APPLICATION OF ROCK MASS CLASSIFICATION SYSTEMS FOR FUTURE SUPPORT DESIGN OF THE DİM TUNNEL NEAR ALANYA

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ABSTRACT

APPLICATION OF ROCK MASS CLASSIFICATION SYSTEMS FOR FUTURE SUPPORT DESIGN OF THE DİM TUNNEL NEAR ALANYA

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In this thesis, the results of a number of rock mass classification systems applied to Dim-highway tunnel study area are presented. The tunnel ground was classified according to Rock Mass Rating (RMR), Modified Rock Mass Rating (M-RMR), Rock Mass Quality (Q,) Geological Strength Index (GSI), and New Austrian Tunneling Method (NATM).

Dim Tunnel has a horse-shoe shape, with a diameter of 10 meters and maximum overburden thickness of 70 meters. During studies, the geological and geotechnical characteristics of the rock mass along the Dim Tunnel route were investigated. The main objective of rock mass classifications carried out in this study was to obtain adequate data that could be used in future excavation and support-design studies. In order to accomplish this task, literature survey was carried out, followed by a comprehensive field study and laboratory testing. Field studies involved detailed discontinuity surveys of the exposed rock mass at the surface and on the cores taken within 10-20 meters of the borehole above the tunnel. A geological map and a geological cross-section along the tunnel axis were also prepared. Finally, correlations between the results of the rock mass classification systems were made carrying out statistical analyses for the Dim Tunnel study area.

The results obtained from the RMR and M-RMR classifications indicate that M-RMR system estimates better rock mass quality ratings at the upper bounds of the rock mass condition, but worst ratings at the lower bounds (RMR is less than 40) as also suggested by the previous studies.

Keywords: Dim Tunnel, GSI system, M-RMR system, RMR system, rock mass classification

ÖZ

ALANYA YAKINLARINDAKİ DİM TÜNELİNİN GELECEĞE YÖNELİK TASARIMI İÇİN KAYA KÜTLESİ SINIFLAMA SİSTEMLERİNİN UYGULANMASI

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Bu tezde, kaya kütlesi sınıflama sistemlerinin Dim karayolu tünelinde uygulanması ile ilgili çalışmalar sunulmuştur. Tünel zemini; Kaya Kütlesi Puanlaması (RMR), Modifiye Edilmiş Kaya Kütlesi Puanlaması (M-RMR), Q-Sistemi, Jeolojik Dayanım İndeksi (GSI) ve Yeni Avusturya Tünelcilik Yöntemi (NATM) kullanılarak sınıflanmıştır.

Yapılması planlanan Atnalı şeklindeki Dim Tüneli, 10 metre çapındadır ve tünel üzerindeki en fazla et kalınlığı 70 metredir. Çalışmalar sırasında, Dim Tüneli güzergahı boyunca kesilecek ve yüzeyde görülen kaya kütlesi ve kaya malzemesinin jeolojik ve jeoteknik özellikleri araştırılmıştır. Bu çalışmadaki kaya kütlesi sınıflamalarının başlıca amacı, ileride yapılacak kazı ve destek tasarımı çalışmaları için gerekli olan verileri elde etmektir. Bu amacı gerçekleştirmek için literatür araştırmasından sonra ayrıntılı arazi çalışmaları ve

laboratuvar deneyleri yapılmıştır. Arazi çalışmaları tünel seviyesinden 10-20 m yukarıda yeralan kesimdeki ve yüzeydeki süreksizliklerin ayrıntılı olarak araştırılmasını içermektedir. Ayrıca jeoloji haritası ve tünel ekseni boyunca jeolojik kesit hazırlanmıştır. Son aşamada, Dim Tüneli çalışma alanı için kaya kütlesi sınıflama sistemlerine ait istatistiksel analizler yapılarak karşılaştırılmıştır.

RMR ve M-RMR sınıflamalarından elde edilen sonuçlara göre M-RMR sistemi sınıflama puanının üst sınır değerlerinde RMR'a göre daha iyi kaya kütlesi puanları, buna karşın alt sınır bölgesinde (40'ın altında) ise daha düşük puanlar vermektedir. Bu sonuçlar daha önce bu konuda yapılan çalışmaları da desteklemektedir.

Anahtar Kelimeler : Dim Tüneli, GSI sistemi, kaya kütlesi sınıflaması, M-RMR sistemi, RMR sistemi

To My Family

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LIST OF ABBREVIATIONS

A_b	Adjustment factor (blasting damage)
A_w	Adjustment factor (major planes of weaknesses)
B	Span or width of the tunnel (m)
BPI	Block Punch Index
BM-RMR	Basic modified rock mass rating
BSTR	Broken rock structure
c	cohesion (kPa)
CUMR	Corrected unit mass rating
CM-RMR	Corrected modified rock mass rating
D	Disturbance factor
E_m	Deformation modulus (GPa)
ESR	Excavation support ratio
F_C	Weathering coefficient
h_t	Rock-load height (m)
H	Overburden or tunnel depth (m)
GSI	Geological strength index
ICR	Intact core recovery
I_{d-2}	Slake-durability index
I_{GW}	Grounwater condition index
I_{JC}	Joint condition index
I_{JO}	Joint orientation index
I_{PL}	Point load strength index
I_{UCS}	Uniaxial compressive strength index
J_a	Joint alteration number
J_n	Joint set number
J_r	Joint roughness number

J_v	Volumetric joint count (joint/m^3)
J_w	Joint water reduction factor
J_S	Joint spacing
K	Horizontal to vertical stress ratio
L	Length of rockbolts
M-RMR	Modified rock mass rating
NATM	New Austrian tunneling method
NGI	Norvegian Geotechnical Institute
Q	Rock mass quality
P	Support pressure (kN/m^2 or MPa)
PHHS	Possible high horizontal stress
RMi	Rock mass index
RMR	Rock mass rating
RMS	Rock mass strength
RQD	Rock quality designation
RSR	Rock structure rating
S	Strength factor
SCR	Surface condition rating
SR	Structure rating
SRF	Stress reduction factor
TCR	Total core recovery
TBM	Tunnel boring machine
t_f	Filling thickness (mm)
UMR	Unit mass rating
URCS	Unified rock mass classification system
WCS	Weakening coefficient system
ϕ	Internal friction angle (^{o})
γ	Density of the rock (N/m^3)
σ_c	Uniaxial compressive strength (MPa)
σ_h	Horizontal stress (MPa)
σ_v	Vertical stress (MPa)

CHAPTER I

INTRODUCTION

1.1 General Remarks

The main purpose of a tunnel design is to use the rock itself as the principal structural material with little disturbance during the excavation and to provide as little support system as possible. For this purpose, determinations of geological and geotechnical conditions existing in a project area is absolutely necessary. The rock mass classification systems are used for preliminary tunnel design as an empirical method.

1.2 Statement of the Problem

To provide input data for empirical design of tunnels it is necessary to determine the geological conditions in the study area and carry out rock mass classification systems in the tunnel ground. The Rock Mass Rating (RMR), Modified Rock Mass Rating (M-RMR), Rock Mass Quality (Q), Geological Strength Index (GSI), and New Austrian Tunneling Method (NATM) are commonly used in rock mass classification systems. In this study, the above mentioned classification systems were used in Dim highway-tunnel project area near Alanya and correlations among these classification systems were performed using statistical methods.

1.3 Objectives of the Thesis

This study has three main objectives. The first one is to investigate the geological and geotechnical characteristics of the rock material and rock mass along the highway tunnel project located at the Alanya-Gazipaşa Road between Km 6+050 and Km 7+400 named as Dim.

