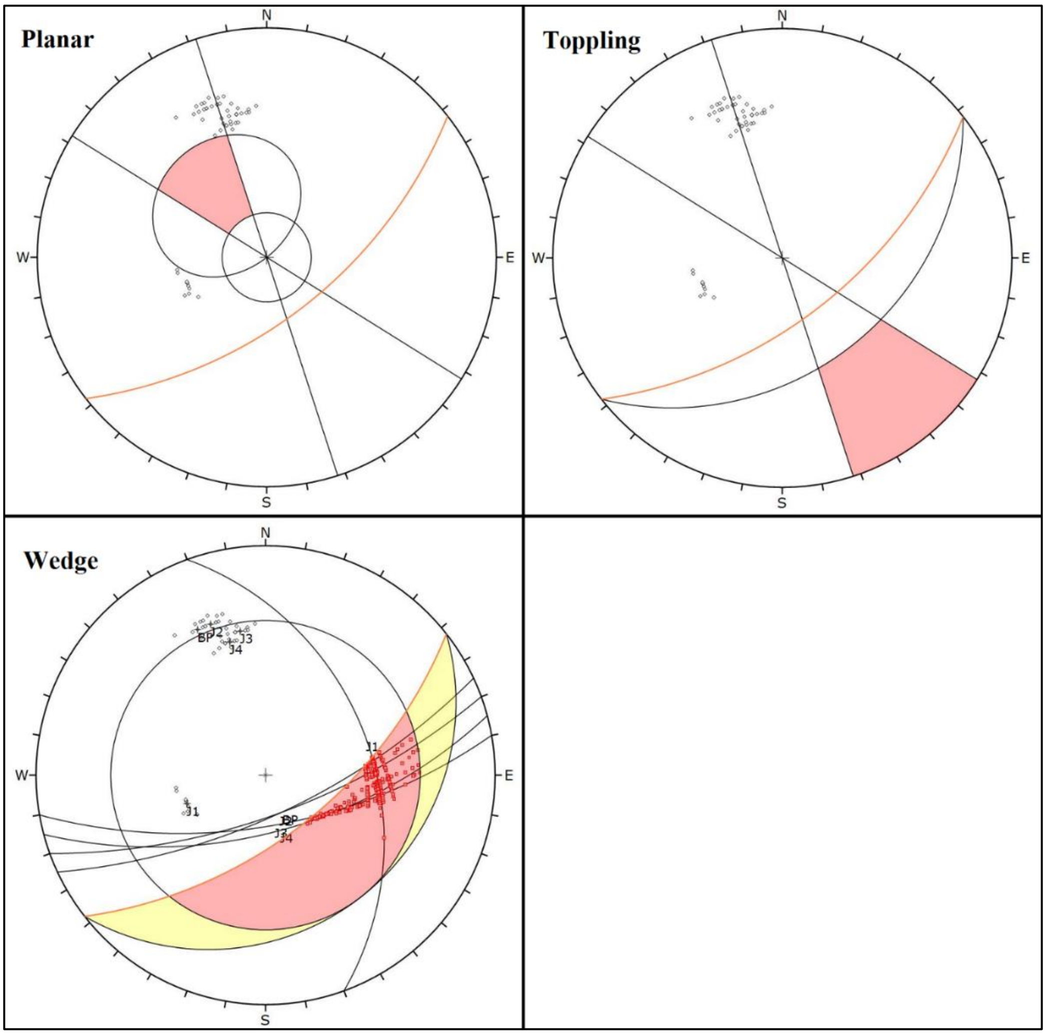


Figure 5.10. Kinematic analyses of MS-6

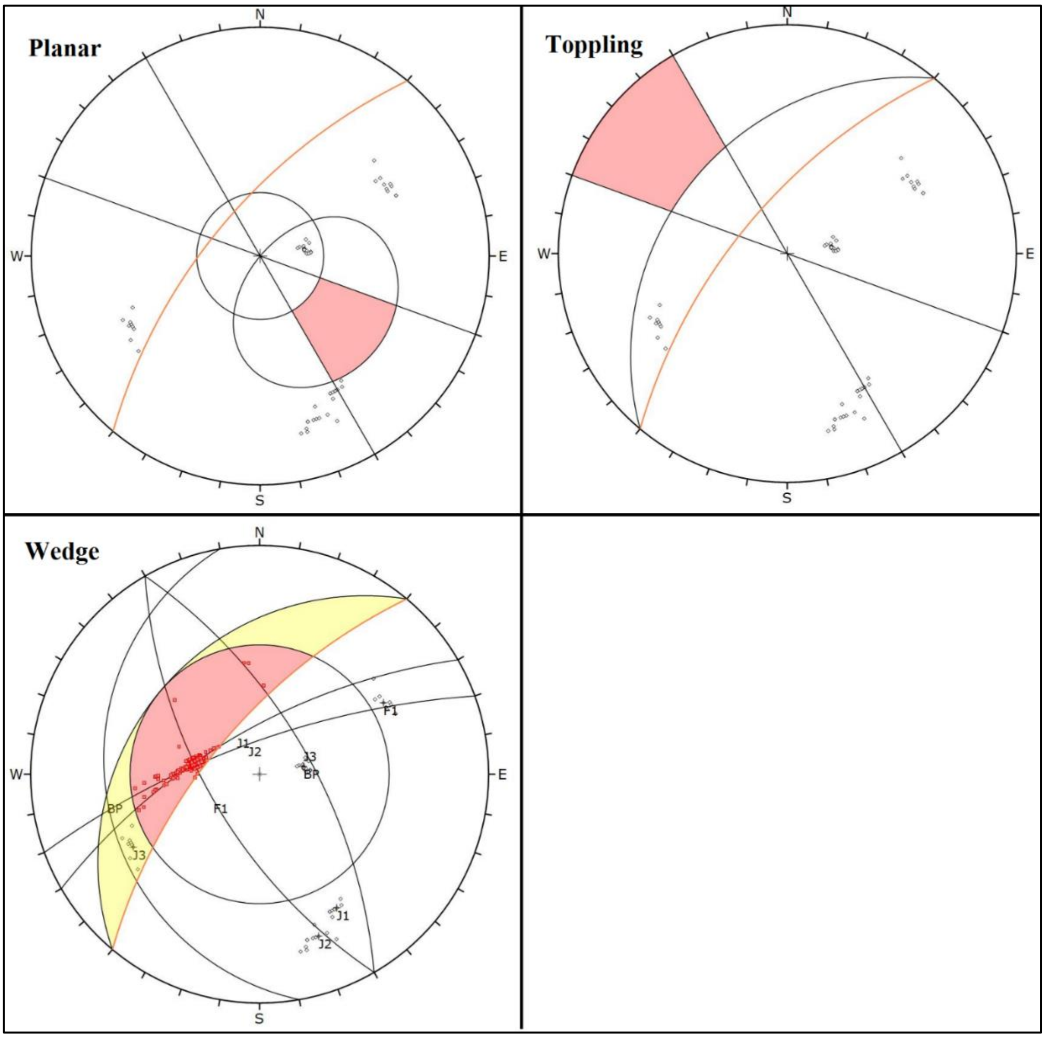


Figure 5.11. Kinematic analyses of MS-7.1

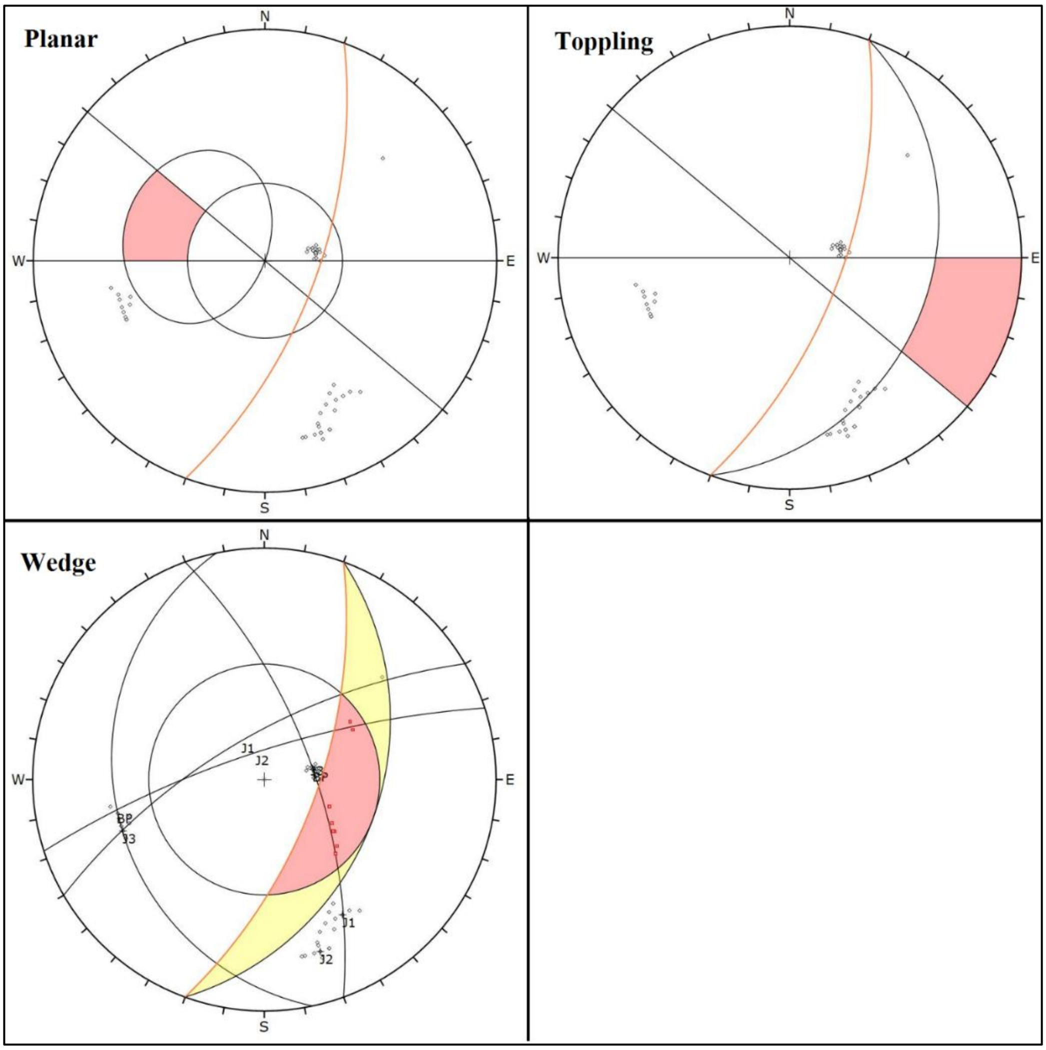


Figure 5.12. Kinematic analyses of MS-7.2

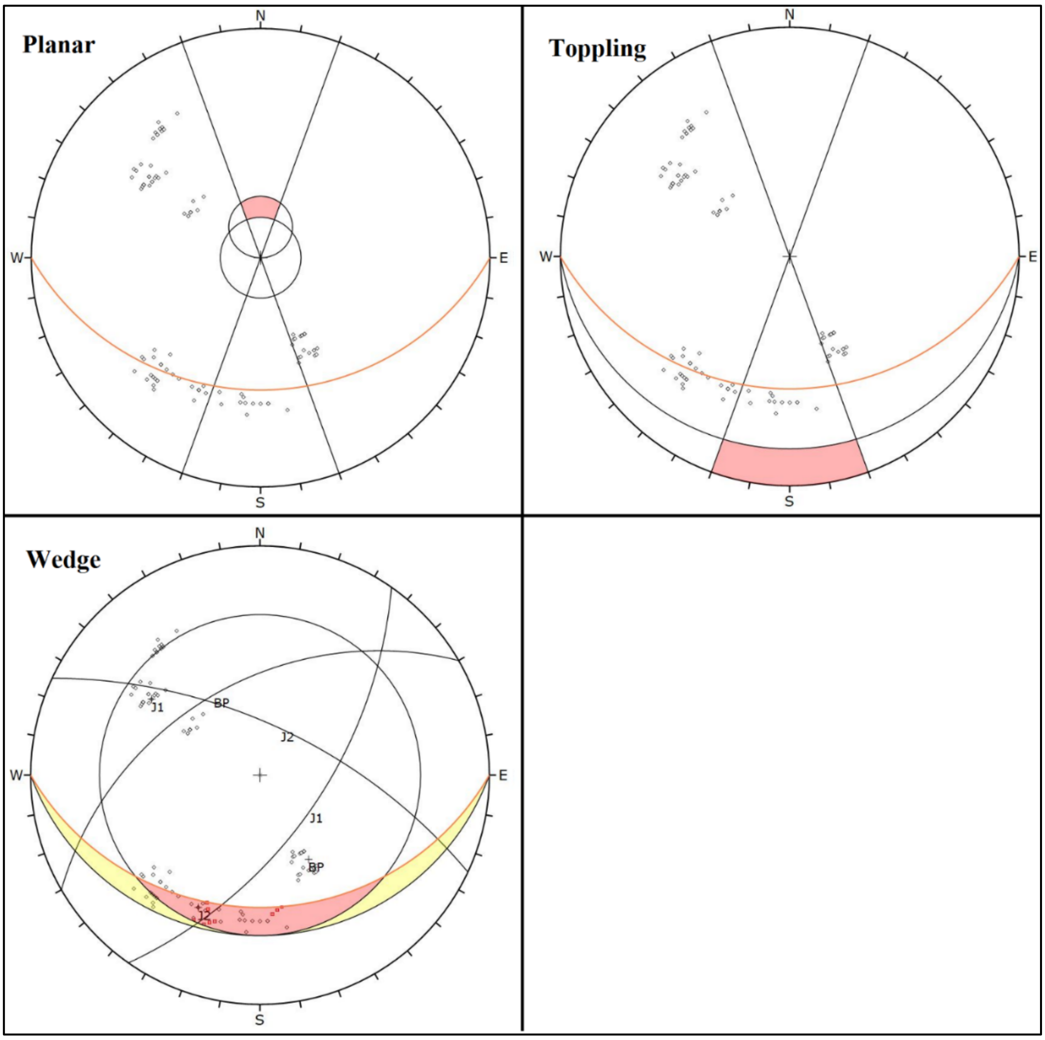


Figure 5.13. Kinematic analyses of MS-8.1

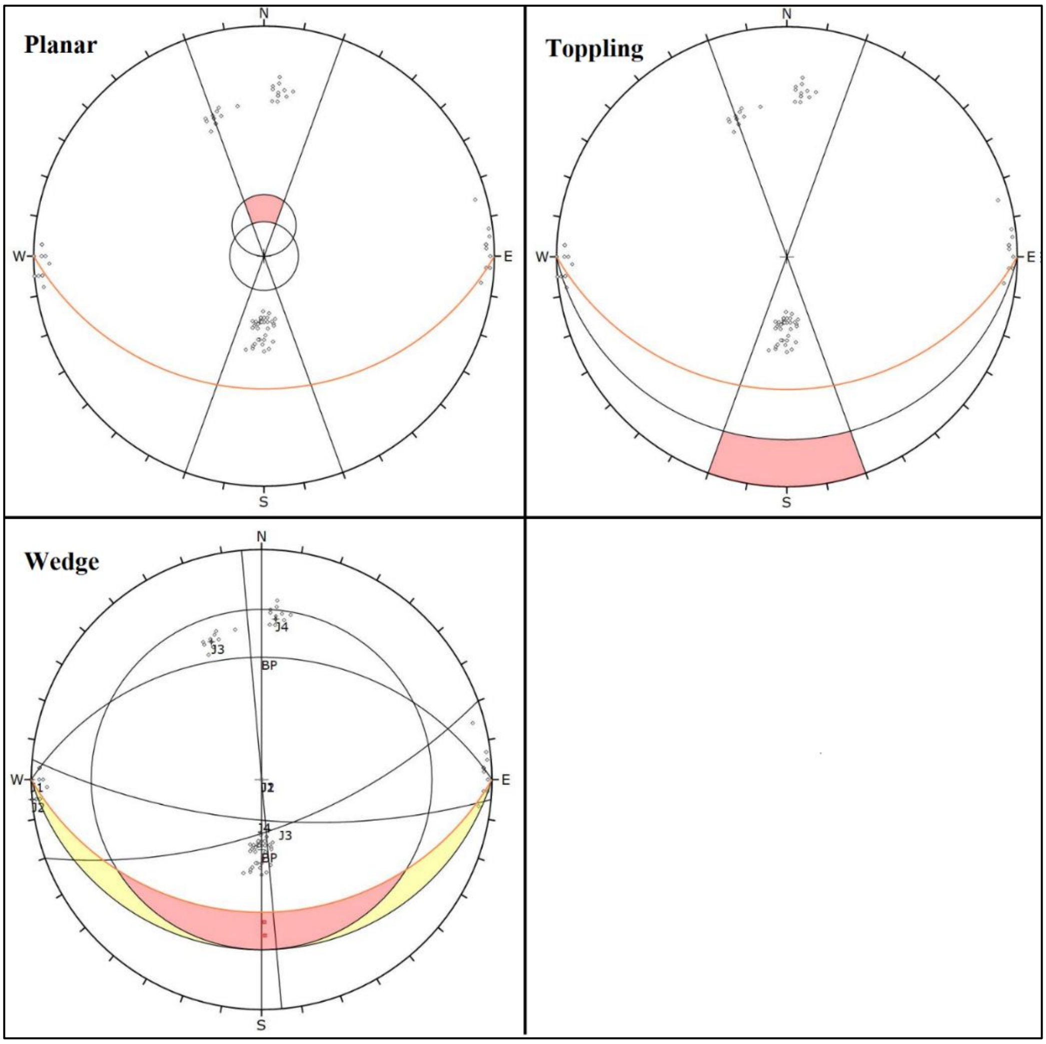


Figure 5.14. Kinematic analyses of MS-8.2

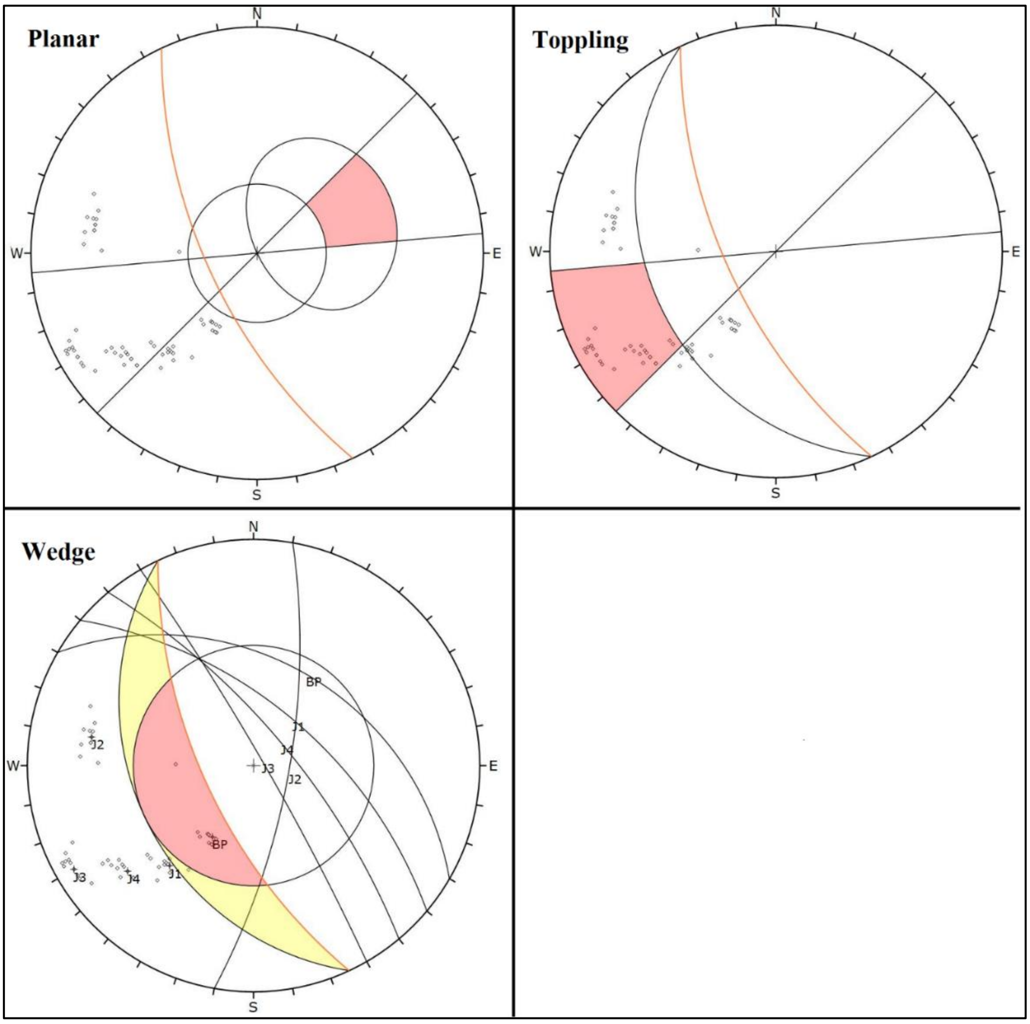


Figure 5.15. Kinematic analyses of MS-9

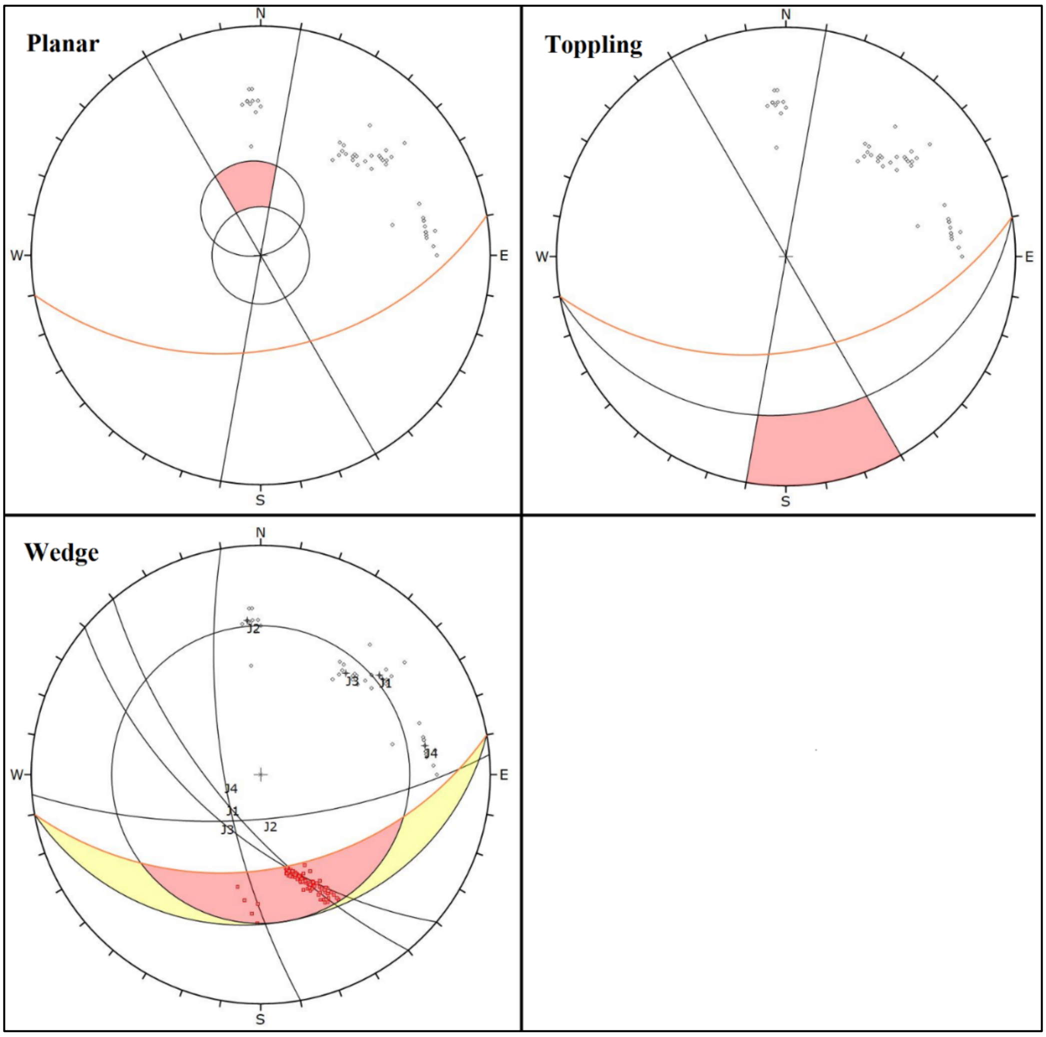


Figure 5.16. Kinematic analyses of MS-10

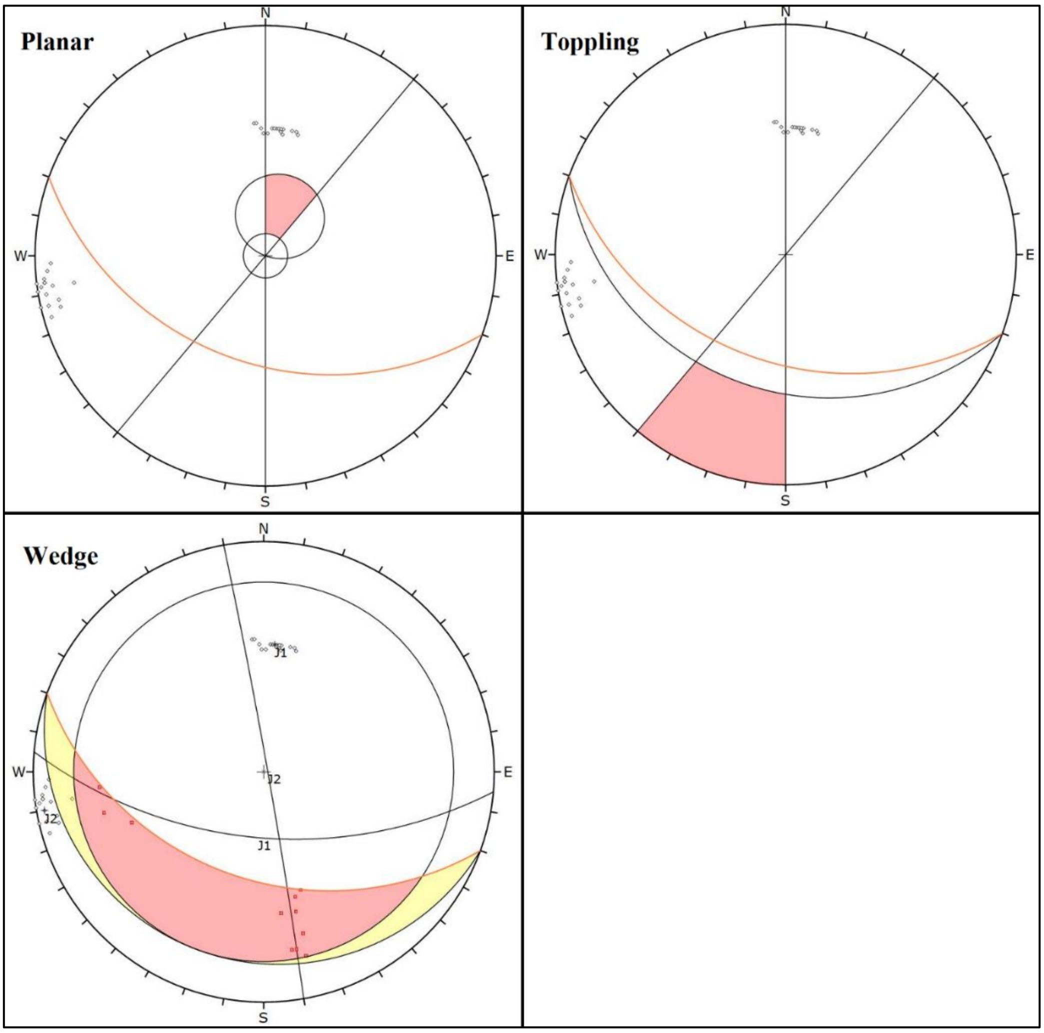


Figure 5.17. Kinematic analyses of MS-11

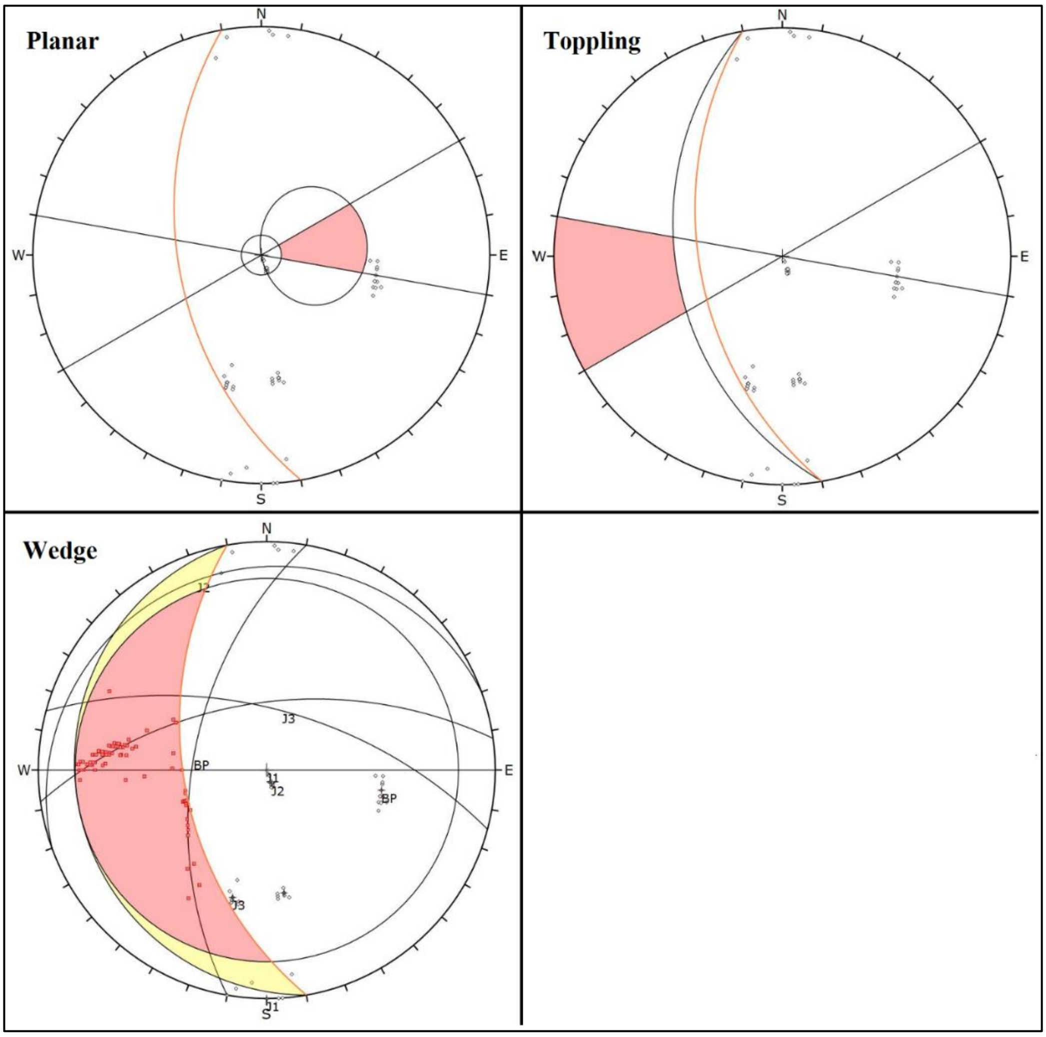


Figure 5.18. Kinematic analyses of MS-12

5.2. Limit Equilibrium Analyses for the Discontinuity-Controlled Rocks

Limit equilibrium analysis for discontinuity-controlled rocks were conducted in order to check the wedge, planar and toppling risks of the critical cut slopes that were determined after kinematic analyses. The resultant factor of safety values of the analyses for discontinuity-controlled rocks are given in Table 5.2. The acceptable factor of safety values should be equal or greater than 1.5 for static conditions and equal or greater than 1.1 for pseudo-static conditions according to limitations of General Directorate of Highways, in order to be at the safe side for each studied cut slopes. Additionally, saturated parameters of the studied cut slopes were used, thus; worsts conditions for each road cuts were considered.

As it was mentioned in the previous chapters, peak ground acceleration (PGA) values were determined from the equation of Idriss (2007) for pseudo-static conditions. In the theory of Kramer (1996), seismic coefficients should be subjected to some measure of the amplitude of the inertial force stimulated in the slope by the dynamic forces produced during a seismic activity. By reason of slopes not being rigid and the lasting of peak acceleration produced during a seismic activity for a short time, seismic coefficients generally correspond to acceleration values below the predicted peak accelerations. In order to reach factor of safety results, three different reduction coefficients are chosen to be used. The horizontal seismic coefficients for this study are 0.65 (Bozorgnia and Bertero, 2004), 0.5 (Hynes-Griffin and Franklin, 1984), and 0.33 (Marcuson, 1981) and the vertical seismic coefficients were taken as 0. The horizontal seismic coefficients of Bozorgnia and Bertero (2004) as 0.65 was used for planar, wedge and toppling failure analysis in order to consider worst conditions and to be at the safe side.

Table 5.2. *Factor of safety values for static and pseudo-static conditions of the critical cut slopes*

	Stop No.	Wedge	Planar	Toppling
Pseudo-static	**MS-1**	13.9	2.1	-
	MS-2.1	0.9	1.0	-
	MS-2.2	1.4	-	-
	MS-2.3	1.7	-	3.1
	MS-3	1.3	-	-
	MS-4	-	-	1.6
	MS-6	1.1	-	-
	MS-7.1	6.9	-	-
	MS-10	25.7	-	-
	MS-12	38.5	-	-
Static	**Stop No.**	**Wedge**	**Planar**	**Toppling**
	MS-2.1	1.1	1.1	-

Wedge type of failures were analyzed by the help of the Swedge (4.0) software (Rocscience, 2004b). Analyses were conducted differently from kinematic analysis by taking into consideration slope geometry, seismic condition, unit weight, cohesion and internal friction angle. According to the results of kinematic analyses performed, cut slopes MS-1, MS-2.1, MS-2.2, MS- 2.3, MS-3, MS-6, MS-7.1, MS-10 and MS-12 were found to be critical for wedge failure.

Wedge failure analysis of MS-1 considering the joints (64/120 and 72/180) shows that this road-cut is stable even in pseudo-static condition with resultant high safety factor as 13.9 (Figure 5.19). The result of the wedge failure analysis of MS-2.1 considering the joints (35/180 and 45/140) gives factor of safety as 0.9 under pseudo static condition that indicates failure (Figure 5.20). However, analysis of MS-2.1 under static condition considering the same discontinuities gives factor of safety as 1.1 (Figure 5.21). Analysis of MS-2.2 by taking into account of the joints (50/040 and 45/140) resulted in wedge failure giving factor of safety as 1.4 under pseudo static condition (Figure 5.22). Likewise, analysis of cut slope MS-2.3 gives safety factor as 1.7 with the critical joints (80/210 and 40/180) (Figure 5.23). The cut slope MS-3 is stable with with factor of safety as 1.3 considering the critical joints (80/040 and

32/160) (Figure 5.24). In a same manner, analyses of MS-6 gives the resultant factor of safety as 1.1 by considering joints (40/070 and 62/165) (Figure 5.25). Wedge failure analysis of one critical joint (68/330) and one critical fault (64/240) of the cut slope MS-7.1 gives the high factor of safety as 6.9 (Figure 5.26). Lastly, analysis of the cut slopes MS-10 and MS-12 demonstrates that these cut slopes are stable against wedge failure considering the critical joints (68/230 and 60/220 for MS-10 and (90/360 and 57/352 for MS-12) giving quite high factor of safeties like 25.7 and 38.5, respectively (Figures 5.27 and 5.28) (Table 5.2).

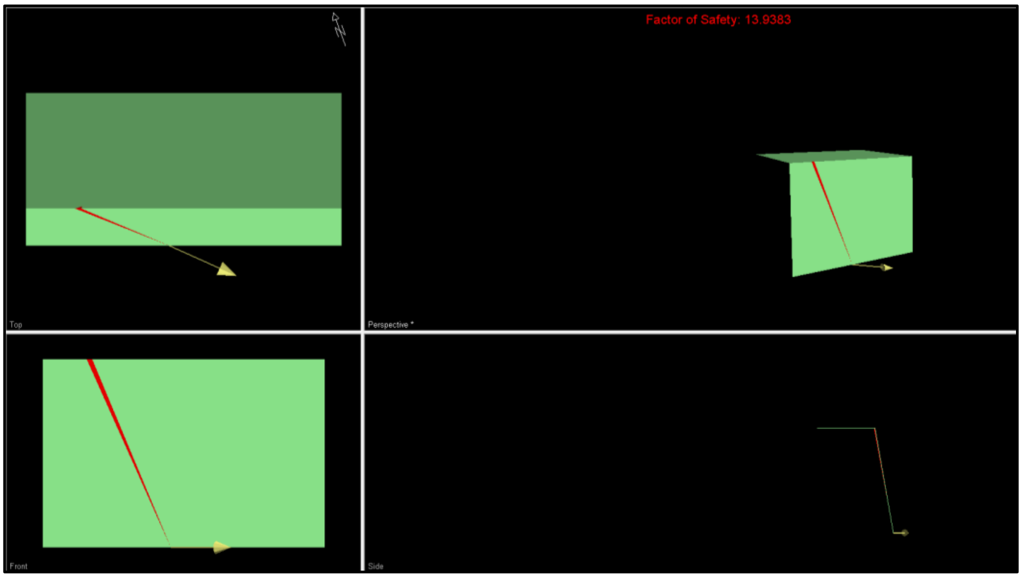


Figure 5.19. Wedge failure analysis of MS-1 (FS=13.9)

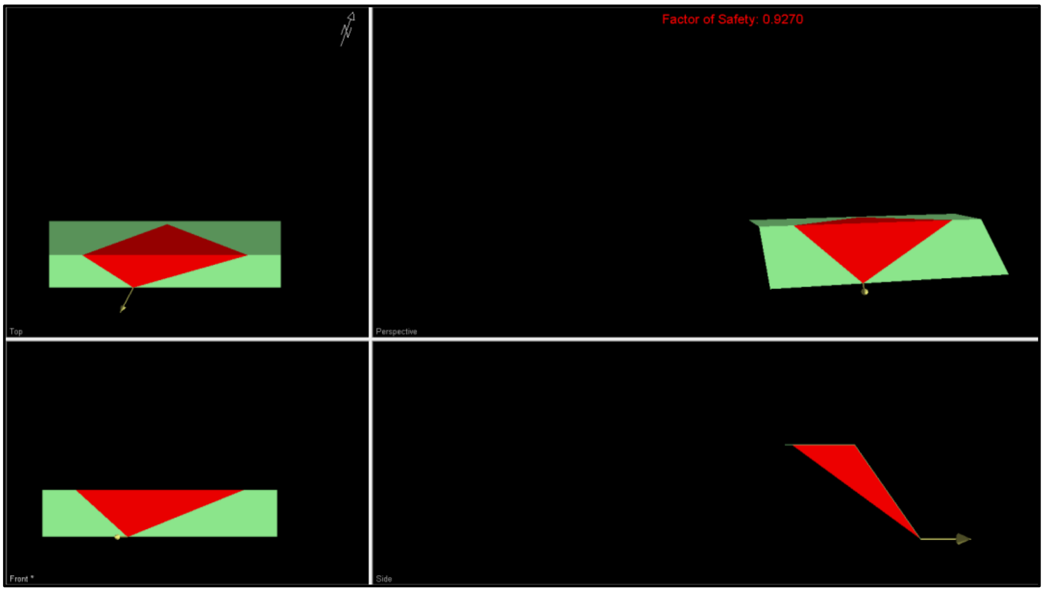


Figure 5.20. Wedge failure analysis of MS-2.1 under Pseudo static Condition (FS=0.9)

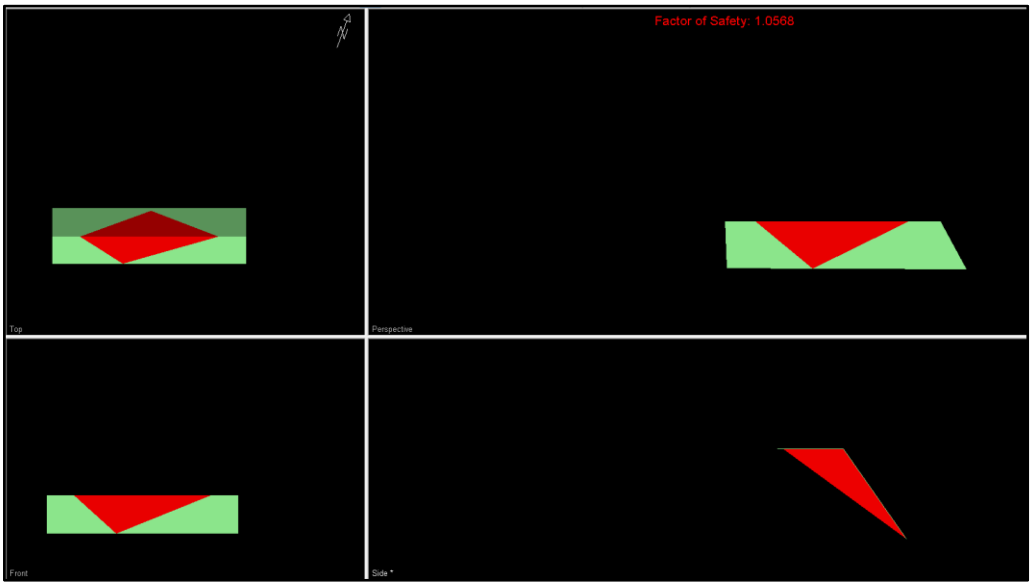


Figure 5.21. Wedge failure analysis of MS-2.1 under Static Condition (FS=1.1)

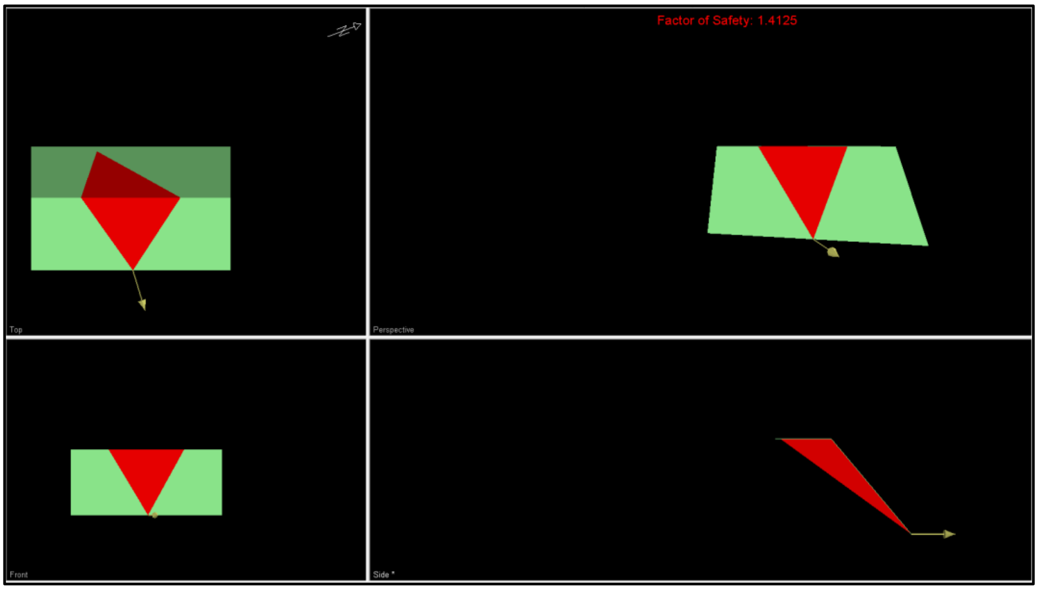


Figure 5.22. Wedge failure analysis of MS-2.2 (FS=1.4)

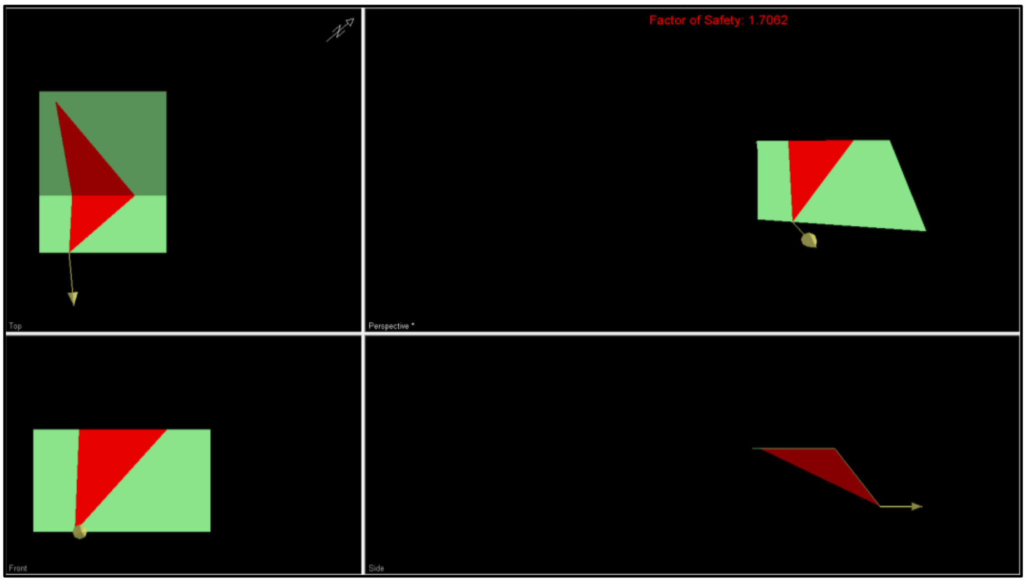


Figure 5.23. Wedge failure analysis of MS-2.3 (FS=1.7)

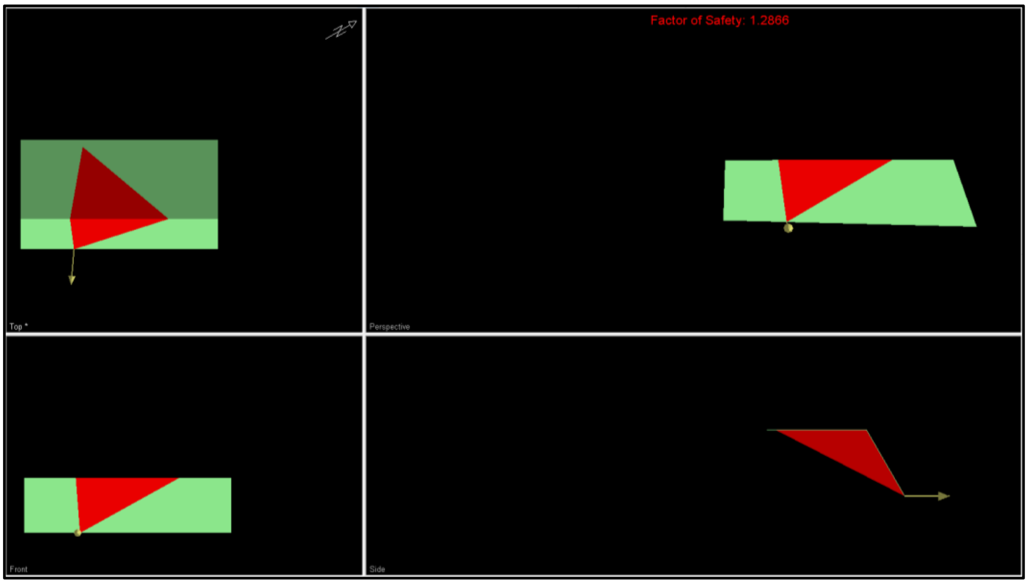


Figure 5.24. Wedge failure analysis of MS-3 (FS=1.3)

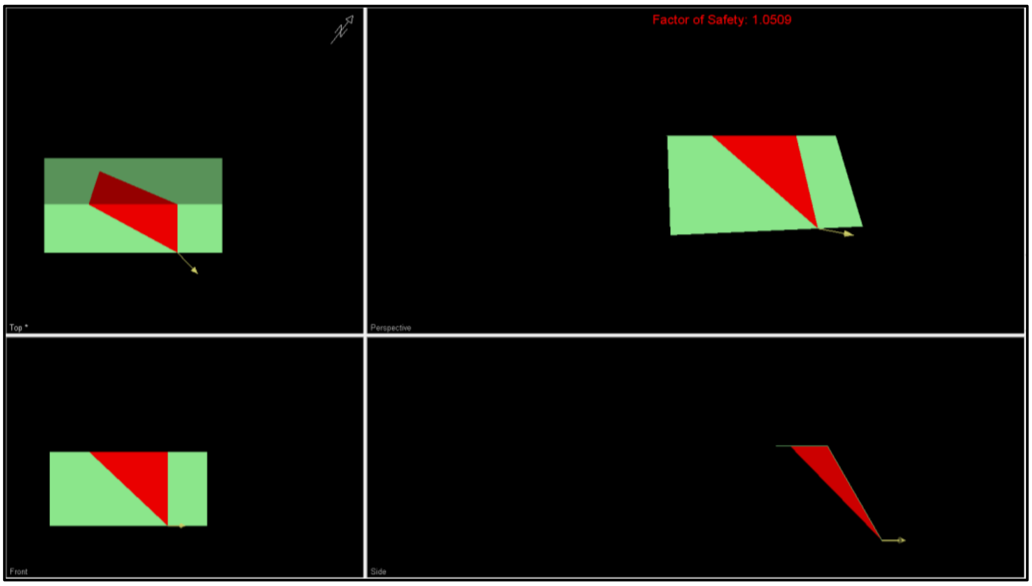


Figure 5.25. Wedge failure analysis of MS-6 (FS=1.1)

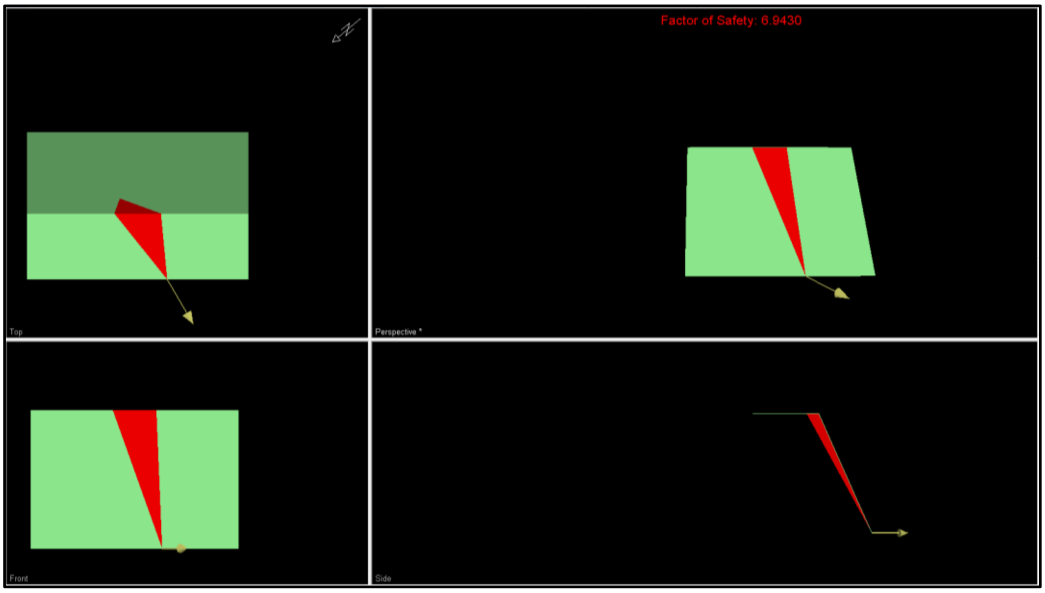


Figure 5.26. Wedge failure analysis of MS-7.1 (FS=6.9)

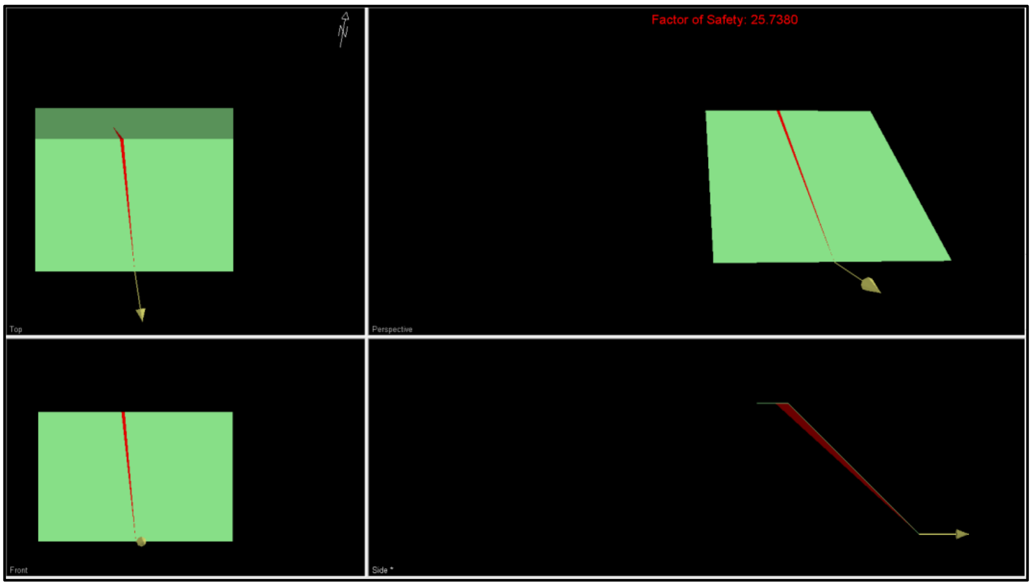


Figure 5.27. Wedge failure analysis of MS-10 (FS=25.7)

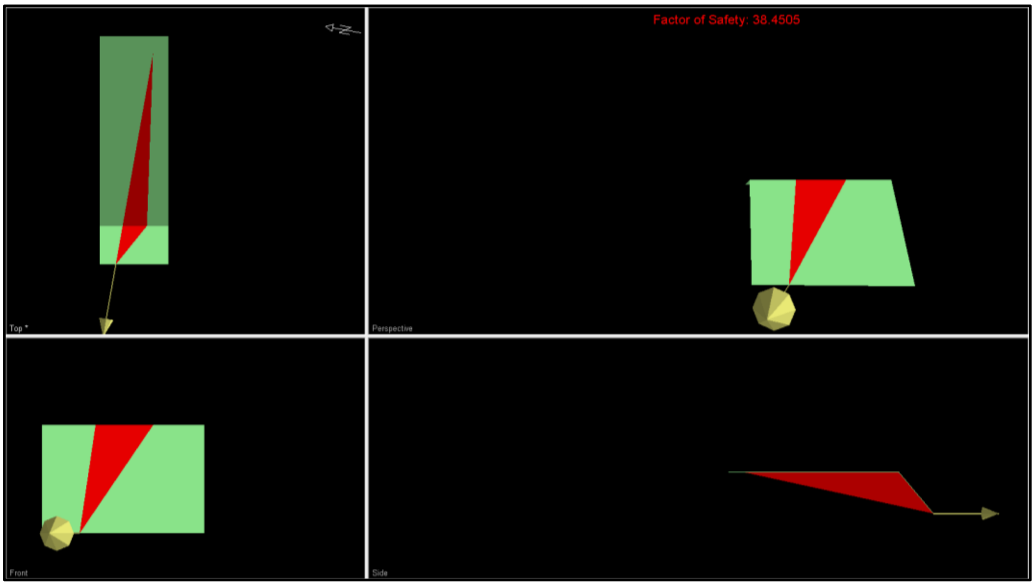


Figure 5.28. Wedge failure analysis of MS-12 (FS=38.5)

As the results of the kinematic analyses, planar sliding can be critical for the road cuts MS-1 and MS-2.1. Planar type of failures was analyzed by the help of the RocPlane (2.0) software (Rocscience, 2005). The analyses were conducted differently from kinematic analysis by taking into consideration slope geometry, seismic condition, unit weight, cohesion and internal friction angle. For the cut slope MS-1 considering the bedding plane (10/240), planar failure analysis showed a factor of safety of 2.1 under pseudo static condition which means the cut slope is stable (Figure 5.29). Planar sliding analysis of the cut slope MS-2.1 gives the resultant factor of safety as 0.97 by considering critical discontinuity (35/145) which is a critical condition under pseudo static condition (Figure 5.30). However, planar failure analysis of MS-2.1 under static condition gives the resultant factor of safety as 1.1 (Figure 5.31) (Table 5.2).