The second objective consist of two stages, namely: i) classification of the rock mass in the study area according to the Rock Mass Rating (RMR), Modified Rock Mass Rating (M-RMR), Rock Mass Quality (Q), Geological Strength Index (GSI), and New Austrian Tunneling Method (NATM), and ii) investigation of correlations between these classification systems.

The third objective is to provide state of the art information on rock mass classification systems used in this study.

1.4 Methodology of the Thesis

The study has been carried out in four stages. In the first stage an extensive literature survey was performed. This survey included the review of rock mass classification systems, excavation and support recommendations and estimation of rock mass strength parameters for the preliminary tunnel design.

The second stage of the study included collection of previous data and reports related to the study area.

The third stage of the study involved field work. During field work, detailed discontinuity survey of exposed rock mass at the surface and on cores obtained from drillings were performed. Rock samples were taken from the core-boxes in order to carry out slake durability testing for each rock type. The other test results required for classifications were obtained from laboratory tests carried out by Petra Engineering.

The fourth stage of the study included the classification of rock masses for each borehole location along the tunnel route and the correlation of the rock mass classification results.

1.5 Thesis Outline

Following the introduction, Chapter 1, the rock mass classification systems and their applications as excavation and support recommendations and estimation of rock mass strength parameters for the preliminary tunnel design are reviewed in Chapter 2, as a part of literature survey.

Chapter 3 includes information about Dim Tunnel, previous geological studies, and geological and geotechnical studies carried out by the author around the tunnel project area.

The rock masses in the study area were classified according to Rock Mass Rating (RMR), Modified Rock Mass Rating (M-RMR), Rock Mass Quality (Q), Geological Strength Index (GSI), and New Austrian Tunneling Method (NATM). The results of the classifications and correlations among these classifications are presented in Chapter 4.

Finally, conclusions and recommendations related to this study are presented in Chapter 5.

CHAPTER II

LITERATURE SURVEY

2.1 Introduction

Basically, there are three different methods used in engineering design. These are empirical, observational, and numerical methods. Empirical design method relates practical experience gained on previous projects to the conditions anticipated at a proposed site and requires experience as well as engineering judgment. Rock mass classification systems are an integral of empirical tunneling design and have been successfully applied throughout the world.

During the feasibility and preliminary design stages of a project, when very little information on the rock mass and its stress and hydrogeological characteristics is available, the use of a rock mass classification can be of considerable benefit. At its simplest, this may involve using the classification scheme as a check list to ensure that all relevant information has been considered. At the other end of the spectrum, one or more rock mass classification schemes can be used to build up a picture of the composition and characteristics of a rock mass to provide initial estimates of support requirements, and to provide estimates of the strength and deformation properties of the rock mass (Hoek et al., 1995).

A rock mass classification system has the following purposes in application (Bieniawski, 1976):

a. To divide a particular rock mass into groups of similar behavior,
b. To provide a basis for understanding the characteristics of each group,
c. To facilitate the planning and design of excavations in rock by yielding quantitative data required for the solution of real engineering problems,
d. To provide a common basis for effective communication among all persons concerned with a geotechnical project.

Ensuring that a classification system has the following attributes can fulfill these purposes:

i. Simple, easy remembered, and understandable,
ii. Each term clear and terminology used is widely acceptable,
iii. Only the most significant properties of rock masses should be included,
iv. Based on measurable parameters that can be determined by relevant tests quickly and cheaply in the field,
v. Based on rating system that can weigh the relative importance of the classification parameters,
vi. Functional by providing quantitative data for the design of tunnel support,
vii. General enough so that the same rock mass will possess the same basic classification for various structures such as slopes, tunnels and foundations.

The classification systems are not recommended for use in detailed and final design, especially for complex underground openings. For these purposes, they need to be further developed (Bieniawski, 1989).

2.2 Rock Mass Classification Systems in General

There are many different rock mass classification systems and the most common ones are shown below in Table-2.1.

Rock mass classification systems have been developing for almost 60 years since Terzaghi (1946) firstly attempted to classify the rock masses for engineering purposes. Terzaghi (1946) classified rock conditions into nine categories ranging from hard and intact rock, class 1, to swelling rock, class 9.

Lauffer (1958) proposed that the stand up time for an unsupported span is related to the quality of the rock mass in which the span is excavated.

The Rock Quality Designation index (RQD) was developed by Deere et al. (1967) to provide a quantitative estimate of rock mass quality from drill core logs. RQD is defined as the percentage of intact pieces longer than 100 mm (4inches) in total length.

Palmström (1982) suggested that, when no core is available, but discontinuity traces are visible in surface exposures or exploration adits, the RQD might be estimated from the number of discontinuities per unit volume. The most important use of RQD is as a component of the RMR and Q rock mass classifications.

Wickham et al. (1972) proposed a quantitative method for describing the quality of a rock mass and for selecting appropriate support on the basic of their Rock Structure Rating (RSR) classification. Although the RSR classification system is not widely used, Wickham et al.'s work played a significant role in the development of the classification systems, which will be mentioned, in the previous paragraphs.

Table 2.1 Major rock mass classification systems (Bieniawski, 1989; Özkan and Ünal, 1996; Ulusay and Sönmez., 2002).

Rock Mass Classification System	Originator	Country of Origin	Application Areas
Rock Load	Terzaghi, 1946	USA	Tunnels with steel Support
Stand-up time	Lauffer, 1958	Australia	Tunneling
New Austrian Tunneling Method (NATM)	Pacher et al., 1964	Austria	Tunneling
Rock Quality Designation (RQD)	Deere et al, 1967	USA	Core logging, tunneling
Rock Structure Rating (RSR)	Wickham et al, 1972	USA	Tunneling
Rock Mass Rating (RMR) Modified Rock Mass Rating (M-RMR)	Bieniawski, 1973 (last modification 1989-USA) Ünal and Özkan, 1990	South Africa Turkey	Tunnels, mines, (slopes, foundations) Mining
Rock Mass Quality (Q)	Barton et al, 1974 (last modification 2002)	Norway	Tunnels, mines, foundations
Strength-Block size	Franklin, 1975	Canada	Tunneling
Basic Geotechnical Classification	ISRM, 1981	International	General
Rock Mass Strength (RMS)	Stille et al, 1982	Sweden	Metal mining
Unified Rock Mass Classification System (URCS)	Williamson, 1984	USA	General Communication
Weakening Coefficient System (WCS)	Singh, 1986	India	Coal mining
Rock Mass Index (RMi)	Palmström, 1996	Sweden	Tunneling
Geological Strength Index (GSI)	Hoek and Brown, 1997	Canada	All underground excavations

For a preliminary tunnel design, at least two classification systems should be applied (Bieniawski, 1989). In this study the most commonly used and applicable classification systems; Rock Mass Rating (RMR), Modified Rock Mass Rating (M-RMR), Rock Mass Quality (Q), Geological Strength Index (GSI) and New Austrian Tunneling Method (NATM) were used. More detailed information will be given about these classification systems in the following chapters.

2.3 Rock Mass Classification Systems Used in This Study

2.3.1 Rock Mass Rating (RMR) System

The Geomechanics Classification or the Rock Mass Rating (RMR) system was developed by Bieniawski in 1973. Significant changes have been made over the years with revisions in 1974, 1976, 1979 and 1989; in this study the discussion is based upon the latest version (Bieniawski, 1989) of the classification system.

The RMR classification has found wide applications in various types of engineering projects, such as tunnels, foundations, and mines but, not in slopes. Most of the applications have been in the field of tunneling.

Originally 49 case histories used in the development and validation of the RMR Classification in 1973, followed by 62 coal mining case histories that were added by 1984 and a further 78 tunneling and mining case histories collected by 1987. To the 1989 version, the RMR system has been used in 351 case histories (Bieniawski, 1989).

This classification of rock masses utilizes the following six parameters, all of which are measurable in the field and some of them may also be obtained from borehole data (Bieniawski, 1989):

a. Uniaxial compressive strength of intact rock material,
b. Rock quality designation (RQD),
c. Spacing of discontinuities,
d. Condition of discontinuities,
e. Groundwater conditions,
f. Orientation of discontinuities.

To apply this classification system, the rock mass along the tunnel route is divided into a number of structural regions, e.g., zones in which certain geological features are more or less uniform within each region. The above six parameters are determined for each structural region from measurements in the field and entered into the standard input data sheets.

The RMR system is presented in Table 2.2. In Section A of Table 2.2, the first five parameters are grouped into five ranges of values. Since the various parameters are not equally important for the overall classification of a rock mass, importance ratings are allocated to the different value ranges of the parameters, a higher rating indicating better rock mass conditions (Bieniawski, 1989).

It is suggested by Bieniawski (1989), however, that the charts A-D in Appendix A as Figure A.1 should be used instead of A1 (uniaxial compressive strength), A2 (RQD) and A3 (spacing of discontinuities) in Table 2.2. These charts are helpful for borderline cases and also remove an impression that abrupt changes in ratings occur between categories Chart D is used if either RQD or discontinuity data are lacking.

Table 2.2 Rock mass rating system (After Bieniawski, 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock metarial	Point-load strength index	> 10 MPa	4-10 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive		
		Uniaxial comp. strength	> 250 MPa	100-250 MPa	50-100 MPa	25-50 MPa	5-25 MPa	1-5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90 % - 100 %	75 % - 90 %	50 % - 75 %	25 % - 50 %	< 25 %		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		> 2 m	0,6 - 2 m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surface Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1 - 5 mm Continuous	Soft gouge > 5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Ground water	Inflow per 10 m tunnel length(1/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0,1	0,1 - 0,2	0,2 - 0,5	> 0,5		
		General Conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Ratings	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2,5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS****

Discontinuity length (persistence) Ratings	< 1 m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Ratings	None 6	< 0,1 mm 5	0,1 - 1,0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Ratings	Very rough 6	Rough 5	Slightyl rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Ratings	None 6	Hard filling <5 mm 4	Hard filling >5 mm 2	Soft filling <5 mm 2	Soft filling >5 mm 0
Weathering Ratings	Unweathered 6	Slightly weathered 5	Moderately 3	Highly Weathered 1	Decomposed 0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**

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

* Some conditions are mutually exclusive. For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly. ** Modified after Wickham et al. (1972) .

*** Instead of A.1, A.2, and A.3 use the charts A-D given in Figure A.1. included in App.A **** Section E is used to calculate basic RMR.

After the importance ratings of the classification parameters are established, the ratings for the five parameters listed in Section A of Table 2.2 are summed up to yield the basic rock mass rating for the structural region under consideration.

At this stage, the influence of strike and dip of discontinuities is included by adjusting the basic rock mass rating according to Section B of Table 2.2. This step is treated separately because the influence of discontinuity orientation depends upon engineering application e.g., tunnel (mine), slope or foundation. It will be noted that the value of the parameters discontinuity orientation is not given quantitative terms but by qualitative descriptions such as favorable. To facilitate a decision whether strike and dip orientations are favorable or not, reference should be made to Section F in Table 2.2, which is based on studies by Wickham et al. (1972).

After the adjustment for discontinuity orientations, the rock mass is classified according to Section C of Table 2.2, which groups the final (adjusted) rock mass ratings (RMR) into five rock mass classes, the full range of the possible RMR values varying from zero to 100. Note that the rock mass classes are in groups of twenty ratings each.

Next, Section D of Table 2.2 gives the practical meaning of each rock mass class by relating it to specific engineering problems. In the case of tunnels and chambers, the output from the RMR System may be used to estimate the stand-up time and the maximum stable rock span for a given RMR (Figure A.2 in Appendix A).

Lauffer (1988) presented a revised stand-up time diagram specifically for tunnel boring machine (TBM) excavation. This diagram is most useful because it demonstrates how the boundaries of RMR classes are shifted for

TBM applications. Thus, an RMR adjustment can be made for machine-excavated rock masses.

Support pressures can be determined from the RMR System as (Ünal, 1992) :

$$P = \left(\frac{100 - RMR}{100}\right) . \gamma . B . S = \gamma . h_t \quad (2.1)$$

$$h_t = \left(\frac{100 - RMR}{100}\right) . B . S \quad (2.2)$$

where

P : is the support pressure in kN/m^2,

h_t : is the rock-load height in meters,

B : is the tunnel width in meters,

S : strength factor (obtained from Figure A.3 included in Appendix A),

γ : is the density of the rock in kN/m^3.

The variation of the rock-loads from Equation 2.1 for various rock classes as a function of roof span is presented in Figure A.4 included in Appendix A.

Using the measured support pressure values from 30-instrumented Indian tunnels, Goel and Jethwa (1991) proposed Equation 2.3 for estimating the short-term support pressure for underground openings in the case of tunneling by conventional blasting method using steel rib supports:

$$P = \left(\frac{0.75 x B^{0.1} x H^{0.5} - RMR}{2RMR}\right) \quad (2.3)$$

where

P : is the support pressure in MPa,

H : is the overburden or tunnel depth in meters (>50 m),

B : is the span of opening in meters.

RMR System provides a set of guidelines for the selection of rock support for tunnels in accordance with Table A.1 given in Appendix A. These guidelines depend on such factors as the depth below surface (in-situ stress), tunnel size and shape, and the method of excavation. Note that the support measures given in Table A.1 are for 10 m span horseshoe shaped tunnel, vertical stress less than 25 MPa and excavated using conventional drilling and blasting procedures.

2.3.2 Modified Rock Mass Rating (M-RMR) System

The rock mass classification systems have been developed for specific purposes and rock mass types, therefore, direct utilization of these systems, in their original form, for characterization of complex rock mass conditions is not always possible. This is probably one of the main reasons why designers continue to originate new systems, or modify and extend the ones that already exist. RMR and Q systems, for example, although widely used in mining and tunneling, can not fully describe the specifications of weak, stratified and clay bearing rock masses in their original form. Consequently, the engineering applications that would be carried out based on original RMR and Q ratings could be inadequate for making design decisions even during the preliminary design stage (Ünal, 1996).

Several modifications have been proposed in order to make the RMR classification more relevant to mining applications. One of these modifications is “The Modified Rock Mass Rating (M-RMR)” system that has been developed by Ünal and Özkan (1990) based on extensive geotechnical investigations carried out in a borax mine, two coal mines, a copper-zinc mine, and a gold mine region in Turkey.

The M-RMR System enables the determination of a quality-rating index (M-RMR) for characterization of rock masses. In general, the M-RMR System is based on the RMR system, developed by Bieniawski (1979, 1989). However new features are added to the system for better characterization of wide ranges of rock mass conditions, including weak, stratified, anisotropic and clay bearing rock masses.

The M-RMR System (Ünal, 1996; Ünal et al., 1997a and 1997b) includes the following new features:

a. Flexibility in determining the input parameters from field survey and/or from core boxes.

b. Inclusion of new parameters to the system, namely: the point load strength index (I_{PL}), Block Punch Index (BPI), weathering coefficient (F_C) which obtained from slake durability test and intact core recovery (ICR).

c. Further description of adjustment factors, reflecting the effects of blasting damage (A_b) and major planes of weaknesses (A_w).

d. Description of the broken rock structures (BSTR) encountered in core boxes and allocation of importance ratings of these regions.

e. Allocation of new joint filling conditions, which can describe what, is physically seen in core boxes.

f. Development of new rating system for orientation of joints, which facilitate the use of the M-RMR System for shafts and slopes in addition to tunnels.

g. Considerations of the definitions and interval suggested by ISRM (1981), in allocating the importance ratings to strength and joint parameters.

h. Fully automatic processing of the collected input data by means of a computer program called ROCKMASS, developed by Ünal and Özkan (1990).