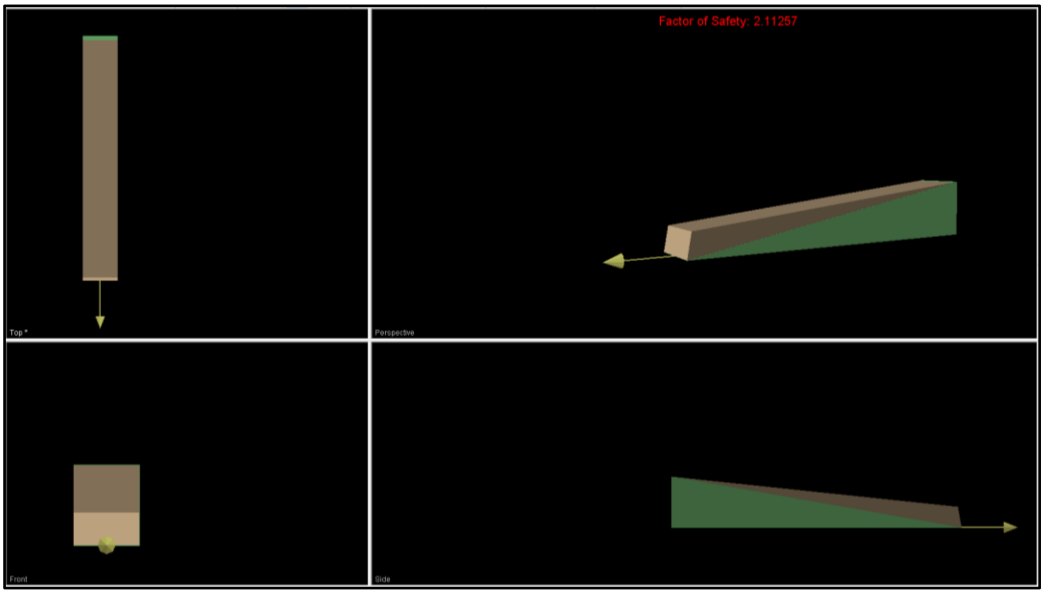


Figure 5.29. Planar failure analysis of MS-1 (FS=2.1)

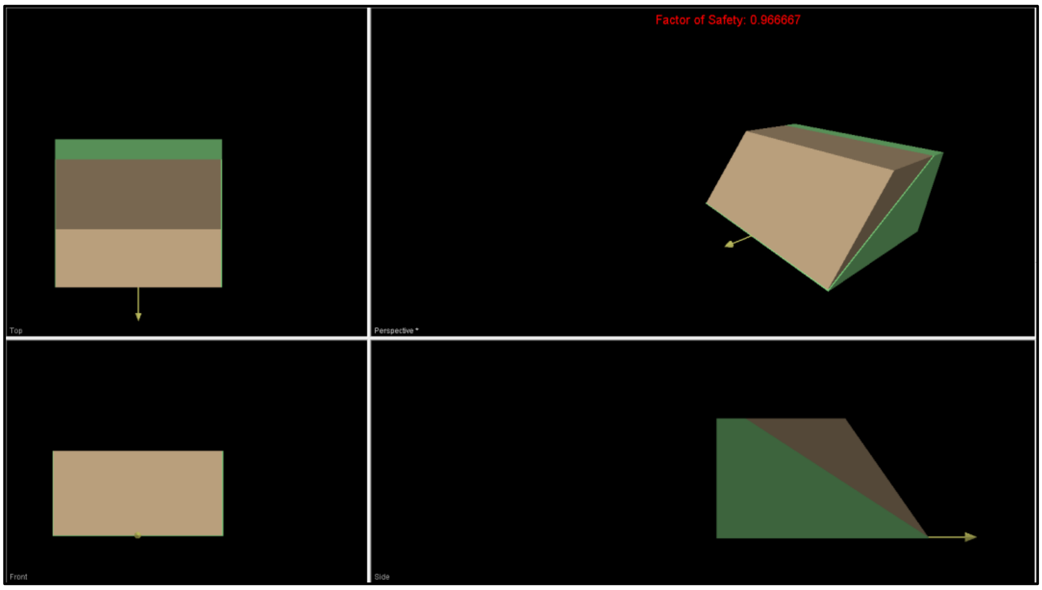


Figure 5.30. Planar failure analysis of MS-2.1 under pseudo static condition (FS=0.97)

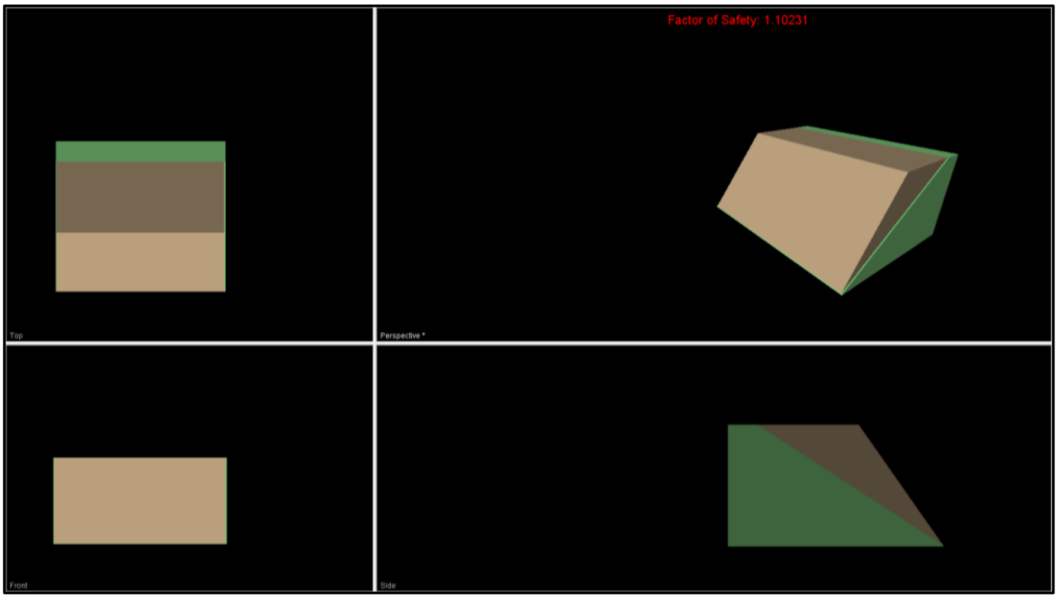


Figure 5.31. Planar failure analysis of MS-2.1 under static condition (FS=1.1)

For the cut slopes MS-2.3 and MS-4 as results of kinematic analysis, possibility of toppling failure was encountered as it was mentioned before. By using RocTopple (1.0) software (Rocscience, 2015), analysis of toppling failure was performed and toppling shows factor of safeties for pseudo-static conditions as 3.1 and 1.6 for the cut slopes MS-2.3 and MS-4, respectively (Figure 5.32 and Figure 5.33). The resultant factor of safeties demonstrate that the cut slopes MS-2.3 and MS-4 are stable considering toppling failure (Table 5.2).

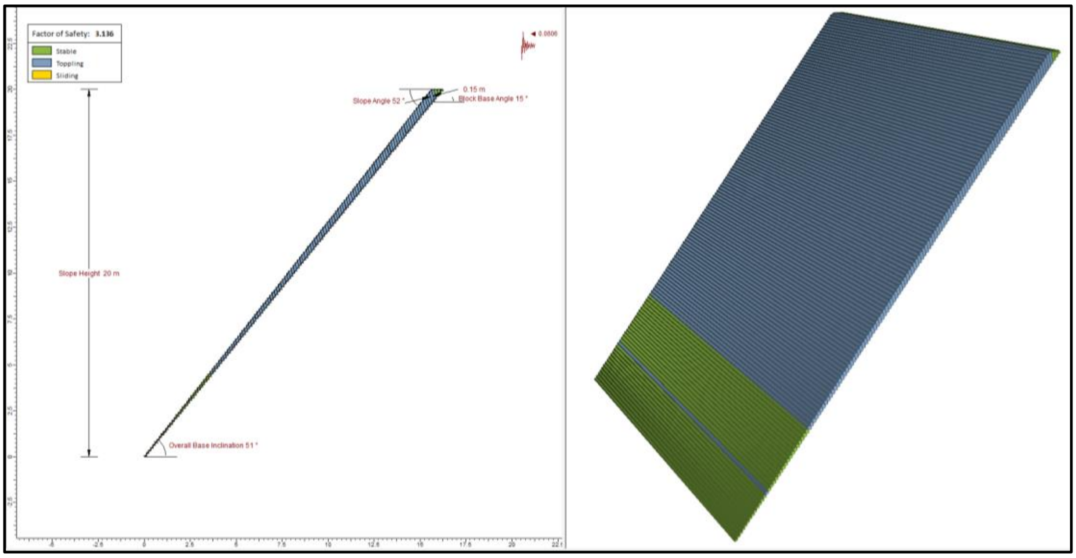


Figure 5.32. Toppling failure analysis of MS-2.3 (FS=3.1)

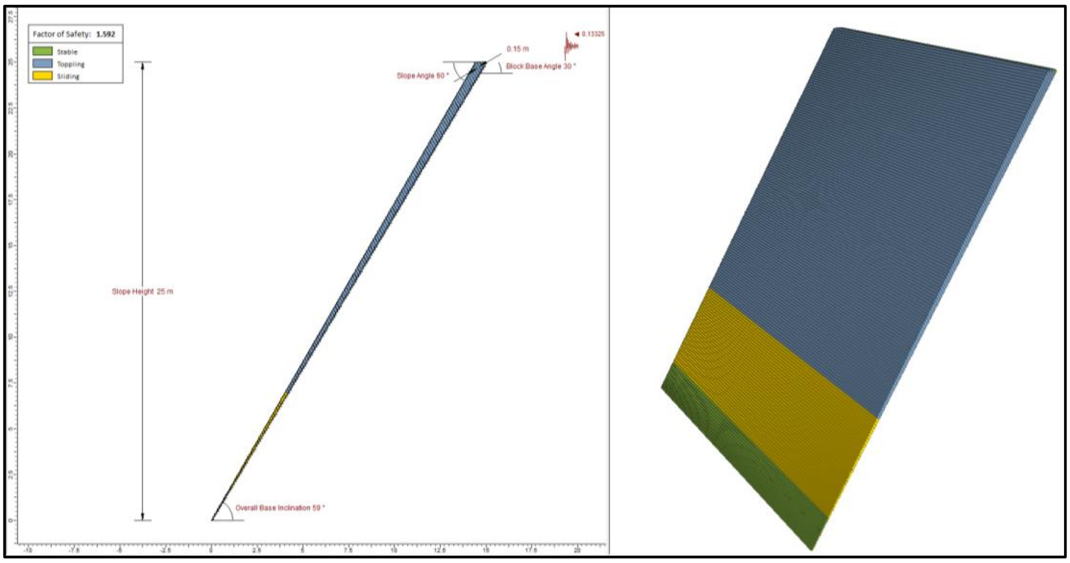


Figure 5.33. Toppling failure analysis of MS-4 (FS=1.6)

5.3. Limit Equilibrium Analyses for the Rock Mass

In order to check the stability condition of the studied road-cuts, limit equilibrium analyses for the rock masses were carried out with the help of Slide (6.0) software (Rocscience, 2011). While applying stability analysis with limit equilibrium methods, parameters such as unit weight, cohesion and internal friction angle, unlike kinematic analysis were considered. Weathered and fresh zones and related rock properties were taken into account for limit equilibrium analysis by considering field observation on weathering degrees and weathering depths that are in the range of slightly to highly weathered and 25 to 40 cm, respectively. For this study, analyses were performed for pseudo-static conditions and as well as static conditions. For both fresh and weathered zones, Hoek – Brown failure criterion was considered. Spencer's method (Spencer, 1967) was used for conducting limit equilibrium analysis to check circular mass failures.

According to field observation and determination of the weathering depth, weathered portion of each cut slopes were bordered, and cohesion values for these zones were taken as 0. The reason is occurrence of surficial failures at the weathered zones of the cut slopes due to disintegration and presence of discontinuities that results in detached rocks from the surface of the slopes. Another parameter used for weathered zones is internal friction angle that can be designated by considering Hoek – Brown classification. Uniaxial compressive strength (UCS), geological strength index (GSI), intact rock constant mi and disturbance factor (D) were considered in order to designate the internal friction angles and cohesion.

Intact uniaxial compressive strength, geological strength index, intact rock constant mi and disturbance factor were also considered for fresh zones of the studied cut slopes for limit equilibrium analysis. Intact UCS values were derived from conversion of the point load test results. Disturbance factor (D) was determined based on the method of excavation of each cut slope. Disturbance factor (D) were taken as 1.0 for one of the studied cut slopes for its excavation method of conventional blasting and for the rest of the cut slopes disturbance factor (D) were taken as 0.7 for mechanical excavation according to Hoek et al. (2002). Intact rock constant mi values were selected according to the related rock types and their textures.

Uniaxial compressive strength values for each road-cuts of both weathered and fresh rock types are listed in Table 5.3. GSI values of the studied road cuts are listed in

Table 5.4 and were determined according to Geological Strength Index (GSI) chart of Marinos and Hoek (2000) (Figure 5.34). The analyses of limit equilibrium for the rock mass were conducted by taking into account of these values. Additionally, stability analyses were performed for GSI values of +/-5 for each road-cut in order to observe the effect of the parameter on factor safety due to its being an interpretive parameter.

Table 5.3. *UCS values for fresh and weathered zones of each road cut*

Stop	Fresh (MPa)	Weathered (MPa)
MS-1	19.40	17.01
MS-2.1	25.03	14.88
MS-2.2	23.90	14.14
MS-2.3	22.76	13.39
MS-3	22.51	17.82
MS-4	36.13	20.32
MS-5	8.15	5.89
MS-6	13.68	7.44
MS-7.1	54.96	41.32
MS-7.2	62.63	60.63
MS-8.1	41.71	28.39
MS-8.2	34.48	5.11
MS-9	16.88	6.69
MS-10	18.34	7.24
MS-11	32.30	26.61
MS-12	18.37	7.25

Table 5.4. *GSI values of each road cut*

Stop	GSI	Stop	GSI
MS-1	55	**MS-7.1**	40
MS-2.1	27	**MS-7.2**	40
MS-2.2	35	**MS-8.1**	30
MS-2.3	25	**MS-8.2**	25
MS-3	35	**MS-9**	20
MS-4	35	**MS-10**	25
MS-5	40	**MS-11**	40
MS-6	30	**MS-12**	20

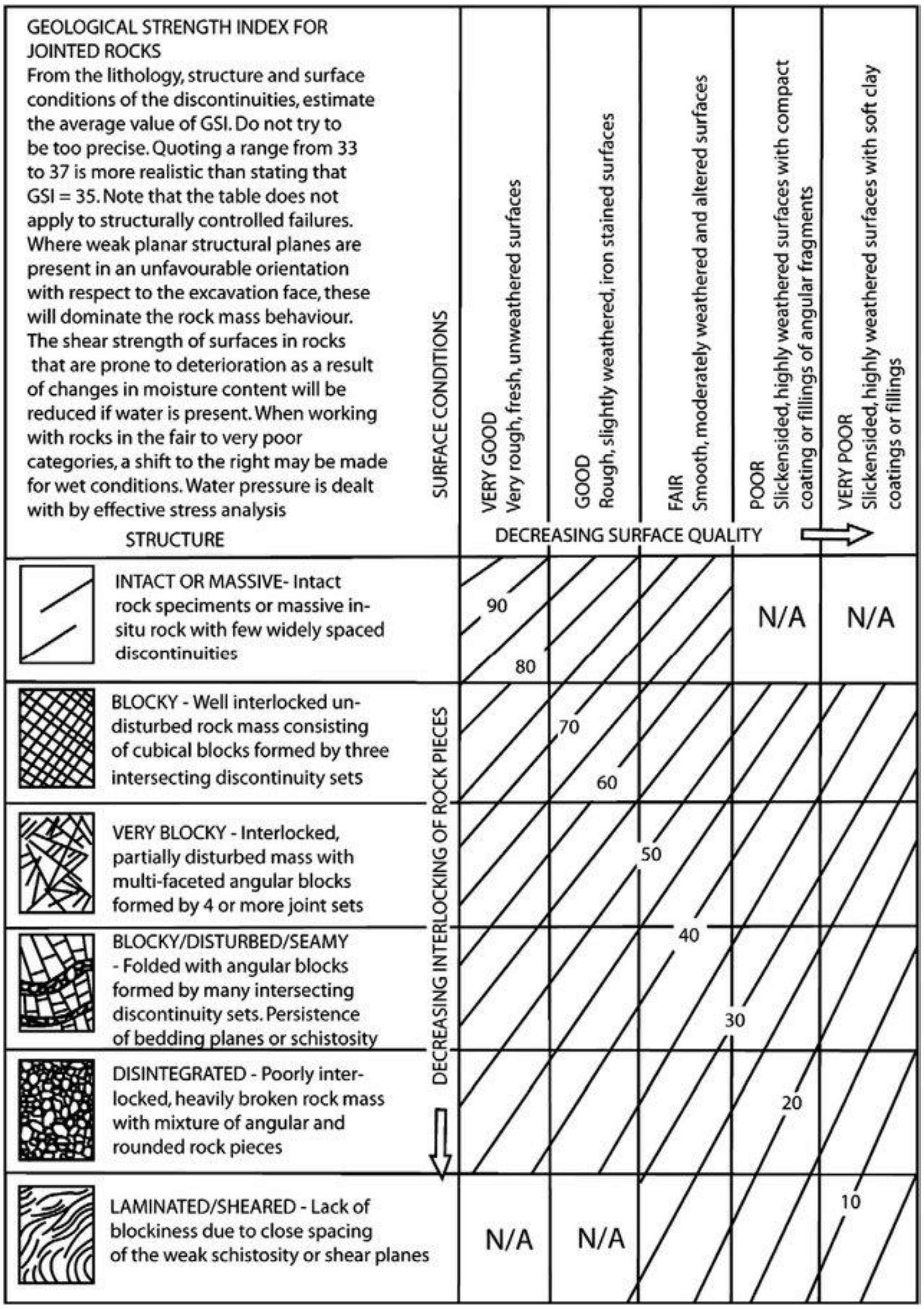


Figure 5.34. Geological Strength Index (GSI) chart (Marinos and Hoek, 2000)

For this study, limit equilibrium analysis performed for pseudo-static conditions as well as static conditions. Considering the results of the mass failure analyses, it can be said that there are no stability problems of circular failures among the studied road-cuts except the particular conditions of the cut slopes MS-2.3, MS-5 and MS-6. In accordance with the results of limit equilibrium analyses, just surficial failures of the studied cut slopes were encountered in the field. According to General Directorate of Highways, factor of safety values should be greater than or equal to 1.5 for static conditions, and 1.1 for pseudo-static conditions. Factor of safety (FS) values for the studied road-cuts under static and pseudo-static conditions including results for +/-5 GSI values and different seismic coefficients respectively are listed in Table 5.5.

Table 5.5. *Factor of safety values for static and pseudo-static conditions of the cut slopes*

	Static			**Pseudostatic**		
Stop	**(GSI-5)**	**GSI**	**(GSI+5)**	**0.65**	**0.5**	**0.33**
MS-1	1.5	1.7	2.1	1.7	1.7	1.7
MS-2.1	1.5	1.8	2.1	1.6	1.7	1.7
MS-2.2	1.8	2.1	2.5	1.9	1.9	2.0
MS-2.3	1.1	1.3	1.6	1.2	1.2	1.3
MS-3	1.5	1.7	2.0	1.5	1.6	1.6
MS-4	1.6	1.8	2.1	1.5	1.6	1.7
MS-5	1.3	1.5	1.7	1.2	1.3	1.3
MS-6	1.2	1.4	1.6	1.0	1.1	1.2
MS-7.1	1.7	2.0	2.3	1.8	1.8	1.9
MS-7.2	3.2	4.1	5.3	3.7	3.8	3.9
MS-8.1	4.5	5.2	6.0	4.0	4.3	4.5
MS-8.2	3.4	3.9	4.5	3.1	3.2	3.5
MS-9	1.9	2.2	2.3	1.8	2.0	2.1
MS-10	1.6	1.9	2.2	1.5	1.6	1.7
MS-11	1.8	2.1	2.4	1.7	1.8	1.9
MS-12	1.7	2.0	2.3	1.7	1.7	1.8

As can be seen in Table 5.5, factor of safety values for the cut slope MS-2.3 are 1.3 for the average GSI and 1.1 for GSI-5 under static conditions (Figures 5.35 and 5.36). Although the factor of safety values are higher than 1, the cut slope MS-2.3 is considered to be risky according to General Directorate of Highways. Except the critical ones, FS values of MS-2.3 for GSI+5 of static condition and pseudo-static conditions for different reduction factors are higher than threshold values.

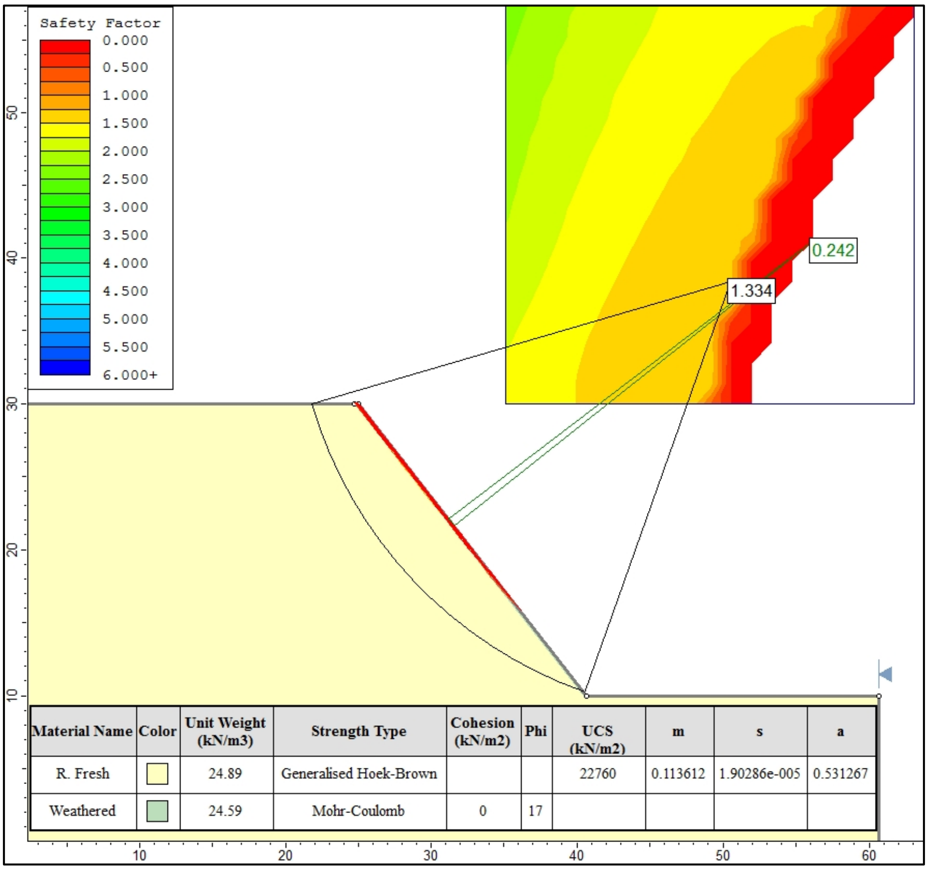


Figure 5.35. Limit equilibrium analysis of the cut slope MS-2.3 (with avarege GSI)

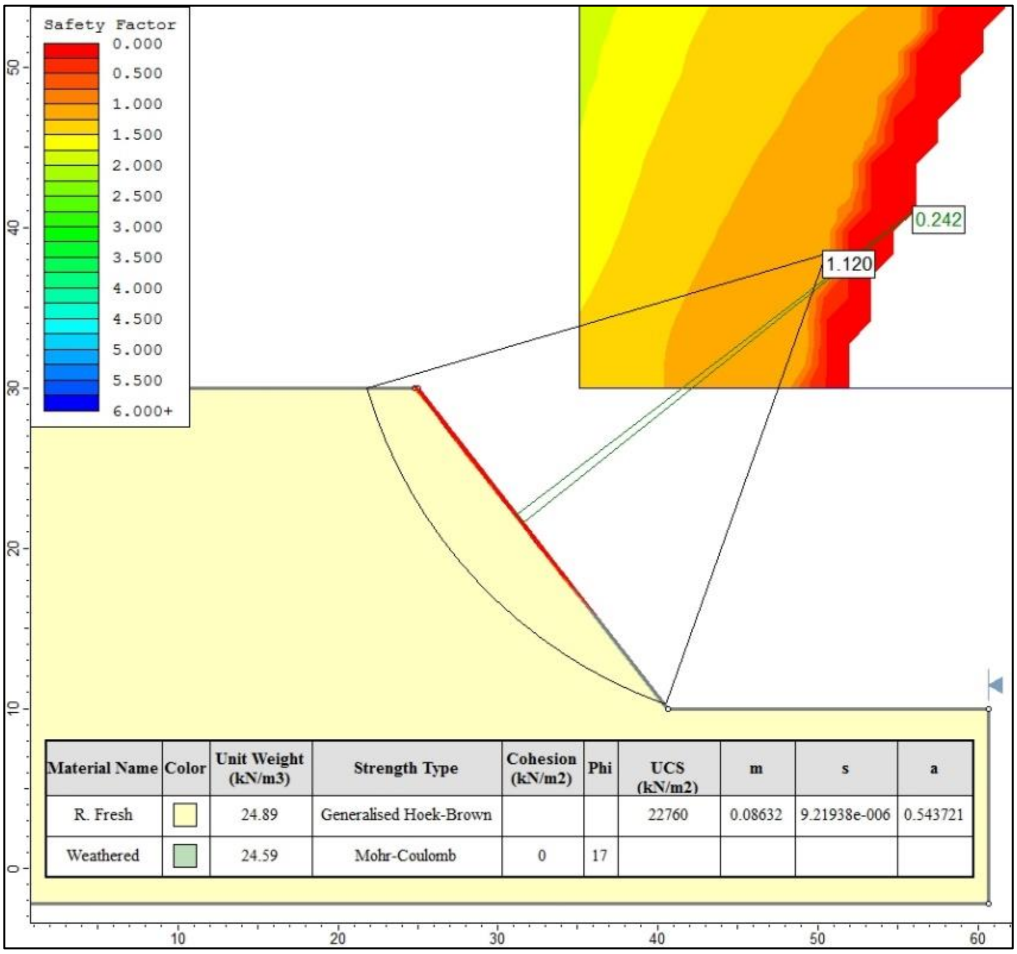


Figure 5.36. Limit equilibrium analysis of the cut slope MS-2.3 (GSI-5)

Likewise, factor of safety for the cut slope MS-5 is 1.3 for GSI-5 under static conditions (Table 5.5, Figure 5.37). Even though, the FS value is higher than 1, the cut slope MS-5 is counted as risky because the FS value is lower than threshold value of General Directorate of Highways. Other than the critical FS value for GSI-5, MS-5 is stable under static and pseudo-static conditions.

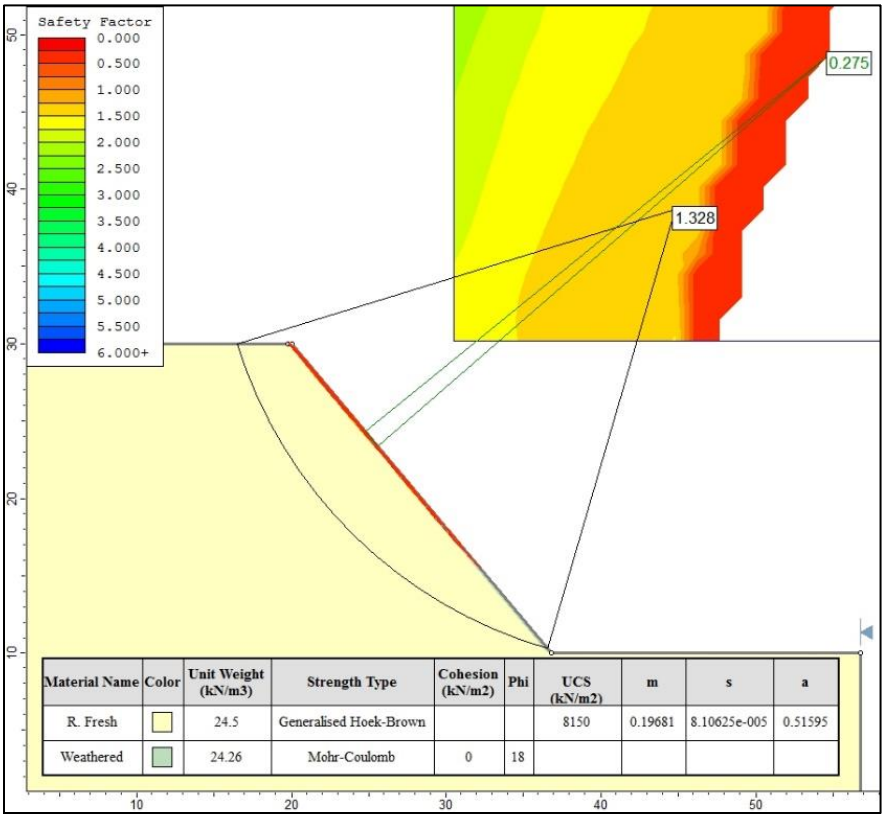
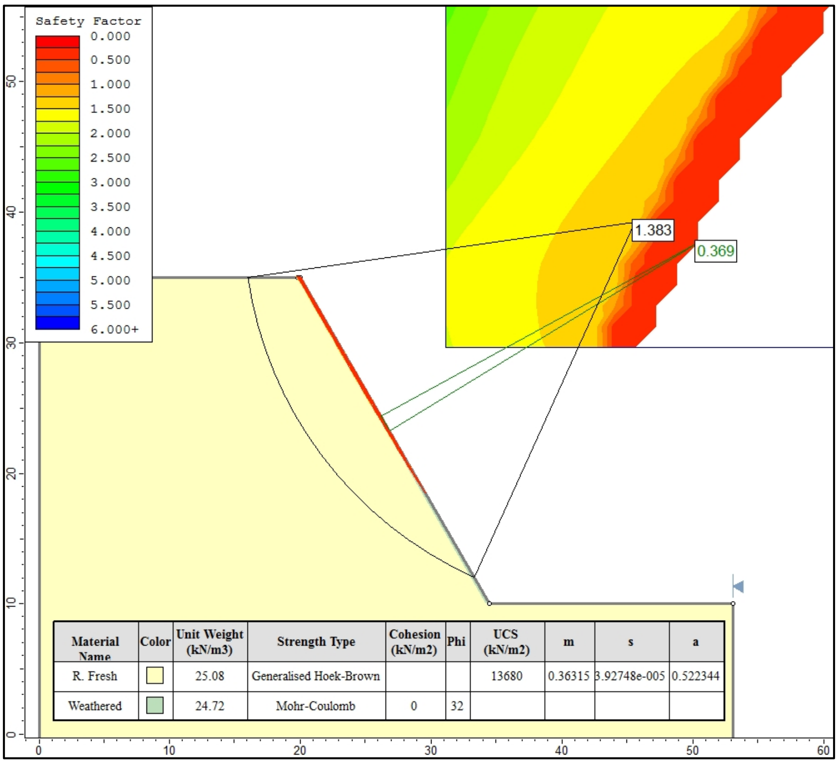


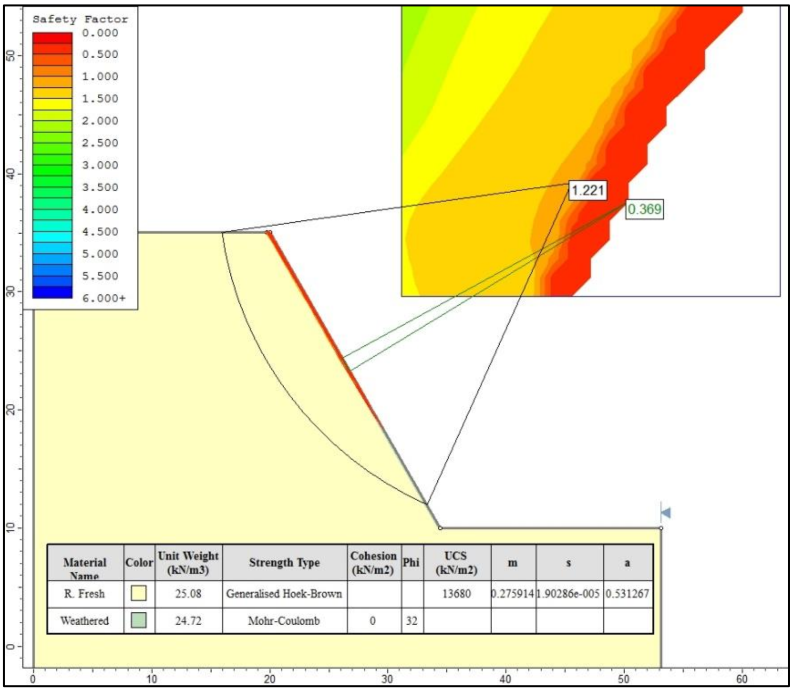
Figure 5.37. Limit equilibrium analysis of the cut slope MS-5 (GSI-5)

As it is shown in Table 5.5, factor of safety values for the cut slope MS-6 is 1.4 for the average GSI, 1.2 for GSI-5 under static conditions and 1.0 under pseudo-static condition with seismic coefficient of 0.65 that are under the threshold values of 1.5 for static and 1.1 for pseudo-static conditions (Figures 5.38, 5.39 and 5.40). Apart from the critical FS values, MS-6 can be considered as stable for GSI+5 under static condition and pseudo-static conditions for reduction factors of 0.5 and 0.33 that have higher values than the related threshold values.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		25.08	Generalised Hoek-Brown			13680	0.36315	3.92748e-005	0.522344
Weathered		24.72	Mohr-Coulomb	0	32				

Figure 5.38. Limit equilibrium analysis of the cut slope MS-6 (with average GSI)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		25.08	Generalised Hoek-Brown			13680	0.275914	1.90286e-005	0.531267
Weathered		24.72	Mohr-Coulomb	0	32				

Figure 5.39. Limit equilibrium analysis of the cut slope MS-6 (GSI-5)

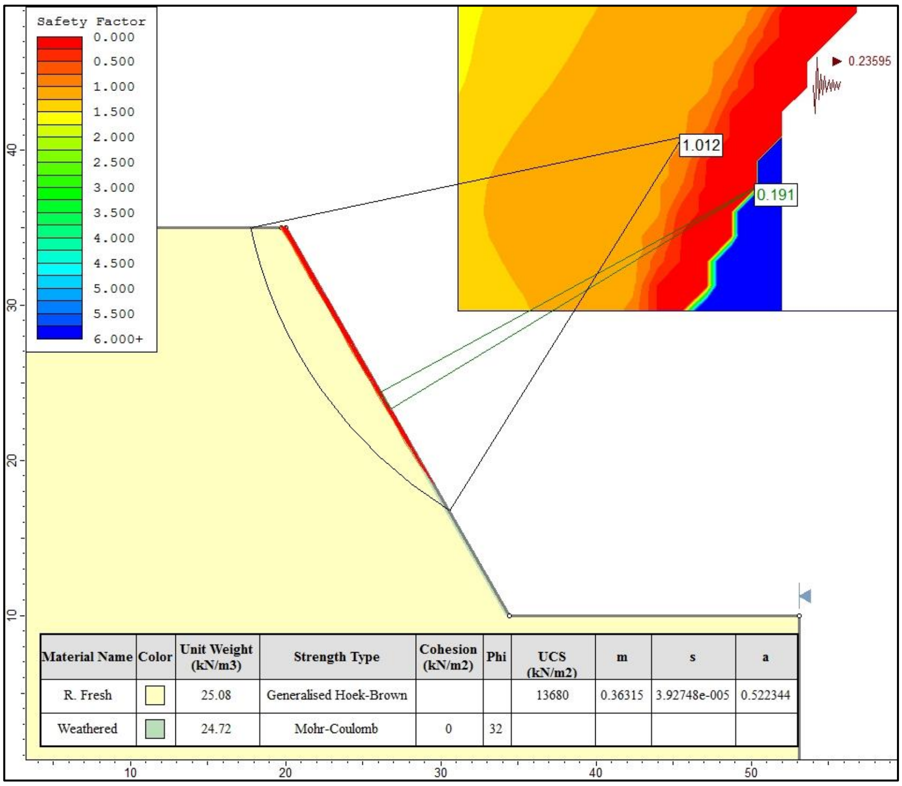


Figure 5.40. Limit equilibrium analysis of the cut slope MS-6 (GSI+5)

Regarding to the mass failure analyses, all cut slopes are stable under both seismic and static conditions except the particular conditions of the cut slopes MS-2.3, MS-5 and MS-6. The results of 2D limit equilibrium analyses for rock mass are compatible with field surveys. The detailed results of the mass failure analyses are attached at Appendix B.

5.4. Rockfall Analyses

Rockfall is defined as sudden downward displacement of rock blocks from slopes (Varnes, 1978). The parameters that are affecting the possibility of rockfall are geometrical characteristics of the slopes, discontinuities, weathering and seismic conditions (Dorren, 2003). Rockfall risks of the studied road-cuts were investigated through 2-dimensional analysis with the help of RocFall 6.0 software (Rocscience,

2016) by using the sizes of the detached rocks measured in the field. By considering unit weight and the volume of the detached rocks, mass values were designated as listed in Table 5.6.

Table 5.6. *Block volume, unit weight and mass used in the rockfall analyses for each road cut*

Stop No.	Maximum Block Volume (m3)	Unit Weight (kN/m3)	Mass (kg)
MS-1	0.0893	24.83	226
MS-2.1	0.0004	24.68	1
MS-2.2	0.0010	24.62	3
MS-2.3	0.0004	24.59	1
MS-3	0.0008	25.67	2
MS-4	0.0031	24.99	8
MS-5	0.0030	24.26	7
MS-6	0.0060	24.72	15
MS-7.1	0.0353	24.90	90
MS-7.2	0.0664	24.60	180
MS-8.1	0.0035	25.34	9
MS-8.2	0.0039	24.65	10
MS-9	0.0005	21.83	1
MS-10	0.0319	23.14	75
MS-11	0.0835	23.57	200
MS-12	0.0005	20.87	1

It is accepted that the location of the rockfall movement is the top of the road-cuts as considering the worst-case scenario. Rn and Rt values which are normal and tangential restitutions and friction angles were designated after conducted back analysis in the field (Table 5.7) according to the already fallen blocks that were observed during field works. Detailed results are given in Appendix B. While performing the analysis, they were assumed that amount of fallen rocks are 1000, roughness of the cut-slope is 0, minimum velocity cut off is 0.1 m/s, throw number is 1000, initial velocity is 1 m/s (+/- 0.5). The results of the rockfall analysis are shown in Figures 5.41-5.56.

Table 5.7. *Summary of Rn, Rt and friction angle for the materials encountered*

Material	Rn	Rt	Φ (°)
Limestone	0.30	0.60	31
Marl	0.28 +/- 0.02	0.62 +/- 0.03	11
Sandstone	0.50 +/- 0.04	0.58 +/- 0.04	24
Drainage Channel	0.06 +/- 0.03	0.80 +/- 0.05	14
Concrete	0,10	0,90	30
Asphalt	0,40	0,90	30

As shown in Figures 5.41, 5.47, 5.49-5.52, there are retaining walls at the cut-slopes of MS-1, MS-5, MS-7.1, MS-7.2, MS-8.1 and MS-8.2 that are constructed from stones and concrete. As rockfall analyses demonstrate, there are only rolling actions of the detached rocks for the related cut-slopes and these retaining walls already prevented rocks rolling down to the road level. In addition to the retaining walls, there are drainage channels in front of these cut-slopes. In line with the field observations, there are almost no detached rocks at drainage channels and at the road levels. At the cut slopes MS-1, MS-7.1 and MS-7.2, large rock blocks were encountered as a field observation but none of them were observed below the retaining walls.

MS-2.1, MS-2.2, MS-2.3, MS-3, MS-6 and MS-12 are the road-cuts that have drainage channels, constructed for the purpose of detached rocks from slope surface being accumulated in, right in front of them. According to the rockfall analyses, there would be just rolling movements of the mostly small-sized detached rocks that are resulted in accumulation into the drainage channels (Figures 5.42-5.45, 5.48 and 5.56). The results of the rockfall analyses are compatible with field observations. In addition, there is a huge accumulation of small rock fragments into the drainage channel of the cut slope MS-2.3.

Furthermore, rockfall analyses were conducted for the cut slopes with 2 benches namely; MS-4 and MS-10 (Figures 5.46 and 5.54). According to analysis, there are also significant bouncing movements of the fallen rocks at the benches of the slope in addition to the rolling movements. However, detached rocks cannot reach the road and they were accumulated in the drainage channels in front of the related two slopes. The results of the rockfall analysis are coherent with field observations that there are no detached rocks at the road. In addition to all of these, there is steel wire mesh on the large part of the cut slope MS-4 as a precaution in order to prevent failure of the detached rocks from the surface. As against the cut slope MS-4, larger blocks were encountered that were detached from the surface of the cut slope MS-10. Nevertheless, none of the fallen rocks were observed on the road.

Lastly, according to the rockfall analyses, the most intense movements of the detached rocks were observed at the cut slopes MS-9 and MS-11 (Figures 5.53, 5.55). Both rolling and bouncing movements were observed at these cut slopes. Due to steep slope, the most intense bouncing movement was encountered at the cut slope MS-9 with very small rock fragments, but none of the detached rocks have reached the road and all of them have accumulated in the drainage channel. Due to the steep slope and height of the cut slope MS-11, both rolling and bouncing movements were encountered at the analysis with large detached blocks, similar to the slope MS-9 where none of the fallen rocks have reached to the road, but they were accumulated in the drainage channel. While reaching the drainage channel, the most the rocks that were taking part in the bouncing movement turned into rolling and then accumulate in the channel or stopped between toe of the slope and drainage channel. The results of the analyses are coherent with the field observations as none of the fallen rocks reach the road.

As a result, rockfall analyses that were conducted with the RocFall 6.0 software (Rocscience, 2016) are compatible with the field observations. The only critical condition observed in the field and also at the analysis is the accumulation of detached rock fragments in the drainage channels. Even though, the rockfall warning sign is observed near the cut slope MS-1, there exist no risks of rockfall that can cause danger in the field.