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

The input parameters required for classification process can be obtained from field or from core box survey. Depending on the type of survey the classification input data worksheets should be completed for each successive structural region or domain.

It is important to notice that based on the observation made in core boxes, the following features should be identified (Ünal, 2002):

i. Possible high horizontal stress (PHHS) zones,

ii. Broken structural zones (BSTR), characterized by heavily fractured nature of the rock, and absence of solid cores,

iii. Low shear strength properties, characterized by planar, smooth and occasionally slickensided joint surfaces,

iv. The effect of fault, existing in the vicinity of the borehole which may be recognized by the relative orientation of the discontinuities, the existence of the shear zones, and the presence of the water under pressure.

Based on the rock mass classification studies, the rock mass rating of each structural region should also be determined and the results should be interpreted in terms of rock mass classes and stability.

Structural regions are the zones of an engineering structure (i.e. tunnel or haulage way) in which geological conditions (e.g. type of rock material, discontinuities, topography, and overburden thickness) and hydrogeological conditions (e.g. surface and groundwater conditions) are similar. Structural domains, on the other hand, are the zones of core boxes in which certain features of the cores (i.e. rock type and joint density) are more or less uniform within each domain. Each shear zone, thick clay or broken zone, and cavity (core-loss) zone should be treated as a structural domain and hence, should be evaluated separately.

The quality-rating index for each structural region or domain, can be obtained either by manual calculations or by utilizing a computer program called ROCKMASS, developed by Ünal and Özkan (1990). In order to determine the M-RMR index manually, the ratings of the six basic input parameters, the weathering coefficient and the two adjustment factors (A_b and A_w) should be considered.

The six input parameters considered in M-RMR system are; uniaxial compressive strength, RQD, condition of discontinuities, joint spacing, groundwater conditions, and orientation of discontinuities. The steps that should be followed for determining the M-RMR value are illustrated in Figure 2.1. If there are more than one joint set in the rock mass, the M-RMR index should be determined by considering each joint set separately and the lowest M-RMR value should be selected as an index representing the structural region (or domain) in question.

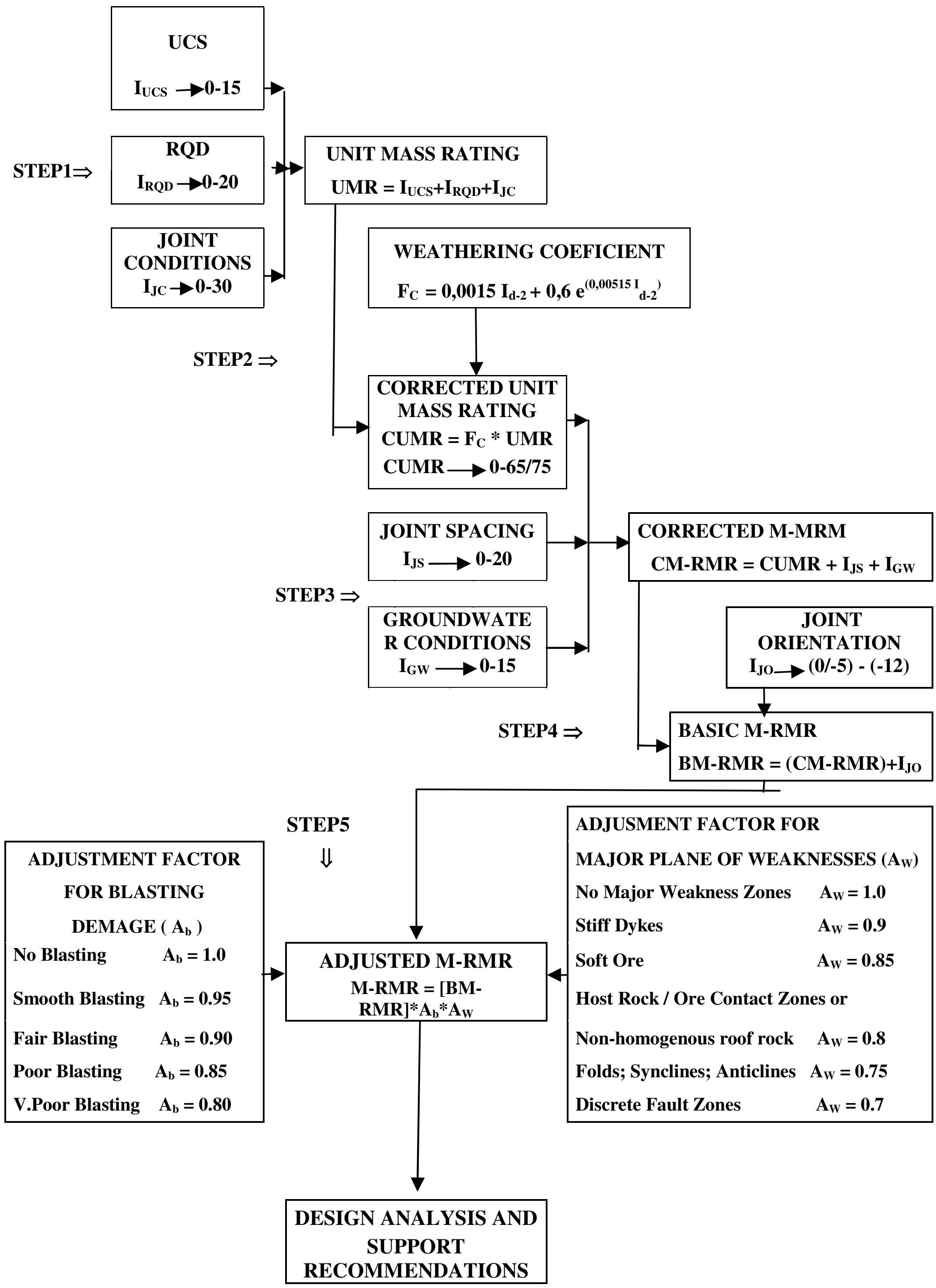


Figure 2.1 The overall structure of the modified Rock Mass Rating, M-RMR, System and the classification steps (After Ünal, 1996).

In order to determine the M-RMR value, the geotechnical data must be converted to numerical values, which reflect the ratings assigned to the input parameters. This can be accomplished by utilizing the Figures A.5 to A.8 given in Appendix A.

Gökçeoğlu and Aksoy (2000) suggested new improvements, such as determination of weathering coefficient by Schmidt hammer and four-cycle slake durability index, to the M-RMR system with their study.

2.3.3 Rock Mass Quality (Q) System

Barton et al. (1974) at the Norvegian Geotechnical Institute (NGI) proposed the Rock Mass Quality (Q) System of rock mass classification on the basis of about 200 case histories of tunnels and caverns. It is a quantitative classification system, and it is an engineering system enabling the design of tunnel supports.

The concept upon which the Q system is based upon three fundamental requirements:

a. Classification of the relevant rock mass quality,
b. Choice of the optimum dimensions of the excavation with consideration given to its intended purpose and the required factor of safety,
c. Estimation of the appropriate support requirements for that excavation.

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

$$Q = \left(\frac{RQD}{J_n}\right) \cdot \left(\frac{J_r}{J_a}\right) \cdot \left(\frac{J_w}{SRF}\right) \qquad (2.4)$$

where

RQD	is the Rock Quality Designation
J_n	is the joint set number
J_r	is the joint roughness number
J_a	is the joint alteration number
J_w	is the joint water reduction factor
SRF	is the stress reduction factor

The numerical value of the index Q varies on logarithmic scale from 0.001 to a maximum of 1000.