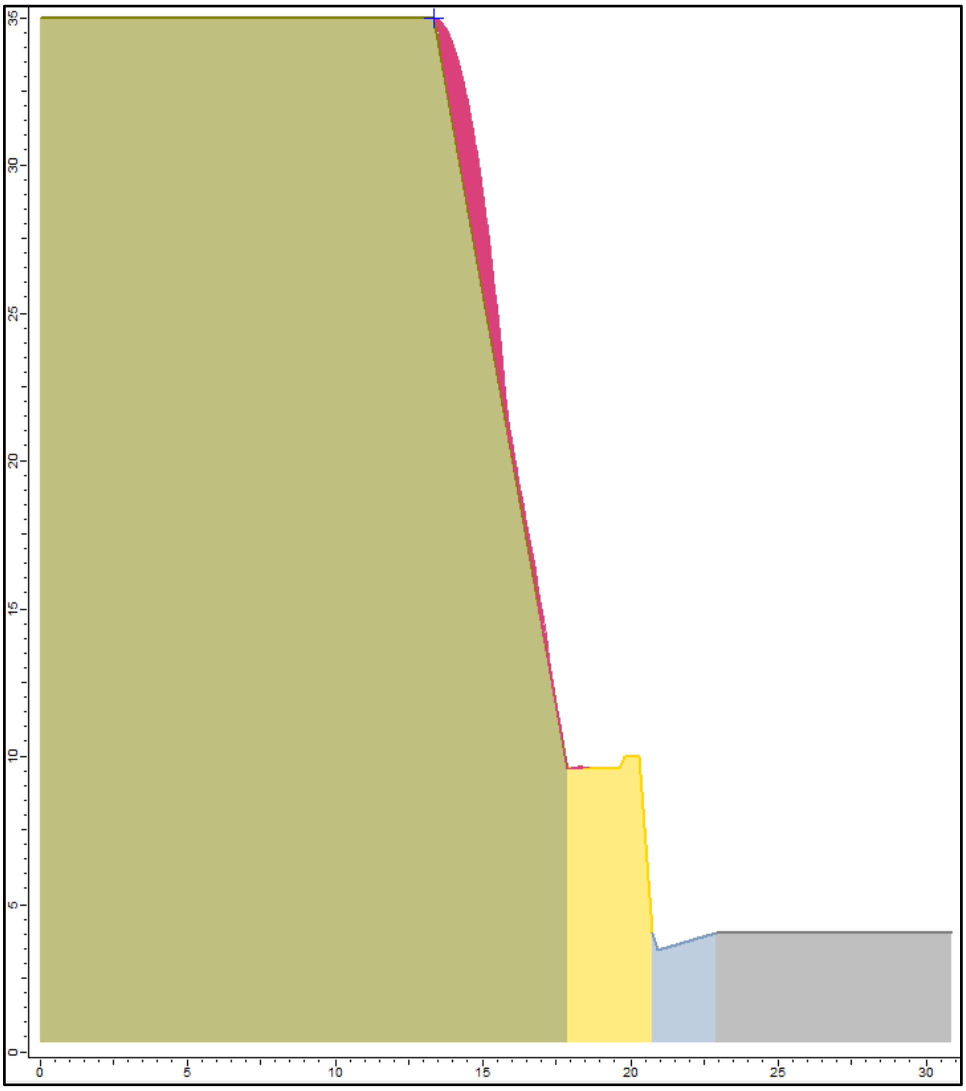


*Figure 5.41.*Rockfall analyses of the cut slope MS-1

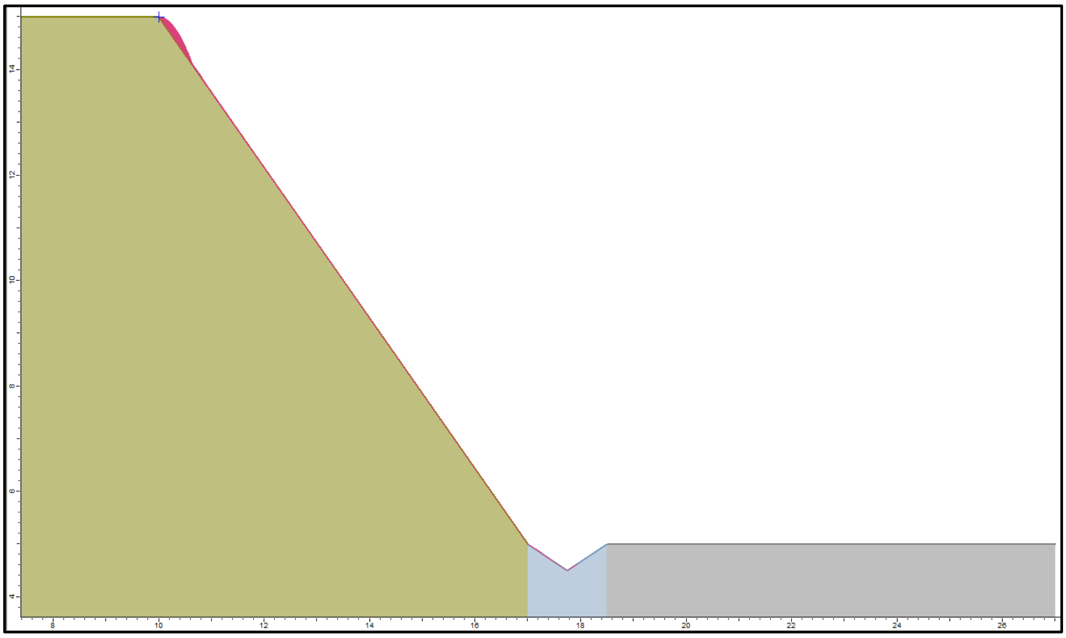


Figure 5.42. Rockfall analyses of the cut slope MS-2.1

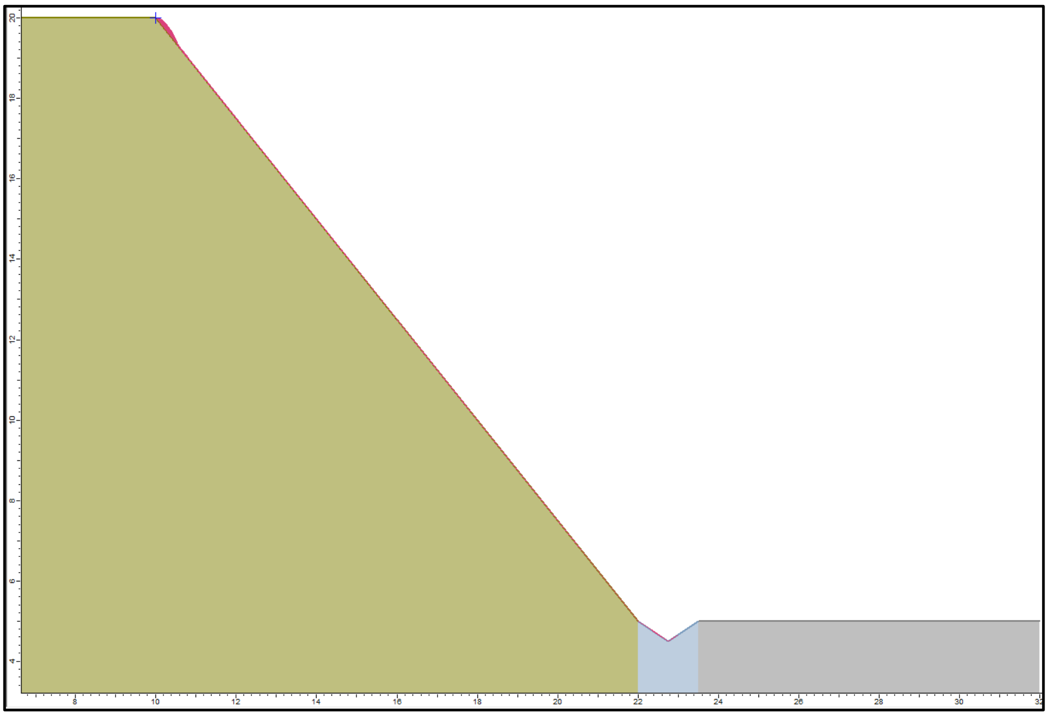


Figure 5.43. Rockfall analyses of the cut slope MS-2.2

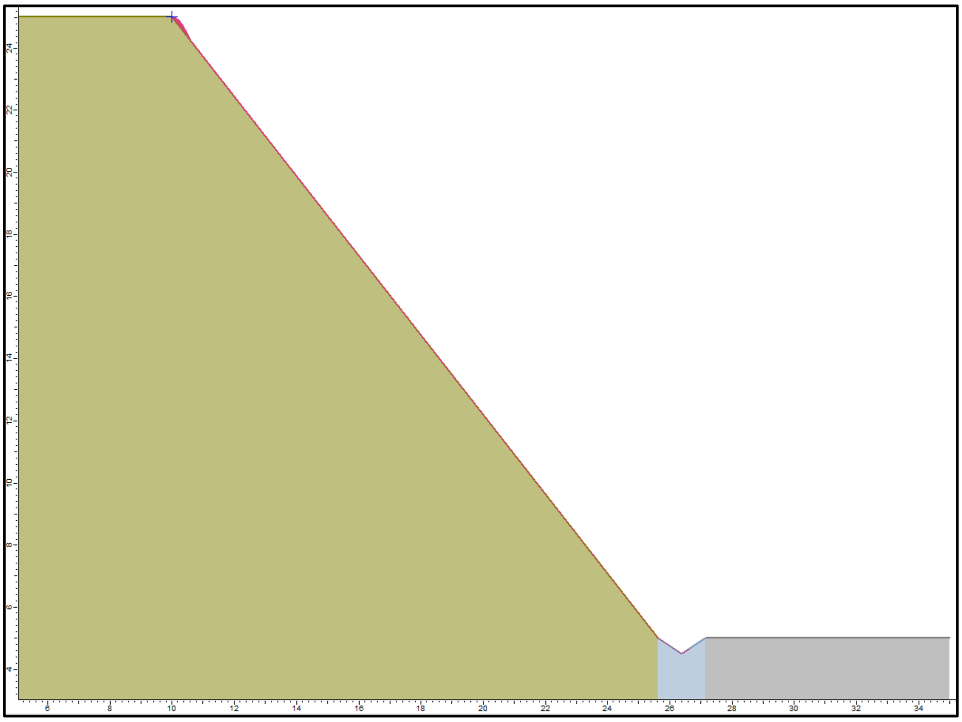


Figure 5.44. Rockfall analyses of the cut slope MS-2.3

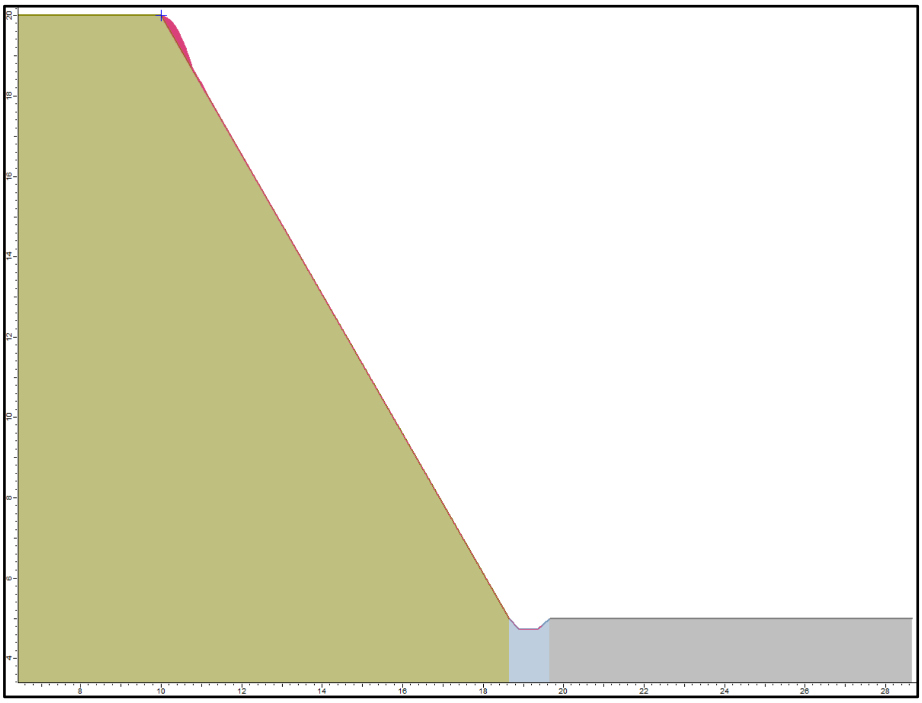


Figure 5.45. Rockfall analyses of the cut slope MS-3

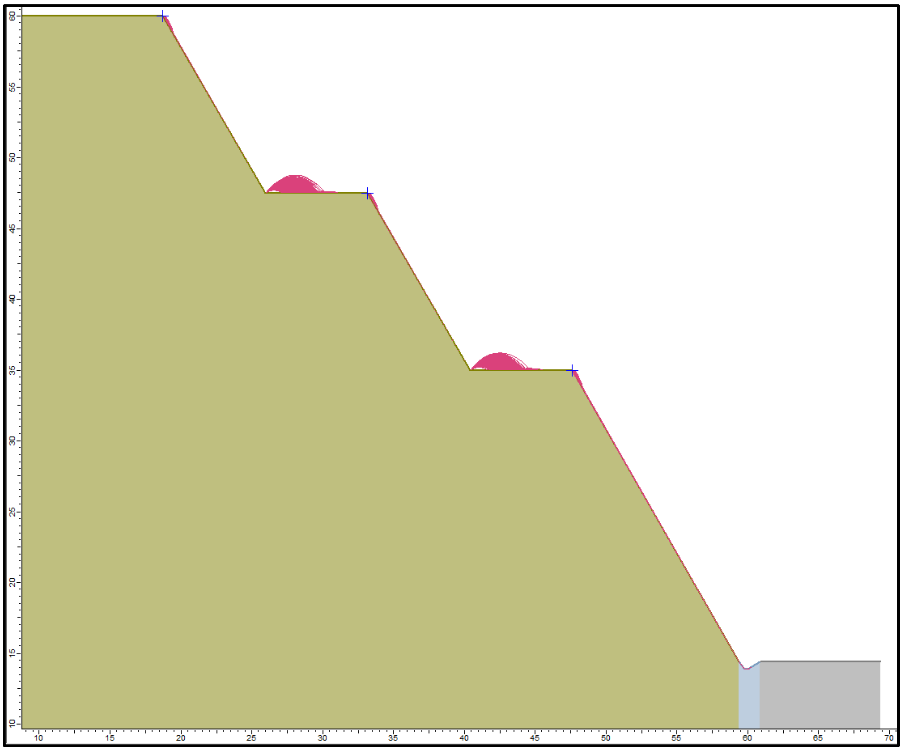


Figure 5.46. Rockfall analyses of the cut slope MS-4

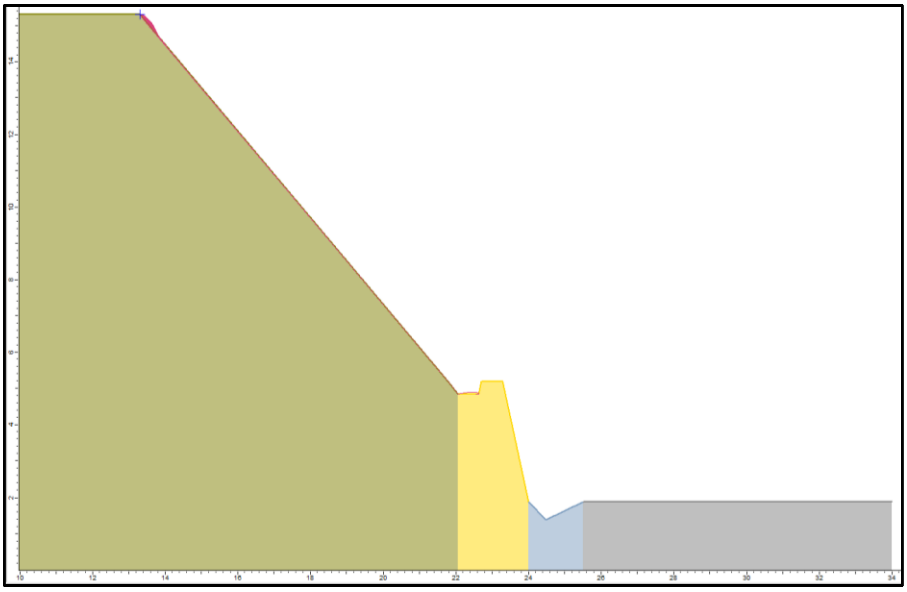


Figure 5.47. Rockfall analyses of the cut slope MS-5

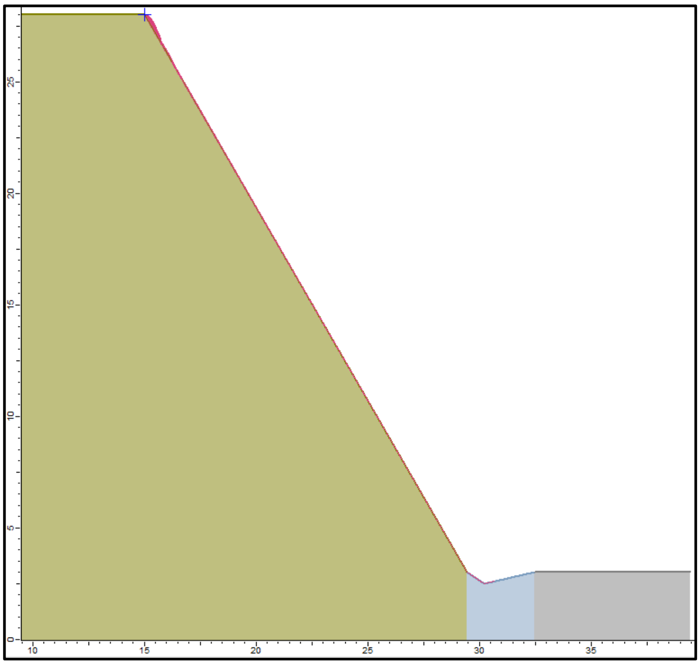


Figure 5.48. Rockfall analyses of the cut slope MS-6

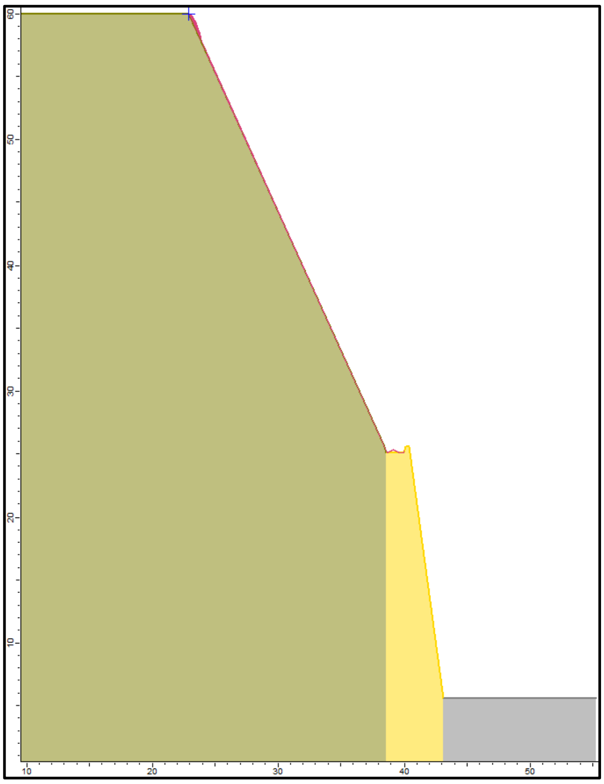


Figure 5.49. Rockfall analyses of the cut slope MS-7.1

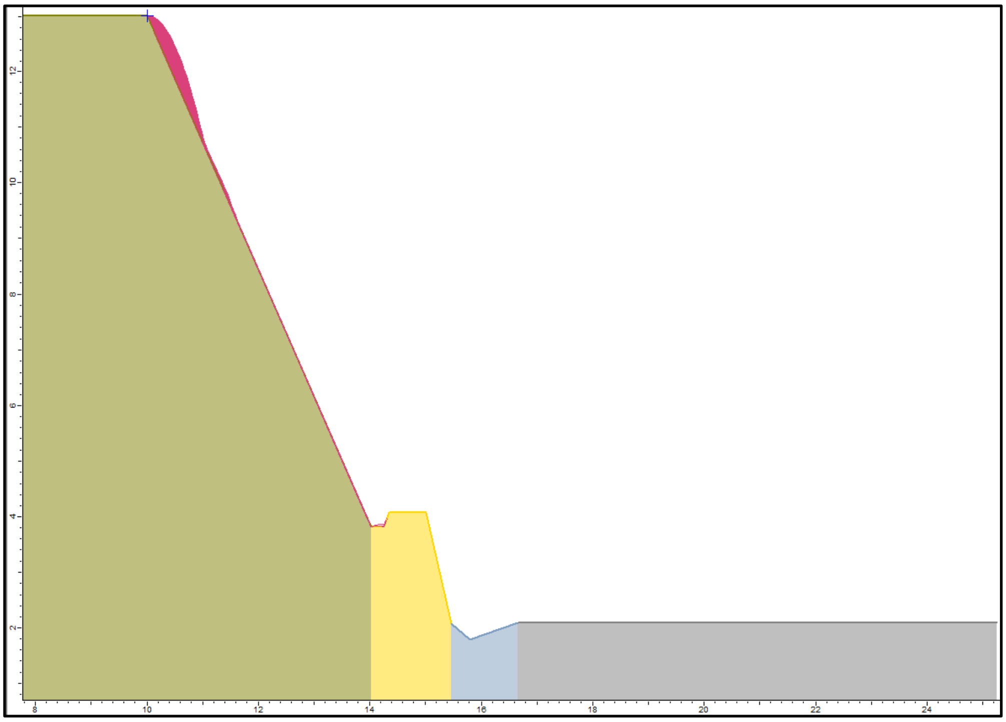


Figure 5.50. Rockfall analyses of the cut slope MS-7.2

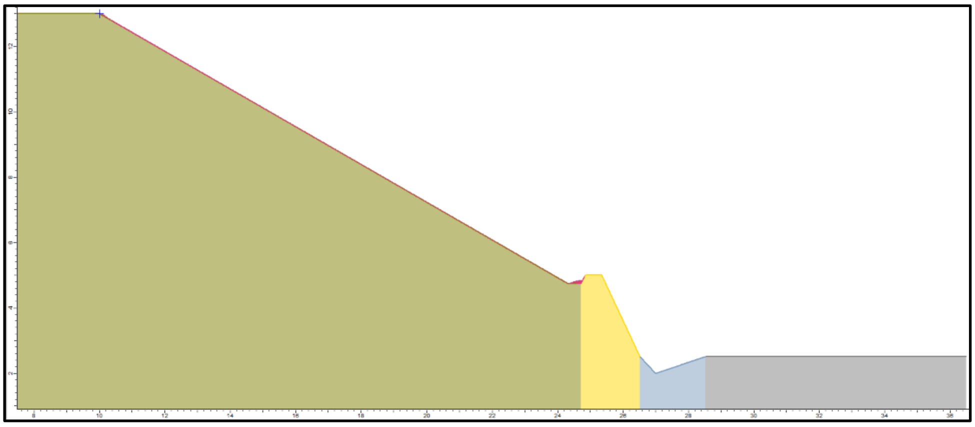


Figure 5.51. Rockfall analyses of the cut slope MS-8.1

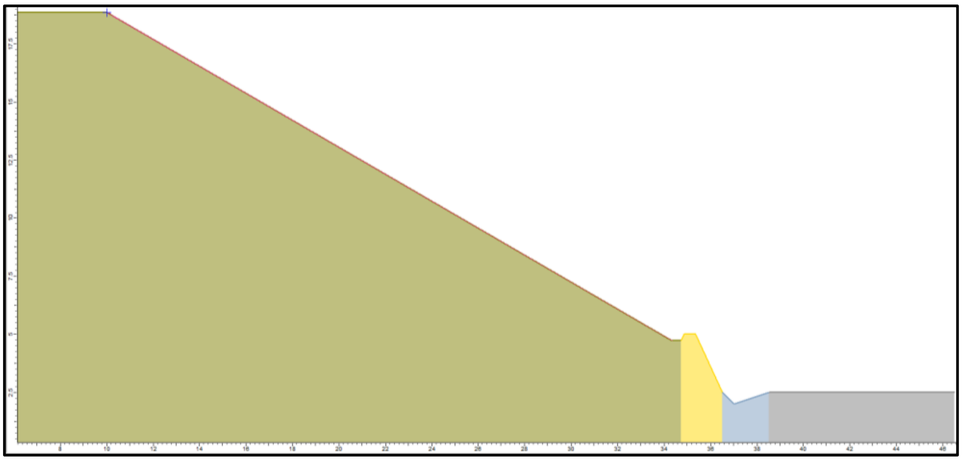


Figure 5.52. Rockfall analyses of the cut slope MS-8.2

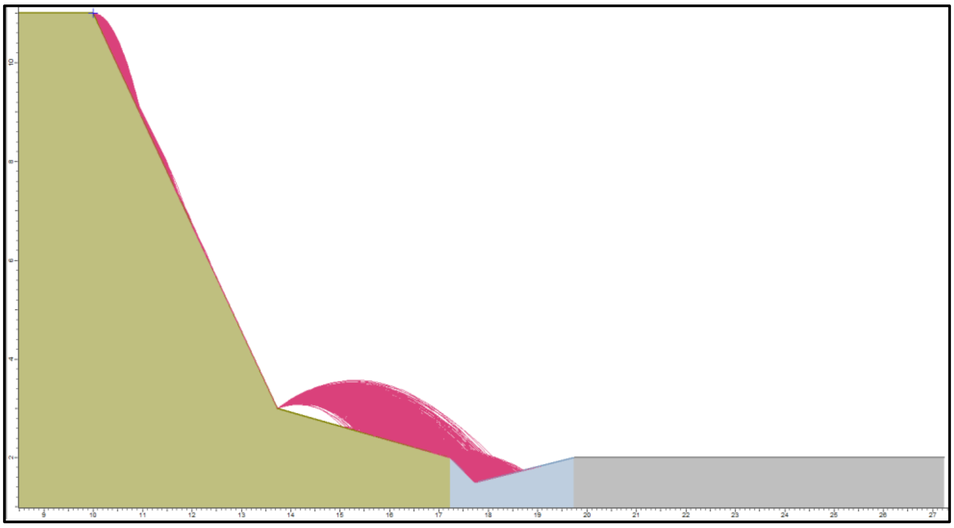


Figure 5.53. Rockfall analyses of the cut slope MS-9

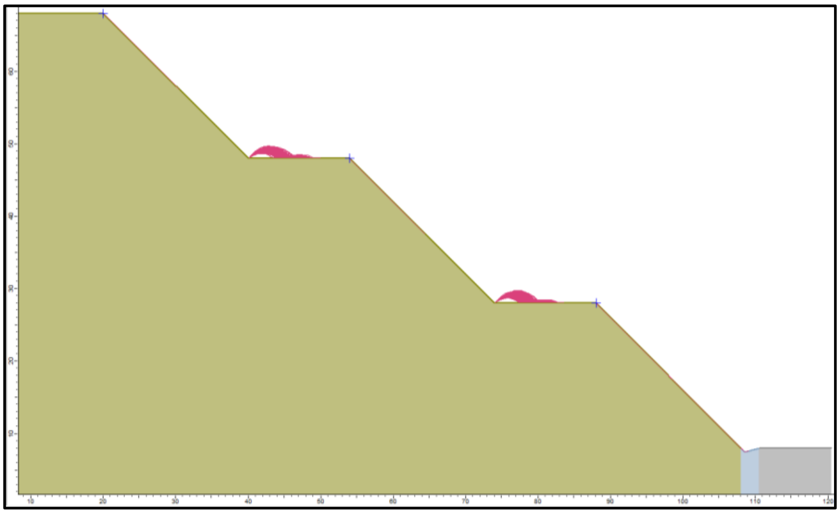


Figure 5.54. Rockfall analyses of the cut slope MS-10

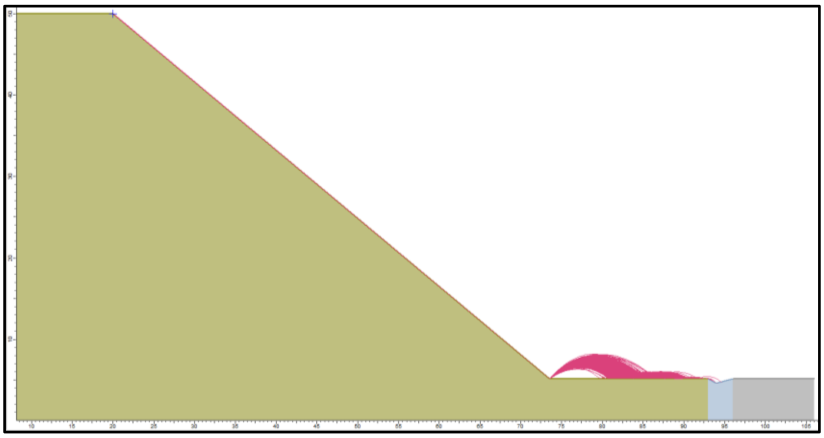


Figure 5.55. Rockfall analyses of the cut slope MS-11

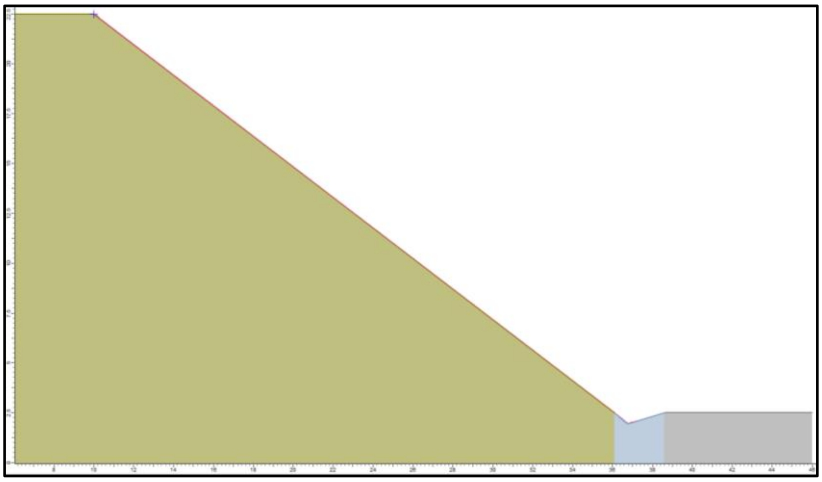


Figure 5.56. Rockfall analyses of the cut slope MS-12

CHAPTER 6

DISCUSSIONS

According to the results of the point load that are listed in Table 4.4, point load strength of the fresh specimens has higher values than the weathered type of rock specimens. Likewise, point load strength indices of the dry rock specimens are higher than the saturated specimens. It can be said that for the fresh rock specimens, strength decrease is approximately 47 % and 50 % for the weathered rock specimens in case of saturation. The maximum strength reduction in saturated conditions is 81 % for the fresh rock specimens and 91 % for the weathered rock specimens of the cut slope MS-4. Strength decrease of the weathered specimens are higher than the decrease of the fresh specimens which can be resulted from the micro fractures of the weathered rock.

For this study, the only mudstone specimens that could be collected in desired sample sizes for to apply point load tests, is from the cut slope MS-6. The mudstone specimens from other cut slopes cannot be gathered in required sizes due to the fractured nature and weathering depth of these flysch type unit. Thus, the mudstone point load results of the cut slope MS-6 is credible for other cut slopes that have mudstone layers. Likewise, fresh marl samples of the cut slope MS-2.3 could not be collected due to depth of weathering that makes impossible to reach fresh type of samples to apply point load test.

As it was mentioned in previous chapters, Schmidt rebound hardness values and the results of point load tests were converted into uniaxial compressive strength values (Table 4.7). It was not possible to apply the Schmidt rebound hardness test for all of the rock units due to weathering and fractured nature of the rock units. As an example, for the mudstone layers, Schmidt rebound test could not be carried due to lack of the required sized intact mudstone specimen without fractures.

According to values converted from Schmidt rebound test into uniaxial compressive strength (Table 4.7), the values obtained from different equations of different researchers generally reveal higher values than the values estimated from point load tests results. For instance, Sachpazis (1990) and Deere and Miller (1966) functions reveal overestimation for weathered and fresh specimens. Contrarily, function of Cargill and Shakoor (1990) shows undervaluing on the conversion of Schmidt rebound values into the point load test results. The plot of uniaxial compressive strength versus Schmidt rebound values obtained from different equations of different researchers mentioned before and this study data for both weathered and fresh rocks is given in Figure 6.1. It can be said that it is impossible to reach a credible equation to reach uniaxial compressive strength values converted from Schmidt hammer rebound data because the coefficient of determination R^2 is too low (0.1209). Likewise, coefficients of determination are considerably low for other rock types (Figures 6.2, 6.3 and 6.4) namely; limestones (0.2076), sandstones (0.3111) and marls (0.5802) that encountered in the study area for fresh and weathered samples. Hence, it is not possible to use the functions for fresh and weathered rock types of limestone, sandstone and marl of the study area in order to designate the uniaxial compressive strength from Schmidt rebound hardness results.

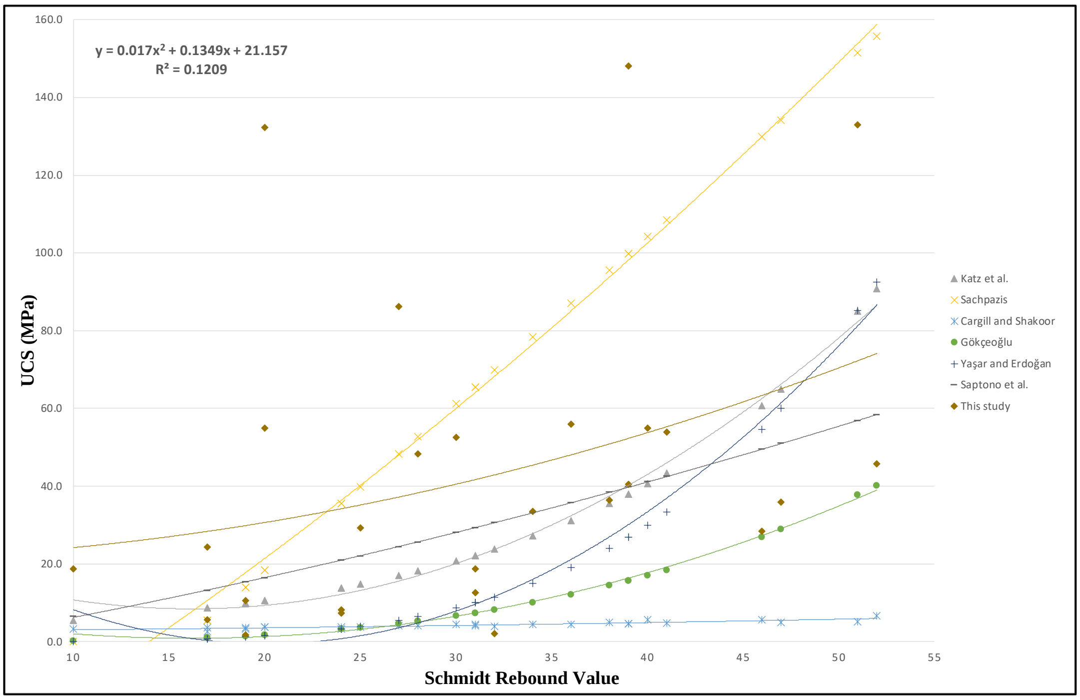


Figure 6.1. The graph of UCS versus Schmidt rebound values considering different equations and this study

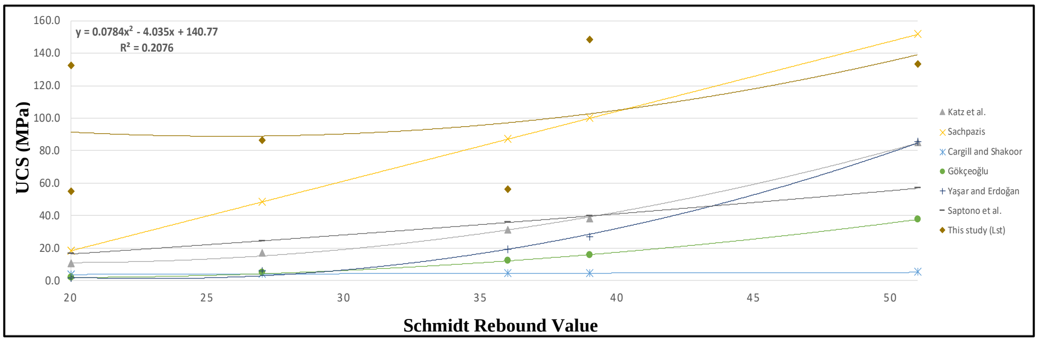


Figure 6.2. The graph of UCS versus Schmidt rebound value for limestone specimens considering different equations and this study

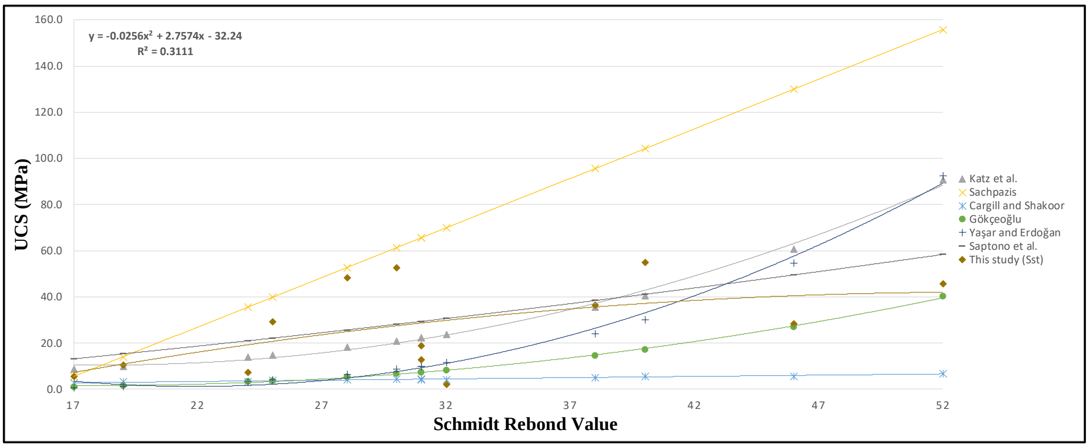


Figure 6.3. The graph of UCS versus Schmidt rebound value for sandstone specimens considering different equations and this study

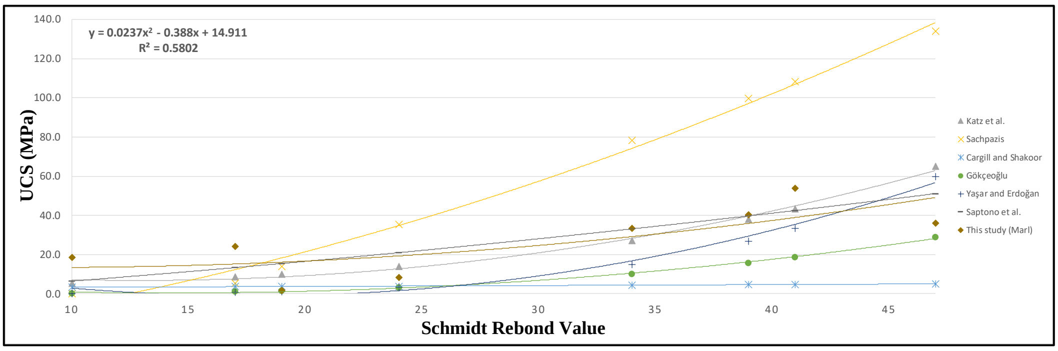


Figure 6.4. The graph of UCS versus Schmidt rebound value for marl specimens considering different equations and this study

In the study area, it is observed that the mudstones layers in flysch type of alternations are more affected from weathering than the other rock units as a weak rock. Along with mudstones, other rocks that were encountered at the studied cut slopes namely; limestone, sandstone and marl are affected from weathering as well especially along their discontinuities. The observed weathering zone at the mudstones are deeper than other rock types according to field observations and in-situ tests of Schmidt rebound hardness test, and it can be said that most of the mudstones at the surface could be crumbled by hand.

According to the results of the slake durability of the specimens that were gathered from the studied road cuts (Table 4.9), the marl specimens of the cut slopes MS-2.1, MS-2.2, MS-3 and MS-4 show very high durability and marl of the cut slope MS-2.3 and mudstone of the cut slope MS-6 reveal high durability by considering $Id_{(2)}$ values in the light of the slake durability classification of Gamble (1971). The expectation about the marl and mudstone is that they would reveal lower durability results by taking into consideration of the field observations and the results of the strength tests performed in the laboratory. However; in reference to ASTM D4644-87 (1998), the marls of MS-2.1, MS-2.2, MS-3 and MS-4 are recorded as Type I, marl of the cut slope MS-2.3 and mudstone of the cut slope MS-6 are recorded as Type II (Table 4.9). While investigating the influence of the number of slaking cycles on slake-durability of the related samples up to 20 cycles, the trends of the related specimens, that show durability against number of cycles applied, do not change. The marl and mudstone of the related cut slopes show higher durability values against most of the other rock types.

The results of the methylene blue adsorption (MBA) test demonstrate that the fresh specimens have results less than or equal to the weathered specimens (Table 4.10). Cation exchange capacity (CEC) results of the weathered and fresh specimens of the studied cut slopes are in the range of 1.5-8.1 meq./100 g. However, methylene blue adsorption (MBA) test results of weathered and fresh specimens of the studied cut slopes are changing between 0.67 and 3.60 g/100 g. High values of methylene adsorption points towards high swelling activity and lower values of absorption mostly indicates low swelling activities (Topal, 1996). Even though the minerals are in wide range, they do not tend to action of swelling.

As it was mentioned in the previous chapter, slope stability analyses were performed for GSI values of +/-5 and for different pseudo-static values for each road-cut in order to observe the possible lowest stability condition, another to say to be at the safe side. Factor of safety values of different pseudo-static values and different GSI values of each cut slope are investigated so as to observe the effect of the parameters on the factor safety values (Figures 6.5 and 6.6).

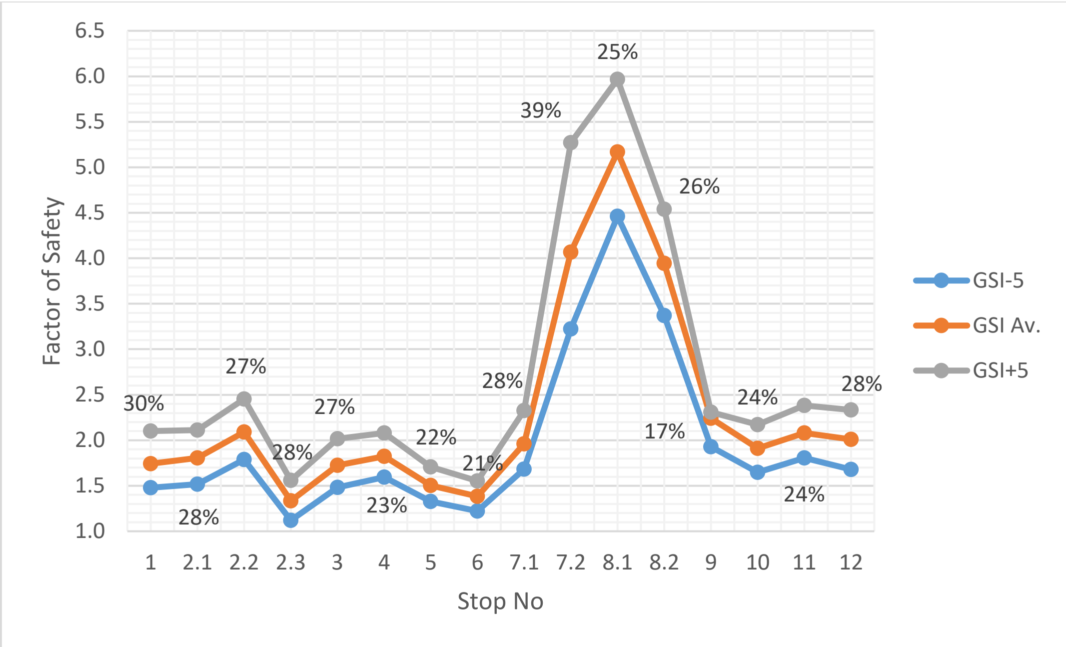


Figure 6.5. Change of factor of safety with different GSI values for each cut

By taking GSI values as +/- 5, factor of safety values of each 16 road cuts show changes. The average of the change in GSI value is 26 % and the maximum change is 39 % for the cut slope MS-7.1 (Figure 6.5). The average change 26 % has a serious impact on safety factor as in the cut slope MS-8.1. As can be seen in Figure 6.5, the average GSI value of the cut slope MS-5 is at the border of the failure condition thus GSI designation is considered to be very important. For this study, assigning of the GSI values were properly carried out through reviewing these conditions.

Stability analysis for the pseudo-static conditions were conducted with different seismic coefficients that are 0.65, 0.5 and, 0.33 of different researchers as Bozorgnia and Bertero (2004), Hynes-Griffin and Franklin (1984), and Marcuson (1981), respectively. In order to perform the pseudo-static analysis, average GSI values for each cut slope were considered with different reduction coefficients. The maximum average decrease of safety factor is 15 % for the seismic coefficient of 0.65 (Bozorgnia and Bertero, 2004). In case Marcuson's (1981) reduction coefficient 0.33 is used for the analysis, average decrease in safety factor is 8 % (Figure 6.6). The critical factor of safety value which is under 1.1 according to limitations of General Directorate of Highways for dynamic conditions was only encountered for the cut slope MS-6 as 1.0 with the reduction coefficient of Bozorgnia and Bertero (2004) (Table 5.5). As reported by Disaster Emergency Management Authority-Presidential of Earthquake Department (AFAD 2019), there were no earthquakes that are higher or equal than 4.0 Mw for past 10 years around the studied cut slopes of this study.

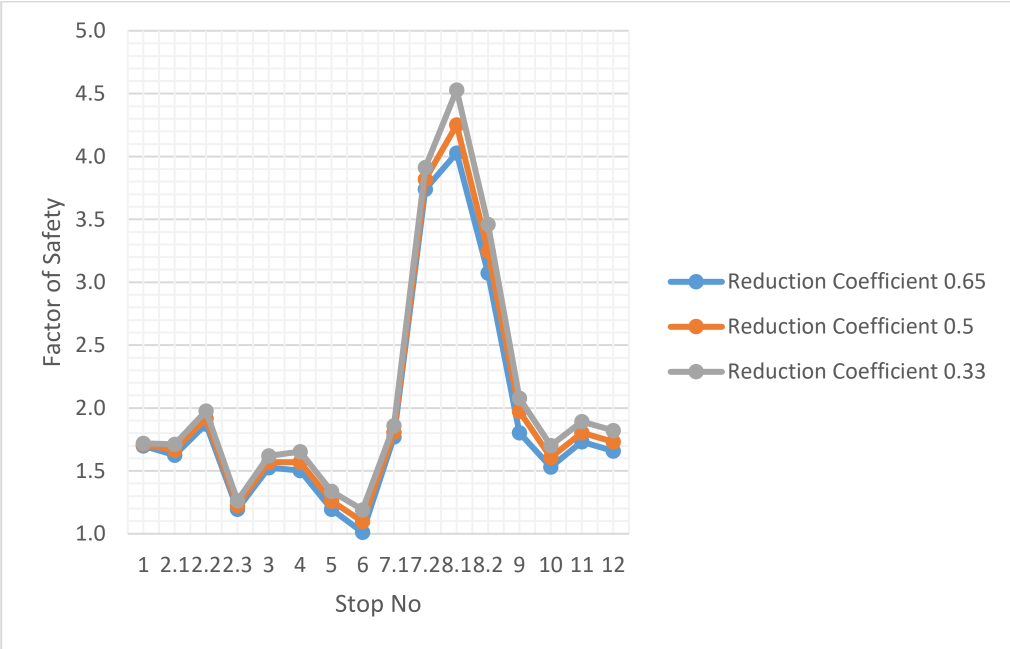


Figure 6.6. Change of factor of safety with different pseudo-static reduction coefficients for each cut slope

CHAPTER 7

CONCLUSIONS

This study has the aim of investigating the stability of sixteen different cut slopes that are located within the borders of Karabük, Zonguldak and Düzce province in Turkey, along Ankara-Karabük, Karabük-Zonguldak, Zonguldak-Ankara, Ereğli-Akçakoca and Düzce-Akçakoca highways. At the studied road cuts, four rock types were encountered that are namely; limestone, sandstone, mudstone and marl. The conclusions achieved are described below on the basis of the stability analysis, field studies, laboratory works and literature research.

- Çaycuma, Karabük, Akveren, Kilimli, Ulus and Çakraz are the formations where 16 examined cut slopes are located. Flysch-type of sedimentary deposits are mostly encountered in the study area.
- By the reason of having heavily fractured and jointed structure and very weak to weak strength, uniaxial compressive strength test could not be applied for the marl and mudstone. UCS tests could be applied only for the limestone and sandstone samples. Correlation coefficients “k-values” for limestone and sandstone were determined in coherent with UCS test and point load tests. For the rock types of mudstone and marl, k-values are designated after literature survey. The values obtained from Schmidt rebound tests were converted into uniaxial compressive strength by the help of equations of different researchers. For the limestone, sandstone and marl, three functions with considerably low correlation coefficients (R^2) were obtained that cannot be used to convert the Schmidt rebound values of the studied rock specimens into uniaxial compressive strength values. The slake durability tests were performed as 20 cycles for each cut slopes to obtain information about durability of rocks. The

results of the slake durability tests are ranging between low durability to very high durability considering $Id_{(2)}$ values. Nearly half of the rock specimens have very high durability by considering two wetting-drying cycles. Methylene blue tests were performed to find cation exchange capacity of the rocks. For the weathered and fresh specimens of the studied cut slopes, cation exchange capacity (CEC) results are in the range of 1.5-8.1 meq./100 g and methylene blue adsorption (MBA) test results are changing between 0.67 and 3.60 g/100 g. The results of the methylene blue adsorption tests indicate that the minerals do not tend to action of excessive swelling.

- The results of the kinematic analyses show that wedge failure possibility is likely at the cut slopes MS-1, MS-2.1, MS-2.2, MS-2.3, MS-3, MS-6, MS-7.1, MS-10 and MS-12. Planar sliding is critical for the cut slopes MS-1 and MS-2.1. Toppling failure possibility is detected at the road-cuts MS-2.3 and MS-4.
- Further analysis of limit equilibrium for the discontinuity-controlled rocks were conducted by taking into consideration of the results of kinematic analysis. The only critical result of the wedge failure analysis is for the cut slope MS-2.1 giving factor of safety as 0.9 under pseudo-static condition. Under static condition analysis of MS-2.1 gives factor of safety as 1.1. The only critical condition for planar sliding analysis is for the cut slope MS-2.1 giving the resultant factor of safety as 0.97 which is a critical condition under pseudo-static condition. Under static condition, planar failure analysis of MS-2.1 gives the resultant factor of safety as 1.1. The result of the toppling failure analysis demonstrate that the cut slopes are stable against toppling movement.
- Limit equilibrium analyses for the rock masses reveal that factor of safety values of static conditions with average GSI, and GSI +/-5 values are ranging between 1.1 and 6.0. For dynamic conditions, factor of safety values are in the range of 1.0 and 4.5. The results of the limit equilibrium analyses for the rock masses are compatible with field observations.

- According to the rockfall analysis that were conducted for all the studied cut slopes, the only critical condition is the accumulation of the detached rock fragments in the drainage channels. The most intense movements of the detached rocks were observed at the cut slopes MS-9 and MS-11 but none of the detached rocks of the road-cuts have reached the road and all of them have accumulated in the drainage channels. The results of the rockfall analysis are found to be compatible with the field observations.
- As a result of the stability analysis, there are no significant stability risks of the studied cut slopes except for the surficial failures of the detached rocks. It can be said that there were no stability risks under static conditions besides already fallen rock fragments according to field observations at the beginning of the study that are matching with the results of the analysis. The detached rocks of the road-cuts have accumulated in the drainage channel in front of the cut slopes. Thus, the drainage channels should be controlled constantly as a prevention in case of debris accumulations.

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APPENDICES

A. LABORATORY TEST RESULTS

Table 0.1 *Porosity and unit weight of slope MS-1 fresh limestone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	127,83	78,16	124,83	3,00	49,67	6,04	24,65	25,25
F2	213,07	130,00	210,01	3,06	83,07	3,68	24,80	25,16
F3	185,16	113,12	182,83	2,33	72,04	3,23	24,90	25,21
F4	203,83	124,90	199,98	3,85	78,93	4,88	24,85	25,33
F5	87,58	53,35	83,64	3,94	34,23	11,51	23,97	25,10
F6	173,32	105,77	168,97	4,35	67,55	6,44	24,54	25,17
F7	126,45	77,36	124,82	1,63	49,09	3,32	24,94	25,27
F8	107,94	65,88	105,03	2,91	42,06	6,92	24,50	25,18
F9	72,32	44,06	69,52	2,80	28,26	9,91	24,13	25,10
F10	45,93	27,94	43,98	1,95	17,99	10,84	23,98	25,05
F11	56,47	34,70	54,27	2,20	21,77	10,11	24,46	25,45

Table 0.2. *Porosity and unit weight of slope MS-1 weathered limestone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	88,45	53,62	82,78	5,67	34,83	16,28	23,32	24,91
W2	94,16	57,77	91,33	2,83	36,39	7,78	24,62	25,38
W3	62,78	38,38	61,13	1,65	24,40	6,76	24,58	25,24
W4	64,00	39,06	62,17	1,83	24,94	7,34	24,45	25,17
W5	287,55	177,40	282,77	4,78	110,15	4,34	25,18	25,61
W6	335,43	205,86	326,89	8,54	129,57	6,59	24,75	25,40
W7	148,98	91,66	145,41	3,57	57,32	6,23	24,89	25,50
W8	198,17	120,32	190,62	7,55	77,85	9,70	24,02	24,97
W9	71,66	43,69	69,32	2,34	27,97	8,37	24,31	25,13
W10	161,79	98,07	156,35	5,44	63,72	8,54	24,07	24,91
W11	55,69	34,00	54,08	1,61	21,69	7,42	24,46	25,19
W12	56,01	34,35	54,55	1,46	21,66	6,74	24,71	25,37

Table 0.3. *Porosity and unit weight of slope MS-2.1 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	155,23	93,81	150,66	4,57	61,42	7,44	24,06	24,79
F2	148,53	89,80	145,20	3,33	58,73	5,67	24,25	24,81
F3	137,26	83,01	134,23	3,03	54,25	5,59	24,27	24,82
F4	97,65	59,07	95,24	2,41	38,58	6,25	24,22	24,83
F5	92,51	55,97	90,22	2,29	36,54	6,27	24,22	24,84
F6	49,82	30,40	48,55	1,27	19,42	6,54	24,53	25,17
F7	80,17	48,49	77,81	2,36	31,68	7,45	24,09	24,83
F8	77,54	46,95	75,30	2,24	30,59	7,32	24,15	24,87
F9	101,52	61,52	98,15	3,37	40,00	8,42	24,07	24,90
F10	100,07	60,53	97,51	2,56	39,54	6,47	24,19	24,83

Table 0.4. *Porosity and unit weight of slope MS-2.1 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	78,59	47,81	75,82	2,77	30,78	9,00	24,16	25,05
W2	70,85	43,19	68,40	2,45	27,66	8,86	24,26	25,13
W3	78,65	47,82	75,68	2,97	30,83	9,63	24,08	25,03
W4	143,80	87,35	138,61	5,19	56,45	9,19	24,09	24,99
W5	113,45	69,22	109,83	3,62	44,23	8,18	24,36	25,16
W6	75,66	46,32	73,50	2,16	29,34	7,36	24,58	25,30
W7	127,68	77,75	123,40	4,28	49,93	8,57	24,25	25,09
W8	127,24	77,15	122,42	4,82	50,09	9,62	23,98	24,92
W9	113,80	69,56	110,60	3,20	44,24	7,23	24,53	25,23
W10	93,11	56,89	90,45	2,66	36,22	7,34	24,50	25,22

Table 0.5. *Porosity and unit weight of slope MS-2.2 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	165,30	100,03	161,89	3,41	65,27	5,22	24,33	24,84
F2	59,36	35,92	57,78	1,58	23,44	6,74	24,18	24,84
F3	190,63	115,19	186,86	3,77	75,44	5,00	24,30	24,79
F4	260,12	157,65	255,87	4,25	102,47	4,15	24,50	24,90
F5	207,69	125,56	203,31	4,38	82,13	5,33	24,28	24,81
F6	60,22	36,49	58,85	1,37	23,73	5,77	24,33	24,89
F7	82,68	50,25	80,75	1,93	32,43	5,95	24,43	25,01
F8	117,23	70,87	114,32	2,91	46,36	6,28	24,19	24,81
F9	171,23	103,49	167,72	3,51	67,74	5,18	24,29	24,80
F10	87,43	52,86	85,22	2,21	34,57	6,39	24,18	24,81
F11	109,65	66,28	106,49	3,16	43,37	7,29	24,09	24,80

Table 0.6. *Porosity and unit weight of slope MS-2.2 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	78,80	47,99	76,37	2,43	30,81	7,89	24,32	25,09
W2	132,79	80,99	129,08	3,71	51,80	7,16	24,45	25,15
W3	312,71	190,79	304,79	7,92	121,92	6,50	24,52	25,16
W4	182,09	111,02	177,34	4,75	71,07	6,68	24,48	25,13
W5	124,17	75,68	120,68	3,49	48,49	7,20	24,41	25,12
W6	223,84	136,72	217,74	6,10	87,12	7,00	24,52	25,21
W7	285,10	173,68	277,96	7,14	111,42	6,41	24,47	25,10
W8	308,83	188,08	301,04	7,79	120,75	6,45	24,46	25,09
W9	79,94	48,74	77,32	2,62	31,20	8,40	24,31	25,13
W10	129,13	78,75	125,58	3,55	50,38	7,05	24,45	25,14
W11	158,14	96,45	153,52	4,62	61,69	7,49	24,41	25,15

Table 0.7. *Porosity and unit weight of slope MS-2.3 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	65,43	38,54	60,54	4,89	26,89	18,19	22,09	23,87
W2	77,55	45,55	71,27	6,28	32,00	19,63	21,85	23,77
W3	60,72	35,61	55,90	4,82	25,11	19,20	21,84	23,72
W4	55,13	32,08	50,41	4,72	23,05	20,48	21,45	23,46
W5	31,17	18,22	27,73	3,44	12,95	26,56	21,01	23,61
W6	53,85	31,42	49,32	4,53	22,43	20,20	21,57	23,55
W7	21,47	12,38	19,44	2,03	9,09	22,33	20,98	23,17
W8	21,59	12,64	19,84	1,75	8,95	19,55	21,75	23,66
W9	35,48	20,86	32,76	2,72	14,62	18,60	21,98	23,81
W10	35,33	20,71	32,49	2,84	14,62	19,43	21,80	23,71
W11	23,86	13,99	21,95	1,91	9,87	19,35	21,82	23,71
W12	26,38	15,45	24,21	2,17	10,93	19,85	21,73	23,68

Table 0.8. *Porosity and unit weight of slope MS-3 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	117,64	72,86	115,14	2,50	44,78	5,58	25,22	25,77
F2	72,36	45,06	71,16	1,20	27,30	4,40	25,57	26,00
F3	56,41	35,15	55,46	0,95	21,26	4,47	25,59	26,03
F4	137,80	85,27	134,46	3,34	52,53	6,36	25,11	25,73
F5	141,11	87,41	138,03	3,08	53,70	5,74	25,22	25,78
F6	99,23	61,42	96,78	2,45	37,81	6,48	25,11	25,75
F7	94,87	59,35	93,37	1,50	35,52	4,22	25,79	26,20
F8	138,05	85,72	134,67	3,38	52,33	6,46	25,25	25,88
F9	43,63	27,20	42,98	0,65	16,43	3,96	25,66	26,05
F10	95,97	59,56	93,97	2,00	36,41	5,49	25,32	25,86
F11	62,36	38,63	61,02	1,34	23,73	5,65	25,23	25,78

Table 0.9. *Porosity and unit weight of slope MS-3 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	146,68	90,86	143,34	3,34	55,82	5,98	25,19	25,78
W2	124,78	77,61	122,71	2,07	47,17	4,39	25,52	25,95
W3	157,93	98,24	154,92	3,01	59,69	5,04	25,46	25,96
W4	109,06	67,34	105,95	3,11	41,72	7,45	24,91	25,64
W5	105,61	65,28	102,98	2,63	40,33	6,52	25,05	25,69
W6	122,52	76,29	120,38	2,14	46,23	4,63	25,54	26,00
W7	71,15	44,05	69,45	1,70	27,10	6,27	25,14	25,76
W8	156,23	97,23	153,59	2,64	59,00	4,47	25,54	25,98
W9	65,41	40,80	64,47	0,94	24,61	3,82	25,70	26,07
W10	60,37	37,47	58,96	1,41	22,90	6,16	25,26	25,86
W11	80,85	50,14	79,07	1,78	30,71	5,80	25,26	25,83

Table 0.10. *Porosity and unit weight of slope MS-4 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	107,21	68,50	105,94	1,27	38,71	3,28	26,85	27,17
F2	84,37	51,52	83,19	1,18	32,85	3,59	24,84	25,20
F3	102,67	64,29	101,47	1,20	38,38	3,13	25,94	26,24
F4	47,23	29,50	46,59	0,64	17,73	3,61	25,78	26,13
F5	68,24	42,77	67,57	0,67	25,47	2,63	26,03	26,28
F6	66,33	41,37	65,13	1,20	24,96	4,81	25,60	26,07
F7	66,86	41,66	65,51	1,35	25,20	5,36	25,50	26,03
F8	114,16	71,38	112,18	1,98	42,78	4,63	25,72	26,18
F9	135,22	84,54	133,45	1,77	50,68	3,49	25,83	26,17
F10	143,57	89,75	141,55	2,02	53,82	3,75	25,80	26,17
F11	78,10	48,86	77,08	1,02	29,24	3,49	25,86	26,20
F12	27,62	17,25	27,12	0,50	10,37	4,82	25,66	26,13
F13	30,39	19,06	30,06	0,33	11,33	2,91	26,03	26,31
F14	46,60	29,17	45,99	0,61	17,43	3,50	25,88	26,23
F15	18,42	11,46	18,04	0,38	6,96	5,46	25,43	25,96
F16	21,79	13,56	21,30	0,49	8,23	5,95	25,39	25,97
F17	32,88	20,46	32,22	0,66	12,42	5,31	25,45	25,97
F18	26,67	16,68	26,27	0,40	9,99	4,00	25,80	26,19
F19	62,13	38,88	61,52	0,61	23,25	2,62	25,96	26,21
F20	26,12	16,30	25,82	0,30	9,82	3,05	25,79	26,09

Table 0.11. *Porosity and unit weight of slope MS-4 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	133,85	83,60	131,48	2,37	50,25	4,72	25,67	26,13
W2	143,80	89,64	140,17	3,63	54,16	6,70	25,39	26,05
W3	129,71	81,09	127,57	2,14	48,62	4,40	25,74	26,17
W4	126,81	79,48	124,85	1,96	47,33	4,14	25,88	26,28
W5	46,89	29,44	46,28	0,61	17,45	3,50	26,02	26,36
W6	103,36	64,74	101,79	1,57	38,62	4,07	25,86	26,25
W7	53,55	33,18	52,29	1,26	20,37	6,19	25,18	25,79
W8	47,16	29,34	46,32	0,84	17,82	4,71	25,50	25,96
W9	20,95	13,07	20,62	0,33	7,88	4,19	25,67	26,08
W10	44,80	27,79	43,79	1,01	17,01	5,94	25,25	25,84
W11	48,45	30,31	47,71	0,74	18,14	4,08	25,80	26,20
W12	46,14	28,75	45,32	0,82	17,39	4,72	25,57	26,03
W13	82,20	51,56	81,04	1,16	30,64	3,79	25,95	26,32
W14	87,99	54,66	86,01	1,98	33,33	5,94	25,32	25,90
W15	53,84	33,20	52,36	1,48	20,64	7,17	24,89	25,59
W16	28,56	17,61	27,75	0,81	10,95	7,40	24,86	25,59
W17	47,42	29,64	46,62	0,80	17,78	4,50	25,72	26,16
W18	60,50	37,40	58,88	1,62	23,10	7,01	25,00	25,69
W19	21,92	13,71	21,55	0,37	8,21	4,51	25,75	26,19
W20	28,94	18,06	28,42	0,52	10,88	4,78	25,63	26,09

Table 0.12. *Porosity and unit weight of slope MS-5 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	61,04	36,52	57,49	3,55	24,52	14,48	23,00	24,42
F2	67,34	40,73	64,09	3,25	26,61	12,21	23,63	24,83
F3	152,89	91,55	144,05	8,84	61,34	14,41	23,04	24,45
F4	107,64	64,17	100,90	6,74	43,47	15,50	22,77	24,29
F5	71,44	42,80	67,32	4,12	28,64	14,39	23,06	24,47
F6	36,03	21,85	34,43	1,60	14,18	11,28	23,82	24,93
F7	85,66	51,80	81,54	4,12	33,86	12,17	23,62	24,82
F8	128,02	77,06	121,25	6,77	50,96	13,28	23,34	24,64
F9	62,81	37,78	59,45	3,36	25,03	13,42	23,30	24,62
F10	48,29	28,88	45,48	2,81	19,41	14,48	22,99	24,41
F11	43,54	26,33	41,49	2,05	17,21	11,91	23,65	24,82
F12	44,22	26,24	41,27	2,95	17,98	16,41	22,52	24,13
F13	28,39	16,72	26,26	2,13	11,67	18,25	22,07	23,87
F14	71,83	43,44	68,40	3,43	28,39	12,08	23,64	24,82
F15	53,61	31,97	49,95	3,66	21,64	16,91	22,64	24,30
F16	51,86	31,02	48,71	3,15	20,84	15,12	22,93	24,41
F17	39,68	23,88	37,49	2,19	15,80	13,86	23,28	24,64
F18	36,46	21,88	34,33	2,13	14,58	14,61	23,10	24,53
F19	59,47	35,45	55,58	3,89	24,02	16,19	22,70	24,29
F20	25,70	15,43	24,36	1,34	10,27	13,05	23,27	24,55
F21	85,48	50,96	80,02	5,46	34,52	15,82	22,74	24,29

Table 0.13. *Porosity and unit weight of slope MS-5 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	44,95	26,75	41,61	3,34	18,20	18,35	22,43	24,23
W2	78,19	46,10	72,54	5,65	32,09	17,61	22,18	23,90
W3	63,27	37,88	59,66	3,61	25,39	14,22	23,05	24,45
W4	26,54	16,16	25,36	1,18	10,38	11,37	23,97	25,08
W5	86,95	52,22	81,98	4,97	34,73	14,31	23,16	24,56
W6	71,07	41,77	65,79	5,28	29,30	18,02	22,03	23,80
W7	223,55	135,13	212,84	10,71	88,42	12,11	23,61	24,80
W8	93,95	56,10	88,31	5,64	37,85	14,90	22,89	24,35
W9	29,25	17,28	27,56	1,69	11,97	14,12	22,59	23,97
W10	95,62	57,61	91,23	4,39	38,01	11,55	23,55	24,68
W11	30,29	18,17	28,66	1,63	12,12	13,45	23,20	24,52
W12	32,08	18,99	29,94	2,14	13,09	16,35	22,44	24,04
W13	27,54	16,55	26,11	1,43	10,99	13,01	23,31	24,58
W14	24,64	14,75	23,22	1,42	9,89	14,36	23,03	24,44
W15	30,74	18,36	28,87	1,87	12,38	15,11	22,88	24,36
W16	35,33	20,92	32,96	2,37	14,41	16,45	22,44	24,05
W17	68,15	40,34	63,61	4,54	27,81	16,33	22,44	24,04
W18	63,06	36,89	57,98	5,08	26,17	19,41	21,73	23,64
W19	44,73	26,43	41,76	2,97	18,30	16,23	22,39	23,98
W20	16,74	9,76	15,35	1,39	6,98	19,91	21,57	23,53
W21	16,22	9,73	15,38	0,84	6,49	12,94	23,25	24,52

Table 0.14. *Porosity and unit weight of slope MS-6 fresh mudstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	85,26	51,07	81,21	4,05	34,19	11,85	23,30	24,46
F2	73,33	43,57	69,16	4,17	29,76	14,01	22,80	24,17
F3	44,78	26,56	42,16	2,62	18,22	14,38	22,70	24,11
F4	130,98	78,08	124,16	6,82	52,90	12,89	23,02	24,29
F5	59,52	35,26	56,06	3,46	24,26	14,26	22,67	24,07
F6	93,95	56,05	89,27	4,68	37,90	12,35	23,11	24,32
F7	84,99	51,06	81,20	3,79	33,93	11,17	23,48	24,57
F8	72,22	42,89	68,26	3,96	29,33	13,50	22,83	24,16
F9	39,73	23,87	37,97	1,76	15,86	11,10	23,49	24,57
F10	59,09	35,90	57,00	2,09	23,19	9,01	24,11	25,00
F11	26,45	15,74	24,97	1,48	10,71	13,82	22,87	24,23
F12	27,47	16,35	26,00	1,47	11,12	13,22	22,94	24,23
F13	16,37	9,85	15,67	0,70	6,52	10,74	23,58	24,63
F14	61,39	36,74	58,49	2,90	24,65	11,76	23,28	24,43
F15	71,01	42,27	67,11	3,90	28,74	13,57	22,91	24,24
F16	51,95	31,40	49,94	2,01	20,55	9,78	23,84	24,80
F17	40,45	24,07	38,31	2,14	16,38	13,06	22,94	24,23
F18	57,15	33,80	53,93	3,22	23,35	13,79	22,66	24,01
F19	30,98	18,40	29,31	1,67	12,58	13,28	22,86	24,16
F20	43,00	25,96	41,27	1,73	17,04	10,15	23,76	24,76
F21	30,88	18,33	29,19	1,69	12,55	13,47	22,82	24,14

Table 0.15. *Porosity and unit weight of slope MS-6 weathered mudstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	76,04	44,97	71,57	4,47	31,07	14,39	22,60	24,01
W2	93,48	55,05	87,67	5,81	38,43	15,12	22,38	23,86
W3	104,23	61,83	98,08	6,15	42,40	14,50	22,69	24,12
W4	96,72	57,40	91,05	5,67	39,32	14,42	22,72	24,13
W5	79,47	46,78	74,26	5,21	32,69	15,94	22,28	23,85
W6	78,78	46,48	73,86	4,92	32,30	15,23	22,43	23,93
W7	59,38	35,10	55,81	3,57	24,28	14,70	22,55	23,99
W8	112,55	66,59	105,83	6,72	45,96	14,62	22,59	24,02
W9	60,24	35,49	56,41	3,83	24,75	15,47	22,36	23,88
W10	75,68	44,90	70,29	5,39	30,78	17,51	22,40	24,12
W11	44,17	26,18	41,61	2,56	17,99	14,23	22,69	24,09
W12	54,89	32,51	51,65	3,24	22,38	14,48	22,64	24,06
W13	49,04	28,86	46,01	3,03	20,18	15,01	22,37	23,84
W14	65,23	38,26	61,02	4,21	26,97	15,61	22,20	23,73
W15	38,34	22,67	36,13	2,21	15,67	14,10	22,62	24,00
W16	38,54	22,48	35,84	2,70	16,06	16,81	21,89	23,54
W17	56,82	33,51	53,35	3,47	23,31	14,89	22,45	23,91
W18	43,96	26,00	41,45	2,51	17,96	13,98	22,64	24,01
W19	32,03	18,88	30,09	1,94	13,15	14,75	22,45	23,89
W20	39,86	23,53	37,58	2,28	16,33	13,96	22,58	23,95

Table 0.16. *Porosity and unit weight of slope MS-6 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	66,29	40,19	63,74	2,55	26,10	9,77	23,96	24,92
F2	107,91	66,71	103,79	4,12	41,20	10,00	24,71	25,69
F3	70,00	42,61	66,81	3,19	27,39	11,65	23,93	25,07
F4	60,74	37,43	58,00	2,74	23,31	11,75	24,41	25,56
F5	140,17	85,90	134,26	5,91	54,27	10,89	24,27	25,34
F6	145,26	88,81	139,91	5,35	56,45	9,48	24,31	25,24
F7	90,24	54,29	86,13	4,11	35,95	11,43	23,50	24,62
F8	97,65	59,28	93,33	4,32	38,37	11,26	23,86	24,97
F9	71,66	44,11	68,42	3,24	27,55	11,76	24,36	25,52
F10	44,23	26,95	42,16	2,07	17,28	11,98	23,93	25,11
F11	33,92	20,93	32,60	1,32	12,99	10,16	24,62	25,62

Table 0.17. *Porosity and unit weight of slope MS-6 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	87,04	53,70	83,01	4,03	33,34	12,09	24,42	25,61
W2	29,72	18,16	28,23	1,49	11,56	12,89	23,96	25,22
W3	95,27	57,73	90,28	4,99	37,54	13,29	23,59	24,90
W4	127,14	77,44	120,94	6,20	49,70	12,47	23,87	25,10
W5	56,24	34,11	53,56	2,68	22,13	12,11	23,74	24,93
W6	76,01	46,83	72,49	3,52	29,18	12,06	24,37	25,55
W7	99,53	63,69	95,08	4,45	35,84	12,42	26,02	27,24
W8	118,30	72,97	112,55	5,75	45,33	12,68	24,36	25,60
W9	137,90	88,78	131,97	5,93	49,12	12,07	26,36	27,54
W10	71,65	43,74	67,80	3,85	27,91	13,79	23,83	25,18
W11	30,57	18,19	28,91	1,66	12,38	13,41	22,91	24,22

Table 0.18. *Porosity and unit weight of slope MS-7.1 fresh limestone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	82,65	50,01	79,51	3,14	32,64	9,62	23,90	24,84
F2	150,52	91,68	145,62	4,90	58,84	8,33	24,28	25,10
F3	118,71	72,48	115,06	3,65	46,23	7,90	24,42	25,19
F4	127,83	78,06	123,87	3,96	49,77	7,96	24,42	25,20
F5	77,72	47,23	74,94	2,78	30,49	9,12	24,11	25,01
F6	82,10	50,13	79,47	2,63	31,97	8,23	24,39	25,19
F7	121,17	73,47	116,75	4,42	47,70	9,27	24,01	24,92
F8	103,69	63,10	100,33	3,36	40,59	8,28	24,25	25,06
F9	69,98	42,65	67,74	2,24	27,33	8,20	24,32	25,12
F10	83,83	50,69	80,66	3,17	33,14	9,57	23,88	24,82
F11	85,05	51,67	82,01	3,04	33,38	9,11	24,10	25,00
F12	93,73	56,73	89,98	3,75	37,00	10,14	23,86	24,85

Table 0.19. *Porosity and unit weight of slope MS-7.1 weathered limestone*

Sample No	**Msat (gr)**	**Msub (gr)**	**Mdry (gr)**	**Vv (cm^3)**	**V (cm^3)**	**Porosity %**	**Dry Unit W. (gr)**	**Sat. Unit W. (gr)**
W1	94,14	56,85	90,46	3,68	37,29	9,87	23,80	24,77
W2	70,08	42,23	67,11	2,97	27,85	10,66	23,64	24,69
W3	92,63	55,98	88,97	3,66	36,65	9,99	23,81	24,79
W4	209,09	126,52	201,13	7,96	82,57	9,64	23,90	24,84
W5	118,86	72,10	114,60	4,26	46,76	9,11	24,04	24,94
W6	95,06	57,43	91,19	3,87	37,63	10,28	23,77	24,78
W7	136,41	82,56	131,27	5,14	53,85	9,55	23,91	24,85
W8	85,95	52,09	82,75	3,20	33,86	9,45	23,97	24,90
W9	66,98	40,60	64,48	2,50	26,38	9,48	23,98	24,91
W10	47,39	28,71	45,63	1,76	18,68	9,42	23,96	24,89
W11	164,61	100,04	159,18	5,43	64,57	8,41	24,18	25,01
W12	67,68	41,61	66,01	1,67	26,07	6,41	24,84	25,47

Table 0.20. *Porosity and unit weight of slope MS-7.2 fresh limestone*

Sample No	**Msat (gr)**	**Msub (gr)**	**Mdry (gr)**	**Vv (cm^3)**	**V (cm^3)**	**Porosity %**	**Dry Unit W. (gr)**	**Sat. Unit W. (gr)**
F1	65,51	39,51	62,93	2,58	26,00	9,92	23,74	24,72
F2	74,01	44,69	71,04	2,97	29,32	10,13	23,77	24,76
F3	50,13	30,13	47,87	2,26	20,00	11,30	23,48	24,59
F4	73,36	44,18	70,22	3,14	29,18	10,76	23,61	24,66
F5	71,45	43,02	68,36	3,09	28,43	10,87	23,59	24,65
F6	118,43	70,59	112,06	6,37	47,84	13,32	22,98	24,29
F7	56,02	33,81	53,73	2,29	22,21	10,31	23,73	24,74
F8	103,88	62,44	99,08	4,80	41,44	11,58	23,45	24,59
F9	139,21	83,68	132,65	6,56	55,53	11,81	23,43	24,59
F10	86,34	52,23	82,87	3,47	34,11	10,17	23,83	24,83
F11	102,16	61,15	97,02	5,14	41,01	12,53	23,21	24,44
F12	66,34	40,11	63,66	2,68	26,23	10,22	23,81	24,81

Table 0.21. *Porosity and unit weight of slope MS-7.2 weathered limestone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	70,15	42,20	66,97	3,18	27,95	11,38	23,51	24,62
W2	76,76	46,04	73,18	3,58	30,72	11,65	23,37	24,51
W3	107,55	64,66	102,70	4,85	42,89	11,31	23,49	24,60
W4	66,37	39,93	63,47	2,90	26,44	10,97	23,55	24,63
W5	79,25	47,55	75,56	3,69	31,70	11,64	23,38	24,53
W6	78,71	47,47	75,37	3,34	31,24	10,69	23,67	24,72
W7	77,50	46,59	74,00	3,50	30,91	11,32	23,49	24,60
W8	116,06	69,80	110,93	5,13	46,26	11,09	23,52	24,61
W9	101,19	60,81	96,51	4,68	40,38	11,59	23,45	24,58
W10	115,06	69,29	109,93	5,13	45,77	11,21	23,56	24,66
W11	121,34	72,92	115,78	5,56	48,42	11,48	23,46	24,58
W12	70,88	42,60	67,66	3,22	28,28	11,39	23,47	24,59

Table 0.22. *Porosity and unit weight of slope MS-8.1 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	218,77	135,43	214,44	4,33	83,34	5,20	25,24	25,75
F2	296,77	183,82	291,16	5,61	112,95	4,97	25,29	25,78
F3	262,53	162,39	257,65	4,88	100,14	4,87	25,24	25,72
F4	235,83	146,15	231,76	4,07	89,68	4,54	25,35	25,80
F5	147,94	91,53	144,86	3,08	56,41	5,46	25,19	25,73
F6	206,70	127,61	202,38	4,32	79,09	5,46	25,10	25,64
F7	180,33	111,80	177,09	3,24	68,53	4,73	25,35	25,81
F8	165,14	101,90	161,23	3,91	63,24	6,18	25,01	25,62
F9	169,95	105,34	166,75	3,20	64,61	4,95	25,32	25,80
F10	196,00	120,29	190,17	5,83	75,71	7,70	24,64	25,40

Table 0.23. *Porosity and unit weight of slope MS-8.1 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	272,15	167,88	266,36	5,79	104,27	5,55	25,06	25,60
W2	95,15	58,06	92,13	3,02	37,09	8,14	24,37	25,17
W3	160,69	98,66	156,17	4,52	62,03	7,29	24,70	25,41
W4	98,10	60,30	95,65	2,45	37,80	6,48	24,82	25,46
W5	231,39	141,38	224,15	7,24	90,01	8,04	24,43	25,22
W6	138,94	85,31	135,35	3,59	53,63	6,69	24,76	25,41
W7	87,14	53,21	84,25	2,89	33,93	8,52	24,36	25,19
W8	96,92	59,49	94,19	2,73	37,43	7,29	24,69	25,40
W9	93,69	57,06	90,43	3,26	36,63	8,90	24,22	25,09
W10	106,31	65,35	103,56	2,75	40,96	6,71	24,80	25,46

Table 0.24. *Porosity and unit weight of slope MS-8.2 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	249,93	154,00	244,44	5,49	95,93	5,72	25,00	25,56
F2	163,76	100,98	160,17	3,59	62,78	5,72	25,03	25,59
F3	214,96	132,66	210,45	4,51	82,30	5,48	25,09	25,62
F4	258,20	159,57	253,50	4,70	98,63	4,77	25,21	25,68
F5	122,15	75,18	119,33	2,82	46,97	6,00	24,92	25,51
F6	124,56	76,63	121,59	2,97	47,93	6,20	24,89	25,49
F7	130,02	80,19	127,13	2,89	49,83	5,80	25,03	25,60
F8	162,22	102,18	161,83	0,39	60,04	0,65	26,44	26,51
F9	117,68	72,45	114,79	2,89	45,23	6,39	24,90	25,52
F10	245,74	150,92	241,38	4,36	94,82	4,60	24,97	25,42
F11	244,66	150,96	240,90	3,76	93,70	4,01	25,22	25,61
F12	208,32	128,18	204,86	3,46	80,14	4,32	25,08	25,50

Table 0.25. *Porosity and unit weight of slope MS-8.2 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	96,00	57,70	91,54	4,46	38,30	11,64	23,45	24,59
W2	216,03	129,18	205,05	10,98	86,85	12,64	23,16	24,40
W3	74,86	45,13	71,64	3,22	29,73	10,83	23,64	24,70
W4	270,09	164,32	260,66	9,43	105,77	8,92	24,18	25,05
W5	50,25	30,43	48,30	1,95	19,82	9,84	23,91	24,87
W6	177,42	106,73	169,18	8,24	70,69	11,66	23,48	24,62
W7	227,39	137,62	218,18	9,21	89,77	10,26	23,84	24,85
W8	234,78	140,53	222,95	11,83	94,25	12,55	23,21	24,44
W9	93,82	56,42	89,46	4,36	37,40	11,66	23,47	24,61
W10	154,66	92,70	147,04	7,62	61,96	12,30	23,28	24,49
W11	122,36	73,25	116,24	6,12	49,11	12,46	23,22	24,44
W12	88,53	53,41	84,61	3,92	35,12	11,16	23,63	24,73

Table 0.26. *Porosity and unit weight of slope MS-9 fresh marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	51,12	28,61	48,10	3,02	22,51	13,42	20,96	22,28
F2	26,94	15,28	24,67	2,27	11,66	19,47	20,76	22,67
F3	71,72	40,15	65,56	6,16	31,57	19,51	20,37	22,29
F4	45,22	25,38	41,47	3,75	19,84	18,90	20,51	22,36
F5	31,89	17,84	29,00	2,89	14,05	20,57	20,25	22,27
F6	164,86	92,86	156,29	8,57	72,00	11,90	21,29	22,46
F7	89,27	49,82	83,52	5,75	39,45	14,58	20,77	22,20
F8	60,73	33,84	56,44	4,29	26,89	15,95	20,59	22,16
F9	98,04	54,96	92,07	5,97	43,08	13,86	20,97	22,33
F10	78,54	44,02	74,27	4,27	34,52	12,37	21,11	22,32
F11	45,92	25,67	42,91	3,01	20,25	14,86	20,79	22,25
F12	105,34	58,97	99,00	6,34	46,37	13,67	20,94	22,29

Table 0.27. *Porosity and unit weight of slope MS-9 weathered marl*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	45,80	25,37	41,06	4,74	20,43	23,20	19,72	21,99
W2	21,65	12,15	19,32	2,33	9,50	24,53	19,95	22,36
W3	55,91	31,25	50,91	5,00	24,66	20,28	20,25	22,24
W4	41,75	23,24	37,73	4,02	18,51	21,72	20,00	22,13
W5	60,28	33,79	55,05	5,23	26,49	19,74	20,39	22,32
W6	57,60	32,08	52,82	4,78	25,52	18,73	20,30	22,14
W7	35,06	19,24	31,68	3,38	15,82	21,37	19,64	21,74
W8	103,47	58,04	94,73	8,74	45,43	19,24	20,46	22,34
W9	62,84	35,43	57,71	5,13	27,41	18,72	20,65	22,49
W10	60,64	33,95	55,30	5,34	26,69	20,01	20,33	22,29
W11	46,39	25,76	42,11	4,28	20,63	20,75	20,02	22,06
W12	19,37	10,87	17,55	1,82	8,50	21,41	20,25	22,36
W13	19,87	11,12	18,05	1,82	8,75	20,80	20,24	22,28
W14	16,40	9,25	15,02	1,38	7,15	19,30	20,61	22,50

Table 0.28. *Porosity and unit weight of slope MS-9 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	100,34	56,11	92,39	7,95	44,23	17,97	20,49	22,25
F2	51,88	29,52	49,00	2,88	22,36	12,88	21,50	22,76
F3	49,08	27,05	44,34	4,74	22,03	21,52	19,74	21,86
F4	107,58	59,16	97,82	9,76	48,42	20,16	19,82	21,80
F5	118,36	65,32	107,92	10,44	53,04	19,68	19,96	21,89
F6	112,69	62,10	100,46	12,23	50,59	24,17	19,48	21,85
F7	33,37	18,67	30,62	2,75	14,70	18,71	20,43	22,27
F8	31,69	17,15	28,09	3,60	14,54	24,76	18,95	21,38
F9	40,83	22,79	37,51	3,32	18,04	18,40	20,40	22,20
F10	23,29	13,03	21,16	2,13	10,26	20,76	20,23	22,27
F11	25,16	13,78	22,30	2,86	11,38	25,13	19,22	21,69
F12	23,26	14,72	20,55	2,71	8,54	31,73	23,61	26,72
F13	19,62	10,79	17,28	2,34	8,83	26,50	19,20	21,80
F14	15,56	8,65	14,10	1,46	6,91	21,13	20,02	22,09
F15	13,45	7,40	12,02	1,43	6,05	23,64	19,49	21,81

Table 0.29. *Porosity and unit weight of slope MS-9 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	75,95	41,19	66,54	9,41	34,76	27,07	18,78	21,43
W2	12,81	7,00	11,50	1,31	5,81	22,55	19,42	21,63
W3	30,83	16,83	27,30	3,53	14,00	25,21	19,13	21,60
W4	13,93	7,63	12,46	1,47	6,30	23,33	19,40	21,69
W5	20,22	10,98	17,64	2,58	9,24	27,92	18,73	21,47
W6	38,65	21,15	34,80	3,85	17,50	22,00	19,51	21,67
W7	25,67	13,96	22,42	3,25	11,71	27,75	18,78	21,50
W8	19,43	10,56	17,28	2,15	8,87	24,24	19,11	21,49
W9	17,38	9,46	15,13	2,25	7,92	28,41	18,74	21,53
W10	10,55	5,72	9,34	1,21	4,83	25,05	18,97	21,43
W11	10,57	5,77	9,51	1,06	4,80	22,08	19,44	21,60
W12	12,82	7,01	11,50	1,32	5,81	22,72	19,42	21,65
W13	14,26	7,98	13,23	1,03	6,28	16,40	20,67	22,28
W14	9,83	5,35	8,66	1,17	4,48	26,12	18,96	21,53

Table 0.30. *Porosity and unit weight of slope MS-10 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	39,93	23,05	37,70	2,23	16,88	13,21	21,91	23,21
F2	101,62	59,01	96,53	5,09	42,61	11,95	22,22	23,40
F3	41,52	24,06	39,08	2,44	17,46	13,97	21,96	23,33
F4	84,15	48,59	78,98	5,17	35,56	14,54	21,79	23,21
F5	46,62	26,97	44,05	2,57	19,65	13,08	21,99	23,27
F6	44,45	25,67	42,01	2,44	18,78	12,99	21,94	23,22
F7	62,43	36,41	59,03	3,40	26,02	13,07	22,26	23,54
F8	91,98	53,22	87,18	4,80	38,76	12,38	22,06	23,28
F9	175,07	101,49	165,97	9,10	73,58	12,37	22,13	23,34
F10	118,69	68,75	112,60	6,09	49,94	12,19	22,12	23,31
F11	115,69	66,11	108,19	7,50	49,58	15,13	21,41	22,89
F12	79,90	45,82	74,88	5,02	34,08	14,73	21,55	23,00

Table 0.31. *Porosity and unit weight of slope MS-10 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	47,45	26,82	43,61	3,84	20,63	18,61	20,74	22,56
W2	62,22	36,04	58,68	3,54	26,18	13,52	21,99	23,31
W3	58,83	34,48	56,02	2,81	24,35	11,54	22,57	23,70
W4	54,64	31,63	51,46	3,18	23,01	13,82	21,94	23,30
W5	89,32	52,01	84,23	5,09	37,31	13,64	22,15	23,49
W6	118,33	68,62	111,40	6,93	49,71	13,94	21,98	23,35
W7	81,78	48,04	78,01	3,77	33,74	11,17	22,68	23,78
W8	101,25	58,85	94,79	6,46	42,40	15,24	21,93	23,43
W9	140,11	80,16	130,26	9,85	59,95	16,43	21,32	22,93
W10	68,55	39,78	64,34	4,21	28,77	14,63	21,94	23,37
W11	89,94	52,05	84,22	5,72	37,89	15,10	21,81	23,29
W12	165,51	88,98	146,22	19,29	76,53	25,21	18,74	21,22

Table 0.32. *Porosity and unit weight of slope MS-11 fresh volcanogenic sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	208,17	129,20	207,23	0,94	78,97	1,19	25,74	25,86
F2	196,87	122,29	196,08	0,79	74,58	1,06	25,79	25,90
F3	186,89	115,56	184,82	2,07	71,33	2,90	25,42	25,70
F4	110,21	68,43	109,61	0,60	41,78	1,44	25,74	25,88
F5	56,00	32,93	54,48	1,52	23,07	6,59	23,17	23,81
F6	152,12	89,54	148,61	3,51	62,58	5,61	23,30	23,85
F7	92,02	54,32	89,93	2,09	37,70	5,54	23,40	23,94
F8	98,99	58,60	97,17	1,82	40,39	4,51	23,60	24,04
F9	140,09	86,36	138,12	1,97	53,73	3,67	25,22	25,58
F10	100,57	59,10	97,88	2,69	41,47	6,49	23,15	23,79
F11	95,40	56,81	93,20	2,20	38,59	5,70	23,69	24,25
F12	144,08	88,54	141,19	2,89	55,54	5,20	24,94	25,45

Table 0.33. *Porosity and unit weight of slope MS-11 weathered volcanogenic sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	150,54	87,55	146,58	3,96	62,99	6,29	22,83	23,44
W2	70,62	41,20	68,71	1,91	29,42	6,49	22,91	23,55
W3	114,45	66,30	111,48	2,97	48,15	6,17	22,71	23,32
W4	153,73	89,59	149,98	3,75	64,14	5,85	22,94	23,51
W5	60,93	35,64	59,37	1,56	25,29	6,17	23,03	23,63
W6	156,44	90,87	152,12	4,32	65,57	6,59	22,76	23,41
W7	95,41	57,17	93,29	2,12	38,24	5,54	23,93	24,48
W8	63,31	37,51	61,71	1,60	25,80	6,20	23,46	24,07
W9	152,11	88,01	147,74	4,37	64,10	6,82	22,61	23,28
W10	62,99	36,25	61,02	1,97	26,74	7,37	22,39	23,11
W11	36,66	21,36	35,59	1,07	15,30	6,99	22,82	23,51
W12	42,97	25,07	41,93	1,04	17,90	5,81	22,98	23,55

Table 0.34. *Porosity and unit weight of slope MS-12 fresh sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
F1	154,89	83,04	136,88	18,01	71,85	25,07	18,69	21,15
F2	86,58	48,15	78,06	8,52	38,43	22,17	19,93	22,10
F3	50,03	27,05	44,63	5,40	22,98	23,50	19,05	21,36
F4	34,60	19,28	31,38	3,22	15,32	21,02	20,09	22,16
F5	29,72	17,14	26,80	2,92	12,58	23,21	20,90	23,18
F6	113,20	63,95	104,88	8,32	49,25	16,89	20,89	22,55
F7	39,63	21,96	35,65	3,98	17,67	22,52	19,79	22,00
F8	37,34	19,93	33,08	4,26	17,41	24,47	18,64	21,04
F9	73,37	40,39	66,26	7,11	32,98	21,56	19,71	21,82
F10	49,18	27,19	43,88	5,30	21,99	24,10	19,58	21,94
F11	39,10	20,55	34,08	5,02	18,55	27,06	18,02	20,68
F12	26,27	13,80	22,88	3,39	12,47	27,19	18,00	20,67

Table 0.35. *Porosity and unit weight of slope MS-12 weathered sandstone*

Sample No	Msat (gr)	Msub (gr)	Mdry (gr)	Vv (cm^3)	V (cm^3)	Porosity %	Dry Unit W. (gr)	Sat. Unit W. (gr)
W1	64,97	35,51	57,89	7,08	29,46	24,03	19,28	21,63
W2	69,64	38,84	62,85	6,79	30,80	22,05	20,02	22,18
W3	52,17	26,23	43,41	8,76	25,94	33,77	16,42	19,73
W4	36,75	18,44	30,48	6,27	18,31	34,24	16,33	19,69
W5	57,41	31,89	51,81	5,60	25,52	21,94	19,92	22,07
W6	67,50	37,22	60,36	7,14	30,28	23,58	19,56	21,87
W7	67,10	32,98	54,53	12,57	34,12	36,84	15,68	19,29
W8	130,86	65,50	108,44	22,42	65,36	34,30	16,28	19,64
W9	80,72	44,36	72,20	8,52	36,36	23,43	19,48	21,78
W10	57,00	31,38	51,44	5,56	25,62	21,70	19,70	21,83
W11	88,59	46,11	75,82	12,77	42,48	30,06	17,51	20,46
W12	89,64	46,39	76,42	13,22	43,25	30,57	17,33	20,33

Table 0.36. *UCS of Stop MS-1 fresh saturated limestone*

	Sample	Area (cm^2)	F (Kgf)	F/A (Kgf/cm^2)	F/A (MPa)
SAT.	F1	25,64	7357	286,89	28,13
SAT.	F2	25,52	11427	447,79	43,91
SAT.	F3	24,88	11721	471,19	46,21

Table 0.37. *UCS of Stop MS-6 weathered dry/saturated sandstone*

	Sample	Area (cm^2)	F (Kgf)	F/A (Kgf/cm^2)	F/A (MPa)
DRY	W1	25,48	3867	151,77	14,88
SAT.	W2	26,02	1298	49,88	4,89
SAT.	W3	26,02	3937	151,34	14,84
SAT.	W4	26,13	2132	81,61	8,00

Table 0.38. *UCS of Stop MS-8.2 fresh dry/saturated sandstone*

	Sample	Area (cm^2)	F (Kgf)	F/A (Kgf/cm^2)	F/A (MPa)
DRY	F1	26,15	7991	305,55	29,96
DRY	F2	25,84	6870	265,88	26,07
DRY	F3	24,80	6353	256,17	25,12
DRY	F4	26,22	10658	406,50	39,86
DRY	F5	25,47	6169	242,18	23,75
DRY	F6	25,65	6137	239,24	23,46
SAT.	F7	25,46	2695	105,85	10,38
SAT.	F8	25,63	6090	237,60	23,30
SAT.	F9	25,94	9333	359,77	35,28
SAT.	F10	25,68	8224	320,19	31,40
SAT.	F11	26,20	8345	318,48	31,23
SAT.	F12	25,79	5276	204,58	20,06
SAT.	F13	25,52	4207	164,86	16,17

Table 0.39. *UCS of Stop MS-8.2 weathered dry/saturated sandstone*

	Sample	**Area (cm^2)**	**F (Kgf)**	**F/A (Kgf/cm^2)**	**F/A (MPa)**
DRY	W1	24,75	5824	235,32	23,08
DRY	W2	25,54	6064	237,45	23,29
SAT.	W3	25,94	3977	153,32	15,04
SAT.	W4	26,15	5765	220,45	21,62
SAT.	W5	25,15	3976	158,10	15,50

Table 0.40. *UCS of Stop MS-10 weathered dry/saturated sandstone*

	Sample	**Area (cm^2)**	**F (Kgf)**	**F/A (Kgf/cm^2)**	**F/A (MPa)**
DRY	W1	25,25	7072	280,06	27,46
DRY	W2	24,85	7400	297,81	29,21
SAT.	W3	24,38	7401	303,52	29,77
SAT.	W4	25,44	6556	257,68	25,27

Table 0.41. *UCS of Stop MS-11 weathered dry/saturated sandstone*

	Sample	**Area (cm^2)**	**F (Kgf)**	**F/A (Kgf/cm^2)**	**F/A (MPa)**
DRY	W1	25,70	5309	206,58	20,26
DRY	W2	25,88	5001	193,27	18,95
DRY	W3	25,71	4999	194,40	19,06
SAT.	W4	25,98	6137	236,23	23,17
SAT.	W5	25,46	2929	115,02	11,28
SAT.	W6	25,59	2548	99,56	9,76
SAT.	W7	25,95	6377	245,75	24,10
SAT.	W8	25,61	2499	97,56	9,57

Table 0.42. *Point load strength of Stop MS-1 fresh dry limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	45,02	18,42	12,62	7,0	723,76	26,90	9,6717	0,7335	7,0944
F2	44,72	32,61	27,72	4,5	1579,16	39,74	2,8496	0,8915	2,5404
F3	49,81	25,20	20,36	7,0	1291,89	35,94	5,4184	0,8479	4,5940
F4	61,55	25,09	20,78	8,0	1629,31	40,36	4,9101	0,8985	4,4117
F5	40,91	20,68	17,74	3,5	924,51	30,41	3,7858	0,7798	2,9522
F6	47,69	38,26	33,66	2,7	2044,90	45,22	1,3204	0,9510	1,2557
F7	42,53	20,87	16,79	2,0	909,65	30,16	2,1986	0,7767	1,7076
F8	34,30	24,67	17,47	1,6	763,34	27,63	2,0961	0,7434	1,5581
F9	38,43	17,56	13,45	3,8	658,45	25,66	5,7711	0,7164	4,1343
F10	37,57	15,72	11,47	2,0	548,95	23,43	3,6433	0,6845	2,4940
F11	21,66	16,41	10,73	1,8	296,07	17,21	6,0797	0,5866	3,5665

Table 0.43. *Point load strength of Stop MS-1 weathered dry limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	39,40	16,08	13,46	0,8	675,57	25,99	1,1842	0,7210	0,8538
W2	33,23	23,70	22,35	2,6	946,10	30,76	2,7481	0,7843	2,1554
W3	26,78	20,06	16,37	3,1	558,46	23,63	5,5510	0,6875	3,8162
W4	30,31	22,01	17,64	2,6	681,11	26,10	3,8173	0,7225	2,7579
W5	44,53	32,20	27,46	9,5	1557,70	39,47	6,0987	0,8885	5,4185
W6	57,05	37,05	29,86	11,0	2170,08	46,58	5,0689	0,9652	4,8927
W7	33,34	36,41	22,14	8,0	940,32	30,66	8,5078	0,7831	6,6627
W8	39,09	21,02	24,03	1,1	1196,60	34,59	0,9193	0,8318	0,7646
W9	22,00	27,61	25,39	3,4	711,57	26,68	4,7782	0,7304	3,4901
W10	41,19	40,55	35,84	1,3	1880,57	43,37	0,6913	0,9313	0,6438
W11	31,57	18,53	16,10	2,4	647,49	25,45	3,7066	0,7134	2,6443
W12	32,47	20,92	17,41	3,7	720,13	26,84	5,1380	0,7326	3,7641

Table 0.44. *Point load strength of Stop MS-1 fresh saturated limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 $(mm)^2$**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	51,50	33,14	25,56	2,60	1676,87	40,95	1,5505	0,9050	1,4032
F2	60,77	45,46	27,87	3,30	2157,53	46,45	1,5295	0,9638	1,4742
F3	43,11	16,91	14,11	1,60	774,88	27,84	2,0648	0,7461	1,5407
F4	51,99	24,81	18,10	2,20	1198,75	34,62	1,8352	0,8321	1,5272
F5	66,06	45,45	39,50	1,90	3324,04	57,65	0,5716	1,0738	0,6138
F6	32,37	17,13	14,27	1,30	588,43	24,26	2,2093	0,6965	1,5388
F7	49,58	23,46	17,83	1,30	1126,13	33,56	1,1544	0,8192	0,9457
F8	37,61	30,39	20,14	2,10	964,92	31,06	2,1763	0,7882	1,7154
F9	62,63	31,57	24,03	2,20	1917,20	43,79	1,1475	0,9358	1,0738
F10	40,83	24,14	17,04	1,40	886,30	29,77	1,5796	0,7716	1,2189
F11	33,81	19,30	13,58	1,40	584,89	24,18	2,3936	0,6955	1,6647

Table 0.45. *Point load strength of Stop MS-1 weathered saturated limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 $(mm)^2$**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	51,76	23,11	18,97	2,30	1250,81	35,37	1,8388	0,8410	1,5465
W2	49,29	24,88	17,66	2,00	1108,87	33,30	1,8036	0,8161	1,4719
W3	39,96	30,56	22,37	2,10	1138,73	33,75	1,8442	0,8215	1,5150
W4	52,71	25,12	20,98	1,10	1408,73	37,53	0,7808	0,8664	0,6765
W5	43,05	13,95	9,24	2,30	506,73	22,51	4,5389	0,6710	3,0455
W6	51,62	34,71	26,72	0,45	1757,05	41,92	0,2561	0,9156	0,2345
W7	44,19	26,57	20,61	1,00	1160,20	34,06	0,8619	0,8254	0,7114
W8	51,53	18,37	12,67	4,40	831,70	28,84	5,2904	0,7595	4,0178
W9	29,40	20,98	15,76	0,80	590,25	24,30	1,3554	0,6971	0,9448
W10	34,78	18,33	15,36	0,70	680,54	26,09	1,0286	0,7223	0,7430
W11	27,06	21,87	19,07	0,80	657,37	25,64	1,2170	0,7161	0,8715

Table 0.46. *Point load strength of Stop MS-2.1 fresh dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	41.88	18.65	14.57	5.4	777.31	27.88	6.9470	0.7467	5.1875
F2	35.86	33.81	28.64	7.0	1308.32	36.17	5.3504	0.8505	4.5507
F3	40.51	34.34	27.13	13.0	1400.05	37.42	9.2854	0.8651	8.0325
F4	30.23	29.61	24.31	8.0	936.17	30.60	8.5455	0.7823	6.6848
F5	28.54	20.44	15.79	7.1	574.07	23.96	12.3678	0.6922	8.5615
F6	28.54	18.73	16.07	5.4	584.25	24.17	9.2426	0.6953	6.4263
F7	31.33	22.16	17.98	8.0	717.60	26.79	11.1483	0.7320	8.1601
F8	23.91	28.10	23.93	6.8	728.87	27.00	9.3295	0.7348	6.8554
F9	30.79	29.33	25.31	4.8	992.73	31.51	4.8351	0.7938	3.8382
F10	29.85	29.06	20.11	11.1	764.69	27.65	14.5156	0.7437	10.7950

Table 0.47. *Point load strength of Stop MS-2.1 weathered dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	38.12	16.88	12.59	8.5	611.38	24.73	13.9030	0.7032	9.7769
W2	35.03	18.94	17.34	1.2	773.78	27.82	1.5508	0.7459	1.1567
W3	33.52	30.05	27.60	2.2	1178.54	34.33	1.8667	0.8286	1.5468
W4	45.26	27.83	25.45	1.2	1467.35	38.31	0.8178	0.8753	0.7158
W5	31.32	28.57	24.19	8.8	965.13	31.07	9.1179	0.7882	7.1871
W6	34.66	21.84	16.40	4.8	724.11	26.91	6.6289	0.7336	4.8630
W7	33.47	31.80	27.32	9.9	1164.84	34.13	8.4990	0.8262	7.0218
W8	41.04	32.17	26.75	7.0	1398.50	37.40	5.0054	0.8648	4.3288
W9	37.35	31.61	25.73	7.0	1224.22	34.99	5.7179	0.8365	4.7832
W10	37.30	18.53	16.11	5.2	765.48	27.67	6.7931	0.7439	5.0532