The numerical values of each of the above parameters are interpreted as follows (Barton et al., 1974). The first quotient (RQD/J_n), representing the structure of the rock mass, is a crude measure of the block or particle size. The second quotient (J_r/J_a) represents the roughness and frictional characteristics of the joint walls or filling materials.The third quotient (J_w/SRF) consists of two stress parameters. SRF is a measure of:

i. loosening load in the case of an excavation through shear zones and clay bearing rock,
ii. rock stress in competent rock, and
iii. squeezing loads in plastic incompetent rocks. It can be regarded as as a total stress parameter.

The parameter J_w is a measure of water pressure. The quotient (J_w/SRF) is a comlicated empirical factor describing the active stress.

Barton et al. (1974) consider the parameters, J_n, J_r, and J_a, as playing a more important role than joint orientation, and if joint orientation had been included, the classification would have been less general. However, orientation is implicit in parameters J_r, and J_a, because they apply to the most unfavorable joints.

The traditional use of the Q-system for rock mass classification and empirical design of rock reinforcement and tunnel support has been extended in several ways in the paper published by Barton (2002a). The classification of individual parameters used to obtain the tunneling Quality Index Q for a rock mass is given in Table 2.3.

Table 2.3 Classification of individual parameters used in the Q System (Barton, 2002a).

A1

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

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

A2

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

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

A3

Joint roughness number		J_r
(a) Rock-wall contact, and (b) rock-wall contact before 10 cm shear		
A	Discontinuous joints	4
B	Rough or irregular, undulating	3
C	Smooth, undulating	2
D	Slickensided, undulating	1.5
E	Rough or irregular, planar	1.5
F	Smooth, planar	1.0
G	Slickensided, planar	0.5

Table 2.3 (Continued).

(c) No rock-wall contact when sheared

H	Zone containing clay minerals thick enough to prevent rock-wall contact.	1.0
J	Sandy, gravely or crushed zone thick enough to prevent rock-wall contact	1.0

Notes: (i) Descriptions refer to small-scale features and intermediate scale features, in that order. (ii) Add 1.0 if the mean spacing of the relevant joint set is greater than 3m. (iii) J_r = 0:5 can be used for planar, slickensided joints having lineations, provided the lineations are oriented for minimum strength. (iv) Jr and J_a classification is applied to the joint set or discontinuity that is least favourable for stability both from the point of view of orientation and shear resistance, τ (where $\tau \approx \sigma_n \tan^{-1} (J_r/J_a)$.

A4

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

A5

	Joint water reduction factor	**Approx. water pres. (kg/cm^2)**	**J_w**
A	Dry excavations or minor inflow, i.e., <5 l/min locally	<1	1.0
B	Medium inflow or pressure, occasional outwash of joint fillings	1–2.5	0.66
C	Large inflow or high pressure in competent rock with unfilled joints	2.5–10	0.5
D	Large in.ow or high pressure, considerable outwash of joint fillings	2.5–10	0.33

Table 2.3 Continued.

E	Exceptionally high inflow or water pressure at blasting, decaying with time	>10	0.2–0.1
F	Exceptionally high inflow or water pressure continuing without noticeable decay	>10	0.1–0.05

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

A6

	Stress reduction factor	**SRF**
	(a) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated	
A	Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)	10
B	Single weakness zones containing clay or chemically disintegrated rock) (depth of excavation ≤50 m	5
C	Single weakness zones containing clay or chemically disintegrated rock (depth of excavation >50m)	2.5
D	Multiple shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
E	Single shear zones in competent rock (clay-free), (depth of excavation ≤50 m)	5.0
F	Single shear zones in competent rock (clay-free), (depth of excavation >50m)	2.5
G	Loose, open joints, heavily jointed or ‘sugar cube’, etc. (any depth)	5.0

	(b) Competent rock, rock stress problems	σ_c/σ_1	σ_θ/σ_c	SRF
H	Low stress, near surface, open joints	200	<0.01	2.5
J	Medium stress, favorable stress condition	200–10	0.01–0.3	1
K	High stress, very tight structure. Usually favorable to stability, may be unfavorable for wall stability	10–5	0.3–0.4	0.5–2
L	Moderate slabbing after >1h in massive rock	5–3	0.5–0.65	5–50
M	Slabbing and rock burst after a few minutes in massive rock	3–2	0.65–1	50–200
N	Heavy rock burst (strain-burst) and immediate dynamic deformations in massive rock	<2	>1	200–400

	(c) Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure	σ_θ/σ_c	SRF
O	Mild squeezing rock pressure	1–5	5–10
P	Heavy squeezing rock pressure	>5	10–20

Table 2.3 (Continued).

		SRF
(d) Swelling rock: chemical swelling activity depending on presence of water		
R	Mild swelling rock pressure	5–10
S	Heavy swelling rock pressure	10–15

Notes: (i) Reduce these values of SRF by 25–50% if the relevant shear zones only influence but do not intersect the excavation. This will also be relevant for characterization. (ii) For strongly anisotropic virgin stress field (if measured): When $5 \leq \sigma_1/\sigma_3 \leq 10$; reduce σ_c to $0.75\sigma_c$: When $\sigma_1=\sigma_3 > 10$; reduce σ_c to $0.5\sigma_c$; where σ_c is the unconfined compression strength, σ_1 and σ_3 are the major and minor principal stresses, and σ_θ the maximum tangential stress (estimated from elastic theory). (iii) Few case records available where depth of crown below surface is less than span width, suggest an SRF increase from 2.5 to 5 for such cases (see H). (iv) Cases L, M, and N are usually most relevant for support design of deep tunnel excavations in hard massive rock masses, with RQD=Jn ratios from about 50–200. (v) For general characterization of rock masses distant from excavation influences, the use of SRF=5, 2.5, 1.0, and 0.5 is recommended as depth increases from say 0–5, 5–25, 25–250 to >250 m. This will help to adjust Q for some of the effective stress effects, in combination with appropriate characterization values of J_w: Correlations with depth- dependent static deformation modulus and seismic velocity will then follow the practice used when these were developed. (vi) Cases of squeezing rock may occur for depth $H > 350Q^{1/3}$ according to Singh [34]. Rock mass compression strength can be estimated from $\sigma_{cm} \approx 5\gamma Q^{1/3}c$ (MPa) where γ is the rock density in t/m^3, and $Qc = Q \times \sigma_c / 100$; Barton (2000).

Most recently, some suggestions, related to Q-System, were made by Ünal (2002). These suggestions are based on the experience gained in applying rock mass classification systems. As experienced before, it was quite difficult to apply the Q-System as suggested by Barton et al. (1974). The difficulty arises, especially in determining the joint alteration number (J_a) and stress reduction factor (SRF) parameters during geotechnical logging, which is not defined by Barton et al. (1974). In order to bring a modest solution to this problem Ünal (2002) made some suggestions for J_a and SRF parameters. These suggestions are presented in Appendix A (Figures A.9 to A.11).

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

$$D_e = \frac{\text{Excavation span, diameter or height (m)}}{\text{Excavation Support Ratio, ESR}} \qquad (2.5)$$

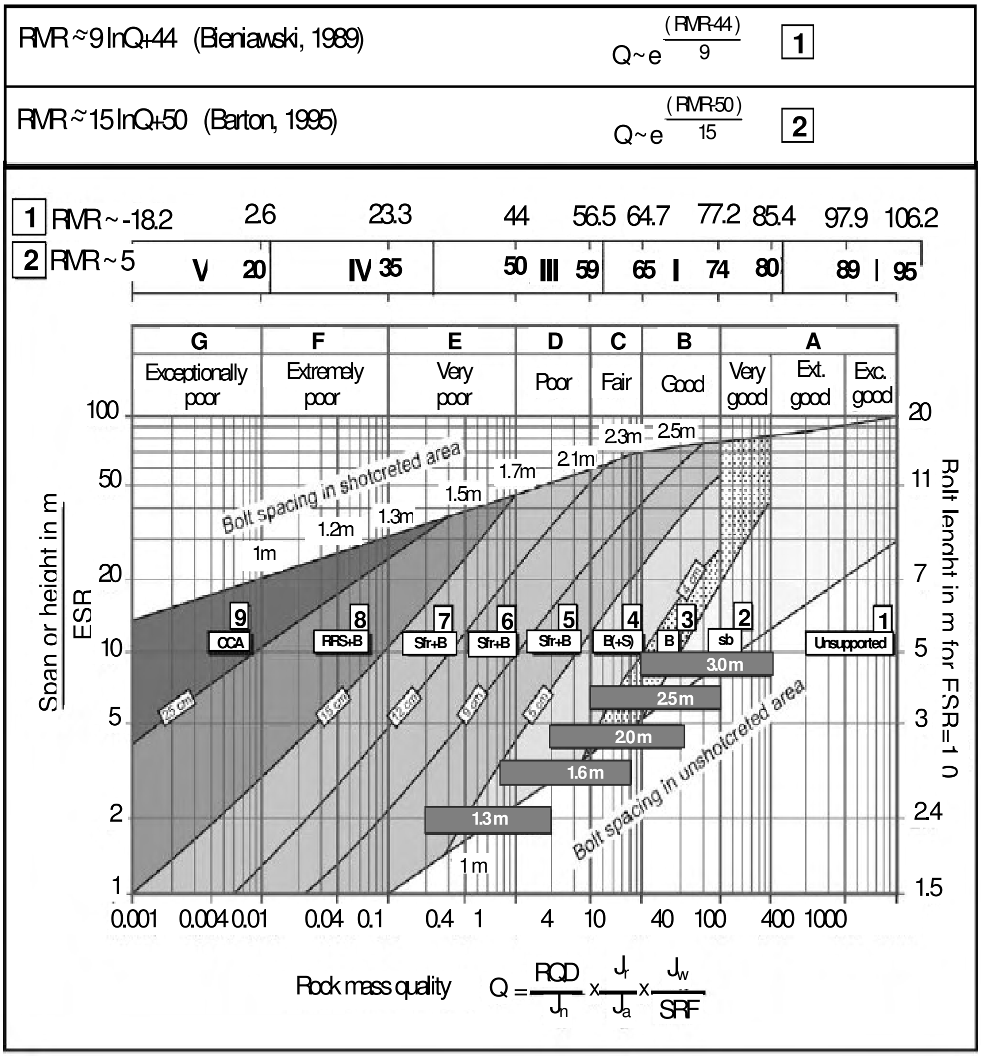
The value of ESR is related to the intended use of the excavation and to the degree of security which is demanded of the support system installed to maintain the stability of the excavation as shown below in Table 2.4.

The equivalent dimension, D_e, plotted against the value of Q, is used to provide 38 support categories in a chart published in the original paper by Barton et al. (1974). This chart has been updated by Grimstad and Barton (1993) to reflect the increasing use of steel fibre reinforced shotcrete in underground excavation support. The original support chart and list of 38 support categories are presented in Appendix A as Figure A.12 and Tables A.2 to A.5.

Table 2.4 Excavation support categories and their ESR values (After Barton et al., 1974).

Excavation Category		ESR Values
A	Temporary mine openings	3-5
B	Permanent mine openings, water tunnels for hydro power (excluding high pressure penstocks), pilot tunnels, drifts and headings for excavations	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, civil defense chambers, portal intersections.	1.3
D	Power stations, major road and railway tunnels, civil defense chambers, portal intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, factories	0.8

The reproduced updated Q-support chart (Barton, 2002a) is shown in Figure 2.2.



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

Figure 2.2 The 1993 updated Q-support chart for selecting permanent B+S(fr) reinforcement and support for tunnels and caverns in rock. The black, highlighted areas show where estimated Q-values and stability are superior in TBM tunnels compared to drill-and-blast tunnels. This means ‘nosupport’ penetrates further (After Barton, 2002a).

Barton et al. (1980) provide additional information on rock bolt length, maximum unsupported spans and roof support pressures to supplement the support recommendations published in the original 1974 paper.

The length (L) of rockbolts can be estimated from the excavation width (B) and the Excavation Support Ratio (ESR):

$$L = \frac{2 + 0.15B}{ESR} \tag{2.6}$$

The maximum unsupported span can be estimated fromthe following expression:

$$\text{Maximum unsupported span} = 2 \,.\, \text{ESR} \,.\, Q^{0.4} \tag{2.7}$$

Based upon analyses of case records, Grimstad and Barton (1993) suggest that the relationship between the value of Q and the permanent roof support pressure P is estimated from:

$$P = \frac{2\sqrt{J_n}\,Q^{-1/3}}{3J_r} \tag{2.8}$$

The original Q-based empirical equation for underground excavation support pressure (Barton et al., 1974), when converted from the original units of kg/cm^2 to MPa, is expressed as follows (Barton, 2002a):

$$P = \frac{J_r}{20xQ^{1/3}} \tag{2.9}$$

2.3.4 Geological Strength Index (GSI)

One of the major problems in designing underground openings is estimating the strength parameters of in situ rock mass. The strength and deformation modulus of closely jointed rock masses cannot be directly determined, since the dimensions of representative specimens are too large for laboratory testing. This limitation results in an important difficulty when studying in jointed rock masses. Hoek and Brown (1980) suggested an empirical failure criterion to overcome this difficulty. The rock mass rating (RMR) classification was introduced into the Hoek–Brown criterion by its originators (Hoek and Brown, 1988) to describe the quality of rock masses. This empirical criterion has been re-evaluated and expanded over the years due to the limitations both in Bieniawki's RMR classification and the equations used by the criterion for very poor-quality rock masses (Hoek, 1983, 1990, 1994; Hoek and Brown, 1988, 1997; Hoek et al., 1992, 2002).

Hoek (1994), Hoek et al (1995), and Hoek and Brown (1997) proposed a new rock mass classification system called "Geological Strength Index, GSI" as a replacement for Bieniawski's RMR to eliminate the limitations rising from the use of RMR classification scheme. The GSI System seems to be more practical than the other classification systems such as Q and RMR when used in the Hoek–Brown failure criterion. Therefore, the GSI value has been more popular input parameter for the Hoek–Brown criterion to estimate the strength and deformation modulus of the jointed rock masses.

In the original form of the GSI System (Hoek and Brown, 1997), the rock mass is classified into 20 different categories with a letter code based upon the visual impression on the rock mass and the surface characteristics of discontinuities and the GSI values ranging between 10 and 85 are estimated (Figure A.13 in Appendix A). Two additional rock mass categories, is called foliated / laminated rock mass structure and massive or intact rock, were introduced into the GSI system by Hoek et al. (1998) and Hoek (1999), respectively as seen in A.15 (Appendix A). Due to the anisotropic and heterogeneous nature of the foliated/laminated rock mass structure category, Marinos and Hoek (2001) also proposed a special GSI chart only for the classification of the heterogeneous rock masses such as flysch.