Table 0.48. *Point load strength of Stop MS-2.1 fresh saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm)^2	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	39,00	14,29	9,46	2,00	469,99	21,68	4,2554	0,6585	2,8021
F2	39,86	26,23	16,63	7,10	844,42	29,06	8,4081	0,7624	6,4099
F3	27,51	15,84	13,09	2,80	458,73	21,42	6,1038	0,6545	3,9949
F4	16,90	16,25	7,92	1,60	170,51	13,06	9,3838	0,5110	4,7954
F5	28,62	14,10	12,46	0,50	454,27	21,31	1,1007	0,6529	0,7186
F6	27,90	22,15	21,28	0,60	756,32	27,50	0,7933	0,7416	0,5884
F7	31,87	28,55	21,67	5,20	879,77	29,66	5,9106	0,7702	4,5524
F8	43,10	29,95	17,63	8,00	967,97	31,11	8,2648	0,7888	6,5194
F9	36,03	28,82	20,11	5,10	923,01	30,38	5,5254	0,7795	4,3071
F10	27,16	20,53	17,20	1,70	595,10	24,39	2,8567	0,6985	1,9954

Table 0.49. *Point load strength of Stop MS-2.1 weathered saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm)^2	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	35,02	20,93	17,69	3,70	789,18	28,09	4,6884	0,7496	3,5143
W2	34,15	22,05	21,54	1,50	937,06	30,61	1,6008	0,7825	1,2525
W3	31,67	23,55	15,26	4,40	615,65	24,81	7,1469	0,7044	5,0346
W4	31,53	25,80	21,73	4,30	872,80	29,54	4,9267	0,7687	3,7870
W5	29,02	27,45	22,12	5,30	817,74	28,60	6,4813	0,7563	4,9015
W6	27,60	16,02	13,68	2,10	480,98	21,93	4,3661	0,6623	2,8916
W7	31,55	14,32	13,76	0,70	553,03	23,52	1,2658	0,6858	0,8681
W8	22,65	20,28	19,23	0,40	554,85	23,56	0,7209	0,6864	0,4948
W9	32,87	16,16	15,10	0,10	632,28	25,15	0,1582	0,7092	0,1122
W10	24,34	13,27	12,70	0,10	393,78	19,84	0,2539	0,6300	0,1600

Table 0.50. *Point load strength of Stop MS-2.2 fresh dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	39,42	32,16	26,63	9,9	1337,27	36,57	7,4032	0,8552	6,3312
F2	36,09	20,07	16,40	9,9	753,98	27,46	13,1303	0,7411	9,7304
F3	46,16	31,17	24,25	9,5	1425,96	37,76	6,6622	0,8690	5,7897
F4	42,98	39,44	34,55	13,0	1891,67	43,49	6,8722	0,9327	6,4095
F5	47,74	32,21	25,72	10,0	1564,17	39,55	6,3932	0,8894	5,6859
F6	27,98	23,63	20,38	7,8	726,41	26,95	10,7377	0,7342	7,8836
F7	46,95	19,42	14,93	6,6	892,95	29,88	7,3913	0,7731	5,7140
F8	44,11	32,11	28,29	10,0	1589,65	39,87	6,2907	0,8930	5,6175
F9	51,52	41,19	34,65	10,1	2274,10	47,69	4,4413	0,9766	4,3374
F10	30,85	19,86	15,84	10,0	622,50	24,95	16,0642	0,7064	11,3477
F11	40,09	23,59	15,53	8,0	793,12	28,16	10,0868	0,7505	7,5701

Table 0.51. *Point load strength of Stop MS-2.2 weathered dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	38,12	20,60	17,45	3,1	847,38	29,11	3,6583	0,7630	2,7914
W2	42,80	26,07	17,10	8,0	932,33	30,53	8,5806	0,7815	6,7054
W3	48,49	35,61	30,31	8,0	1872,27	43,27	4,2729	0,9303	3,9749
W4	41,07	35,09	28,89	14,2	1511,48	38,88	9,3948	0,8818	8,2842
W5	38,86	31,79	24,92	10,0	1233,62	35,12	8,1062	0,8381	6,7941
W6	48,89	29,29	23,17	12,1	1443,03	37,99	8,3851	0,8716	7,3087
W7	50,65	48,86	43,66	13,0	2817,04	53,08	4,6148	1,0303	4,7546
W8	62,02	29,02	26,31	12,0	2078,66	45,59	5,7730	0,9549	5,5126
W9	28,98	20,55	16,50	6,9	609,13	24,68	11,3276	0,7026	7,9585
W10	37,26	29,51	24,48	9,0	1161,94	34,09	7,7457	0,8257	6,3954
W11	49,31	20,22	18,11	8,8	1137,58	33,73	7,7357	0,8213	6,3535

Table 0.52. *Point load strength of Stop MS-2.2 fresh saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	40,62	35,23	25,81	14,00	1335,54	36,55	10,4826	0,8549	8,9619
F2	51,32	25,34	17,82	6,80	1165,00	34,13	5,8369	0,8262	4,8226
F3	44,12	32,47	27,77	6,10	1560,78	39,51	3,9083	0,8889	3,4741
F4	53,66	40,40	34,39	7,00	2350,79	48,48	2,9777	0,9847	2,9323
F5	57,47	24,00	18,75	8,50	1372,69	37,05	6,1922	0,8608	5,3303
F6	40,94	25,38	22,25	5,20	1160,40	34,06	4,4812	0,8254	3,6988
F7	40,57	22,06	14,16	5,00	731,81	27,05	6,8324	0,7356	5,0256
F8	45,16	20,65	14,61	10,00	840,49	28,99	11,8978	0,7615	9,0597
F9	48,82	31,04	28,56	9,00	1776,18	42,14	5,0671	0,9181	4,6520
F10	48,42	43,13	35,93	8,80	2216,22	47,08	3,9707	0,9703	3,8529
F11	45,00	26,99	21,48	6,00	1231,34	35,09	4,8727	0,8377	4,0821

Table 0.53. *Point load strength of Stop MS-2.2 weathered saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	51,21	33,00	25,16	13,00	1641,33	40,51	7,9204	0,9001	7,1295
W2	32,86	20,48	14,77	2,10	618,27	24,87	3,3966	0,7052	2,3952
W3	36,80	29,07	22,20	5,40	1040,71	32,26	5,1887	0,8032	4,1678
W4	49,80	37,53	32,72	8,00	2075,74	45,56	3,8540	0,9546	3,6790
W5	44,14	40,38	33,78	7,10	1899,43	43,58	3,7380	0,9336	3,4898
W6	33,44	25,87	23,14	5,30	985,73	31,40	5,3767	0,7924	4,2606
W7	36,42	30,65	25,08	2,20	1163,58	34,11	1,8907	0,8260	1,5617
W8	40,70	30,77	24,08	7,60	1248,48	35,33	6,0874	0,8406	5,1173
W9	42,22	27,46	20,66	10,00	1111,17	33,33	8,9996	0,8165	7,3482
W10	41,22	16,76	12,95	1,60	680,00	26,08	2,3529	0,7222	1,6992
W11	25,20	17,65	14,17	3,90	454,88	21,33	8,5736	0,6531	5,5996

Table 0.54. *Point load strength of Stop MS-2.3 weathered dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	30,95	15,61	13,42	1,2	529,11	23,00	2,2680	0,6783	1,5383
W2	37,06	20,71	18,06	2,0	852,62	29,20	2,3457	0,7642	1,7926
W3	31,17	18,21	17,96	0,6	713,14	26,70	0,8414	0,7308	0,6149
W4	30,65	17,93	14,82	1,8	578,64	24,05	3,1107	0,6936	2,1576
W5	27,75	13,44	12,34	1,4	436,22	20,89	3,2094	0,6463	2,0743
W6	27,36	12,37	9,79	2,4	341,22	18,47	7,0337	0,6078	4,2752
W7	23,83	12,65	10,46	1,3	317,53	17,82	4,0941	0,5970	2,4441
W8	22,08	13,22	12,11	2,1	340,62	18,46	6,1652	0,6076	3,7457
W9	23,58	18,73	16,92	2,6	508,25	22,54	5,1156	0,6715	3,4350
W10	24,93	17,24	17,02	0,6	540,52	23,25	1,1100	0,6819	0,7569
W11	18,33	13,83	12,16	3,1	283,94	16,85	10,9178	0,5805	6,3381
W12	21,69	14,51	13,75	0,7	379,92	19,49	1,8425	0,6244	1,1504

Table 0.55. *Point load strength of Stop MS-2.3 weathered saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	21,37	20,61	15,28	0,50	415,97	20,40	1,2020	0,6387	0,7677
W2	22,02	17,20	12,20	0,40	342,22	18,50	1,1688	0,6083	0,7110
W3	26,78	17,24	16,90	0,10	576,54	24,01	0,1734	0,6930	0,1202
W4	21,05	15,33	10,86	0,20	291,21	17,06	0,6868	0,5842	0,4012
W5	27,05	11,11	9,66	0,30	332,87	18,24	0,9013	0,6041	0,5444
W6	21,60	16,37	10,77	0,15	296,35	17,21	0,5062	0,5868	0,2970
W7	23,80	17,10	15,23	0,01	461,75	21,49	0,0217	0,6556	0,0142
W8	16,42	13,22	12,48	0,20	261,05	16,16	0,7661	0,5685	0,4355
W9	25,98	14,40	8,85	0,05	292,90	17,11	0,1707	0,5851	0,0999
W10	19,70	16,10	13,90	0,40	348,83	18,68	1,1467	0,6112	0,7008
W11	19,27	13,40	9,37	0,30	230,01	15,17	1,3043	0,5507	0,7183
W12	18,30	15,35	11,05	0,30	257,60	16,05	1,1646	0,5666	0,6598
W13	24,13	10,95	7,27	0,20	223,47	14,95	0,8950	0,5468	0,4894

Table 0.56. *Point load strength of Stop MS-3 fresh dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	32,13	21,36	16,87	7,9	690,49	26,28	11,4412	0,7249	8,2942
F2	25,65	22,88	16,49	12,0	538,81	23,21	22,2712	0,6814	15,1746
F3	23,24	19,98	15,84	8,9	468,94	21,66	18,9788	0,6581	12,4900
F4	28,18	22,78	19,43	7,0	697,50	26,41	10,0358	0,7268	7,2938
F5	40,37	19,46	14,76	10,0	759,06	27,55	13,1742	0,7423	9,7793
F6	27,72	17,98	13,04	6,1	460,47	21,46	13,2473	0,6551	8,6785
F7	34,38	12,29	8,88	3,2	388,91	19,72	8,2281	0,6280	5,1675
F8	41,68	30,57	29,43	2,6	1562,60	39,53	1,6639	0,8892	1,4795
F9	28,12	17,89	13,38	8,5	479,29	21,89	17,7344	0,6617	11,7350
F10	39,40	19,05	15,31	9,9	768,43	27,72	12,8835	0,7446	9,5929
F11	26,84	20,62	17,62	2,2	602,45	24,54	3,6518	0,7006	2,5586

Table 0.57. *Point load strength of Stop MS-3 weathered dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	41,17	32,58	25,82	14,8	1354,15	36,80	10,9293	0,8579	9,3762
W2	42,26	20,42	18,95	3,3	1020,16	31,94	3,2348	0,7992	2,5854
W3	39,79	31,73	27,38	5,9	1387,83	37,25	4,2512	0,8632	3,6696
W4	44,13	18,95	12,96	2,2	728,57	26,99	3,0196	0,7347	2,2186
W5	34,72	22,35	17,90	4,0	791,70	28,14	5,0524	0,7502	3,7901
W6	35,32	21,22	19,21	4,8	864,33	29,40	5,5534	0,7668	4,2584
W7	26,30	21,62	19,38	3,9	649,29	25,48	6,0065	0,7139	4,2879
W8	31,59	30,40	24,65	9,8	991,97	31,50	9,8794	0,7937	7,8409
W9	32,84	25,59	22,04	10,9	922,03	30,36	11,8217	0,7793	9,2126
W10	36,37	20,69	15,58	9,0	721,84	26,87	12,4681	0,7330	9,1396
W11	29,42	24,17	19,60	7,0	734,56	27,10	9,5295	0,7362	7,0160

Table 0.58. *Point load strength of Stop MS-3 fresh saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	35,73	21,75	14,79	3,80	673,18	25,95	5,6448	0,7204	4,0663
F2	32,67	26,81	20,72	5,10	862,32	29,37	5,9143	0,7664	4,5325
F3	26,59	15,14	10,51	2,40	356,00	18,87	6,7416	0,6143	4,1413
F4	39,46	22,91	18,30	5,00	919,90	30,33	5,4354	0,7788	4,2333
F5	28,75	19,83	13,26	2,00	485,64	22,04	4,1183	0,6639	2,7341
F6	51,32	21,75	16,58	3,20	1083,93	32,92	2,9522	0,8115	2,3956
F7	55,43	21,64	18,57	2,50	1311,25	36,21	1,9066	0,8510	1,6225
F8	28,97	16,55	16,12	0,30	594,90	24,39	0,5043	0,6984	0,3522
F9	46,22	28,60	24,04	4,50	1415,45	37,62	3,1792	0,8674	2,7578
F10	31,34	19,36	18,24	1,10	728,21	26,99	1,5106	0,7346	1,1097
F11	27,47	21,39	17,02	3,60	595,59	24,40	6,0444	0,6986	4,2229

Table 0.59. *Point load strength of Stop MS-3 weathered saturated marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	34,65	29,38	18,38	7,00	811,30	28,48	8,6282	0,7548	6,5122
W2	37,09	17,73	16,01	2,50	756,45	27,50	3,3049	0,7417	2,4512
W3	45,17	27,73	24,62	3,10	1416,67	37,64	2,1882	0,8676	1,8986
W4	31,76	20,97	16,12	2,30	652,19	25,54	3,5266	0,7147	2,5204
W5	38,74	22,51	18,12	5,30	894,23	29,90	5,9269	0,7734	4,5836
W6	25,08	19,88	17,71	0,70	565,82	23,79	1,2371	0,6897	0,8533
W7	28,06	25,86	19,26	3,70	688,45	26,24	5,3744	0,7244	3,8932
W8	46,55	23,56	20,41	4,20	1210,30	34,79	3,4702	0,8341	2,8946
W9	45,43	34,35	28,11	2,10	1626,80	40,33	1,2909	0,8981	1,1594
W10	45,19	24,98	21,47	0,70	1235,96	35,16	0,5664	0,8385	0,4749
W11	40,74	22,31	19,54	2,10	1014,09	31,84	2,0708	0,7981	1,6526

Table 0.60. *Point load strength of Stop MS-4 fresh dry marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	30,56	16,78	11,97	10,5	465,99	21,59	22,5326	0,6571	14,8054
F2	31,46	21,16	14,71	4,9	589,52	24,28	8,3118	0,6969	5,7921
F3	34,45	22,12	18,73	15,0	821,97	28,67	18,2488	0,7572	13,8186
F4	34,47	19,05	11,35	9,8	498,39	22,32	19,6634	0,6682	13,1391
F5	37,98	13,81	9,36	2,7	452,86	21,28	5,9621	0,6524	3,8896
F6	28,06	16,22	14,37	1,7	513,66	22,66	3,3096	0,6733	2,2282
F7	32,20	14,10	11,00	7,0	451,21	21,24	15,5138	0,6518	10,1118
F8	15,45	15,28	10,33	9,6	203,31	14,26	47,2185	0,5340	25,2155
F9	20,89	12,19	10,66	7,0	283,68	16,84	24,6758	0,5804	14,3217
F10	24,95	15,12	11,23	6,0	356,93	18,89	16,8101	0,6147	10,3331

Table 0.61. *Point load strength of Stop MS-4 fresh saturated marl in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	50,02	44,29	37,32	5,0	2378,02	48,76	2,1026	0,9876	2,0765
F2	38,23	36,71	32,08	5,5	1562,32	39,53	3,5204	0,8891	3,1300
F3	31,09	29,86	25,15	6,5	996,07	31,56	6,5257	0,7945	5,1846
F4	41,03	39,74	35,53	1,7	1857,06	43,09	0,9154	0,9284	0,8499
F5	25,24	23,93	21,27	6,5	683,89	26,15	9,5044	0,7232	6,8737
F6	34,93	32,92	29,05	4,2	1292,63	35,95	3,2492	0,8480	2,7552
F7	30,33	25,81	23,42	0,8	904,88	30,08	0,8841	0,7756	0,6857
F8	33,22	29,34	27,71	2,5	1172,64	34,24	2,1319	0,8276	1,7643
F9	18,56	16,51	15,20	2,7	359,38	18,96	7,5130	0,6157	4,6261
F10	19,58	18,51	15,99	2,5	398,83	19,97	6,2683	0,6320	3,9615

Table 0.62. *Point load strength of Stop MS-4 weathered dry marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	43,40	16,09	8,60	6,0	475,46	21,81	12,6192	0,6604	8,3335
W2	23,55	16,09	11,13	3,2	333,90	18,27	9,5837	0,6045	5,7937
W3	26,16	10,65	7,84	5,8	261,27	16,16	22,1995	0,5686	12,6220
W4	37,79	11,73	7,30	4,8	351,42	18,75	13,6588	0,6123	8,3634
W5	16,70	12,21	8,63	3,0	183,59	13,55	16,3404	0,5206	8,5063
W6	29,36	9,38	5,81	4,8	217,30	14,74	22,0891	0,5430	11,9939
W7	38,95	8,03	4,71	4,7	233,70	15,29	20,1113	0,5529	11,1204
W8	18,89	17,89	15,90	4,3	382,61	19,56	11,2385	0,6255	7,0293
W9	41,44	12,88	8,16	6,0	430,76	20,75	13,9287	0,6443	8,9740
W10	29,11	10,87	9,73	3,2	360,82	19,00	8,8688	0,6164	5,4664

Table 0.63. *Point load strength of Stop MS-4 fresh dry marl in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	40,49	27,77	22,83	4,2	1177,56	34,32	3,5667	0,8284	2,9548
W2	31,80	18,69	13,49	1,5	546,47	23,38	2,7449	0,6838	1,8768
W3	41,28	28,09	23,62	1,7	1242,08	35,24	1,3687	0,8396	1,1491
W4	33,09	14,96	13,66	3,2	575,81	24,00	5,5574	0,6928	3,8500
W5	24,17	19,46	15,52	3,3	477,86	21,86	6,9058	0,6612	4,5662
W6	30,03	26,07	21,73	4,6	831,28	28,83	5,5337	0,7594	4,2021
W7	37,30	28,07	23,22	3,9	1103,32	33,22	3,5348	0,8151	2,8811
W8	32,62	25,82	20,48	13,9	851,03	29,17	16,3332	0,7638	12,4759
W9	42,45	21,86	19,70	5,4	1065,31	32,64	5,0690	0,8079	4,0955
W10	45,01	25,40	19,96	3,1	1144,46	33,83	2,7087	0,8226	2,2281

Table 0.64. *Point load strength of Stop MS-4 fresh saturated marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	33,61	10,36	5,95	4,0	254,75	15,96	15,7016	0,5650	8,8713
F2	37,51	21,89	16,71	6,0	798,46	28,26	7,5145	0,7518	5,6491
F3	25,07	15,00	9,71	4,8	310,10	17,61	15,4788	0,5935	9,1860
F4	27,12	17,43	12,10	6,0	418,03	20,45	14,3531	0,6395	9,1783
F5	28,12	13,30	8,90	4,9	318,81	17,86	15,3695	0,5976	9,1846
F6	45,56	16,70	12,71	7,0	737,67	27,16	9,4894	0,7370	6,9939
F7	43,08	20,76	16,17	6,0	887,39	29,79	6,7614	0,7719	5,2189
F8	40,31	14,43	7,60	6,9	390,26	19,76	17,6804	0,6286	11,1134
F9	29,19	15,39	12,80	3,1	475,96	21,82	6,5131	0,6606	4,3023
F10	22,19	16,53	11,02	7,9	311,51	17,65	25,3605	0,5941	15,0675

Table 0.65. *Point load strength of Stop MS-4 weathered dry marl in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	40,53	37,78	32,97	2,9	1702,26	41,26	1,7036	0,9084	1,5475
F2	34,04	29,09	24,31	6,5	1054,16	32,47	6,1661	0,8058	4,9688
F3	29,54	28,51	26,13	5,8	983,29	31,36	5,8986	0,7919	4,6712
F4	42,10	39,61	35,65	1,6	1911,93	43,73	0,8369	0,9352	0,7826
F5	38,34	37,63	33,70	5,4	1645,93	40,57	3,2504	0,9008	2,9279
F6	54,08	48,07	39,67	4,1	2732,93	52,28	1,5002	1,0225	1,5340
F7	36,98	34,94	27,14	4,2	1278,52	35,76	3,2851	0,8457	2,7780
F8	38,31	36,03	29,56	1,4	1442,60	37,98	0,9705	0,8716	0,8458
F9	39,78	22,79	20,27	0,5	1027,19	32,05	0,4868	0,8006	0,3897
F10	40,42	39,55	35,10	5,3	1807,31	42,51	2,9325	0,9221	2,7041

Table 0.66. *Point load strength of Stop MS-4 weathered saturated marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	50,22	16,65	9,77	4,4	625,03	25,00	7,0396	0,7071	4,9778
W2	35,93	12,79	6,54	1,6	299,34	17,30	5,3451	0,5882	3,1442
W3	24,68	15,30	9,98	6,9	313,77	17,71	21,9909	0,5952	13,0891
W4	38,46	12,16	9,88	3,1	484,06	22,00	6,4042	0,6633	4,2482
W5	33,10	12,10	9,80	0,4	413,22	20,33	0,9680	0,6376	0,6172
W6	24,73	16,21	11,88	2,2	374,26	19,35	5,8783	0,6220	3,6564
W7	33,11	19,55	15,38	4,6	648,70	25,47	7,0911	0,7137	5,0610
W8	25,57	18,83	13,26	5,2	431,92	20,78	12,0392	0,6447	7,7618
W9	31,77	17,77	13,01	3,3	526,53	22,95	6,2674	0,6774	4,2458
W10	40,25	19,57	15,62	4,9	800,90	28,30	6,1181	0,7523	4,6029

Table 0.67. *Point load strength of Stop MS-4 weathered saturated marl in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	18,76	13,02	10,51	1,4	251,17	15,85	5,5739	0,5630	3,1381
W2	25,96	21,89	19,58	1,3	647,51	25,45	2,0077	0,7134	1,4323
W3	22,11	19,81	17,02	3,0	479,38	21,89	6,2581	0,6617	4,1412
W4	51,30	50,29	48,05	0,9	3140,08	56,04	0,2866	1,0586	0,3034
W5	42,25	40,88	37,62	6,8	2024,77	45,00	3,3584	0,9487	3,1860
W6	32,50	31,71	30,75	0,9	1273,09	35,68	0,7069	0,8448	0,5972
W7	36,07	35,08	34,25	0,8	1573,75	39,67	0,5083	0,8907	0,4528
W8	28,30	27,23	23,14	0,9	834,22	28,88	1,0789	0,7600	0,8200
W9	30,27	28,21	24,30	1,3	937,02	30,61	1,3874	0,7824	1,0855
W10	35,67	33,78	25,81	5,2	1172,79	34,25	4,4339	0,8276	3,6695

Table 0.68. *Point load strength of Stop MS-5 fresh dry marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	33,15	12,85	8,53	3,2	360,22	18,98	8,8836	0,6161	5,4732
F2	31,83	14,27	10,48	2,6	424,94	20,61	6,1185	0,6421	3,9286
F3	25,30	10,58	9,41	1,6	303,28	17,41	5,2757	0,5902	3,1135
F4	26,05	10,47	8,28	3,8	274,77	16,58	13,8298	0,5758	7,9629
F5	31,38	11,66	7,15	3,1	285,82	16,91	10,8461	0,5815	6,3068
F6	27,71	16,55	13,60	1,5	480,07	21,91	3,1245	0,6620	2,0684
F7	48,93	13,33	8,74	4,1	544,77	23,34	7,5260	0,6832	5,1420
F8	48,50	14,71	13,51	1,9	834,69	28,89	2,2763	0,7601	1,7303
F9	41,42	10,75	6,65	2,9	350,88	18,73	8,2649	0,6121	5,0587
F10	19,22	10,83	8,66	2,9	212,03	14,56	13,6772	0,5397	7,3809

Table 0.69. *Point load strength of Stop MS-5 fresh dry marl in horizontal direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	32,34	30,72	26,98	1,6	1111,51	33,34	1,4395	0,8166	1,1754
F2	34,09	31,83	26,77	2,0	1162,53	34,10	1,7204	0,8258	1,4207
F3	40,06	38,66	32,81	1,4	1674,35	40,92	0,8361	0,9046	0,7564
F4	38,27	37,27	34,45	0,8	1679,49	40,98	0,4763	0,9053	0,4312
F5	32,21	23,22	21,42	2,1	878,90	29,65	2,3893	0,7700	1,8398
F6	20,43	18,57	17,11	2,2	445,30	21,10	4,9405	0,6496	3,2096
F7	30,02	29,77	28,31	2,0	1082,63	32,90	1,8473	0,8112	1,4986
F8	34,98	33,51	28,93	1,9	1289,14	35,90	1,4739	0,8474	1,2489
F9	32,31	30,36	26,57	1,3	1093,60	33,07	1,1887	0,8133	0,9668
F10	28,04	22,99	23,49	0,7	839,06	28,97	0,8343	0,7611	0,6350
F11	21,77	14,92	9,25	1,2	256,53	16,02	4,6779	0,5660	2,6476

Table 0.70. *Point load strength of Stop MS-5 weathered dry marl in vertical direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	34,40	17,37	15,62	1,7	684,49	26,16	2,4836	0,7234	1,7965
W2	27,76	14,17	9,60	2,0	339,49	18,43	5,8913	0,6070	3,5763
W3	38,35	17,85	11,71	5,3	572,07	23,92	9,2645	0,6916	6,4077
W4	36,57	13,34	10,48	2,5	488,22	22,10	5,1206	0,6648	3,4040
W5	30,75	14,93	8,94	2,3	350,20	18,71	6,5677	0,6118	4,0180
W6	35,28	13,05	9,70	1,3	435,94	20,88	2,9820	0,6462	1,9270
W7	33,78	16,33	12,05	3,2	518,53	22,77	6,1712	0,6749	4,1647
W8	39,09	16,10	11,32	2,5	563,69	23,74	4,4350	0,6891	3,0561
W9	27,18	14,14	13,90	1,4	481,28	21,94	2,9089	0,6624	1,9268
W10	43,57	19,45	13,47	3,8	747,63	27,34	5,0827	0,7395	3,7587

Table 0.71. *Point load strength of Stop MS-5 weathered dry marl in horizontal direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	35,08	33,67	31,52	0,8	1408,56	37,53	0,5680	0,8664	0,4921
W2	27,03	20,60	17,75	0,4	611,19	24,72	0,6545	0,7032	0,4602
W3	30,10	25,49	25,00	1,4	958,60	30,96	1,4605	0,7869	1,1493
W4	29,54	13,50	13,47	0,3	506,88	22,51	0,5919	0,6710	0,3972
W5	29,81	27,01	24,07	1,7	914,05	30,23	1,8599	0,7776	1,4462
W6	32,16	31,30	30,02	0,2	1229,86	35,07	0,1626	0,8375	0,1362
W7	39,79	34,82	27,83	2,9	1410,64	37,56	2,0558	0,8667	1,7818
W8	38,83	36,90	30,69	1,0	1518,08	38,96	0,6587	0,8828	0,5815
W9	25,50	23,29	21,01	0,1	682,49	26,12	0,1465	0,7228	0,1059
W10	44,28	42,21	38,36	1,7	2163,80	46,52	0,7857	0,9645	0,7578

Table 0.72. *Point load strength of Stop MS-5 fresh saturated marl in vertical direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	51,06	14,09	5,57	1,9	362,30	19,03	5,2443	0,6170	3,2357
F2	42,14	15,27	9,93	0,4	533,06	23,09	0,7504	0,6795	0,5099
F3	46,12	16,16	7,48	0,6	439,46	20,96	1,3653	0,6475	0,8840
F4	62,36	15,70	10,18	0,5	808,69	28,44	0,6183	0,7542	0,4663
F5	42,46	16,53	8,73	1,0	472,20	21,73	2,1178	0,6592	1,3961
F6	24,66	14,76	9,24	0,5	290,27	17,04	1,7226	0,5837	1,0055
F7	39,84	10,33	5,35	0,1	271,52	16,48	0,3683	0,5741	0,2114
F8	31,24	13,01	7,06	1,1	280,96	16,76	3,9151	0,5790	2,2669
F9	33,73	13,57	9,50	0,5	408,20	20,20	1,2249	0,6357	0,7786
F10	20,94	13,08	8,63	0,3	230,21	15,17	1,3032	0,5509	0,7179
F11	22,58	11,08	8,45	0,5	243,06	15,59	2,0571	0,5584	1,1487

Table 0.73. *Point load strength of Stop MS-5 fresh saturated marl in horizontal direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	44,62	40,88	35,05	0,1	1992,27	44,63	0,0502	0,9448	0,0474
F2	48,96	42,13	40,10	0,3	2501,01	50,01	0,1200	1,0001	0,1200
F3	45,00	31,04	28,70	0,1	1645,22	40,56	0,0608	0,9007	0,0547
F4	31,51	20,27	17,65	0,1	708,47	26,62	0,1411	0,7296	0,1030
F5	23,09	22,95	21,37	0,1	628,58	25,07	0,1591	0,7081	0,1127
F6	20,65	18,90	18,17	0,1	477,98	21,86	0,2092	0,6613	0,1383
F7	40,40	37,40	34,61	0,5	1781,20	42,20	0,2807	0,9187	0,2579
F8	36,84	30,48	26,73	0,1	1254,44	35,42	0,0797	0,8416	0,0671
F9	30,44	29,51	28,96	0,1	1122,98	33,51	0,0890	0,8187	0,0729
F10	28,98	25,74	22,13	0,1	816,98	28,58	0,1224	0,7561	0,0925
F11	40,37	38,66	36,00	0,3	1851,36	43,03	0,1620	0,9277	0,1503

Table 0.74. *Point load strength of Stop MS-5 weathered saturated marl in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	32,40	14,21	6,77	0,8	279,42	16,72	2,8630	0,5782	1,6554
W2	35,19	18,17	7,79	0,3	349,21	18,69	0,8591	0,6113	0,5252
W3	50,32	27,09	23,78	0,7	1524,34	39,04	0,4592	0,8837	0,4058
W4	35,07	14,50	7,65	0,6	341,76	18,49	1,7556	0,6081	1,0675
W5	35,39	14,94	10,28	0,6	463,45	21,53	1,2946	0,6562	0,8495
W6	37,42	15,03	10,95	0,3	521,97	22,85	0,5747	0,6760	0,3885
W7	25,81	11,36	8,29	0,3	272,57	16,51	1,1006	0,5746	0,6325
W8	36,03	14,97	10,14	0,3	465,41	21,57	0,6446	0,6569	0,4234
W9	28,31	16,02	7,54	0,5	271,92	16,49	1,8388	0,5743	1,0560
W10	29,39	19,51	13,45	0,7	503,56	22,44	1,3901	0,6699	0,9313

Table 0.75. *Point load strength of Stop MS-5 weathered saturated marl in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	38,42	37,32	36,06	0,1	1764,87	42,01	0,0567	0,9166	0,0519
W2	19,33	17,01	16,01	0,1	394,23	19,86	0,2537	0,6302	0,1598
W3	35,08	34,92	34,51	0,1	1542,18	39,27	0,0648	0,8862	0,0575
W4	93,42	91,21	88,28	0,1	10505,88	102,50	0,0095	1,4318	0,0136
W5	58,98	56,47	55,97	0,1	4205,24	64,85	0,0238	1,1388	0,0271
W6	38,96	35,89	33,62	0,1	1668,58	40,85	0,0599	0,9039	0,0542
W7	54,85	49,30	41,84	0,7	2923,47	54,07	0,2394	1,0399	0,2490
W8	44,16	43,02	39,40	0,1	2216,44	47,08	0,0451	0,9704	0,0438
W9	28,65	24,37	21,39	0,1	780,67	27,94	0,1281	0,7475	0,0958
W10	38,59	33,79	32,02	0,1	1574,08	39,67	0,0635	0,8908	0,0566
W11	49,82	47,60	33,47	0,1	2124,17	46,09	0,0471	0,9601	0,0452
W12	62,87	50,70	42,59	0,1	3411,00	58,40	0,0293	1,0808	0,0317
W13	27,84	22,44	20,76	0,1	736,25	27,13	0,1358	0,7367	0,1001
W14	40,74	33,89	28,40	0,1	1473,91	38,39	0,0678	0,8763	0,0595

Table 0.76. *Point load strength of Stop MS-6 fresh dry mudstone in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	28,61	13,24	11,11	1,9	404,91	20,12	4,6924	0,6344	2,9768
F2	28,77	13,82	10,62	3,0	389,22	19,73	7,7077	0,6282	4,8416
F3	21,26	14,77	10,50	3,3	284,37	16,86	11,6046	0,5807	6,7393
F4	37,64	16,17	13,79	6,1	661,22	25,71	9,2254	0,7171	6,6159
F5	36,65	15,67	9,09	3,4	424,39	20,60	8,0114	0,6419	5,1424
F6	28,31	20,34	18,41	2,0	663,93	25,77	3,0124	0,7179	2,1625
F7	29,82	19,83	16,70	3,6	634,39	25,19	5,6748	0,7097	4,0276
F8	28,72	21,59	15,28	6,0	559,03	23,64	10,7328	0,6877	7,3805
F9	32,91	20,10	18,09	4,1	758,40	27,54	5,4061	0,7421	4,0121
F10	25,14	16,37	13,38	2,7	428,50	20,70	6,3010	0,6434	4,0543
F11	41,05	13,45	8,92	4,8	466,45	21,60	10,2904	0,6572	6,7632

Table 0.77. *Point load strength of Stop MS-6 fresh dry mudstone in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	30,76	18,37	15,17	3,5	594,43	24,38	5,8880	0,6983	4,1116
F2	32,78	30,45	25,96	4,3	1084,04	32,92	3,9667	0,8115	3,2188
F3	40,02	33,18	32,97	0,8	1680,84	41,00	0,4760	0,9055	0,4310
F4	33,87	31,06	29,06	2,6	1253,84	35,41	2,0736	0,8415	1,7450
F5	40,08	38,57	35,62	2,1	1818,66	42,65	1,1547	0,9235	1,0664
F6	22,98	21,91	20,55	2,3	601,58	24,53	3,8233	0,7004	2,6778
F7	30,11	29,65	28,35	0,9	1087,41	32,98	0,8277	0,8121	0,6721
F8	30,86	26,32	24,64	3,5	968,65	31,12	3,6133	0,7890	2,8507
F9	28,10	25,68	22,76	4,1	814,72	28,54	5,0324	0,7556	3,8023
F10	33,78	31,96	30,02	3,5	1291,82	35,94	2,7094	0,8478	2,2971

Table 0.78. *Point load strength of Stop MS-6 weathered dry mudstone in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	21,05	16,05	14,36	1,3	385,07	19,62	3,3760	0,6265	2,1150
W2	40,10	15,47	12,53	1,0	640,07	25,30	1,5623	0,7113	1,1113
W3	37,01	16,64	15,40	1,8	726,06	26,95	2,4791	0,7341	1,8200
W4	37,07	26,71	24,22	1,8	1143,74	33,82	1,5738	0,8224	1,2943
W5	34,73	17,93	14,92	0,5	660,09	25,69	0,7575	0,7168	0,5430
W6	28,54	20,61	15,15	3,2	550,80	23,47	5,8097	0,6851	3,9803
W7	34,92	18,54	17,42	2,3	774,91	27,84	2,9681	0,7462	2,2146
W8	33,98	21,17	18,04	1,7	780,89	27,94	2,1770	0,7476	1,6275
W9	22,91	19,39	17,77	0,6	518,61	22,77	1,1569	0,6749	0,7808
W10	23,72	20,19	18,17	1,6	549,03	23,43	2,9142	0,6846	1,9950

Table 0.79. *Point load strength of Stop MS-6 weathered dry mudstone in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	53,73	48,00	41,80	1,2	2861,04	53,49	0,4194	1,0343	0,4338
W2	43,28	39,66	38,04	1,5	2097,29	45,80	0,7152	0,9570	0,6845
W3	28,76	27,33	26,56	2,6	973,08	31,19	2,6719	0,7899	2,1105
W4	30,76	29,59	24,89	2,4	975,31	31,23	2,4608	0,7903	1,9448
W5	33,60	25,57	24,50	1,5	1048,66	32,38	1,4304	0,8048	1,1511
W6	31,26	30,64	28,32	0,5	1127,75	33,58	0,4434	0,8195	0,3634
W7	28,70	25,36	23,05	1,5	842,72	29,03	1,7800	0,7620	1,3563
W8	32,21	30,80	26,59	0,8	1091,04	33,03	0,7332	0,8128	0,5960
W9	33,94	25,05	24,44	1,6	1056,68	32,51	1,5142	0,8063	1,2209
W10	32,78	31,96	28,91	1,3	1207,22	34,75	1,0769	0,8336	0,8977

Table 0.80. *Point load strength of Stop MS-6 fresh saturated mudstone in vertical direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm)^2	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	29,59	14,38	10,28	0,6	387,50	19,68	1,5484	0,6275	0,9715
F2	28,02	10,56	7,93	1,5	283,06	16,82	5,2993	0,5801	3,0740
F3	27,67	10,93	6,12	1,1	215,72	14,69	5,0992	0,5420	2,7637
F4	22,55	14,83	11,77	0,5	338,11	18,39	1,4788	0,6064	0,8968
F5	26,19	11,96	7,23	2,0	241,21	15,53	8,2914	0,5573	4,6211
F6	39,43	13,95	8,01	1,7	402,34	20,06	4,2253	0,6334	2,6762
F7	29,84	11,91	6,28	1,2	238,72	15,45	5,0268	0,5559	2,7943
F8	31,46	10,96	9,18	0,3	367,90	19,18	0,8154	0,6194	0,5051
F9	19,27	15,20	11,49	1,1	282,05	16,79	3,9000	0,5796	2,2603
F10	37,43	16,20	9,46	1,1	451,07	21,24	2,4387	0,6517	1,5894
F11	29,34	10,87	6,95	1,2	259,76	16,12	4,6196	0,5678	2,6228

Table 0.81. *Point load strength of Stop MS-6 fresh saturated mudstone in horizontal direction*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm)^2	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	26,23	24,32	22,46	1,2	750,48	27,39	1,5990	0,7402	1,1836
F2	36,48	31,43	27,03	0,8	1256,12	35,44	0,6369	0,8419	0,5362
F3	37,09	36,51	33,36	1,1	1576,21	39,70	0,6979	0,8911	0,6219
F4	32,07	31,69	22,72	1,2	928,19	30,47	1,2928	0,7806	1,0092
F5	42,28	40,03	36,83	0,5	1983,66	44,54	0,2521	0,9438	0,2379
F6	46,22	44,43	39,97	1,7	2353,39	48,51	0,7224	0,9850	0,7115
F7	33,04	24,57	22,52	1,8	947,85	30,79	1,8990	0,7847	1,4902
F8	32,29	26,47	21,47	1,7	883,14	29,72	1,9249	0,7709	1,4840
F9	29,36	25,46	21,62	1,1	808,62	28,44	1,3603	0,7541	1,0259
F10	29,19	25,11	21,02	0,3	781,62	27,96	0,3838	0,7478	0,2870

Table 0.82. *Point load strength of Stop MS-6 weathered saturated mudstone in vertical direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	27,36	11,73	10,68	0,2	372,24	19,29	0,5373	0,6212	0,3338
W2	28,97	14,81	9,11	0,5	336,20	18,34	1,4872	0,6056	0,9006
W3	33,36	20,45	15,03	0,7	638,73	25,27	1,0959	0,7110	0,7792
W4	41,12	13,85	9,33	0,8	488,73	22,11	1,6369	0,6649	1,0884
W5	25,94	17,55	11,59	0,8	382,99	19,57	2,0888	0,6256	1,3068
W6	27,74	16,23	14,53	0,3	513,46	22,66	0,5843	0,6732	0,3933
W7	34,14	13,91	13,15	0,1	571,90	23,91	0,1749	0,6916	0,1209
W8	23,64	19,95	15,84	1,2	477,02	21,84	2,5156	0,6609	1,6626
W9	22,75	12,65	8,59	0,7	248,95	15,78	2,8119	0,5617	1,5796
W10	25,15	15,61	13,24	1,0	424,19	20,60	2,3575	0,6418	1,5130

Table 0.83. *Point load strength of Stop MS-6 weathered saturated mudstone in horizontal direction*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	41,28	35,23	33,17	1,2	1744,28	41,76	0,6880	0,9139	0,6288
W2	38,16	34,15	32,22	0,4	1566,26	39,58	0,2554	0,8897	0,2272
W3	34,03	31,54	27,66	0,7	1199,07	34,63	0,5838	0,8322	0,4858
W4	34,49	32,50	28,85	0,3	1267,56	35,60	0,2367	0,8438	0,1997
W5	41,03	37,23	34,23	0,5	1789,12	42,30	0,2795	0,9198	0,2570
W6	33,47	31,69	28,09	0,4	1197,67	34,61	0,3340	0,8320	0,2779
W7	41,04	39,97	39,05	0,8	2041,54	45,18	0,3919	0,9506	0,3725
W8	29,23	25,95	19,26	1,0	717,16	26,78	1,3944	0,7318	1,0205
W9	23,39	22,60	20,11	0,3	599,20	24,48	0,5007	0,6997	0,3503
W10	33,28	31,10	27,62	0,6	1170,95	34,22	0,5124	0,8273	0,4239
W11	49,63	47,57	45,82	0,8	2896,87	53,82	0,2762	1,0375	0,2865

Table 0.84. *Point load strength of Stop MS-6 fresh dry sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	28,09	19,37	13,23	9,0	473,41	21,76	19,0108	0,6597	12,5408
F2	33,15	30,79	25,00	7,0	1055,73	32,49	6,6305	0,8061	5,3450
F3	35,64	24,84	19,99	12,0	907,57	30,13	13,2221	0,7762	10,2633
F4	30,59	17,52	14,91	4,2	581,02	24,10	7,2287	0,6943	5,0191
F5	34,98	24,50	19,99	5,5	890,76	29,85	6,1745	0,7726	4,7704
F6	44,33	19,57	16,13	5,4	910,88	30,18	5,9283	0,7769	4,6059
F7	41,31	31,28	25,23	11,0	1327,71	36,44	8,2850	0,8537	7,0726
F8	39,92	21,03	14,22	5,5	723,14	26,89	7,6058	0,7334	5,5778
F9	37,84	30,58	25,59	9,5	1233,54	35,12	7,7014	0,8381	6,4547
F10	44,89	16,87	13,42	5,4	767,42	27,70	7,0366	0,7443	5,2376
F11	20,93	16,05	12,93	6,1	344,75	18,57	17,6942	0,6094	10,7825

Table 0.85. *Point load strength of Stop MS-6 weathered dry sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	45,26	16,51	13,74	2,1	792,19	28,15	2,6509	0,7503	1,9889
W2	26,81	16,04	13,01	3,1	444,33	21,08	6,9768	0,6493	4,5300
W3	37,66	16,02	12,34	2,1	592,01	24,33	3,5473	0,6976	2,4745
W4	28,34	20,83	17,66	0,8	637,56	25,25	1,2548	0,7106	0,8917
W5	33,70	30,02	22,98	3,5	986,53	31,41	3,5478	0,7926	2,8119
W6	37,70	22,56	17,67	4,8	848,61	29,13	5,6563	0,7633	4,3174
W7	37,46	35,73	33,13	3,6	1580,96	39,76	2,2771	0,8918	2,0306
W8	38,03	30,02	24,92	6,0	1207,27	34,75	4,9699	0,8336	4,1430
W9	38,75	15,55	11,68	1,6	576,56	24,01	2,7751	0,6930	1,9231
W10	28,69	14,26	11,45	1,6	418,47	20,46	3,8234	0,6396	2,4456
W11	32,27	19,43	16,27	3,5	668,83	25,86	5,2330	0,7192	3,7635

Table 0.86. *Point load strength of Stop MS-6 fresh saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 $(mm)^2$**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	47,89	21,23	15,58	2,0	950,48	30,83	2,1042	0,7852	1,6523
F2	49,28	23,82	17,87	2,2	1121,83	33,49	1,9611	0,8185	1,6051
F3	45,93	13,75	7,86	1,2	459,89	21,44	2,6093	0,6549	1,7089
F4	55,20	13,02	7,55	1,3	530,90	23,04	2,4487	0,6788	1,6622
F5	34,31	24,75	20,87	2,4	912,17	30,20	2,6311	0,7772	2,0449
F6	54,24	25,87	20,04	2,9	1384,67	37,21	2,0944	0,8627	1,8068
F7	45,42	40,02	30,54	3,3	1767,04	42,04	1,8675	0,9169	1,7124
F8	32,94	27,36	19,92	2,0	835,88	28,91	2,3927	0,7604	1,8194
F9	43,90	35,54	29,67	3,7	1659,25	40,73	2,2299	0,9026	2,0127
F10	27,60	24,68	21,43	2,2	753,46	27,45	2,9199	0,7409	2,1634
F11	27,24	23,82	18,60	1,8	645,43	25,41	2,7888	0,7128	1,9879

Table 0.87. *Point load strength of Stop MS-6 weathered saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 $(mm)^2$**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	54,74	22,02	15,03	1,5	1048,08	32,37	1,4312	0,8047	1,1516
W2	37,93	24,54	20,98	0,6	1013,72	31,84	0,5919	0,7980	0,4723
W3	35,39	23,06	23,04	1,1	1038,71	32,23	1,0590	0,8029	0,8502
W4	34,40	29,33	23,12	1,8	1013,16	31,83	1,7766	0,7979	1,4175
W5	33,12	27,74	17,11	1,2	721,89	26,87	1,6623	0,7330	1,2185
W6	49,75	30,78	20,01	2,2	1268,15	35,61	1,7348	0,8439	1,4641
W7	56,24	31,09	25,41	1,5	1820,46	42,67	0,8240	0,9238	0,7612
W8	45,32	19,68	18,79	0,5	1084,79	32,94	0,4609	0,8116	0,3741
W9	39,51	25,27	19,64	1,6	988,50	31,44	1,6186	0,7930	1,2835
W10	38,80	22,61	17,71	1,0	875,35	29,59	1,1424	0,7692	0,8788
W11	26,98	20,69	12,29	0,9	422,40	20,55	2,1307	0,6411	1,3660

Table 0.88. *Point load strength of Stop MS-7.1 fresh dry limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	43,83	16,94	11,74	7,9	655,50	25,60	12,0519	0,7156	8,6241
F2	39,34	28,84	24,68	4,6	1236,83	35,17	3,7192	0,8387	3,1192
F3	40,60	23,06	19,39	8,0	1002,85	31,67	7,9773	0,7958	6,3486
F4	37,19	26,88	21,29	12,0	1008,63	31,76	11,8973	0,7970	9,4819
F5	33,64	23,48	18,81	8,0	806,07	28,39	9,9246	0,7535	7,4787
F6	37,76	19,43	14,44	8,8	694,59	26,36	12,6693	0,7260	9,1982
F7	37,01	29,54	25,10	9,5	1183,38	34,40	8,0279	0,8295	6,6588
F8	41,20	17,24	10,80	10,2	566,83	23,81	17,9949	0,6900	12,4173
F9	27,65	22,09	19,20	8,0	676,28	26,01	11,8294	0,7212	8,5312
F10	37,85	18,70	16,18	8,0	780,14	27,93	10,2545	0,7474	7,6643
F11	38,10	17,13	13,20	9,0	640,66	25,31	14,0480	0,7115	9,9951
F12	49,45	18,44	13,36	9,2	841,59	29,01	10,9316	0,7617	8,3267

Table 0.89. *Point load strength of Stop MS-7.1 weathered dry limestone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm^2)**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	36,33	20,34	14,50	12,0	671,06	25,90	17,8821	0,7198	12,8713
W2	36,96	18,04	17,08	4,2	804,17	28,36	5,2227	0,7531	3,9333
W3	42,47	18,72	13,44	10,0	727,13	26,97	13,7527	0,7344	10,0996
W4	50,27	27,79	23,13	7,1	1481,20	38,49	4,7934	0,8773	4,2054
W5	46,40	21,84	18,00	8,1	1063,95	32,62	7,6131	0,8077	6,1491
W6	38,63	21,24	17,34	7,1	853,30	29,21	8,3206	0,7643	6,3598
W7	29,95	27,85	23,12	5,4	882,09	29,70	6,1218	0,7707	4,7182
W8	41,15	17,96	13,33	5,4	698,76	26,43	7,7279	0,7271	5,6190
W9	37,16	19,05	14,54	6,2	688,29	26,24	9,0079	0,7244	6,5250
W10	31,37	15,10	12,52	4,3	500,32	22,37	8,5945	0,6688	5,7484
W11	46,25	30,49	24,51	11,9	1444,06	38,00	8,2407	0,8718	7,1841
W12	36,39	19,21	16,72	5,9	775,08	27,84	7,6121	0,7462	5,6801

Table 0.90. *Point load strength of Stop MS-7.1 fresh saturated limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	40.59	31.44	23.98	4.5	1239.93	35.21	3.6292	0.8392	3.0456
F2	29.69	13.33	10.44	2.5	394.86	19.87	6.3314	0.6304	3.9914
F3	35.70	26.19	20.47	3.8	930.93	30.51	4.0819	0.7812	3.1887
F4	30.58	23.47	18.65	3.5	726.52	26.95	4.8175	0.7342	3.5371
F5	37.28	17.23	10.76	2.5	511.00	22.61	4.8924	0.6724	3.2896
F6	23.77	16.72	13.05	3.1	395.16	19.88	7.8450	0.6305	4.9465
F7	43.30	22.83	19.58	1.6	1080.02	32.86	1.4815	0.8107	1.2011
F8	37.51	24.64	18.67	4.0	892.12	29.87	4.4837	0.7729	3.4654
F9	31.48	28.27	24.73	2.5	991.72	31.49	2.5209	0.7936	2.0006
F10	30.30	16.24	14.14	3.3	545.79	23.36	6.0463	0.6836	4.1330
F11	26.19	18.48	14.34	1.9	478.43	21.87	3.9714	0.6614	2.6267
F12	48.40	22.28	18.54	0.7	1143.10	33.81	0.6124	0.8223	0.5036
F13	29.52	15.68	11.61	2.1	436.60	20.89	4.8099	0.6464	3.1094