However, the GSI classification scheme, in its existing form, leads to rough estimates of the GSI values (Sönmez and Ulusay, 1999). Therefore, Sönmez and Ulusay (1999) made an attempt for the first time to provide a more quantitative numerical basis for evaluating GSI as a contributory use of the GSI system by introducing new parameters and ratings, such as surface condition rating (SCR) and structure rating (SR) (Figure A.14 in Appendix A). In this modification, the original skeleton of the GSI System has been preserved, and SR and SCR are based on volumetric joint count (J_v) and estimated from the input parameters of RMR scheme (e.g. roughness, weathering and infilling). Then this chart was slightly modified by Sönmez and Ulusay (2002) and defined by fuzzy sets by Sönmez et al. (2003). In this version of the quantitative GSI chart, intact or massive rock mass included into the system as previously suggested by Hoek (1999) as given in Figure 2.3.

In recent years, the GSI system has been used extensively in many countries and lots of studies have been done to quantify GSI system parameters to better classify jointed rock masses for engineering purposes. The quantified GSI chart, building on the concept of block size and condition, developed by Cai, et al. (2003), and fuzzy-based quantitative GSI chart of Sönmez et al. (2004a) are presented as Figures A.16 and A.17 in Appendix A.

A computer program “RocLab” was developed (Hoek et al., 2002) to determine the rock mass strength parameters (cohesion, internal friction angle) by using GSI.

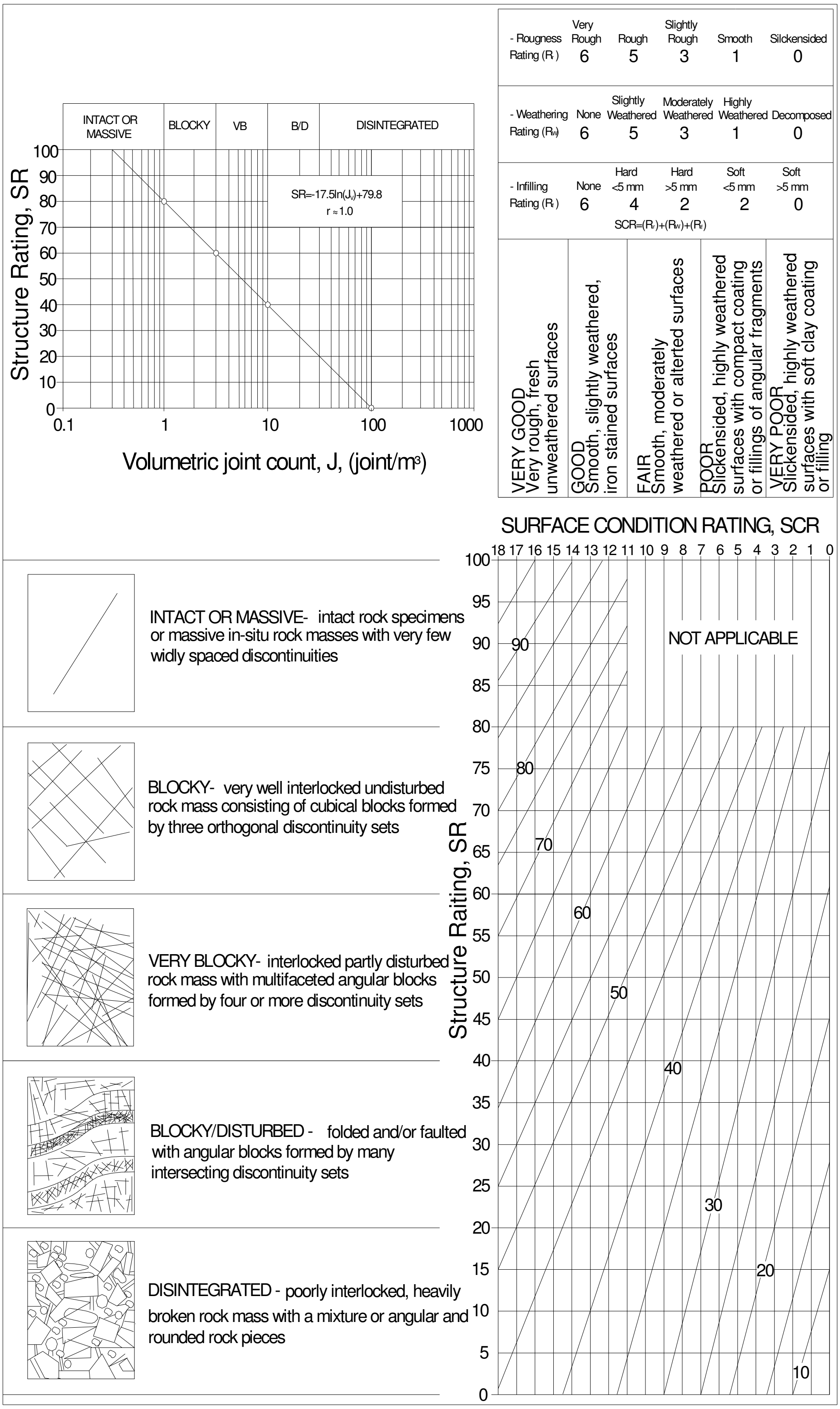


Figure 2.3 The modified GSI classification suggested by Sönmez and Ulusay (2002).

2.3.5 The New Austrian Tunneling Method (NATM)

The New Austrian Tunneling Method (NATM) was developed by Rabcevicz, Müller and Pacher between 1957 and 1965 in Austria. NATM features a qualitative ground classification system that must be considered within the overall context of the NATM (Bieniawski, 1989).

In essence, NATM is a approach or philosophy integrating the principles of the behavior of rock masses under load and monitoring the performance of underground excavations during construction. The NATM iss not a set of specific excavation and support techniques. It involves a combination of many established ways of excavation and tunneling, but the difference is the continual monitoring of the rock movement and the revision of support to obtain the most stable and economical lining. However, a number of other aspects are also pertinent in making the NATM more of a concept or philosophy than a method (Bieniawski, 1989).

Müller (1978) considers the NATM as a concept that observes certain principles. Although he has listed no less than 22 principles, there are seven most important features on which the NATM based (Bieniawski, 1989):

1. *Mobilization of the Strength of the Rock Mass.* The method relies on the inherent strength of the surrounding rock mass being conserved as the main component of the tunnel support. Primary support is directed to enable the rock to support itself. It follows that the support must have suitable load deformation characteristics and be placed at the correct time.

2. *Shotcrete Protection.* In order to preserve the load-carrying capacity of the rock mass, loosening and excessive rock deformations must be minimized. This is achieved by applying a thin layer of shotcrete, sometimes together with a suitable system of rock bolting, immediately after face advance. It is essential

that the support system used remains in full contact with the rock and deforms with it. While the NATM involves shotcrete, it does not mean that the use of shotcrete alone constitutes the NATM.

3. *Measurements.* The NATM requires the installation of sophisticated instrumentation at the time the initial shotcrete lining is placed, to monitor the deformations of the excavation and the buildup of load in the support. This provides information on tunnel stability and permits optimization of the formation of a load-bearing ring of rock strata. The timing of the placement of the support is of vital importance.

4. *Flexible Support.* The NATM is characterized by versatility and adaptability leading to flexible rather than rigid tunnel support. Thus, active rather than passive support is advocated, and strengthening is not by a thicker concrete lining but by a flexible combination of rock bolts, wire mesh, and steel ribs. The primary support will partly or fully represent the total support required and the dimensioning of the secondary support will depend on the results of the measurements.

5. *Closing of Invert.* Since a tunnel is a thick walled tube, the c1osing of the invert to form a load-bearing ring of the rock mass is essential. This is crucial in soft-ground tunneling, where the invert should be closed quickly and no section of the excavated tunnel surface should be left unsupported even temporarily. However, for tunnels in rock, support should not be installed too early since the load-bearing capability of the rock mass would not be fully mobilized. For rock tunnels, the rock mass must be permitted to deform sufficiently before the support takes full effect.