Table 0.91. *Point load strength of Stop MS-7.1 weathered saturated limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	36.62	26.22	23.76	1.20	1108.40	33.29	1.0826	0.8160	0.8834
W2	34.12	30.80	23.99	3.60	1042.72	32.29	3.4525	0.8036	2.7745
W3	43.95	27.16	20.78	6.10	1163.42	34.11	5.2432	0.8259	4.3306
W4	42.47	23.05	17.59	2.20	951.65	30.85	2.3118	0.7855	1.8158
W5	35.70	26.95	22.77	4.60	1035.53	32.18	4.4422	0.8022	3.5637
W6	41.26	25.39	17.67	2.40	928.74	30.48	2.5841	0.7807	2.0175
W7	34.65	29.30	23.44	3.80	1034.64	32.17	3.6728	0.8021	2.9458
W8	31.71	26.09	22.39	1.60	904.44	30.07	1.7690	0.7756	1.3720
W9	43.08	39.00	31.23	4.20	1713.87	41.40	2.4506	0.9099	2.2299
W10	38.54	27.24	22.77	1.80	1117.91	33.44	1.6102	0.8177	1.3167
W11	37.03	14.98	10.05	2.90	474.08	21.77	6.1171	0.6599	4.0367
W12	50.37	30.04	17.68	1.10	1134.45	33.68	0.9696	0.8208	0.7958

Table 0.92. *Point load strength of Stop MS-7.2 fresh dry limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	40,44	18,83	16,99	5,3	875,26	29,58	6,0554	0,7692	4,6579
F2	28,11	20,14	17,61	7,0	630,60	25,11	11,1006	0,7087	7,8668
F3	35,79	23,83	20,96	7,0	955,62	30,91	7,3251	0,7863	5,7597
F4	28,42	23,38	22,68	9,5	821,10	28,65	11,5698	0,7570	8,7587
F5	35,16	25,77	22,04	9,1	987,17	31,42	9,2183	0,7927	7,3074
F6	24,51	17,50	14,12	6,0	440,87	21,00	13,6095	0,6480	8,8193
F7	35,15	17,89	13,77	10,8	616,58	24,83	17,5160	0,7047	12,3437
F8	38,69	21,18	17,23	11,6	849,21	29,14	13,6598	0,7634	10,4283
F9	44,76	18,55	16,36	11,0	932,83	30,54	11,7920	0,7816	9,2163
F10	40,68	18,87	15,23	3,5	789,24	28,09	4,4346	0,7496	3,3241
F11	38,81	31,48	25,42	7,8	1256,75	35,45	6,2065	0,8420	5,2260
F12	34,91	18,40	14,79	5,4	657,73	25,65	8,2100	0,7162	5,8799

Table 0.93. *Point load strength of Stop MS-7.2 weathered dry limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	30,78	20,35	16,64	10,0	652,46	25,54	15,3267	0,7147	10,9547
W2	28,24	22,34	17,02	9,0	612,29	24,74	14,6990	0,7035	10,3405
W3	32,81	17,45	14,23	6,0	594,76	24,39	10,0881	0,6984	7,0455
W4	30,15	20,76	18,35	8,1	704,78	26,55	11,4929	0,7287	8,3745
W5	34,07	21,34	15,82	10,5	686,61	26,20	15,2926	0,7239	11,0706
W6	31,75	27,99	25,04	8,0	1012,76	31,82	7,8992	0,7978	6,3019
W7	32,86	19,08	14,63	6,0	612,41	24,75	9,7974	0,7035	6,8926
W8	45,20	21,70	20,07	7,1	1155,62	33,99	6,1439	0,8246	5,0660
W9	44,12	17,57	14,65	3,7	823,39	28,69	4,4936	0,7576	3,4042
W10	43,91	18,76	14,90	7,5	833,45	28,87	8,9987	0,7599	6,8378
W11	34,27	26,23	24,08	7,0	1051,24	32,42	6,6588	0,8053	5,3621
W12	34,52	23,02	19,01	7,0	835,96	28,91	8,3736	0,7604	6,3676

Table 0.94. *Point load strength of Stop MS-7.2 fresh saturated limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	33,11	29,39	25,20	4,9	1062,89	32,60	4,6101	0,8075	3,7226
F2	34,96	23,21	16,55	4,5	737,05	27,15	6,1054	0,7369	4,4989
F3	31,49	24,92	20,41	3,7	818,74	28,61	4,5191	0,7565	3,4187
F4	52,65	20,62	15,20	3,9	1019,46	31,93	3,8255	0,7991	3,0570
F5	46,28	23,09	17,12	5,0	1009,32	31,77	4,9538	0,7971	3,9488
F6	44,07	30,40	26,28	4,2	1475,36	38,41	2,8468	0,8765	2,4951
F7	41,92	29,21	24,70	5,4	1319,01	36,32	4,0940	0,8523	3,4892
F8	38,43	19,17	16,16	2,3	791,12	28,13	2,9073	0,7500	2,1805
F9	36,14	29,36	24,11	3,7	1109,98	33,32	3,3334	0,8163	2,7210
F10	38,01	32,60	25,46	7,0	1232,78	35,11	5,6782	0,8380	4,7583
F11	43,48	35,12	27,17	6,0	1504,91	38,79	3,9870	0,8808	3,5118
F12	38,83	35,89	29,10	6,5	1439,43	37,94	4,5157	0,8711	3,9336

Table 0.95. *Point load strength of Stop MS-7.2 weathered saturated limestone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	36,38	31,63	28,00	3,20	1297,63	36,02	2,4660	0,8488	2,0932
W2	37,80	30,50	22,11	7,50	1064,66	32,63	7,0445	0,8078	5,6907
W3	31,69	18,84	12,44	3,20	502,20	22,41	6,3720	0,6695	4,2659
W4	50,30	16,86	14,50	4,50	929,11	30,48	4,8434	0,7808	3,7816
W5	34,78	27,03	21,30	4,10	943,71	30,72	4,3445	0,7838	3,4054
W6	47,65	32,13	26,18	6,00	1589,14	39,86	3,7756	0,8929	3,3713
W7	47,76	21,36	13,55	2,30	824,39	28,71	2,7899	0,7578	2,1142
W8	42,71	28,85	21,09	5,40	1147,46	33,87	4,7061	0,8231	3,8735
W9	30,29	22,53	16,48	3,30	635,90	25,22	5,1895	0,7102	3,6854
W10	42,21	25,41	23,63	4,40	1270,60	35,65	3,4629	0,8443	2,9239
W11	42,49	36,03	28,17	5,00	1524,77	39,05	3,2792	0,8837	2,8979
W12	24,45	19,39	15,92	2,50	495,85	22,27	5,0418	0,6673	3,3647

Table 0.96. *Point load strength of Stop MS-8.1 fresh dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	49,44	29,90	24,17	7,0	1522,25	39,02	4,5985	0,8834	4,0621
F2	44,98	37,18	24,49	15,0	1403,26	37,46	10,6894	0,8656	9,2524
F3	48,17	46,62	36,73	15,0	2253,87	47,47	6,6552	0,9744	6,4850
F4	55,59	26,22	19,20	15,9	1359,65	36,87	11,6942	0,8588	10,0425
F5	54,79	16,77	12,46	11,1	869,66	29,49	12,7636	0,7680	9,8022
F6	50,19	27,20	18,44	10,0	1178,99	34,34	8,4819	0,8287	7,0288
F7	42,86	34,40	25,66	17,9	1401,00	37,43	12,7766	0,8652	11,0545
F8	47,48	26,33	22,08	9,0	1335,49	36,54	6,7391	0,8549	5,7614
F9	38,90	21,31	15,23	8,8	754,71	27,47	11,6601	0,7412	8,6430
F10	36,60	28,95	24,13	8,3	1125,04	33,54	7,3775	0,8190	6,0425

Table 0.97. *Point load strength of Stop MS-8.1 weathered dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	46,68	28,06	21,15	14,0	1257,68	35,46	11,1316	0,8422	9,3749
W2	37,24	15,68	12,86	7,0	610,07	24,70	11,4741	0,7028	8,0645
W3	40,49	21,73	16,66	9,1	859,32	29,31	10,5898	0,7657	8,1085
W4	28,91	19,80	16,10	9,0	592,93	24,35	15,1788	0,6979	10,5926
W5	32,48	30,37	27,24	3,5	1127,08	33,57	3,1231	0,8194	2,5591
W6	33,67	30,41	26,91	9,0	1154,22	33,97	7,7975	0,8243	6,4275
W7	36,29	26,52	20,83	6,5	962,96	31,03	6,7500	0,7878	5,3177
W8	35,28	26,56	23,91	9,0	1074,58	32,78	8,3754	0,8097	6,7815
W9	38,35	17,43	13,95	4,1	681,51	26,11	6,0161	0,7226	4,3471
W10	36,89	28,40	25,50	6,9	1198,34	34,62	5,7580	0,8321	4,7910

Table 0.98. *Point load strength of Stop MS-8.1 fresh saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	65,74	38,40	27,45	10,00	2298,81	47,95	4,3501	0,9792	4,2598
F2	46,08	39,31	32,94	11,00	1933,60	43,97	5,6889	0,9378	5,3350
F3	56,45	33,50	24,90	12,50	1790,58	42,32	6,9810	0,9199	6,4221
F4	39,58	26,91	26,64	1,10	1343,20	36,65	0,8189	0,8562	0,7011
F5	44,51	39,13	32,58	9,20	1847,31	42,98	4,9802	0,9271	4,6174
F6	38,97	24,32	19,54	7,00	970,03	31,15	7,2163	0,7892	5,6954
F7	47,31	38,05	29,49	11,00	1777,29	42,16	6,1892	0,9182	5,6832
F8	47,51	41,91	37,23	6,00	2253,24	47,47	2,6628	0,9744	2,5945
F9	30,50	19,23	15,48	2,20	601,45	24,52	3,6578	0,7004	2,5618
F10	34,03	18,58	14,96	4,50	648,52	25,47	6,9389	0,7137	4,9520
F11	49,07	16,66	13,98	2,40	873,88	29,56	2,7464	0,7689	2,1117
F12	35,16	16,49	13,97	3,45	625,71	25,01	5,5137	0,7073	3,8999

Table 0.99. *Point load strength of Stop MS-8.1 weathered saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	43,02	24,64	19,08	1,90	1045,63	32,34	1,8171	0,8042	1,4613
W2	43,07	18,87	14,33	0,70	786,23	28,04	0,8903	0,7489	0,6667
W3	48,92	35,91	30,06	12,40	1873,29	43,28	6,6194	0,9304	6,1586
W4	50,96	19,61	13,83	4,90	897,80	29,96	5,4578	0,7741	4,2250
W5	45,47	42,17	30,23	10,00	1751,03	41,85	5,7109	0,9148	5,2245
W6	33,86	23,68	18,52	5,15	798,84	28,26	6,4469	0,7518	4,8471
W7	34,03	15,76	13,78	1,50	597,37	24,44	2,5110	0,6992	1,7556
W8	50,09	14,10	11,02	1,80	703,17	26,52	2,5598	0,7283	1,8642
W9	36,60	16,17	11,82	1,90	551,10	23,48	3,4477	0,6852	2,3624
W10	39,10	12,13	9,45	2,70	470,69	21,70	5,7362	0,6587	3,7785
W11	29,14	17,36	13,47	0,80	500,02	22,36	1,5999	0,6687	1,0700
W12	30,55	16,05	10,15	2,00	395,01	19,87	5,0632	0,6305	3,1922
W13	25,90	22,15	17,32	1,20	571,45	23,91	2,0999	0,6914	1,4520

Table 0.100. *Point load strength of Stop MS-8.2 fresh dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	48,29	34,52	27,16	17,5	1670,77	40,88	10,4742	0,9042	9,4703
F2	43,59	29,42	21,59	15,2	1198,86	34,62	12,6787	0,8322	10,5507
F3	45,80	36,45	28,37	15,0	1655,22	40,68	9,0623	0,9020	8,1746
F4	49,23	43,52	33,65	18,4	2110,31	45,94	8,7191	0,9585	8,3575
F5	53,73	20,72	16,06	12,0	1099,24	33,15	10,9166	0,8143	8,8895
F6	51,19	19,06	13,03	12,0	849,69	29,15	14,1228	0,7635	10,7833
F7	35,48	29,11	23,49	12,0	1061,69	32,58	11,3028	0,8073	9,1243
F8	41,21	35,39	31,20	6,0	1637,90	40,47	3,6632	0,8997	3,2957
F9	39,03	20,37	18,48	6,5	918,82	30,31	7,0743	0,7786	5,5081
F10	57,18	30,69	21,99	11,0	1601,77	40,02	6,8674	0,8947	6,1441
F11	47,41	38,99	31,49	17,0	1901,84	43,61	8,9387	0,9339	8,3480
F12	47,61	34,15	26,34	14,1	1597,51	39,97	8,8262	0,8941	7,8913

Table 0.101. *Point load strength of Stop MS-8.2 weathered dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	38,87	15,52	12,89	1,5	638,26	25,26	2,3501	0,7108	1,6705
W2	46,14	34,44	26,30	4,1	1545,84	39,32	2,6523	0,8868	2,3519
W3	44,10	16,63	14,42	2,9	810,09	28,46	3,5181	0,7545	2,6544
W4	46,11	41,13	34,58	6,5	2031,19	45,07	3,2001	0,9494	3,0382
W5	29,12	14,42	13,53	2,0	501,90	22,40	3,9848	0,6694	2,6674
W6	44,38	32,00	29,54	1,6	1670,04	40,87	0,9581	0,9041	0,8661
W7	47,06	37,20	33,69	4,6	2019,68	44,94	2,2776	0,9481	2,1593
W8	55,31	31,03	24,82	3,3	1748,78	41,82	1,8870	0,9145	1,7257
W9	36,70	20,64	19,17	1,9	896,23	29,94	2,1200	0,7738	1,6404
W10	45,64	32,93	29,78	2,2	1731,41	41,61	1,2649	0,9123	1,1539
W11	45,35	25,95	20,52	1,5	1185,45	34,43	1,2653	0,8298	1,0500
W12	38,26	23,41	20,47	2,1	997,68	31,59	2,1049	0,7948	1,6730

Table 0.102. *Point load strength of Stop MS-8.2 fresh saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	51,60	21,51	15,34	1,90	1008,34	31,75	1,8843	0,7969	1,5016
F2	52,12	27,68	20,99	0,70	1393,63	37,33	0,5023	0,8641	0,4340
F3	51,39	22,15	18,48	12,40	1209,79	34,78	10,2497	0,8341	8,5488
F4	37,04	14,17	11,03	4,90	520,45	22,81	9,4150	0,6755	6,3596
F5	46,40	17,78	14,42	10,00	852,34	29,19	11,7324	0,7641	8,9651
F6	54,78	18,68	14,33	5,15	1000,00	31,62	5,1500	0,7953	4,0957
F7	39,81	13,39	11,72	1,50	594,36	24,38	2,5237	0,6983	1,7623
F8	34,62	13,53	11,18	2,10	493,06	22,20	4,2591	0,6664	2,8383
F9	29,38	17,15	15,18	1,80	568,14	23,84	3,1682	0,6904	2,1875
F10	39,16	19,15	15,33	1,90	764,74	27,65	2,4845	0,7437	1,8477
F11	29,07	25,67	21,50	2,00	796,18	28,22	2,5120	0,7512	1,8871

Table 0.103. *Point load strength of Stop MS-8.2 weathered saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	53,16	42,07	36,49	1,80	2471,09	49,71	0,7284	0,9971	0,7263
W2	35,83	14,86	11,79	1,10	538,13	23,20	2,0441	0,6811	1,3923
W3	36,63	24,65	21,64	0,70	1009,77	31,78	0,6932	0,7972	0,5526
W4	31,01	19,12	16,19	0,30	639,56	25,29	0,4691	0,7112	0,3336
W5	43,96	37,13	31,23	0,60	1748,88	41,82	0,3431	0,9145	0,3138
W6	40,59	25,29	22,01	0,90	1138,07	33,74	0,7908	0,8214	0,6496
W7	40,46	30,16	26,06	0,90	1343,17	36,65	0,6701	0,8561	0,5737
W8	49,54	37,70	33,51	0,90	2114,76	45,99	0,4256	0,9590	0,4081
W9	42,27	36,71	32,12	1,20	1729,57	41,59	0,6938	0,9120	0,6328
W10	47,11	16,48	15,34	0,30	920,60	30,34	0,3259	0,7790	0,2539
W11	42,67	35,73	33,29	0,80	1809,53	42,54	0,4421	0,9224	0,4078

Table 0.104. *Point load strength of Stop MS-9 fresh dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	24.53	21.87	16.43	2.7	513.41	22.66	5.2589	0.6732	3.5402
F2	23.20	18.50	13.63	2.1	402.82	20.07	5.2132	0.6336	3.3029
F3	33.29	30.40	28.41	3.1	1204.80	34.71	2.5730	0.8332	2.1438
F4	43.12	14.61	12.34	1.7	677.84	26.04	2.5080	0.7216	1.8098
F5	38.46	13.78	10.30	6.4	504.63	22.46	12.6824	0.6703	8.5008
F6	41.43	26.15	23.77	4.1	1254.51	35.42	3.2682	0.8417	2.7507
F7	40.86	24.60	19.94	3.4	1037.90	32.22	3.2759	0.8027	2.6295
F8	43.36	15.22	12.49	1.8	689.89	26.27	2.6091	0.7248	1.8910
F9	42.19	22.89	15.82	4.1	850.25	29.16	4.8221	0.7637	3.6825
F10	36.26	27.26	25.41	2.7	1173.72	34.26	2.3004	0.8278	1.9042
F11	49.58	20.12	17.46	2.3	1102.76	33.21	2.0857	0.8150	1.6997
F12	33.35	18.32	15.84	3.5	672.95	25.94	5.2010	0.7203	3.7463

Table 0.105. *Point load strength of Stop MS-9 weathered dry marl*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	30.10	21.35	17.51	1.0	671.40	25.91	1.4894	0.7199	1.0722
W2	23.38	16.41	13.75	0.9	409.52	20.24	2.1977	0.6362	1.3981
W3	32.87	20.08	18.03	0.8	754.96	27.48	1.0597	0.7413	0.7855
W4	26.71	19.80	17.81	1.3	605.99	24.62	2.1452	0.7017	1.5052
W5	34.07	22.82	20.35	1.4	883.22	29.72	1.5851	0.7710	1.2221
W6	34.04	21.47	17.81	1.5	772.30	27.79	1.9423	0.7455	1.4480
W7	26.21	20.95	17.25	1.2	575.95	24.00	2.0835	0.6928	1.4435
W8	39.17	30.83	28.30	1.5	1412.12	37.58	1.0622	0.8669	0.9209
W9	39.63	20.35	19.81	0.8	1000.09	31.62	0.7999	0.7953	0.6362
W10	30.36	24.96	21.16	0.9	818.37	28.61	1.0998	0.7564	0.8319
W11	26.40	19.15	16.72	1.2	562.30	23.71	2.1341	0.6887	1.4697
W12	21.57	19.29	16.35	1.6	449.26	21.20	3.5614	0.6511	2.3188
W13	27.02	13.29	12.42	1.3	427.50	20.68	3.0409	0.6431	1.9555
W14	20.09	18.27	16.82	0.7	430.46	20.75	1.6262	0.6442	1.0475

Table 0.106. *Point load strength of Stop MS-9 fresh saturated marl*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	26.27	17.08	13.43	1.8	449.43	21.20	4.0050	0.6512	2.6079
F2	29.07	20.17	15.87	1.7	587.70	24.24	2.8927	0.6963	2.0142
F3	45.47	29.97	23.46	1.7	1358.89	36.86	1.2510	0.8586	1.0742
F4	34.29	31.19	28.51	0.9	1245.36	35.29	0.7227	0.8401	0.6071
F5	32.16	25.46	21.60	1.3	884.91	29.75	1.4691	0.7713	1.1331
F6	31.73	21.29	19.60	2.2	792.24	28.15	2.7769	0.7503	2.0835
F7	39.13	16.43	13.08	1.7	652.00	25.53	2.6074	0.7146	1.8633
F8	34.26	25.67	24.17	1.5	1054.86	32.48	1.4220	0.8060	1.1461
F9	29.48	14.55	12.47	2.3	468.30	21.64	4.9114	0.6579	3.2311
F10	38.20	20.20	15.53	1.5	755.73	27.49	1.9848	0.7415	1.4717
F11	35.71	24.77	17.44	1.8	793.35	28.17	2.2689	0.7506	1.7029
F12	30.48	14.30	12.46	1.7	483.80	22.00	3.5139	0.6633	2.3306

Table 0.107. *Point load strength of Stop MS-9 weathered saturated marl*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	28.45	22.48	17.53	0.50	635.32	25.21	0.7870	0.7100	0.5588
W2	30.16	16.65	13.88	0.60	533.27	23.09	1.1251	0.6796	0.7646
W3	29.77	28.68	25.88	0.80	981.46	31.33	0.8151	0.7916	0.6452
W4	30.50	16.89	15.07	0.90	585.52	24.20	1.5371	0.6957	1.0693
W5	29.40	27.29	24.45	0.60	915.71	30.26	0.6552	0.7780	0.5097
W6	32.52	18.42	16.03	0.80	664.07	25.77	1.2047	0.7179	0.8649
W7	33.15	28.59	26.15	0.60	1104.30	33.23	0.5433	0.8152	0.4429
W8	22.85	15.25	13.08	0.80	380.74	19.51	2.1012	0.6247	1.3126
W9	24.86	18.96	15.07	0.80	477.25	21.85	1.6763	0.6610	1.1080
W10	26.71	21.76	20.84	0.70	709.09	26.63	0.9872	0.7298	0.7204
W11	38.43	27.48	21.48	0.50	1051.56	32.43	0.4755	0.8053	0.3829
W12	24.93	18.24	14.12	0.20	448.42	21.18	0.4460	0.6508	0.2903

Table 0.108. *Point load strength of Stop MS-9 fresh dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	47.70	28.05	24.32	1.8	1477.79	38.44	1.2180	0.8768	1.0680
F2	35.21	19.98	18.61	3.1	834.72	28.89	3.7138	0.7602	2.8231
F3	32.76	21.62	20.19	4.2	842.58	29.03	4.9847	0.7619	3.7980
F4	44.69	29.45	22.58	5.6	1285.48	35.85	4.3564	0.8468	3.6890
F5	40.48	29.87	28.79	6.1	1484.61	38.53	4.1088	0.8778	3.6069
F6	46.11	25.55	18.42	1.4	1081.97	32.89	1.2939	0.8111	1.0495
F7	28.01	16.22	13.43	4.2	479.20	21.89	8.7646	0.6617	5.7993
F8	33.60	17.20	13.95	3.4	597.10	24.44	5.6942	0.6991	3.9807
F9	25.89	19.96	15.02	1.5	495.37	22.26	3.0280	0.6672	2.0203
F10	19.55	17.15	10.87	1.3	270.71	16.45	4.8022	0.5736	2.7547
F11	25.67	14.63	13.78	1.2	450.61	21.23	2.6630	0.6516	1.7352
F12	22.57	17.01	16.68	1.7	479.58	21.90	3.5448	0.6618	2.3460
F13	21.28	13.00	9.90	2.1	268.37	16.38	7.8250	0.5724	4.4790
F14	19.05	16.54	14.99	2.0	363.77	19.07	5.4980	0.6176	3.3957
F15	18.13	13.76	12.96	0.9	299.32	17.30	3.0068	0.5882	1.7687

Table 0.109. *Point load strength of Stop MS-9 weathered dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	30.21	22.38	20.12	0.9	774.30	27.83	1.1623	0.7460	0.8671
W2	25.18	20.71	12.61	0.7	404.48	20.11	1.7306	0.6342	1.0976
W3	18.45	14.33	12.47	1.5	293.08	17.12	5.1180	0.5851	2.9948
W4	26.28	18.07	17.48	1.3	585.19	24.19	2.2215	0.6956	1.5452
W5	26.16	16.66	15.20	0.9	506.54	22.51	1.7768	0.6709	1.1921
W6	27.52	17.80	15.98	1.2	560.22	23.67	2.1420	0.6880	1.4738
W7	23.17	18.27	14.98	0.7	442.15	21.03	1.5832	0.6485	1.0267
W8	16.30	13.52	11.96	0.8	248.34	15.76	3.2214	0.5614	1.8085
W9	18.27	15.30	14.30	0.6	332.82	18.24	1.8028	0.6040	1.0890
W10	16.84	13.93	10.88	0.5	233.40	15.28	2.1422	0.5528	1.1842
W11	15.24	11.31	10.08	0.4	195.69	13.99	2.0440	0.5289	1.0812
W12	19.52	17.30	14.01	0.8	348.38	18.66	2.2964	0.6110	1.4030

Table 0.110. *Point load strength of Stop MS-9 fresh saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	25.95	22.26	10.13	2.80	334.87	18.30	8.3614	0.6050	5.0584
F2	27.01	16.53	11.63	2.10	400.16	20.00	5.2479	0.6325	3.3194
F3	25.06	21.14	20.09	1.60	641.34	25.32	2.4948	0.7117	1.7755
F4	25.17	20.22	13.22	1.10	423.88	20.59	0.2359	0.6417	0.1514
F5	30.31	19.01	11.03	1.20	425.88	20.64	2.8177	0.6424	1.8102
F6	18.94	14.53	13.68	0.70	330.06	18.17	2.1208	0.6028	1.2784
F7	20.88	16.24	15.42	1.20	410.15	20.25	2.9257	0.6364	1.8620
F8	23.14	17.65	37.23	1.70	445.41	21.10	3.8167	0.6497	2.4797
F9	27.65	13.09	15.48	0.90	332.86	18.24	2.7039	0.6041	1.6333
F10	27.29	15.79	14.96	0.80	514.51	22.68	1.5549	0.6735	1.0473
F11	23.18	16.16	13.98	1.20	427.58	20.68	2.8065	0.6431	1.8048
F12	19.56	17.05	13.97	0.90	388.21	19.70	2.3183	0.6277	1.4553

Table 0.111. *Point load strength of Stop MS-9 weathered saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	23.41	19.99	16.10	1.10	480.13	21.91	2.2911	0.6620	1.5167
W2	30.00	24.79	18.46	0.70	705.48	26.56	0.9922	0.7288	0.7232
W3	42.52	28.89	26.49	0.60	1434.85	37.88	0.4182	0.8704	0.3640
W4	29.34	22.45	21.66	0.40	809.56	28.45	0.4941	0.7544	0.3727
W5	32.36	27.23	24.02	1.20	990.17	31.47	1.2119	0.7933	0.9614
W6	40.55	26.78	25.86	0.80	1335.83	36.55	0.5989	0.8550	0.5120
W7	30.84	20.88	18.20	0.60	715.02	26.74	0.8391	0.7313	0.6137
W8	24.07	13.62	11.98	0.90	367.34	19.17	2.4501	0.6191	1.5169
W9	26.99	20.14	19.15	0.50	658.42	25.66	0.7594	0.7164	0.5440
W10	32.28	22.87	15.13	0.10	622.16	24.94	0.1607	0.7063	0.1135
W11	23.35	16.41	14.08	0.40	418.81	20.46	0.9551	0.6398	0.6110
W12	21.50	14.68	11.61	1.10	317.98	17.83	3.4593	0.5972	2.0659
W13	27.57	22.34	16.13	0.80	566.50	23.80	1.4122	0.6899	0.9743
W14	31.17	11.88	8.75	1.10	347.44	18.64	3.1660	0.6106	1.9331
W15	22.33	19.08	19.99	0.90	568.63	23.85	1.5827	0.6906	1.0930
W16	21.38	11.84	9.66	0.40	263.10	16.22	1.5204	0.5696	0.8659
W17	20.87	13.75	10.98	0.30	291.91	17.09	1.0277	0.5846	0.6008
W18	24.62	13.63	11.75	0.30	368.52	19.20	0.8141	0.6196	0.5044
W19	22.23	15.73	14.27	0.20	404.10	20.10	0.4949	0.6341	0.3138
W20	27.02	14.09	13.37	0.30	460.20	21.45	0.6519	0.6550	0.4270

Table 0.112. *Point load strength of Stop MS-10 fresh dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	21,71	16,12	13,11	4,4	362,57	19,04	12,1356	0,6171	7,4890
F2	50,70	21,96	15,19	9,0	981,06	31,32	9,1737	0,7915	7,2608
F3	26,93	18,04	15,76	0,4	540,66	23,25	0,7398	0,6819	0,5045
F4	35,73	22,52	17,81	2,6	810,64	28,47	3,2073	0,7546	2,4203
F5	32,33	16,07	12,06	3,9	496,69	22,29	7,8520	0,6676	5,2422
F6	28,44	22,08	20,50	1,2	742,70	27,25	1,6157	0,7383	1,1929
F7	33,12	21,43	19,43	1,1	819,77	28,63	1,3418	0,7567	1,0154
F8	28,21	26,11	22,32	4,2	802,10	28,32	5,2363	0,7526	3,9409
F9	39,60	29,43	23,41	7,0	1180,94	34,36	5,9275	0,8290	4,9141
F10	36,61	31,54	26,13	7,5	1218,62	34,91	6,1545	0,8356	5,1425
F11	43,26	33,70	30,72	3,4	1692,93	41,15	2,0084	0,9071	1,8219
F12	40,51	22,14	20,72	1,6	1069,26	32,70	1,4964	0,8087	1,2101

Table 0.113. *Point load strength of Stop MS-10 weathered dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	24,25	19,90	16,84	0,6	520,22	22,81	1,1534	0,6754	0,7790
W2	34,31	24,72	23,54	1,0	1028,86	32,08	0,9719	0,8009	0,7785
W3	31,03	20,49	18,38	2,0	726,54	26,95	2,7528	0,7342	2,0212
W4	29,17	20,05	18,47	2,0	686,33	26,20	2,9140	0,7238	2,1093
W5	35,29	26,99	25,13	0,8	1129,73	33,61	0,7081	0,8199	0,5806
W6	37,13	27,45	24,15	1,2	1142,28	33,80	1,0505	0,8222	0,8637
W7	35,19	30,34	29,93	1,2	1341,70	36,63	0,8944	0,8559	0,7655
W8	35,68	22,50	16,60	1,2	754,51	27,47	1,5904	0,7412	1,1788
W9	42,86	36,58	34,87	2,8	1903,86	43,63	1,4707	0,9342	1,3739
W10	37,78	16,34	15,28	1,3	735,39	27,12	1,7678	0,7365	1,3019
W11	35,98	27,98	24,23	2,1	1110,57	33,33	1,8909	0,8164	1,5437
W12	45,00	31,07	25,77	6,1	1477,26	38,44	4,1293	0,8768	3,6204

Table 0.114. *Point load strength of Stop MS-10 fresh saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	43,30	34,97	28,26	2,3	1558,80	39,48	1,4755	0,8886	1,3111
F2	39,74	19,90	17,82	4,9	902,12	30,04	5,4316	0,7751	4,2098
F3	47,35	25,80	23,06	2,4	1390,94	37,30	1,7254	0,8637	1,4902
F4	43,61	21,18	18,65	3,4	1036,08	32,19	3,2816	0,8023	2,6330
F5	30,52	19,71	17,54	2,2	681,94	26,11	3,2261	0,7227	2,3315
F6	38,94	27,99	24,77	4,5	1228,72	35,05	3,6624	0,8373	3,0665
F7	44,79	31,86	30,68	2,3	1750,52	41,84	1,3139	0,9148	1,2019
F8	43,82	35,30	29,40	2,6	1641,16	40,51	1,5842	0,9001	1,4260
F9	45,36	21,48	17,34	1,5	1001,96	31,65	1,4971	0,7957	1,1912
F10	42,90	24,60	24,27	3,7	1326,35	36,42	2,7896	0,8535	2,3808
F11	46,36	32,85	29,58	2,5	1746,92	41,80	1,4311	0,9143	1,3084
F12	33,11	16,41	13,37	0,5	563,92	23,75	0,8866	0,6892	0,6110

Table 0.115. *Point load strength of Stop MS-10 weathered saturated sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	28,13	18,95	17,28	0,1	619,22	24,88	0,1615	0,7055	0,1139
W2	36,19	19,75	17,47	0,3	805,40	28,38	0,3725	0,7534	0,2806
W3	33,24	23,60	23,36	0,7	989,15	31,45	0,7077	0,7931	0,5613
W4	43,82	24,20	21,04	0,2	1174,49	34,27	0,1703	0,8279	0,1410
W5	35,19	30,19	28,90	0,4	1295,53	35,99	0,3088	0,8485	0,2620
W6	36,00	19,70	17,51	3,6	803,01	28,34	4,4832	0,7528	3,3750
W7	39,88	27,25	26,35	1,1	1338,65	36,59	0,8217	0,8554	0,7029
W8	30,90	12,61	10,86	1,4	427,48	20,68	3,2750	0,6430	2,1060
W9	42,28	21,89	20,15	1,7	1085,28	32,94	1,5664	0,8117	1,2715
W10	34,27	31,16	30,01	0,5	1310,12	36,20	0,3816	0,8508	0,3247
W11	46,98	29,33	27,28	2,2	1632,63	40,41	1,3475	0,8990	1,2114
W12	39,21	24,49	21,74	0,5	1085,89	32,95	0,4605	0,8118	0,3738

Table 0.116. *Point load strength of Stop MS-11 fresh dry volcanogenic sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	46,45	22,76	21,69	25,0	1283,44	35,83	19,4789	0,8465	16,4882
F2	39,76	18,44	16,66	11,0	843,82	29,05	13,0359	0,7622	9,9362
F3	36,67	28,40	21,17	11,0	988,92	31,45	11,1232	0,7931	8,8214
F4	44,07	27,08	23,45	9,3	1316,49	36,28	7,0643	0,8519	6,0178
F5	32,16	23,91	20,83	0,8	853,37	29,21	0,9375	0,7644	0,7166
F6	45,61	30,03	25,20	2,8	1464,17	38,26	1,9123	0,8748	1,6729
F7	43,43	28,05	20,84	3,3	1152,97	33,96	2,8622	0,8241	2,3587
F8	28,83	23,95	22,70	7,9	833,68	28,87	9,4760	0,7599	7,2010
F9	34,20	31,45	28,04	7,8	1221,62	34,95	6,3850	0,8361	5,3384
F10	27,58	23,61	19,30	4,1	678,08	26,04	6,0465	0,7217	4,3635
F11	27,26	16,06	11,65	4,5	404,56	20,11	11,1232	0,6343	7,0549
F12	26,32	20,02	18,46	5,9	618,94	24,88	9,5324	0,7054	6,7241

Table 0.117. *Point load strength of Stop MS-11 weathered dry volcanogenic sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	54,35	32,56	19,48	25,0	1348,71	36,72	18,5362	0,8570	15,8860
W2	41,36	34,38	29,76	11,0	1567,99	39,60	7,0153	0,8899	6,2431
W3	57,51	24,68	20,03	11,0	1467,42	38,31	7,4961	0,8753	6,5613
W4	35,78	29,21	26,39	9,3	1202,85	34,68	7,7317	0,8329	6,4393
W5	29,53	26,33	22,79	0,8	857,31	29,28	0,9332	0,7652	0,7141
W6	44,99	27,27	24,75	2,8	1418,47	37,66	1,9740	0,8679	1,7132
W7	38,76	24,55	19,70	3,3	972,70	31,19	3,3926	0,7898	2,6794
W8	40,58	24,60	17,96	7,9	928,43	30,47	8,5090	0,7806	6,6425
W9	53,02	20,80	14,73	7,8	994,88	31,54	7,8401	0,7943	6,2270
W10	46,89	25,15	21,44	4,1	1280,66	35,79	3,2015	0,8460	2,7085
W11	41,25	21,41	15,34	4,5	806,08	28,39	5,5826	0,7535	4,2067
W12	43,19	27,74	23,47	5,9	1291,30	35,93	4,5690	0,8478	3,8734

Table 0.118. *Point load strength of Stop MS-11 fresh saturated volcanogenic sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	30,09	22,16	19,81	8,5	759,34	27,56	11,1939	0,7424	8,3101
F2	35,65	24,55	18,40	1,8	835,62	28,91	2,1541	0,7604	1,6379
F3	54,74	19,95	17,13	1,4	1194,52	34,56	1,1720	0,8314	0,9744
F4	43,44	35,51	33,48	2,5	1852,70	43,04	1,3494	0,9278	1,2520
F5	47,14	33,11	29,27	1,3	1757,69	41,92	0,7396	0,9157	0,6773
F6	30,90	24,45	22,57	4,6	888,42	29,81	5,1777	0,7721	3,9977
F7	37,64	28,64	20,36	6,0	976,24	31,24	6,1460	0,7905	4,8585
F8	39,94	36,12	29,24	2,1	1487,70	38,57	1,4116	0,8783	1,2398
F9	37,31	19,90	17,75	0,3	843,63	29,05	0,3556	0,7622	0,2710
F10	43,38	30,01	23,00	7,0	1271,01	35,65	5,5074	0,8444	4,6505
F11	22,32	18,93	17,47	3,5	496,73	22,29	7,0461	0,6676	4,7043
F12	28,16	22,46	18,12	7,9	650,01	25,50	12,1536	0,7141	8,6786

Table 0.119. *Point load strength of Stop MS-11 weathered saturated volcanogenic sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 $(mm)^2$	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	43,21	34,46	31,94	4,3	1758,12	41,93	2,4458	0,9158	2,2397
W2	50,68	22,41	19,92	2,6	1286,05	35,86	2,0217	0,8469	1,7122
W3	30,93	26,41	21,99	2,2	866,43	29,44	2,5391	0,7673	1,9482
W4	29,43	24,90	19,70	5,1	738,56	27,18	6,9053	0,7372	5,0909
W5	39,73	28,87	25,60	2,1	1295,65	36,00	1,6208	0,8485	1,3752
W6	33,01	18,27	14,70	5,4	618,15	24,86	8,7358	0,7052	6,1601
W7	34,99	30,77	28,13	1,4	1253,85	35,41	1,1166	0,8415	0,9396
W8	40,63	25,95	22,24	2,1	1151,10	33,93	1,8243	0,8237	1,5028
W9	30,01	27,75	23,82	4,6	910,62	30,18	5,0515	0,7769	3,9244
W10	48,34	22,36	20,70	1,5	1274,70	35,70	1,1767	0,8450	0,9944
W11	32,91	28,30	27,18	2,3	1139,48	33,76	2,0185	0,8217	1,6585
W12	27,52	20,33	15,66	6,0	549,00	23,43	10,9290	0,6846	7,4815

Table 0.120. *Point load strength of Stop MS-12 fresh dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
F1	34,72	29,12	24,18	1,5	1069,46	32,70	1,4026	0,8087	1,1343
F2	41,07	19,23	18,01	0,1	942,26	30,70	0,1061	0,7835	0,0832
F3	26,09	17,45	10,71	0,4	355,95	18,87	1,1237	0,6143	0,6903
F4	29,05	14,34	11,29	0,8	417,80	20,44	1,9148	0,6394	1,2243
F5	20,07	17,78	13,68	0,5	349,75	18,70	1,4296	0,6116	0,8743
F6	43,71	36,02	31,97	2,5	1780,14	42,19	1,4044	0,9186	1,2901
F7	29,55	16,50	14,05	0,6	528,89	23,00	1,1345	0,6782	0,7694
F8	32,49	17,73	14,49	2,4	599,72	24,49	4,0019	0,6998	2,8007
F9	31,26	18,93	16,59	0,3	660,64	25,70	0,4541	0,7170	0,3256
F10	34,53	21,67	18,96	0,4	834,00	28,88	0,4796	0,7600	0,3645
F11	28,59	24,53	20,84	1,0	759,00	27,55	1,3175	0,7423	0,9780
F12	26,64	15,35	12,17	1,2	413,00	20,32	2,9055	0,6375	1,8524

Table 0.121. *Point load strength of Stop MS-12 weathered dry sandstone*

Sample No	W (mm)	D (mm)	D' (mm)	P (kN)	De^2 (mm^2)	De (mm)	Is (MPa)	F	Is(50) (MPa)
W1	32,07	23,02	20,07	1,4	819,93	28,63	1,7075	0,7568	1,2921
W2	31,94	21,16	17,37	0,1	706,75	26,58	0,1415	0,7292	0,1032
W3	33,57	23,22	20,96	0,4	896,34	29,94	0,4463	0,7738	0,3453
W4	25,51	22,55	17,19	0,8	558,62	23,64	1,4321	0,6875	0,9846
W5	24,12	12,58	10,38	0,4	318,94	17,86	1,2542	0,5976	0,7495
W6	33,31	26,74	23,70	0,8	1005,66	31,71	0,7955	0,7964	0,6335
W7	40,61	19,44	13,58	0,1	702,53	26,51	0,1423	0,7281	0,1036
W8	40,28	34,23	31,53	0,4	1617,87	40,22	0,2472	0,8969	0,2218
W9	28,60	22,23	20,77	0,4	756,72	27,51	0,5286	0,7417	0,3921
W10	26,87	18,28	17,62	0,6	603,12	24,56	0,9948	0,7008	0,6972
W11	31,60	22,90	18,51	0,9	745,12	27,30	1,2079	0,7389	0,8925
W12	35,55	27,17	24,89	0,8	1127,18	33,57	0,7097	0,8194	0,5816

Table 0.122. *Point load strength of Stop MS-12 fresh saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
F1	51,77	18,97	13,77	0,1	908,12	30,14	0,1101	0,7763	0,0855
F2	34,57	29,18	23,21	0,6	1022,13	31,97	0,5870	0,7996	0,4694
F3	21,31	20,53	18,90	0,1	513,07	22,65	0,1949	0,6731	0,1312
F4	43,97	16,34	12,42	0,2	695,68	26,38	0,2875	0,7263	0,2088
F5	28,72	17,04	11,38	0,2	416,35	20,40	0,4804	0,6388	0,3069
F6	41,88	15,50	11,48	0,1	612,46	24,75	0,1633	0,7035	0,1149
F7	38,52	17,69	10,99	0,4	539,28	23,22	0,7417	0,6815	0,5055
F8	34,24	16,45	11,54	0,1	503,35	22,44	0,1987	0,6699	0,1331
F9	37,23	19,48	15,03	0,1	712,82	26,70	0,1403	0,7307	0,1025
F10	39,83	16,92	12,91	0,3	655,04	25,59	0,4580	0,7155	0,3277
F11	31,16	22,43	20,38	0,1	808,97	28,44	0,1236	0,7542	0,0932
F12	48,13	17,28	12,22	0,1	749,23	27,37	0,1335	0,7399	0,0988

Table 0.123. *Point load strength of Stop MS-12 weathered saturated sandstone*

Sample No	**W (mm)**	**D (mm)**	**D' (mm)**	**P (kN)**	**De^2 (mm)^2**	**De (mm)**	**Is (MPa)**	**F**	**Is(50) (MPa)**
W1	37,07	18,51	14,19	0,1	670,09	25,89	0,1492	0,7195	0,1074
W2	28,88	23,63	20,88	0,3	768,17	27,72	0,3905	0,7445	0,2908
W3	45,62	32,80	29,00	0,2	1685,32	41,05	0,1187	0,9061	0,1075
W4	30,29	18,45	17,13	0,1	660,98	25,71	0,1513	0,7171	0,1085
W5	54,01	20,26	14,25	0,5	980,44	31,31	0,5100	0,7914	0,4036
W6	39,73	25,73	20,84	0,1	1054,74	32,48	0,0948	0,8059	0,0764
W7	30,80	19,36	17,03	0,1	668,18	25,85	0,1497	0,7190	0,1076
W8	30,12	20,43	14,61	0,1	560,58	23,68	0,1784	0,6881	0,1228
W9	41,91	30,73	27,55	0,2	1470,85	38,35	0,1360	0,8758	0,1191
W10	50,63	21,58	18,58	0,2	1198,35	34,62	0,1669	0,8321	0,1389
W11	41,51	19,20	18,22	0,1	963,46	31,04	0,1038	0,7879	0,0818
W12	27,01	21,02	19,52	0,1	671,64	25,92	0,1489	0,7199	0,1072

Table 0.124. *Slake durability of MS-1*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Limestone	562.56	553.02	98.30	549.27	97.64	504.95	89.76	Type I	High
W	Limestone	566.96	559.23	98.64	554.70	97.84	501.06	88.38	Type II	High

Table 0.125. *Slake durability of MS-2.1*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	512.99	510.81	99.58	509.75	99.37	496.50	96.79	Type I	Very High
W	Marl	574.73	571.48	99.43	570.11	99.20	551.64	95.98	Type I	Very High

Table 0.126. *Slake durability of MS-2.2*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	532.46	530.51	99.63	529.83	99.51	520.18	97.69	Type I	Very High
W	Marl	584.88	582.32	99.56	581.21	99.37	570.83	97.60	Type I	Very High

Table 0.127. *Slake durability of MS-2.3*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
W	Marl	536.77	524.37	97.69	514.27	95.81	399.64	74.45	Type II	High

Table 0.128. *Slake durability of MS-3*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	565.15	562.64	99.56	560.89	99.25	542.82	96.05	Type I	Very High
W	Marl	510.44	506.55	99.24	504.88	98.91	473.55	92.77	Type I	Very High

Table 0.129. *Slake durability of MS-4*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	579.54	574.67	99.16	572.82	98.84	551.18	95.11	Type I	Very High
W	Marl	568.01	562.79	99.08	560.48	98.67	538.18	94.75	Type II	Very High

Table 0.130. *Slake durability of MS-5*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	542.26	526.21	97.04	513.63	94.72	420.09	77.47	Type II	Medium High
W	Marl	529.93	503.81	95.07	486.58	91.82	368.58	69.55	Type II	Medium High

Table 0.131. *Slake durability of MS-6*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	547.26	538.80	98.45	534.06	97.59	491.90	89.88	Type I	High
W	Sandstone	559.11	546.94	97.82	540.44	96.66	481.08	86.04	Type II	High
W	Mudstone	537.23	529.47	98.56	525.05	97.73	483.50	90.00	Type II	High

Table 0.132. *Slake durability of MS-7.1*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Limestone	532.73	529.74	99.44	528.68	99.24	514.70	96.62	Type I	Very High
W	Limestone	588.09	581.93	98.95	579.10	98.47	550.96	93.69	Type I	Very High

Table 0.133. *Slake durability of MS-7.2*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Limestone	565.14	561.95	99.44	560.41	99.16	542.55	96.00	Type I	Very High
W	Limestone	592.02	587.31	99.20	585.35	98.87	563.01	95.10	Type I	Very High

Table 0.134. *Slake durability of MS-8.1*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	554.72	550.33	99.21	547.70	98.73	523.25	94.33	Type I	Very High
W	Sandstone	510.14	503.78	98.75	500.45	98.10	471.03	92.33	Type I	Very High

Table 0.135. *Slake durability of MS-8.2*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	571.50	567.09	99.23	564.41	98.76	541.72	94.79	Type I	Very High
W	Sandstone	591.90	540.40	91.30	506.48	85.57	245.91	41.55	Type II	Medium

Table 0.136. *Slake durability of MS-9*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Marl	548.81	522.01	95.12	500.42	91.18	428.43	78.07	Type II	Medium High
W	Marl	544.36	442.96	81.37	378.30	69.49	46.64	8.57	Type III	Medium
F	Sandstone	527.11	347.25	65.88	274.36	52.05	57.75	10.96	Type III	Low
W	Sandstone	536.64	396.26	73.84	315.18	58.73	43.35	8.08	Type III	Low

Table 0.137. *Slake durability of MS-10*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	564.44	558.45	98.94	555.24	98.37	522.90	92.64	Type I	High
W	Sandstone	543.19	534.86	98.47	528.83	97.36	461.66	84.99	Type II	High

Table 0.138. *Slake durability of MS-11*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	592.44	587.06	99.09	583.73	98.53	556.76	93.98	Type I	Very High
W	Sandstone	536.14	528.17	98.51	524.73	97.87	498.54	92.99	Type I	High

Table 0.139. *Slake durability of MS-12*

	Rock Type	Start W. (g)	1st Cycle W. (g)	Id(1)	2nd Cycle W. (g)	Id(2)	20th Cycle W. (g)	Id(20)	Type	Durability
F	Sandstone	554.88	532.26	95.92	512.45	92.35	296.04	53.35	Type II	Medium High
W	Sandstone	546.22	497.23	91.03	462.71	84.71	227.64	41.68	Type III	Medium

Table 0.140 *Detailed results of the slake durability tests*

Slope	C	Rock Type	Id(1)	Id(2)	Id(3)	Id(4)	Id(5)	Id(6)	Id(7)	Id(8)	Id(9)	Id(10)	Id(11)	Id(12)	Id(13)	Id(14)	Id(15)	Id(16)	Id(17)	Id(18)	Id(19)	Id(20)
MS-1	F	Limestone	98.30	97.64	97.02	96.38	95.69	95.14	94.75	94.33	93.91	93.46	93.05	92.67	92.22	91.89	91.44	91.11	90.75	90.41	90.08	89.76
	W		98.64	97.84	97.09	96.82	96.48	95.85	95.27	94.64	94.12	93.59	93.03	92.48	91.95	91.28	90.66	90.26	89.73	89.32	88.87	88.38
MS-2.1	F	Marl	99.58	99.37	99.23	99.00	98.74	98.62	98.44	98.37	98.12	98.01	97.91	97.73	97.60	97.39	97.29	97.19	97.07	96.95	96.92	96.79
	W		99.43	99.20	98.91	98.58	98.40	98.28	98.03	97.85	97.62	97.53	97.38	97.27	97.11	97.00	96.66	96.50	96.34	96.18	96.13	95.98
MS-2.2	F	Marl	99.63	99.51	99.32	99.10	98.97	98.88	98.70	98.61	98.54	98.51	98.42	98.36	98.23	98.20	97.98	97.94	97.87	97.72	97.70	97.69
	W		99.56	99.37	99.25	99.00	98.89	98.76	98.65	98.49	98.39	98.33	98.24	98.21	98.10	97.95	97.91	97.84	97.80	97.66	97.62	97.60
MS-2.3	W	Marl	97.69	95.81	93.79	91.41	89.13	87.08	85.58	84.17	83.01	81.89	81.05	80.28	79.68	79.26	78.27	77.73	77.16	76.39	75.52	74.45
MS-3	F	Marl	99.56	99.25	98.92	98.70	98.48	98.24	98.07	97.90	97.69	97.54	97.37	97.28	97.16	96.98	96.76	96.63	96.45	96.29	96.14	96.05
	W		99.24	98.91	98.58	98.24	98.08	97.80	97.67	97.48	97.37	97.19	97.00	96.86	96.70	96.52	96.35	95.77	94.92	94.21	93.51	92.77
MS-4	F	Marl	99.16	98.84	98.48	98.17	97.92	97.66	97.44	97.23	97.03	96.83	96.67	96.51	96.30	96.13	95.93	95.76	95.61	95.38	95.28	95.11
	W		99.08	98.67	98.38	98.05	97.77	97.57	97.33	97.10	96.83	96.66	96.45	96.32	96.10	95.89	95.70	95.56	95.40	95.20	94.94	94.75
MS-5	F	Marl	97.04	94.72	93.09	91.43	89.71	88.01	86.57	85.33	84.16	83.09	82.23	81.41	80.59	79.73	78.78	77.99	77.84	77.66	77.58	77.47
	W		95.07	91.82	89.35	87.24	85.55	84.13	82.68	81.40	80.05	78.75	77.66	76.69	75.72	74.88	73.60	72.61	71.74	71.06	70.18	69.55
MS-6	F	Sandstone	98.45	97.59	97.03	96.33	95.83	95.27	94.86	94.45	94.00	93.57	93.22	92.78	92.61	91.97	91.49	91.13	90.75	90.41	90.17	89.88
	W		97.82	96.66	95.51	94.65	93.95	93.28	92.41	91.73	91.12	90.60	90.10	89.60	89.13	88.87	88.08	87.67	87.26	86.77	86.35	86.04
	W	Mudstone	98.56	97.73	97.19	96.53	95.90	95.27	95.06	94.45	94.07	93.62	93.39	93.03	92.78	92.37	91.70	91.41	90.96	90.70	90.34	90.00
MS-7.1	F	Limestone	99.44	99.24	98.90	98.79	98.56	98.37	98.24	98.02	97.92	97.86	97.67	97.60	97.49	97.35	97.23	97.05	96.96	96.85	96.78	96.62
	W		98.95	98.47	97.98	97.65	97.32	96.98	96.72	96.35	96.07	95.94	95.65	95.48	95.27	94.98	94.76	94.51	94.31	94.10	93.92	93.69
MS-7.2	F	Limestone	99.44	99.16	99.05	98.62	98.44	98.22	98.07	97.82	97.65	97.46	97.35	97.21	96.99	96.88	96.66	96.54	96.40	96.25	96.19	96.00
	W		99.20	98.87	98.59	98.21	97.94	97.62	97.42	97.14	96.99	96.77	96.64	96.50	96.27	96.12	95.92	95.74	95.58	95.43	95.22	95.10
MS-8.1	F	Sandstone	99.21	98.73	98.53	98.08	97.75	97.47	97.24	96.93	96.87	96.75	96.21	96.06	95.80	95.59	95.32	95.13	94.89	94.71	94.35	94.33
	W		98.75	98.10	97.67	96.95	96.48	96.08	95.85	95.50	95.25	94.88	94.61	94.38	94.02	93.89	93.46	93.22	93.02	92.78	92.54	92.33
MS-8.2	F	Sandstone	99.23	98.76	98.51	98.13	97.82	97.55	97.35	97.10	96.88	96.69	96.48	96.32	96.10	95.96	95.63	95.49	95.29	95.10	94.97	94.79
	W		91.30	85.57	81.11	76.47	72.38	69.36	66.20	63.51	60.70	58.07	55.72	53.49	51.13	49.08	47.42	45.98	44.87	43.80	42.52	41.55
MS-9	F	Marl	95.12	91.18	88.47	85.55	83.70	82.27	81.50	80.91	80.60	80.22	79.94	79.69	79.47	79.24	79.02	78.86	78.69	78.55	78.26	78.07
	W		81.37	69.49	60.92	52.74	46.33	40.50	36.30	32.02	28.13	25.00	22.33	19.92	17.91	16.10	14.47	12.99	11.50	10.36	9.49	8.57
	F	Sandstone	65.88	52.05	42.97	35.52	30.25	26.20	22.10	19.61	17.69	16.45	15.20	14.43	13.79	13.26	12.55	12.02	11.74	11.35	11.19	10.96
	W		73.84	58.73	48.52	39.24	33.77	29.44	24.78	21.59	19.12	17.01	15.44	14.03	12.84	11.93	10.94	10.21	9.56	8.92	8.50	8.08
MS-10	F	Sandstone	98.94	98.37	97.77	97.29	96.87	96.51	96.26	95.91	95.55	95.35	95.01	94.79	94.45	94.17	93.86	93.60	93.36	93.11	92.90	92.64
	W		98.47	97.36	96.21	95.28	94.39	93.57	92.94	92.26	91.49	90.97	90.30	89.67	89.01	88.42	87.83	87.19	86.62	86.00	85.53	84.99
MS-11	F	Sandstone	99.09	98.53	98.26	97.70	97.37	97.03	96.72	96.48	96.14	95.78	95.52	95.32	95.13	94.95	94.71	94.55	94.39	94.23	94.07	93.98
	W		98.51	97.87	97.08	96.40	96.03	95.71	95.49	95.21	94.94	94.84	94.61	94.47	94.21	94.04	93.84	93.66	93.48	93.30	93.20	92.99
MS-12	F	Sandstone	95.92	92.35	89.13	85.18	82.21	79.06	76.42	73.78	71.15	69.24	67.10	65.43	63.42	61.83	60.29	58.81	57.28	55.77	54.66	53.35
	W		91.03	84.71	79.56	74.81	70.94	67.35	64.32	61.81	59.42	57.32	55.25	53.16	51.29	49.71	48.02	46.47	45.04	43.90	42.77	41.68

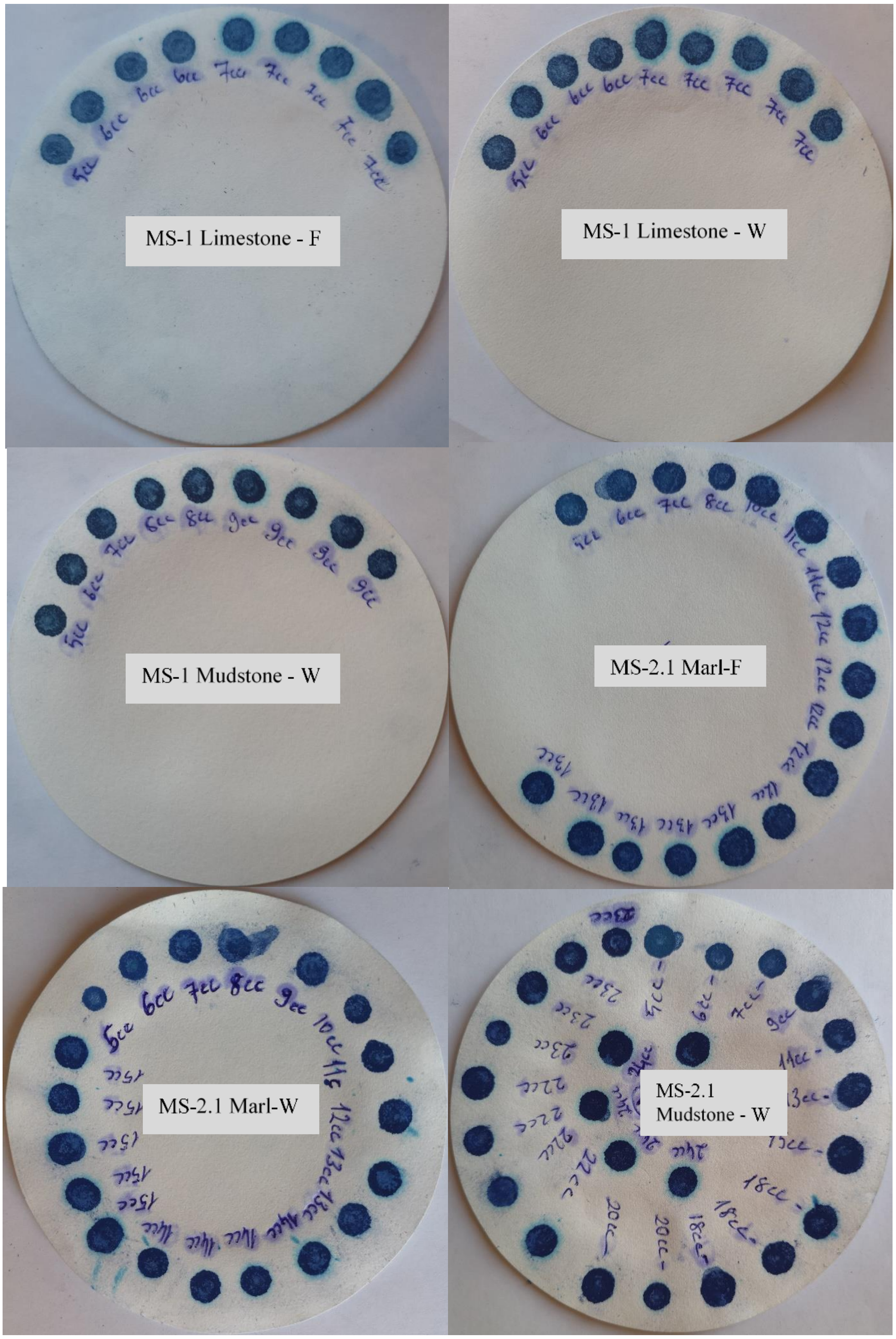


Figure 0.1 Methylene blue test results of Stop MS-1 and MS-2.1

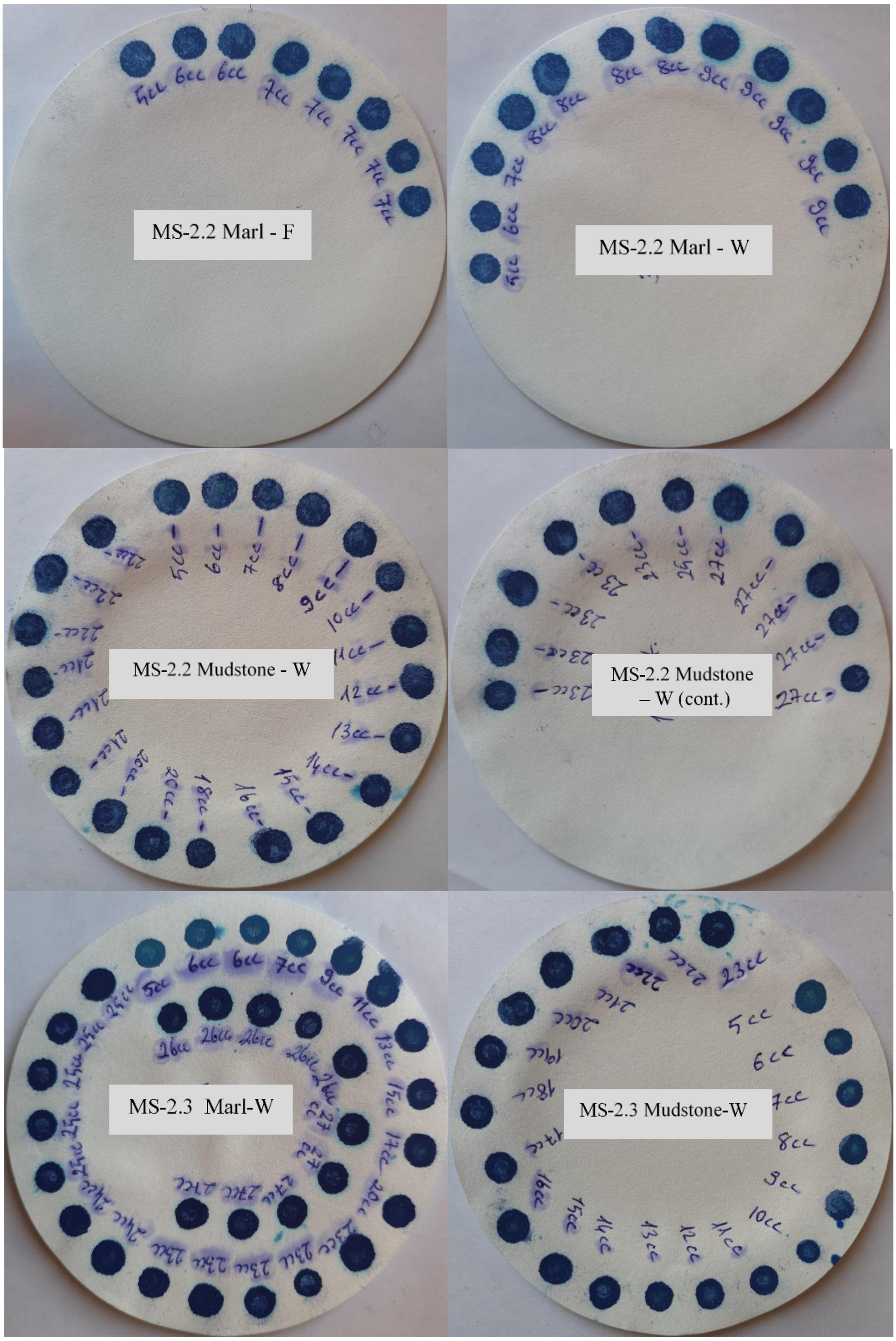


Figure 0.2. Methylene blue test results of Stop MS-2.2 and MS-2.3

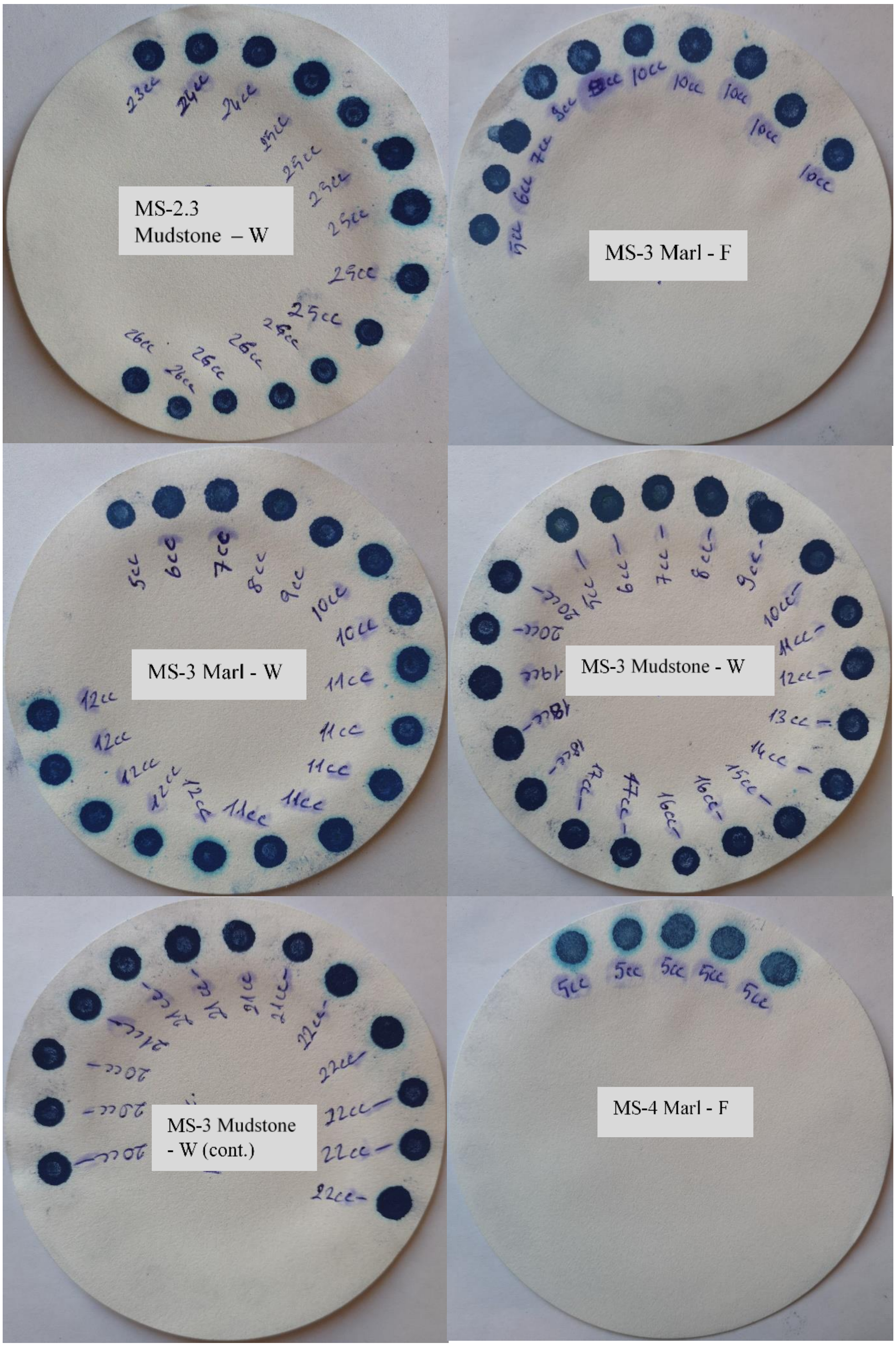


Figure 0.3. Methylene blue test results of Stop MS-2.3, MS-3 and MS-4

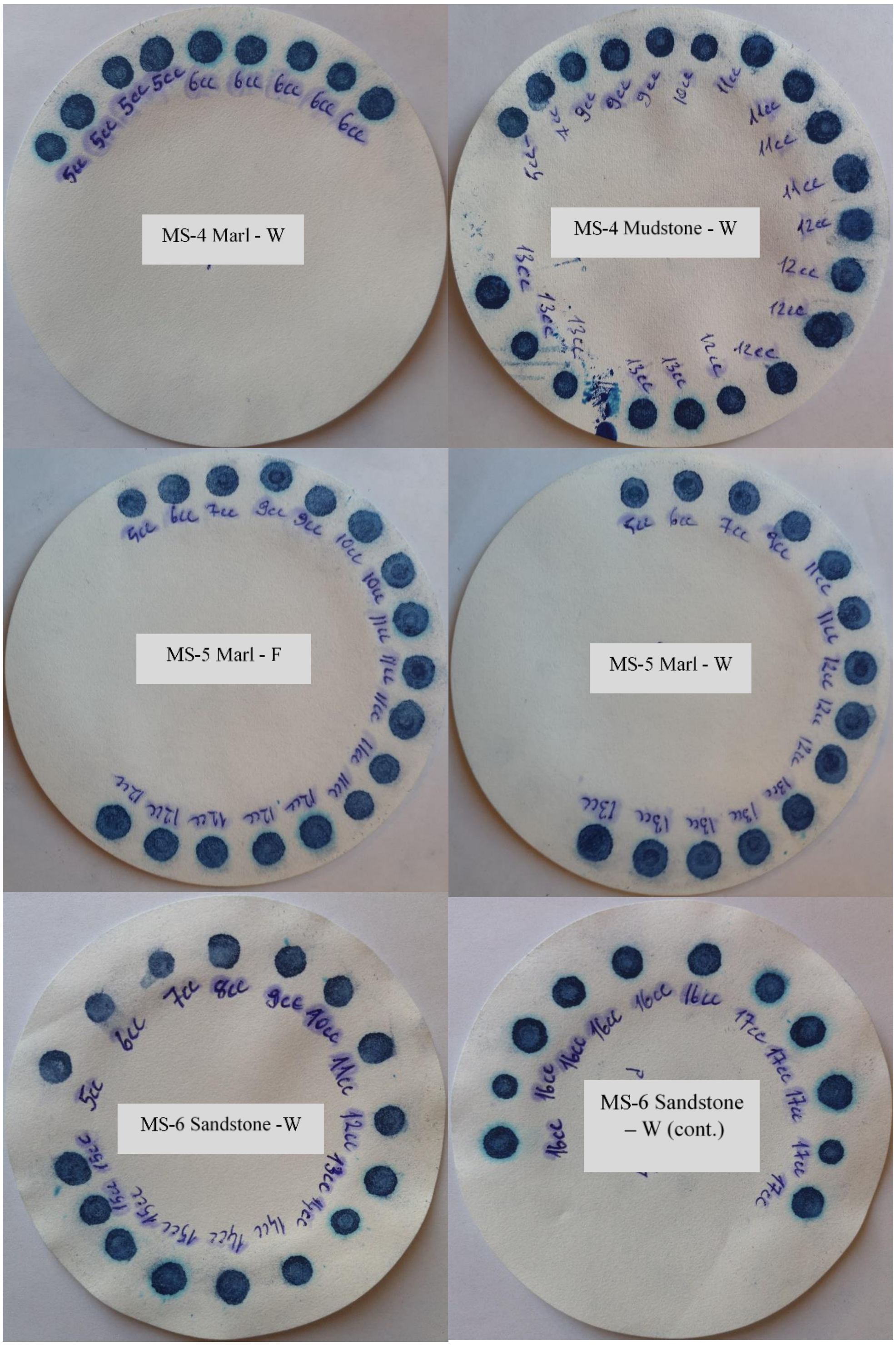


Figure 0.4. Methylene blue test results of Stop MS-4, MS-5 and MS-6

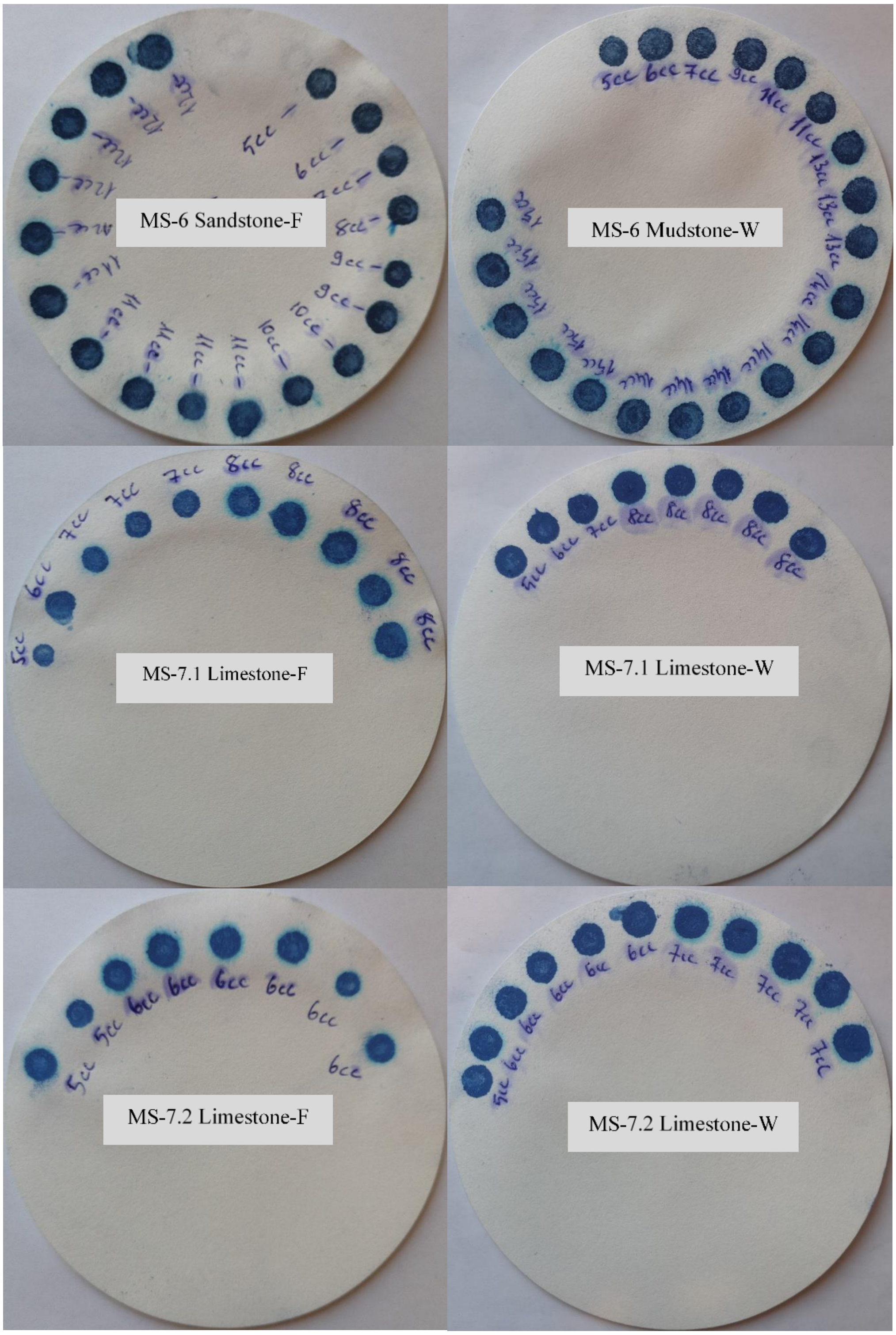


Figure 0.5. Methylene blue test results of Stop MS-6, MS-7.1 and MS-7.2

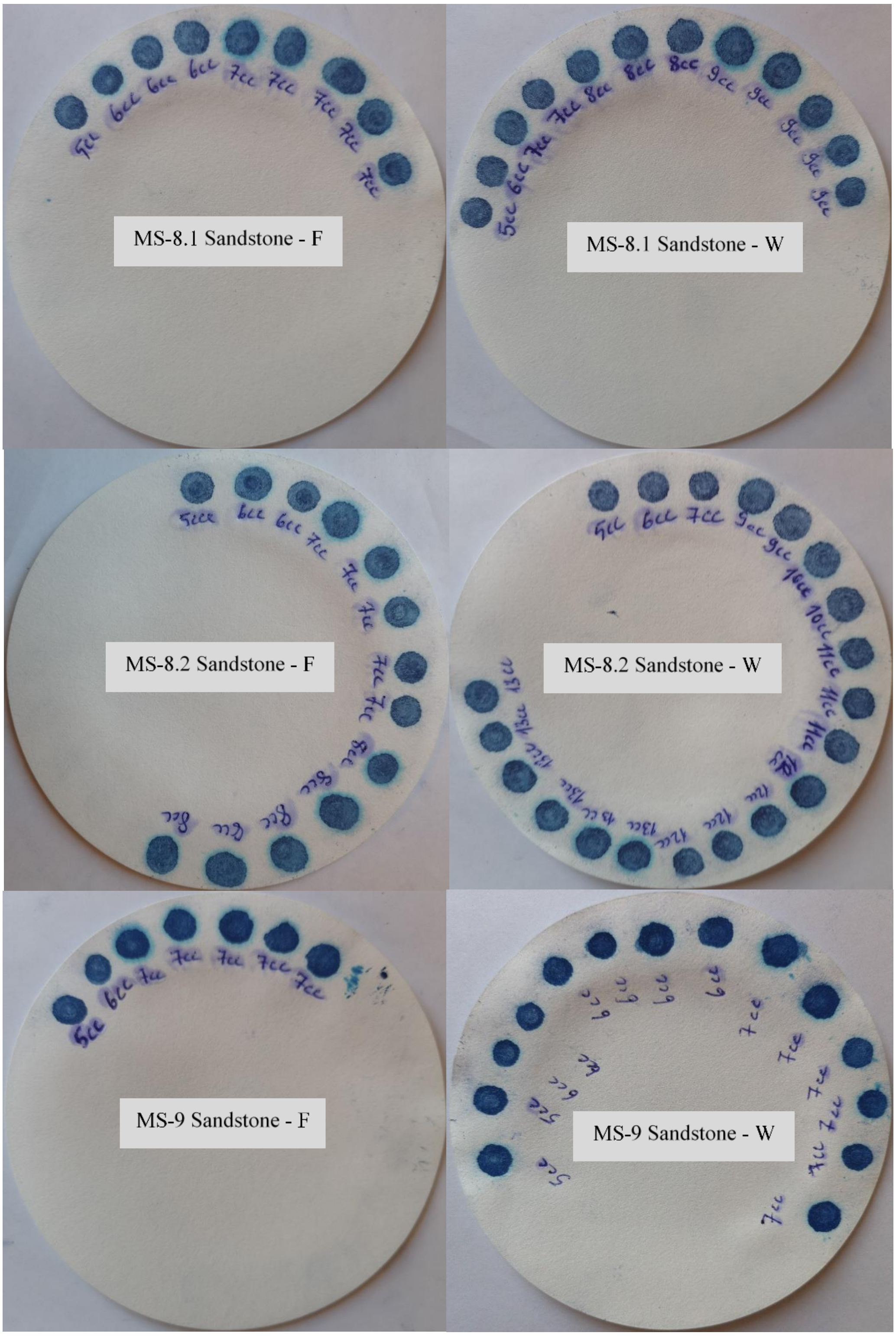


Figure 0.6. Methylene blue test results of Stop MS-8.1, MS-8.2 and MS-9

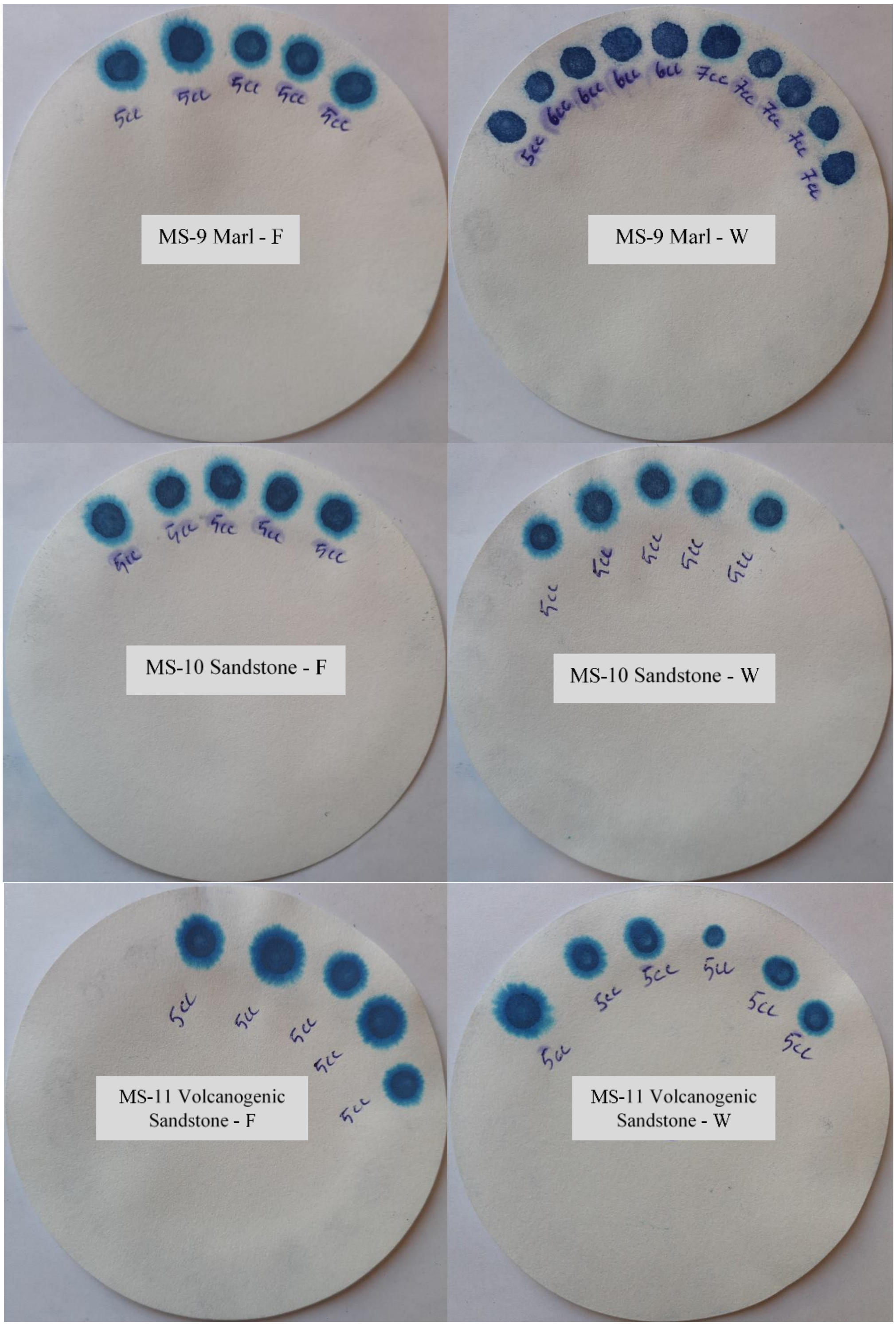


Figure 0.7. Methylene blue test results of Stop MS-9, MS-10 and MS-11

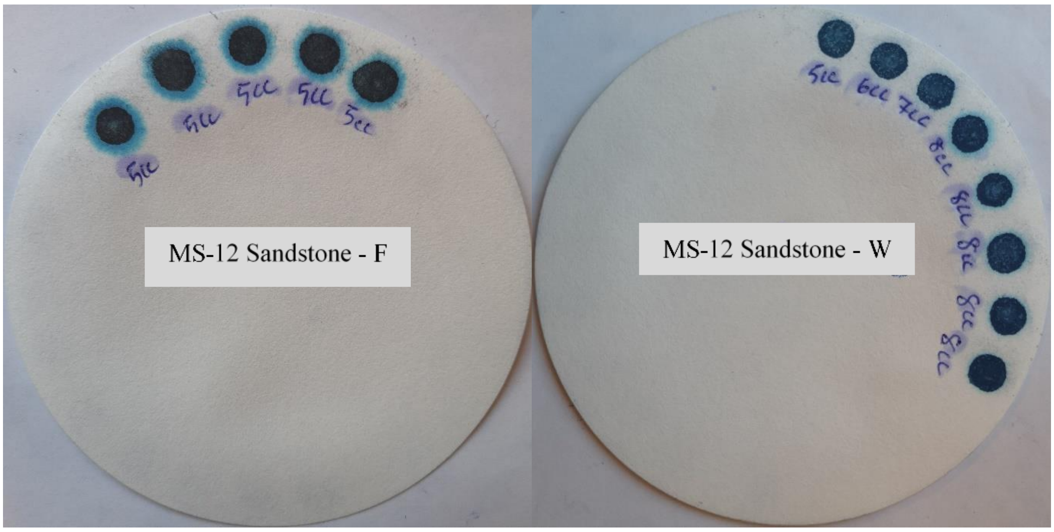
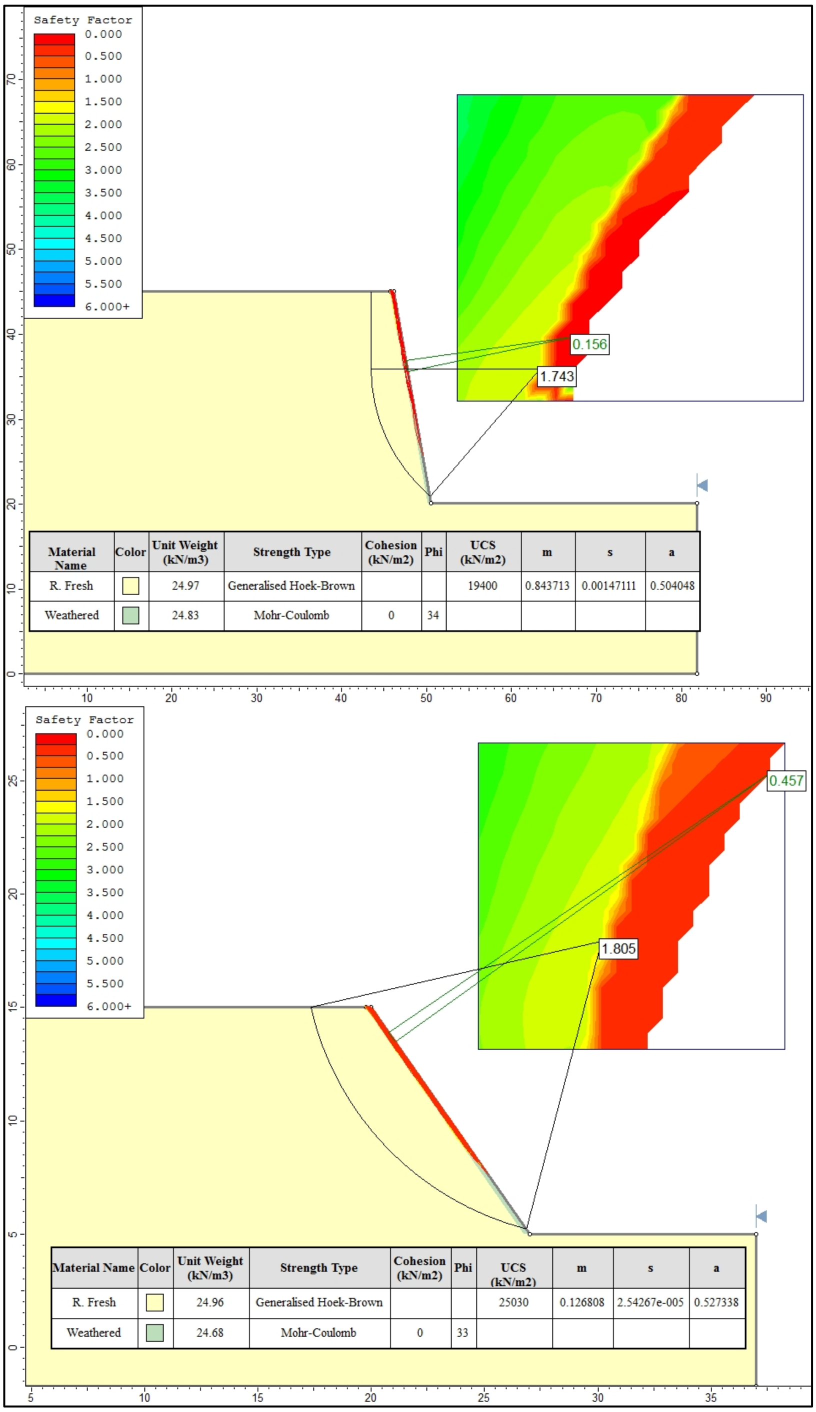


Figure 0.8. Methylene blue test results of Stop MS-12

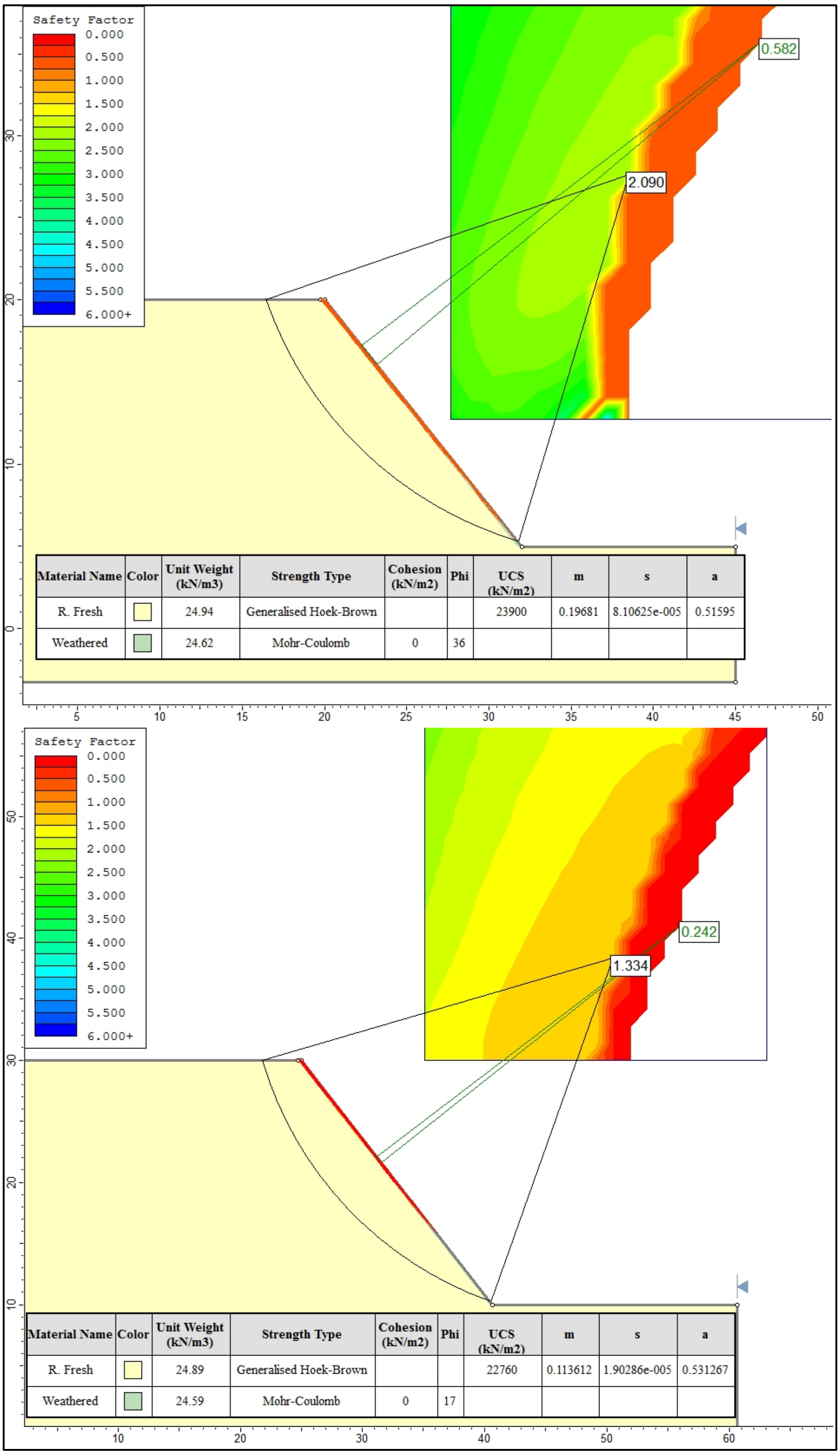
B. ANALYSES RESULTS



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.97	Generalised Hoek-Brown			19400	0.843713	0.00147111	0.504048
Weathered		24.83	Mohr-Coulomb	0	34				

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.96	Generalised Hoek-Brown			25030	0.126808	2.54267e-005	0.527338
Weathered		24.68	Mohr-Coulomb	0	33				

Figure 0.9. Limit equilibrium analyses of MS-1 and MS-2.1



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.94	Generalised Hoek-Brown			23900	0.19681	8.10625e-005	0.51595
Weathered		24.62	Mohr-Coulomb	0	36				

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.89	Generalised Hoek-Brown			22760	0.113612	1.90286e-005	0.531267
Weathered		24.59	Mohr-Coulomb	0	17				

Figure 0.10. Limit equilibrium analyses of MS-2.2 and MS-2.3

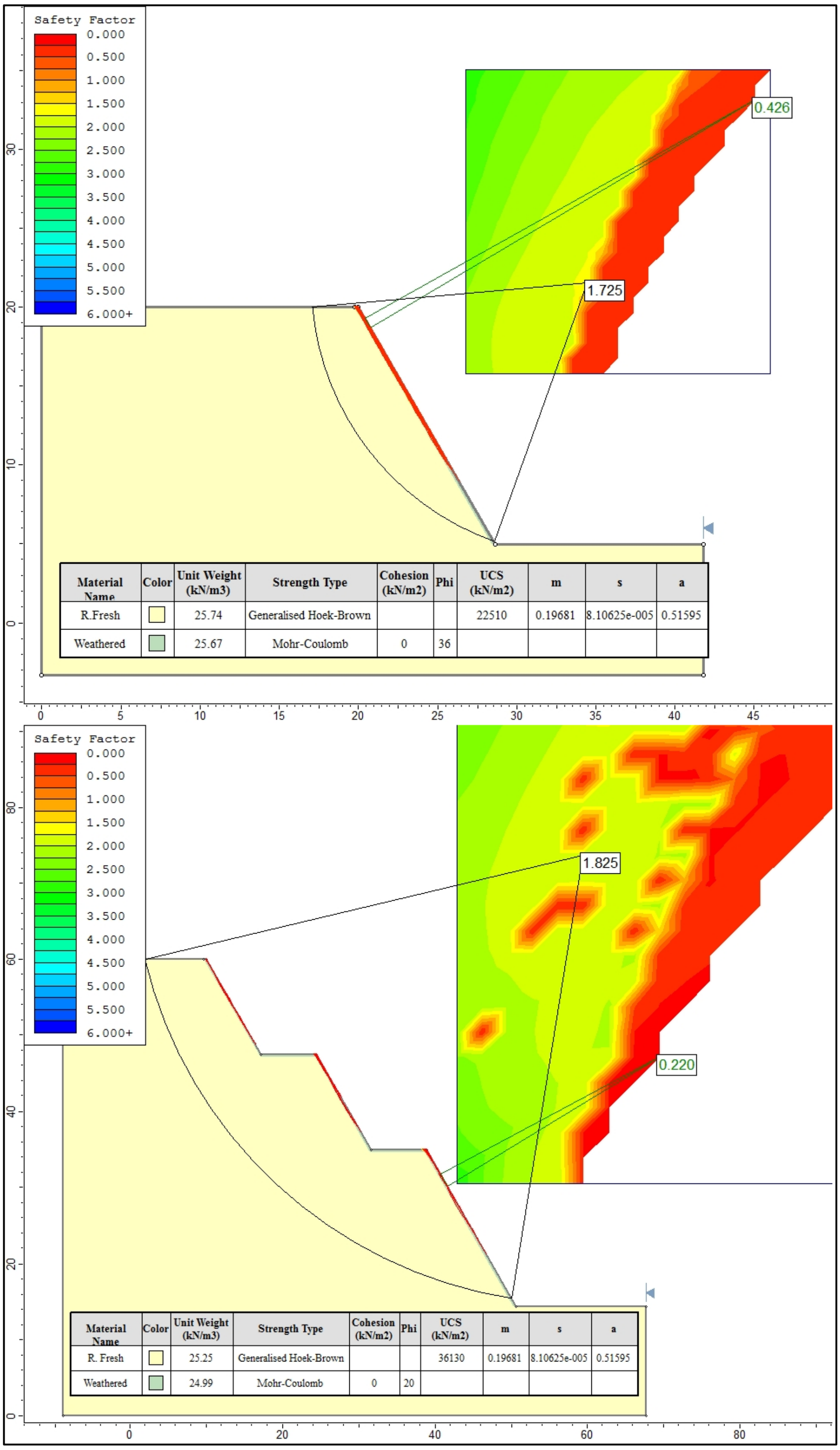
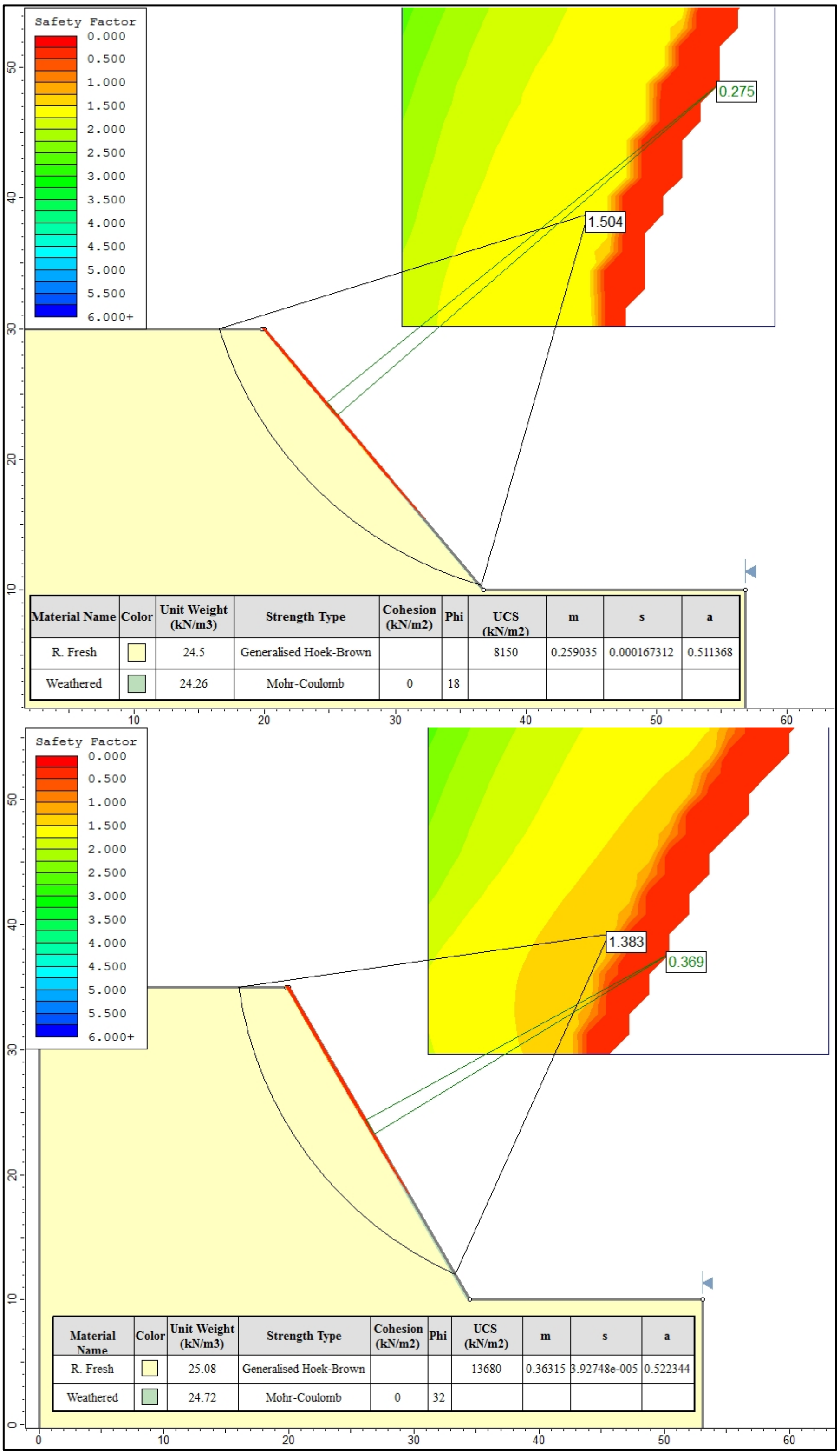


Figure 0.11. Limit equilibrium analyses of MS-3 and MS-4



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.5	Generalised Hoek-Brown			8150	0.259035	0.000167312	0.511368
Weathered		24.26	Mohr-Coulomb	0	18				

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		25.08	Generalised Hoek-Brown			13680	0.36315	3.92748e-005	0.522344
Weathered		24.72	Mohr-Coulomb	0	32				

Figure 0.12. Limit equilibrium analyses of MS-5 and MS-6

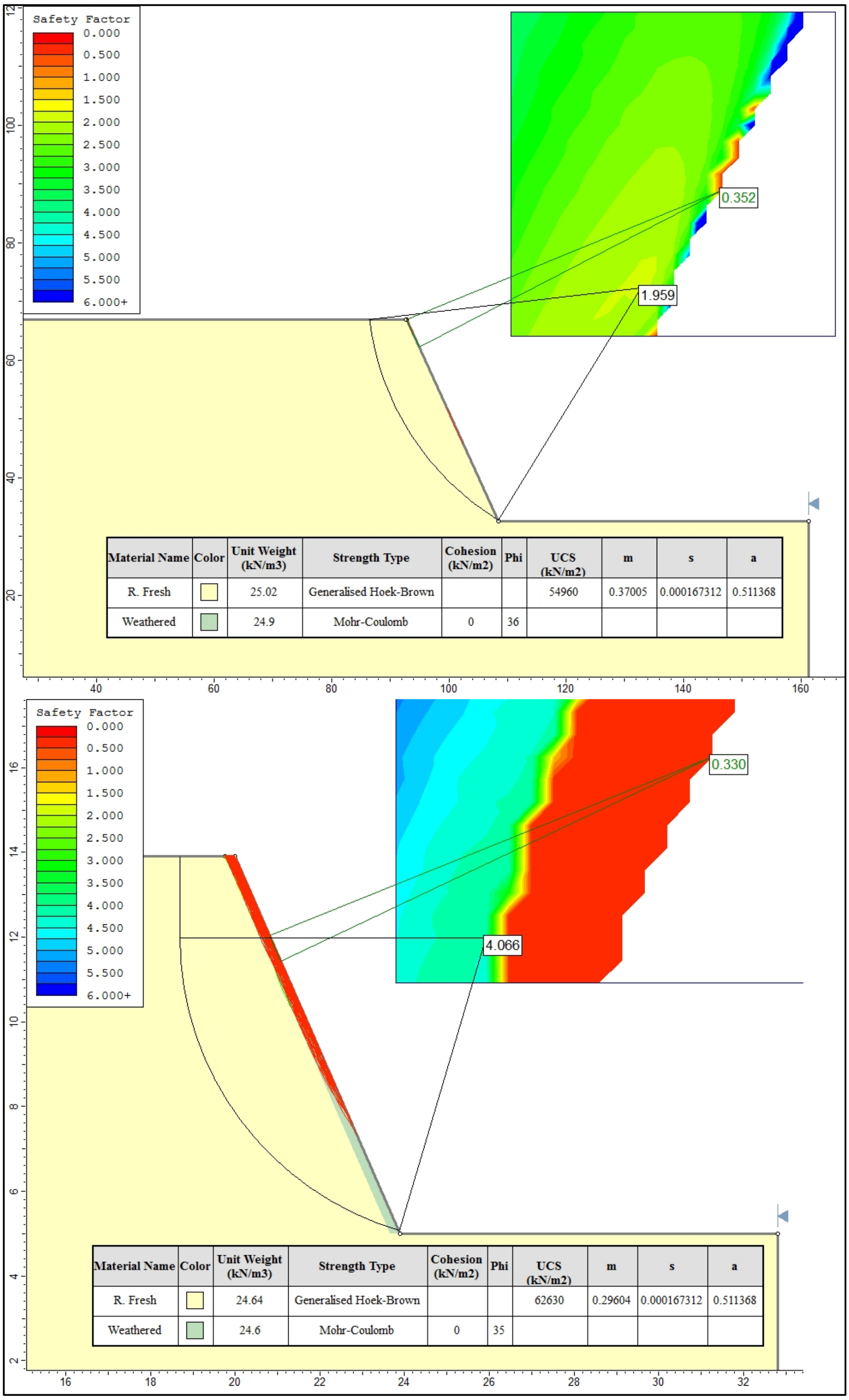


Figure 0.13. Limit equilibrium analyses of MS-7.1 and MS-7.2

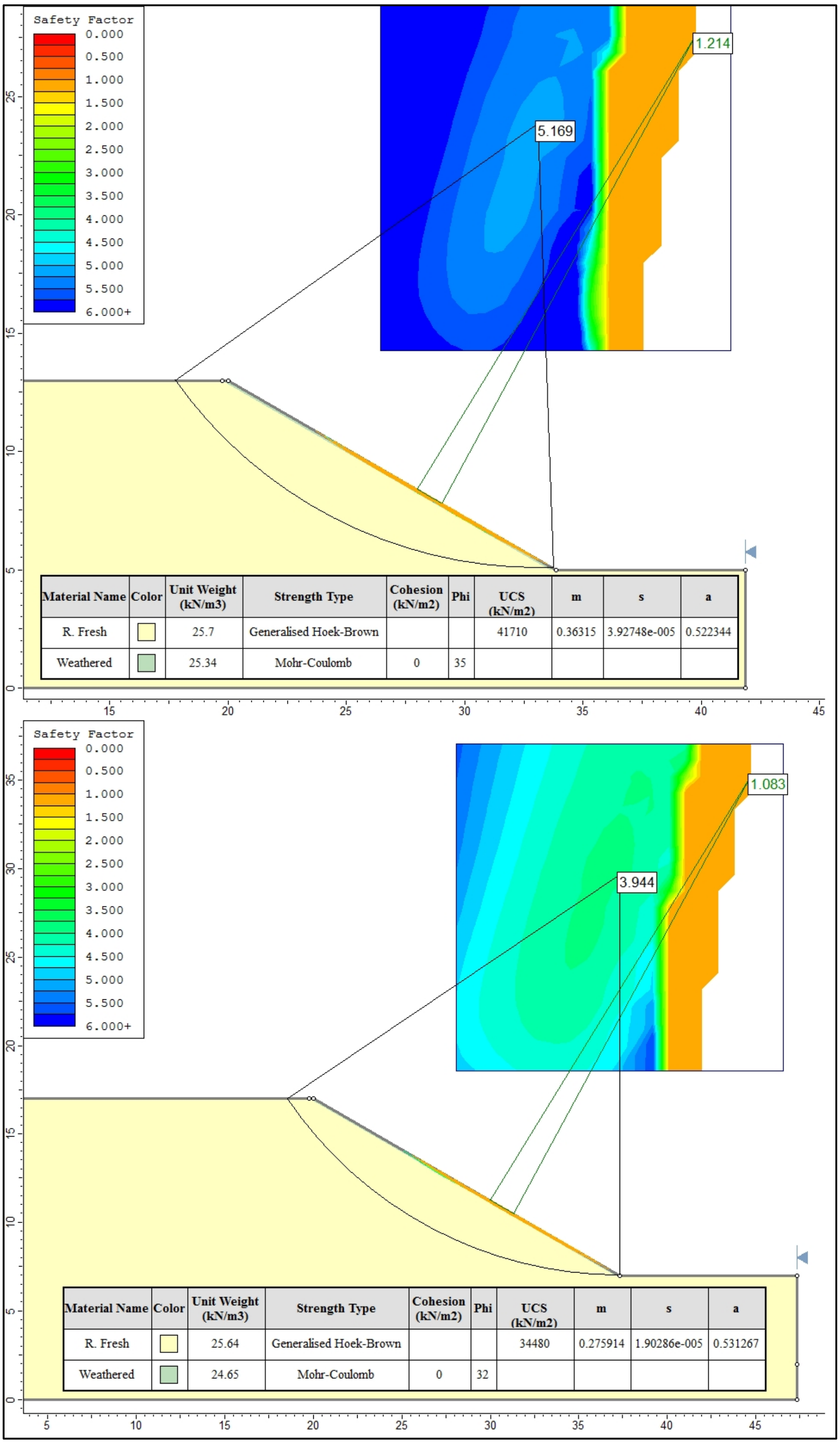


Figure 0.14. Limit equilibrium analyses of MS-8.1 and MS-8.2

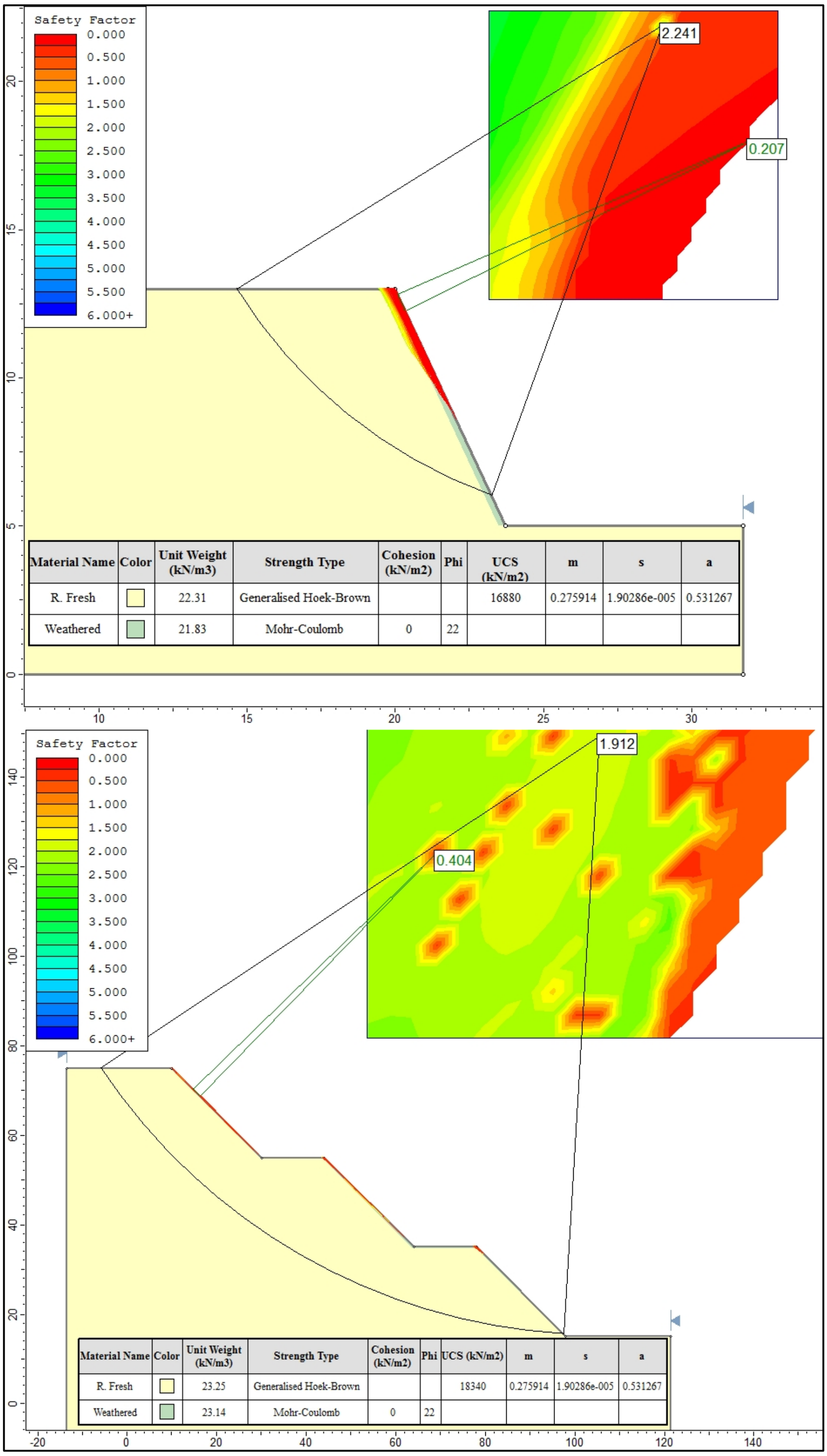
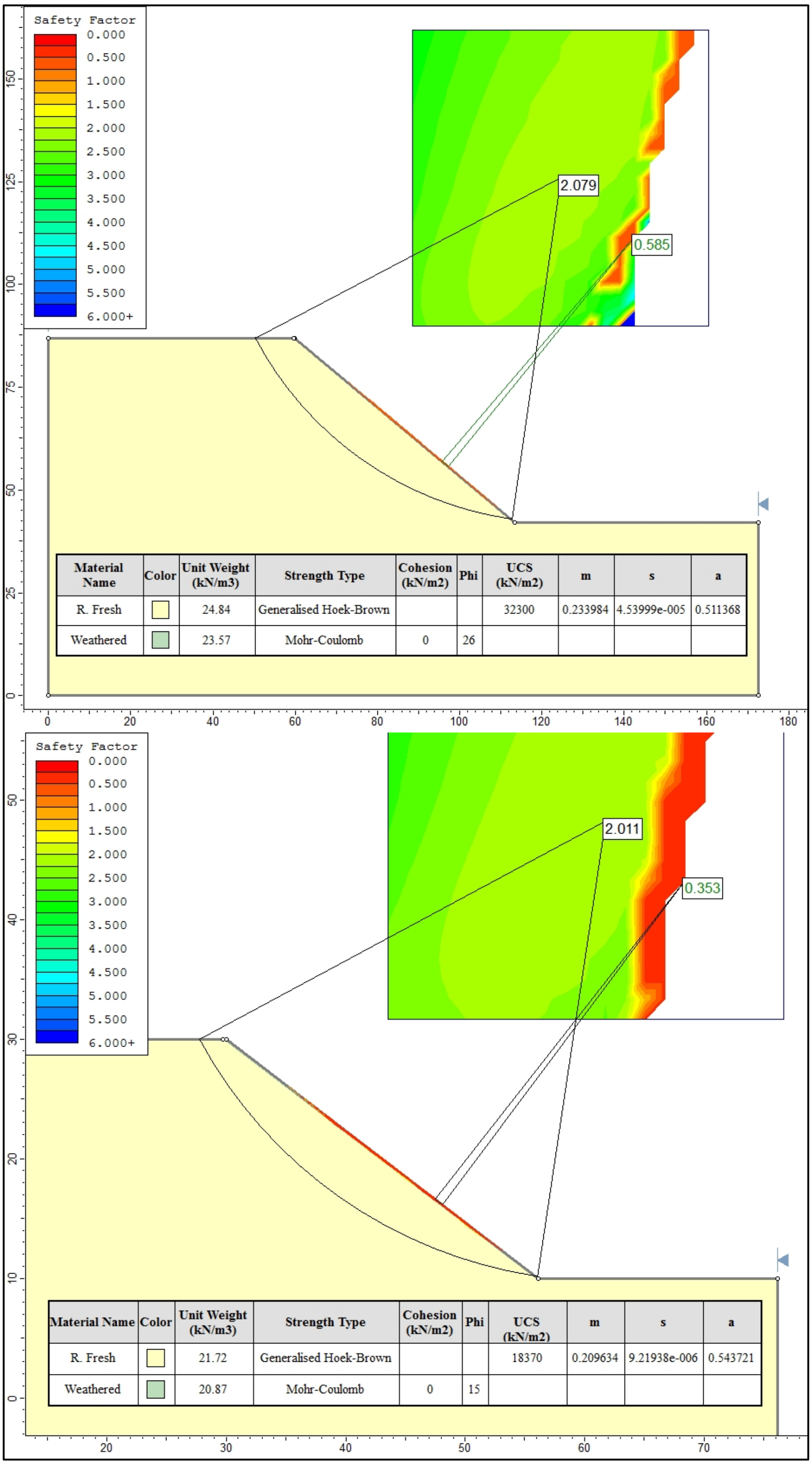


Figure 0.15. Limit equilibrium analyses of MS-9 and MS-10



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		24.84	Generalised Hoek-Brown			32300	0.233984	4.53999e-005	0.511368
Weathered		23.57	Mohr-Coulomb	0	26				

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	UCS (kN/m2)	m	s	a
R. Fresh		21.72	Generalised Hoek-Brown			18370	0.209634	9.21938e-006	0.543721
Weathered		20.87	Mohr-Coulomb	0	15				

Figure 0.16. Limit equilibrium analyses of MS-11 and MS-12

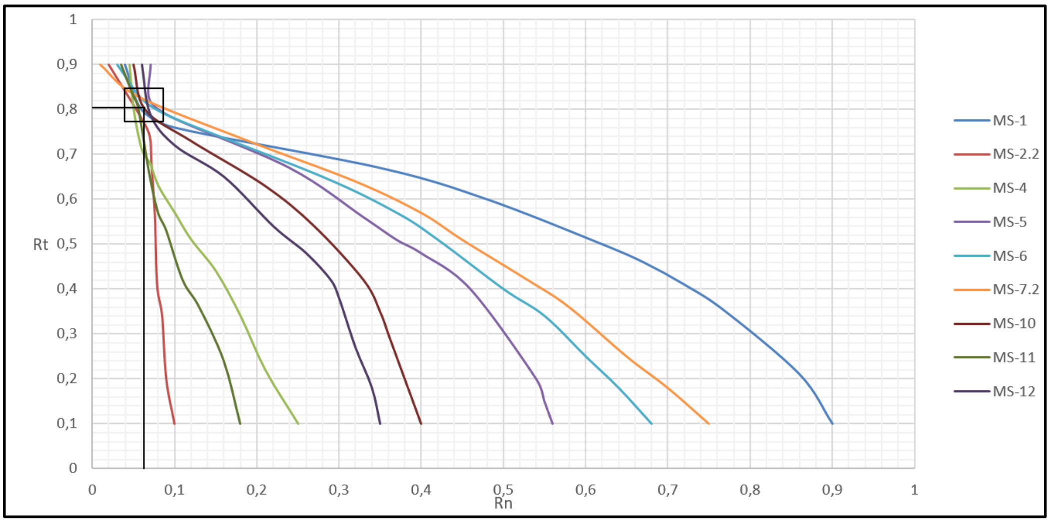


Figure 0.17. Rn and Rt values of drainage channel in front of the slopes

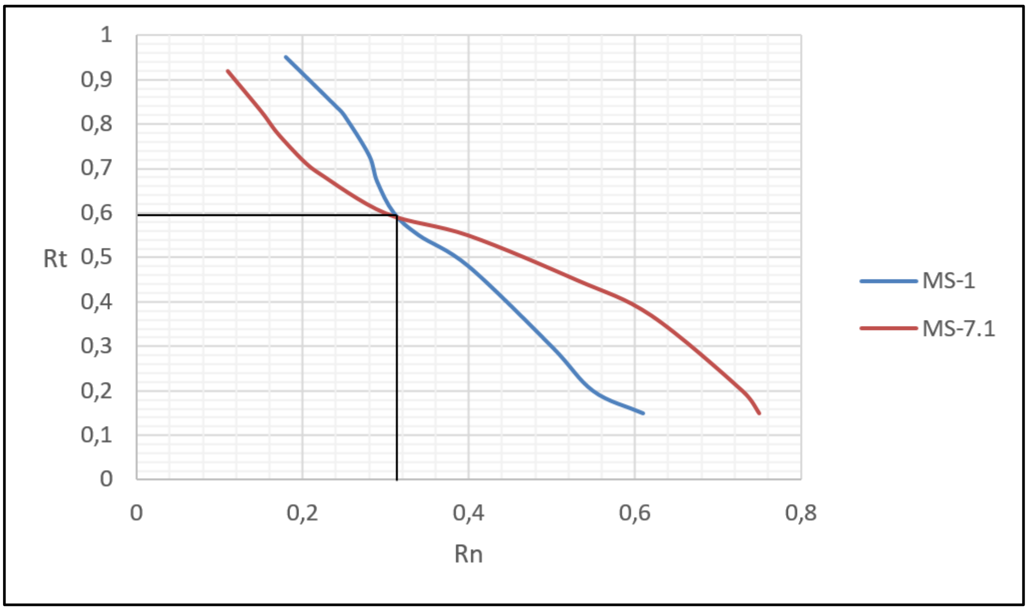


Figure 0.18. Rn and Rt values of limestone at stopes MS-1 and MS-7.1

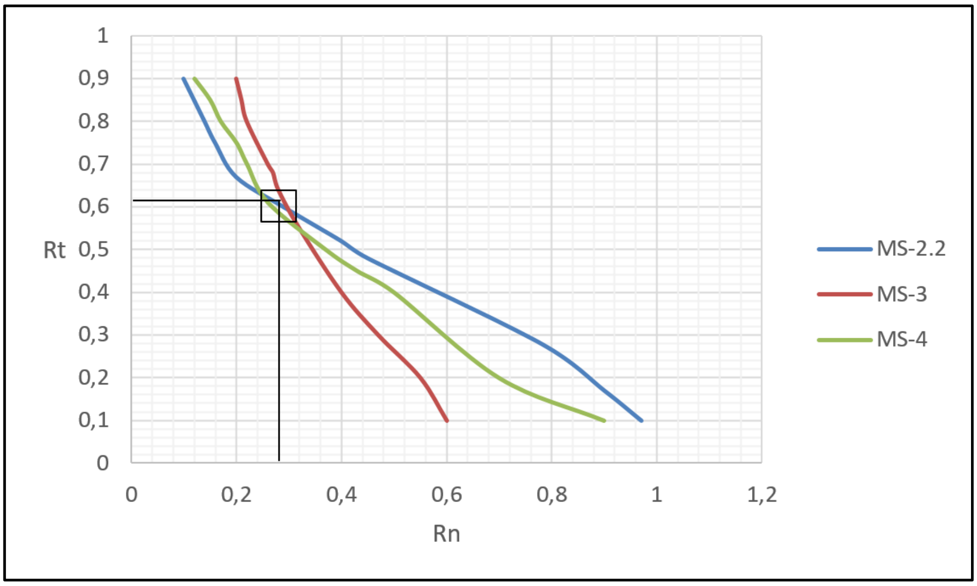


Figure 0.19. Rn and Rt values of marl at stopes MS-2.2, MS-3 and MS-4

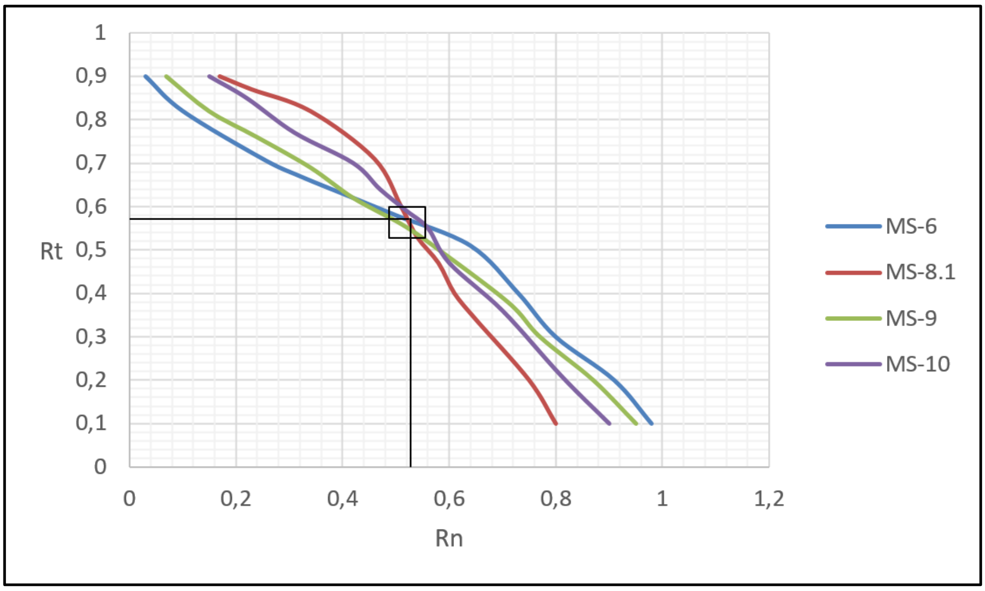


Figure 0.20. Rn and Rt values of sandstone at stopes MS-6, MS-8.1, MS-9 and MS-10

DATA COLLECTION TABLE						
Stope No.	**MS-1**	**Coordinates**	**X:**	410411	**Y:**	4585059

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa (Mudstone)	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa (Limestone)	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows

Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered	1.00
Crushed intact rock	0.62		Slightly	0.95
Lithology			Moderately	0.90
Mudstone : 30 %, dark Gray, 10-15 cm thick			Highly	0.62
Limestone : 70 %, yellow-light yellow, 1.5 m thick			Completely	0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Strike (degrees)	110	Stable	1	**Rockfall**	Large Limestone Blocks
Dip (degrees)	80 S	Small problem	2	"Landslide Site" signboard near the slope	
Slope height (m)	25	Large problem	3		

Discontinuities (B: Bedding; J: Joint)	**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)	150	30	90	155	160
Dip (degrees)	10 W	64 SE	72 S	12 W	15 W
Spacing (DS) (cm)	Lst: 90cm, Mdst: 60cm	5cm	20cm	12cm	10cm

Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Smooth Planar	Rough Planar	Smooth Planar	Smooth Planar
Infill M.	Clay material / CaCO3, 2mm-1mm	2 mm	1 mm	2 mm	2 mm	1 mm
Persistence	consistent with spacing and bedding planes					
Aperture	1 mm - 2 mm - 5 mm - 8 mm	2 mm	4mm	5mm	8 mm	1mm
Wall Strength	Lst Weathered : 20 SC, Lst Fresh : 36 SC,	Bedding Plane : 36 SC,		Mudst.<10 SC		
Sample Bag #	240 LST F, 240 LST W	**UCS**	+	**Photo.**	#1:joint, #2: bedding plane	

Figure 0.21 Data collection table for the cut slope MS-1

DATA COLLECTION TABLE						
Stope No.	**MS-2.1**	**Coordinates**	**X:**	412773	**Y:**	4581259

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa (Mudstone)	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa (Marl)	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows

		Weathering degree (WE)		
Fractured intact rock	0.67		Unweathered	1.00
Crushed intact rock	0.62		Slightly (Marl)	0.95
Lithology			Moderately (Mudst.)	0.90
Mudstone-Marl Alternation			Highly	0.62
Marl : 80 %, white, ligth colored Mudstone : 20 % brown, greenish			Completely	0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Strike (degrees)	070	Stable	1	**Rockfall**	Surficial Degradation
Dip (degrees)	55 SE	Small problem	2	Most of the joints are bed confined. (+...**J5:**050/45, 5cm, **J6:**150/75, 2cm) (J: 4,3,4,3,4 X 6,2,3,5,2 cm avg.)	
Slope height (m)	10 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		**B**	**J1**	**J2**	**J3**	**J4+..**
Strike (degrees)		125-135-315-125	270	235	215	155
Dip (degrees)		75S-78S-73S-83S	35S	35S	90S	70S
Spacing (DS) (cm)		10 cm-20 marl	5cm mudst.	20cm marl	12cm mudst.	10cm marl
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Rough Planar	R.Undu-lating	R.Undu-lating	Rough Planar	Rough Planar
Infill M.	< 5mm clay infill	2 mm	1 mm	1mm	2 mm	1 mm
Persistence	consistent with spacings, bedding planes are more persistant					
Aperture	1-2 mm	2 mm	1mm	1mm	2mm	1mm
Wall Strength	Bedding P. Weath.: 34 SC, Bedding P. Fresh: 40SC	Marl Fresh: 47 SC		Mudst. <10SC	Marl Joint<10SC	
Sample Bag #	241-F, 241-W	**UCS**	X	**Photo.**	#1-2: bedding plane, #3: joint	

Figure 0.22 Data collection table for the cut slope MS-2.1

DATA COLLECTION TABLE								
Stope No.	**MS-2.2**	**Coordinates**	**X:**	412220		**Y:**	4581167	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa (Mudstone)			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa (Marl)			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly (Marl)		0.95
Lithology						Moderately (Mudst.)		0.90
Mudstone : 25 %, gray, dark gray, greenish						Highly		0.62
Marl : 75 %, white, gray, light colored						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Strike (degrees)	021	Stable	1	**Rockfall**	max. 10 cm block size			
Dip (degrees)	50 SE	Small problem	2	Joints are bed confined				
Slope height (m)	15 m	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)				048	310	310	090	050
Dip (degrees)				42 N	80 SW	50 NE	70 S	45 SE
Spacing (DS) (cm)				Mudst: 5-6 cm	Marl:15-20 cm	40 cm	30 cm	10 cm
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness				Rough Planar	Smooth Planar	Smooth Planar	Rough Planar	Smooth Planar
Infill M.	clay material <5mm			2 mm	4mm	2 mm	2 mm	1 mm
Persistence	consistent with spacings, bedding planes are more persistant							
Aperture	2 mm - 3 mm			2 mm	4mm	3mm	2mm	2mm
Wall Strength	Marl Fresh : 40 SC			Marl Bedding Plane : 39 SC		Mudst. Fresh < 10 SC		Marl J.<10 sc
Sample Bag #	241-2 F, 241-2 W	**UCS**	+			**Photo.**	#1: Bedding Plane, #2: Joint	

Figure 0.23 Data collection table for the cut slope MS-2.2

DATA COLLECTION TABLE								
Stope No.	**MS-2.3**	**Coordinates**	**X:**	412676		**Y:**	4581115	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa (Mudst, Marl)			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly		0.95
Lithology						Moderately		0.90
Mudstone: 30 %, thin bedded, 1 cm-0.5 cm						Highly		0.62
Marl : 70 %, thind bedded, 5 cm- 10 cm - 5 cm - 8 cm						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Strike (degrees)	40	Stable	1	**Rockfall**	Surficial Degradation			
Dip (degrees)	52 SE	Small problem	2	<1 cm mostly, 0.5 cm - cm rarely				
Slope height (m)	20 m	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)				230	120	090	110	240
Dip (degrees)				42 NW	80 W	40 S	45 NE	75 NW
Spacing (DS) (cm)				2-15 cm	1 cm	0.5 cm	1 cm	5cm
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness				R.Undu-lating	R.Undu-lating	Rough Planar	R.Undu-lating	Rough Planar
Infill M.	clay material <5 mm-2mm			2 mm	2mm	1mm	2mm	1 mm
Persistence	spacing are consistent with bedding planes							
Aperture	1 mm - 2 mm			2 mm	2mm	1mm	2mm	2mm
Wall Strength	Marl weath: 10 SC, Marl Fresh: 10 SC,			Mudst. Weath. <10 SC		Mudst. Fresh <10 SC		Bedding Pl. <10 SC
Sample Bag #	241-3 W MARL	**UCS**	X			**Photo.**	**#1: bedding plane, #2: joint**	

Figure 0.24 Data collection table for the cut slope MS-2.3

DATA COLLECTION TABLE								
Stope No.	**MS-3**	**Coordinates**	**X:**	229449		**Y:**	4568565	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa (Mudstone)			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa (Marl)			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly		0.95
Lithology						Moderately		0.90
Marl : 90 %, light greenish, gray,						Highly		0.62
Mudstone : 10 %, light brownish, oxidized,						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Strike (degrees)	030	Stable	1	**Rockfall**	Surficial degradation, 1 cm- 5 cm- 10 cm rock fall			
Dip (degrees)	60 SE	Small problem	2					
Slope height (m)	15 m	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)				100	130	070	110	020
Dip (degrees)				60 NE	80 NE	32 SW	65 NE	72 SE
Spacing (DS) (cm)				Marl : 5cm -	Mudst: 7 cm- 3 cm		3cm	4cm
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness				Smooth Planar	Smooth Planar	Smooth Planar	Smooth Planar	Rough Planar
Infill M.	clay material 1-2mm thick			1 mm	2 mm	2 mm	1 mm	1 mm
Persistence	consistent with spacing							
Aperture	1-2 mm			1 mm	2mm	2mm	1mm	1mm
Wall Strength	Mudstone Weath.<10 SC, Mudst. Fresh <10 SC			Marl Fr.<10 SC		Marl Weath. <10 SC		
Sample Bag #	242-MARL F/W, 242 MUDST. W	**UCS**	X			**Photo.**	#1 : Joint, #2: bedding plane	

Figure 0.25 Data collection table for the cut slope MS-3

DATA COLLECTION TABLE					
Stope No.	**MS-4**	**Coordinates**	**X:** 451137	**Y:**	4561727

Excavation Method (ME)		Intact Rock Strength (IRS)	
Natural/hand-made	1.00	<1.25 MPa (M	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows
Fractured intact rock	0.67		
Crushed intact rock	0.62		

Lithology	Weathering degree (WE)		
		Unweathered	1.00
		Slightly	0.95
		Moderately	0.90
Marl : % 50, dark gray, 10 cm - 20 cm		Highly	0.62
Mudstone : % 50, Dark gray, 50 cm		Completely	0.35

Slope		Slope Stability		OBSERVATIONS	
Strike (degrees)	050	Stable	1	**Rockfall**	5-10 cm
Dip (degrees)	60 N	Small problem	2		
Slope height (m)	50	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		B	J1	J2	J3	J4
Strike (degrees)		040	130	110		
Dip (degrees)		60 SE	60 SE	60 SE		
Spacing (DS) (cm)		10 cm marl	15 cm mudst.	5cm		
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Rough Planar	Smooth Planar	Smooth Planar		
Infill M.	2 mm clay, 0.5 cm-1 cm calcite	7cm	3cm	2 mm		
Persistence						
Aperture	10 cm-5 cm, 1 mm-2 mm	10cm	4cm	2mm		
Wall Strength	Marl weath.<10 SC, Marl Fresh:17 SC	Bedding Pl.<10SC	Mudst. Fr<10S	Mudst. W<10S		

Sample Bag #	243-MARL F/W, 243 MUDST. W	**UCS**	X	**Photo.**	**#1: Joint, #2: Bedding Pl.**

Figure 0.26 Data collection table for the cut slope MS-4

DATA COLLECTION TABLE						
Stope No.	**MS-5**	**Coordinates**	**X:**	469821	**Y:**	4556901

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows
Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered: 1.00
Crushed intact rock	0.62		Slightly: 0.95
Lithology			Moderately: 0.90
Marl: Gray, Locally laminated, rarely 10-20 cm thick bedded			Highly: 0.62
			Completely: 0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Dip direction (degrees)	170	Stable	1	**Rockfall**	Surficial degradation, 10-20 cm blocks
Dip (degrees)	50 NE	Small problem	2		
Slope height (m)	15	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)		175	080			
Dip (degrees)		20 SW	85N			
Spacing (DS) (cm)		20 cm	10 cm			
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Rough Planar			
Infill M.	clay material	2 mm	2 mm			
Persistence						
Aperture		2 mm	2 mm			
Wall Strength	Marl Weath. <10 SC					

Sample Bag #	244-F, 244-W	**UCS**	X	**Photo.**	**#1 : Joint, #2: Bedding Pl.**

Figure 0.27 Data collection table for the cut slope MS-5

DATA COLLECTION TABLE					
Stope No.	**MS-6**	**Coordinates**	**X:** 471819	**Y:**	4547439

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows

Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered	1.00
Crushed intact rock	0.62		Slightly	0.95
Lithology			Moderately	0.90
Sandstone : % 60, yellow, brownish, 50 cm- 100 cm			Highly	0.62
Mudstone : % 40, grayish, 10 cm			Completely	0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Dip direction (degrees)	052	Stable	1	**Rockfall**	10 cm, 20 cm, 30 cm blocks
Dip (degrees)	60 SE	Small problem	2		
Slope height (m)	25 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)		065	160	070	080	075
Dip (degrees)		70 S	40 N	70S	65S	62S
Spacing (DS) (cm)		30 cm	20 cm	5 cm	10 cm	7 cm
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Smooth Planar	Smooth Planar	Smooth Planar	Smooth Planar
Infill M.	Calcite filling, 2 mm - 4 mm	4 mm	3 mm	3 mm	2 mm	1 mm
Persistence	consistent with bedding plane					
Aperture		4 mm	4mm	3 mm	2 mm	2 mm
Wall Strength	Sandstone Weath.: 19 SC, Sandst. Fresh: 25 SC	Mudst< 10 SC				

Sample Bag #	247 SST F/W, 247 MARL F/W	**UCS**	+	**Photo.**	**#1: Joint, #2: Bedding Pl.**

Figure 0.28 Data collection table for the cut slope MS-6

DATA COLLECTION TABLE					
Stope No.	**MS-7.1**	**Coordinates**	**X:** 363033	**Y:**	4558815

Excavation Method (ME)		**Intact Rock Strength (IRS)**	
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows
Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered 1.00
Crushed intact rock	0.62		Slightly 0.95
Lithology			Moderately 0.90
Limestone : white, rarely yellowish - brownish			Highly 0.62
			Completely 0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Dip direction (degrees)	040	Stable	1	**Rockfall**	20 cm max., 5-10 cm / 6-7 cm blocks
Dip (degrees)	66 N	Small problem	2	Fault : 150 / 64 N	
Slope height (m)	35 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)	**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)	170	060	170	070	150
Dip (degrees)	22 S	68 N	22 S	74 N	65 N
Spacing (DS) (cm)	25 cm	5 cm	10 cm	4 cm	5 cm

Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Smooth Planar	Rough Planar	Rough Planar	Smooth Planar
Infill M.	Clay 4 mm - 2mm	1 mm	2 mm	3 mm	4 mm	3 mm
Persistence	consistent with bedding plane					
Aperture	1 mm - 4 mm	1 mm	2 mm	3 mm	4 mm	4 mm
Wall Strength	Limestone Fresh: 39 SC, Limestone Weath: 27 SC					

Sample Bag #	78 A- F, 78 A-W	**UCS**	+	**Photo.**	**#1: Joint, #2: Bedding Pl.**

Figure 0.29 Data collection table for the cut slope MS-7.1

<table>
<tr><th colspan="8">DATA COLLECTION TABLE</th></tr>
<tr><td>Slope No.</td><td>MS-7.2</td><td>Coordinates</td><td>X:</td><td colspan="2">363026</td><td>Y:</td><td>4558878</td></tr>
<tr><td colspan="3">Excavation Method (ME)</td><td colspan="5">Intact Rock Strength (IRS)</td></tr>
<tr><td colspan="2">Natural/hand-made</td><td>1.00</td><td colspan="2"><1.25 MPa</td><td colspan="3">Crumbles in hand</td></tr>
<tr><td colspan="2">Pneumatic hammer excavation</td><td>0.76</td><td colspan="2">1.25-5 MPa</td><td colspan="3">Thin slabs break easy in hand</td></tr>
<tr><td colspan="2">Pre-splitting/smooth wall blasting</td><td>0.99</td><td colspan="2">5-12.5 MPa</td><td colspan="3">Thin slabs broken by heavy hand pressure</td></tr>
<tr><td colspan="2">Conventional blasting with result:</td><td></td><td colspan="2">12.5-50 MPa</td><td colspan="3">Lumps broken by light hammer blows</td></tr>
<tr><td colspan="2">Good</td><td>0.77</td><td colspan="2">50-100 MPa</td><td colspan="3">Lumps broken by heavy hammer blows</td></tr>
<tr><td colspan="2">Open discontinuities</td><td>0.75</td><td colspan="2">100-200 MPa</td><td colspan="3">Lumps only chip by heavy hammer blows</td></tr>
<tr><td colspan="2">Dislodged blocks</td><td>0.72</td><td colspan="2">>200 MPa</td><td colspan="3">Rocks ring on hammer blows</td></tr>
<tr><td colspan="2">Fractured intact rock</td><td>0.67</td><td colspan="2" rowspan="7">Weathering degree (WE)</td><td colspan="2">Unweathered</td><td>1.00</td></tr>
<tr><td colspan="2">Crushed intact rock</td><td>0.62</td><td colspan="2">Slightly</td><td>0.95</td></tr>
<tr><td colspan="3">Lithology</td><td colspan="2">Moderately</td><td>0.90</td></tr>
<tr><td colspan="3">Limestone : white, rarely yellowish - brownish</td><td colspan="2">Highly</td><td>0.62</td></tr>
<tr><td colspan="3"></td><td colspan="2">Completely</td><td>0.35</td></tr>
</table>

<table>
<tr><th colspan="2">Slope</th><th colspan="2">Slope Stability</th><th colspan="4">OBSERVATIONS</th></tr>
<tr><td>Dip direction (degrees)</td><td>020</td><td>Stable</td><td>1</td><td>Rockfall</td><td colspan="3">5-10 cm block size</td></tr>
<tr><td>Dip (degrees)</td><td>64 S</td><td>Small problem</td><td>2</td><td colspan="4" rowspan="2"></td></tr>
<tr><td>Slope height (m)</td><td>8 m</td><td>Large problem</td><td>3</td></tr>
</table>

<table>
<tr><th colspan="3">Discontinuities (B: Bedding; J: Joint)</th><th>B</th><th>J1</th><th>J2</th><th>J3</th><th>J4</th></tr>
<tr><td colspan="3">Strike (degrees)</td><td>168</td><td>060</td><td>170</td><td>072</td><td>160</td></tr>
<tr><td colspan="3">Dip (degrees)</td><td>24 S</td><td>68 N</td><td>25 S</td><td>76 N</td><td>66 N</td></tr>
<tr><td colspan="3">Spacing (DS) (cm)</td><td>25 cm</td><td>10 cm</td><td>5 cm</td><td>5 cm</td><td>5 cm</td></tr>
<tr><th colspan="3">Condition of discontinuities</th><th>B</th><th>J1</th><th>J2</th><th>J3</th><th>J4</th></tr>
<tr><td>Roughness</td><td colspan="2"></td><td>Rough Planar</td><td>Rough Planar</td><td>Smooth Planar</td><td>Smooth Planar</td><td>Smooth Planar</td></tr>
<tr><td>Infill M.</td><td colspan="2">Clay 4 mm - 2mm</td><td>2 mm</td><td>3 mm</td><td>2 mm</td><td>4 mm</td><td>2 mm</td></tr>
<tr><td>Persistence</td><td colspan="2">consistent with bedding plane</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Aperture</td><td colspan="2">approx. 2 mm</td><td>2 mm</td><td>3 mm</td><td>2 mm</td><td>4 mm</td><td>2 mm</td></tr>
<tr><td>Wall Strength</td><td colspan="2">Limestone Fresh: 51 SC, Limestone Weath: 20 SC</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sample Bag #</td><td>78 B F, 78 B W</td><td>UCS</td><td colspan="2">+</td><td>Photo.</td><td colspan="2">#1: Joint, #2: Bedding Pl.</td></tr>
</table>

Figure 0.30 Data collection table for the cut slope MS-7.2

DATA COLLECTION TABLE								
Stope No.	**MS-8.1**	**Coordinates**	**X:**	346847		**Y:**	4538211	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly		0.95
Lithology						Moderately		0.90
Sandstone : Gray (surface staning), brownish (weathered surface)						Highly		0.62
						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Dip direction (degrees)	090	Stable	1	**Rockfall**	max. 4-5 cm blocks			
Dip (degrees)	30 S	Small problem	2					
Slope height (m)	8 m	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)				060	035-032-050-030	130-115-090-130		
Dip (degrees)				42N-50N	60-62-70-40 N	65-65-65-70 S		
Spacing (DS) (cm)				1-2-7-6-8-4-5 cm	2-3-4,12-9-6-13-15 cm	15-13-9-9-2-3-4 cm		
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness	Rough Planar: large scale			Rough Planar	Rough Planar	Rough Planar		
Infill M.	Clayey sand-sandy clay			2 cm	1 mm	4 mm		
Persistence	consistent with spacing, beddind planes are more consistent							
Aperture	5 mm- 2 cm (rare)- 1 mm- 5 mm			5 cm	1 mm	5mm		
Wall Strength	Sst. Weath.:28SC, Sst W: 28 SC			Sandst. Fr.:30SC				
Sample Bag #	85 G.1 W 85G.1 F	**UCS**	X			**Photo.**	**#1: Bedding Plane**	

Figure 0.31 Data collection table for the cut slope MS-8.1

DATA COLLECTION TABLE								
Stope No.	**MS-8.2**	**Coordinates**	**X:**	346826		**Y:**	4538155	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly		0.95
Lithology						Moderately		0.90
Sandstone : Gray (surface staning), brownish (weathered surface)						Highly		0.62
						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Dip direction (degrees)	090	Stable	1	**Rockfall**	**max. 4-5 cm blocks**			
Dip (degrees)	30 S	Small problem	2					
Slope height (m)	10	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)				270-270-270	180-175	070-095		
Dip (degrees)				30N-32N-40N	90-90 N	65-70 S		
Spacing (DS) (cm)				7-8-6-5-7-40-35-20	2-4-8-6-3-20	13-7-6-26-25		
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness	Rough Planar: large scale			Rough Planar	Rough Planar	Rough Planar		
Infill M.	Clayey sand-sandy clay			5 mm	8 mm	3 mm		
Persistence	consistent with spacing, beddind planes are more consistent							
Aperture	>5 mm, not more than 2 cm			8 mm	10 mm	5 mm		
Wall Strength	Sandst. Weath.:30SC, Sst W: 31 SC			Sandst. Fr.:40SC				
Sample Bag #	85 GU2-F, 85 GU2-W	**UCS**	+			**Photo.**	+	

Figure 0.32 Data collection table for the cut slope MS-8.2

DATA COLLECTION TABLE						
Stope No.	**MS-9**	**Coordinates**	**X:**	349457	**Y:**	4543406

Excavation Method (ME)		**Intact Rock Strength (IRS)**		
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand	
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand	
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure	
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows	
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows	
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows	
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows	
Fractured intact rock	0.67	**Weathering degree (WE)**	Unweathered	1.00
Crushed intact rock	0.62		Slightly	0.95
Lithology			Moderately	0.90
Sandstone : % 65, yellowish white, 2 m			Highly	0.62
Marl : % 35, yellowish, ligth brown, 1 m			Completely	0.35

Slope		**Slope Stability**		**OBSERVATIONS**	
Dip direction (degrees)	155	Stable	1	**Rockfall**	4-5 cm block size
Dip (degrees)	65 SW	Small problem	2		
Slope height (m)	8 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)		**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)		120	130	190	150	140
Dip (degrees)		40 NE	60 NE	72 SE	85 NE	72 NE
Spacing (DS) (cm)		8-5-4-3-2 cm	2-3-6 cm			
Condition of discontinuities		**B**	**J1**	**J2**	**J3**	**J4**
Roughness		Smooth Planar	Smooth Planar	Smooth Planar	Rough Planar	Rough Planar
Infill M.	silt-clayey sand-sandy clay	2 mm	4 mm	4 mm	2 mm	1 mm
Persistence	consistent with spacing, bedding planes are more consistent					
Aperture	2mm - 5mm - 1 mm	2 mm	4mm	5mm	2 mm	1mm
Wall Strength	Sandst. Weath < 10 SC, Sandst. Fresh: 32 SC	Marl Weath:19 SC		Marl Fresh: 24 SC		

Sample Bag #	86-F, 86-W	**UCS**	X	**Photo.**	#1:Marl, #2:Sst, #3 Bedding Pl.

Figure 0.33 Data collection table for the cut slope MS-9

DATA COLLECTION TABLE								
Stope No.	**MS-10**	**Coordinates**	**X:**	349152		**Y:**	4543498	
Excavation Method (ME)			**Intact Rock Strength (IRS)**					
Natural/hand-made		1.00	<1.25 MPa			Crumbles in hand		
Pneumatic hammer excavation		0.76	1.25-5 MPa			Thin slabs break easy in hand		
Pre-splitting/smooth wall blasting		0.99	5-12.5 MPa			Thin slabs broken by heavy hand pressure		
Conventional blasting with result:			12.5-50 MPa			Lumps broken by light hammer blows		
Good		0.77	50-100 MPa			Lumps broken by heavy hammer blows		
Open discontinuities		0.75	100-200 MPa			Lumps only chip by heavy hammer blows		
Dislodged blocks		0.72	>200 MPa			Rocks ring on hammer blows		
Fractured intact rock		0.67	**Weathering degree (WE)**			Unweathered		1.00
Crushed intact rock		0.62				Slightly		0.95
Lithology						Moderately		0.90
Sandstone: Volcanogenic sandstone, locally andesite fragments						Highly		0.62
3 benches						Completely		0.35
Slope		**Slope Stability**		**OBSERVATIONS**				
Dip direction (degrees)	260	Stable	1	**Rockfall**	5-10 cm, max. 30 cm block size			
Dip (degrees)	45 SE	Small problem	2					
Slope height (m)	60 m	Large problem	3					
Discontinuities (B: Bedding; J: Joint)				**B**	**J1**	**J2**	**J3**	**J4**
Strike (degrees)					140	085	130	170
Dip (degrees)					68 W	68 S	60 SW	72 W
Spacing (DS) (cm)					10 cm	4 cm	2 cm	5 cm
Condition of discontinuities				**B**	**J1**	**J2**	**J3**	**J4**
Roughness					Smooth Planar	Rough Planar	Smooth Planar	Smooth Planar
Infill M.	-				-	-	-	-
Persistence								
Aperture	2 mm - 3 mm - 1 mm				3 mm	2 mm	2 mm	1mm
Wall Strength	Sandstone Weath: 31 SC			Sandstone Fresh: 46 SC				
Sample Bag #	87-F, 87-W	**UCS**	X			**Photo.**	**#1: Joint**	

Figure 0.34 Data collection table for the cut slope MS-10

DATA COLLECTION TABLE

Stope No.	MS-11	Coordinates	X:	348780	Y:	4543830

Excavation Method (ME)		Intact Rock Strength (IRS)	
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 Mpa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows

Excavation Method (ME), continued		Weathering degree (WE)	
Fractured intact rock	0.67	Unweathered	1.00
Crushed intact rock	0.62	Slightly	0.95
Lithology		Moderately	0.90
Sandstone: reddish brown, yellowish brown		Highly	0.62
		Completely	0.35

Slope		Slope Stability		OBSERVATIONS	
Dip direction (degrees)	110	Stable	1	**Rockfall**	70 cm, 50 cm, 10 cm block size
Dip (degrees)	40 S	Small problem	2		
Slope height (m)	40 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)	B	J1	J2	J3	J4
Strike (degrees)		095	170		
Dip (degrees)		58 S	88 E		
Spacing (DS) (cm)		35 cm	20 cm		

Condition of discontinuities			J1	J2	J3	J4
Roughness	Smooth Planar Large Scale		Smooth Planar	Smooth Planar		
Infill M.	-		-	-		
Persistence						
Aperture	1 mm - 2 mm - 3 mm		3 mm	2 mm		
Wall Strength	V. Sst Fresh: 52 SC	V. Sst Weathered: 38 SC				

Sample Bag #	88-F, 88-W	**UCS**	+	**Photo.**	**#1: discont.**

Figure 0.35 Data collection table for the cut slope MS-11

DATA COLLECTION TABLE

Stope No.	MS-12	Coordinates	X:	348829	Y:	4544221

Excavation Method (ME)		Intact Rock Strength (IRS)	
Natural/hand-made	1.00	<1.25 MPa	Crumbles in hand
Pneumatic hammer excavation	0.76	1.25-5 MPa	Thin slabs break easy in hand
Pre-splitting/smooth wall blasting	0.99	5-12.5 MPa	Thin slabs broken by heavy hand pressure
Conventional blasting with result:		12.5-50 MPa	Lumps broken by light hammer blows
Good	0.77	50-100 MPa	Lumps broken by heavy hammer blows
Open discontinuities	0.75	100-200 MPa	Lumps only chip by heavy hammer blows
Dislodged blocks	0.72	>200 MPa	Rocks ring on hammer blows
Fractured intact rock	0.67		
Crushed intact rock	0.62		

Lithology	Weathering degree (WE)		
		Unweathered	1.00
		Slightly	0.95
		Moderately	0.90
Sandstone : Brownish - yellowish		Highly	0.62
		Completely	0.35

Slope		Slope Stability		OBSERVATIONS	
Dip direction (degrees)	170	Stable	1	Rockfall	3-4-5 cm
Dip (degrees)	50 SW	Small problem	2		
Slope height (m)	15 m	Large problem	3		

Discontinuities (B: Bedding; J: Joint)	B	J1	J2	J3	J4
Strike (degrees)	010	090	070	105	82
Dip (degrees)	54 NW	90 NW	7 NW	60 N	57 N
Spacing (DS) (cm)	4-5 cm	3 cm	2 cm	3 cm	2 cm

Condition of discontinuities		B	J1	J2	J3	J4
Roughness		Rough Undulating	Smooth Und.	Smooth Und.	Smooth Und.	Smooth Und.
Infill M.	clay infill 2 mm- 4 mm	2 mm	2 mm	4 mm	2 mm	2 mm
Persistence	consistent with bedding plane					
Aperture	2 mm - 1 mm - 4 mm	2 mm	3 mm	4mm	2 mm	2mm
Wall Strength	Bedding Plane : 14 SC	Sandst Weath: 17 SC		Sandst. Fresh: 24 SC		

Sample Bag #	89-F, 89-W	UCS	X	Photo.	#1 : Bedding Plane, #2 :Sst W

Figure 0.36 Data collection table for the cut slope MS-12