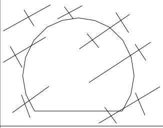
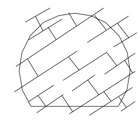
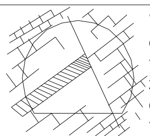
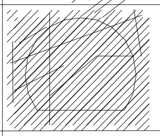
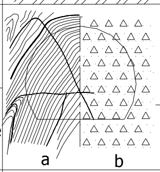
6. *Contractual Arrangements.* The preceding main principles of the NATM will only be successful if special contractual arrangements are made. Since the NATM is based on monitoring measurements, changes in support and

construction methods should be possible. This, however, is only possible if the contractual system is such that changes during construction are permissible (Spaun, 1977).

7. *Rock Mass Classification Determines Support Measures.* Payment for support is based on a rock mass classification after each drill and blast round. In some countries this is not acceptable contractually, and this is why the method has received limited attention in the United States.

According to NATM, the rock mass is classified without a numerical quality rating; ground conditions are described qualitatively. The Austrian ONORM B2203 of October 1994 is based on the suggestions by Rabcewicz et al. (1964) as seen in Figure 2.4. The main rock mass classes and behaviour of rock masses for each rock mass group according to the ONORM B2203 are given in Table A.6 included in Appendix A

A critical analysis of the principles of the complete New Austrian Tunneling Method (NATM) "edifice of thoughts" has been published by Kovari (1994). The author claimed that: "The NATM is based on two basic erreneous concept". The most recently published paper by Kovari (2004) traces the fascinating history of rock bolts and the NATM or the sprayed concrete lining method from its beginnings and shows how it developed on a broad international front in its theoretical and technological aspects. This paper describes numerous examples of civil engineering work wordwide with early application of rock bolting. In concluding, it is demonstrated that NATM is in many respects borrowed and has created much confusion amongst professional engineers by dint of its psedudo-scientific basis (Kovari, 2004).

ROCK MASS CLASSIFICATION IN TUNNELING					
CLASS No	CLASS NAME			GEOMECHANICAL BEHAVIOUR	WATER EFFECT
I	STRONG get slightly fragile by time		Dense, uncertain discontinuity traces	Uniaxial compressive strength of rock is higher than the tangential stress on the opening wall	None
II	FRAGILE get very fragile by time		Certain discontinuities due to the bedding and jointing, locally clayey joint fillings	No I: continuously stable (precautions to rock burst) No II: continuously stable with the support of the bench	Not significant
III	FRIABLE		Wide and effective crushing, fucturing, mylonite zones in all directions, clayey fillings	Tangential stress on the excavation wall is higher than or equal to resistance of the rock. Open or close load bearing arch is necessary	Very effective on joint fillings
IV	SQUEEZING		Crushed, folded thick mylonite zones, very well squeezed, cohesive soil	Due to tangential stresses on the excavation wall is higher than the bearing capacity of the rock, rock behaves plastically. Deforming towards opening No IV : slow and minor rate No V: fast and effective rate Horizontal stress and floor heaving are expected. Load bearing close arch that should be installed immediately after excavation is necessary	Highly effective on joint fillings and rock mass quality
V a	VERY SQUEEZING potential to swelling		Completely crushed, mylonitized and doughed rock		Very high, softening
V b	SQUEEZING Low cohessive soil		Low cohessive weathered soil		
VI	Special Type (Flowing)	Non-cohessive, flowing soil		Similar with V and special precautions are necessary	Very much

Not: This table were prepared according to Pacher and Rabcewicz.'s studies.

Figure 2.4 The NATM's rock mass classes (Ayaydın, 1986).

2.3.6 Correlations between the RMR, M-RMR, Q, GSI and NATM

The RMR, M-RMR, Q and GSI classification systems are based on the quantitative properties of rock mass, but NATM is qualitative classification system. However, the basic idea of the support systems is close to each other. For the tunnel designs, these classification systems are used together as empirical aproach.

Various empirical correlations have been made between RMR and Q classification in previous studies. The most popular and applicable one is proposed by Bieniawski (1976) is given in Table 2.6.

Also different correlations proposed between GSI and RMR (Hoek, et al., 1995), GSI and Q (Hoek, et al., 1995), and M-RMR and Q (Ünal, 1996) as given in Table 2.5.

Table 2.5 Correlations between the classification systems

Originator of empirical equation	Equation
Bieniawski (1976)	RMR = 9 lnQ + 44
Hoek et al. (1995)	$GSI = RMR_{76}$ (use of 1976 version of RMR) $GSI = RMR_{89} - 5$ (use of 1989 version of RMR)
Hoek et al. (1995)	GSI = 9 lnQ' + 44 (Q': $\frac{RQD}{Jn}\frac{Jr}{Ja}$)
Ünal (1996)	M-RMR = 9.66 lnQ + 37.9

2.4 Estimation of Rock Mass Strength and Deformation Modulus

One of the major problems in designing underground openings is estimating the strength parameters of in-situ rock mass. Determination of the strength of closely jointed rock masses is difficult since the size of representative specimens sometimes is too large for laboratory testing.

This difficulty can be overcome by using the Hoek-Brown failure criterion. Since its introduction in 1980, the criterion has been refined and expended over the years (1983, 1988. 1992, 1995, 2002). A brief history of the development of the Hoek-Brown failure criterion and summary of equations, which are used for estimation of rock mass strength parameters are published by Hoek (2004) and presented in Appendix A.I.

The results of the back analysis of the slope instabilities in closely jointed rock masses by Sönmez and Ulusay (1999 and 2002) indicated that the disturbance effect due to the influence of the method of excavation could not be ignored. For this reason, a disturbance factor, which should be used in the determination of rock mass constants considered by the Hoek-Brown failure criterion, was suggested by these investigators.

The latest version of Hoek-Brown failure criterion was proposed by Hoek et al. (2002). It represents a major re-examination of the entire Hoek-Brown failure criterion and new derivations of the relationships between rock mass strength parameters (m,s) and GSI. A disturbance factor (D), which is also considered by the empirical equation for estimating the deformation modulus of rock masses in conjuction with the GSI, was also included to deal with blast damage. The guidelines for estimating disturbance factor D are given in Appendix A.II. Also a computer program *RocLab*, which includes all of these new derivations, was developed to determine the rock mass strength parameters (cohesion, internal friction angle) by using GSI.

The deformation modulus (E_m) of a rock mass is an important parameter in any form of numerical analysis and in the interpretation of monitored deformation around underground openings. Since this parameter is very difficult and expensive to determine in the field, several attempts have been made to develop methods for estimating its value, based upon rock mass classifications (Hoek et al., 1995).

The first empirical model for prediction of the deformation modulus of rock masses was developed by Bieniawski (1978). After Bieniawski's empirical equation, some other empirical approaches such as Barton et al. (1980), Serafim and Pereira (1983), Nicholson and Bieniawski (1990), Mitri et al. (1994), Hoek and Brown (1997), Palmström and Singh (2001), Barton

(2002), Hoek, et al. (2002) and Kayabaşı et al. (2003) have been proposed to estimate the deformation modulus of rock masses. Such empirical approaches are open to improvement because they are based limited collected data.

The equations proposed by Bieniawski (1978), Serafim and Pereira (1983), Nicholson and Bieniawski (1990) and Mitriet al.(1994) consider Bieniawski's RMR (1989) while Barton's equation (1980, 2002b) estimates the deformation modulus by considering the Q-values. The equation proposed by Hoek and Brown (1997) is a modified form of Serafim and Pereira's equation (1983) and it is based on the GSI. Palmström and Singh (2001) also suggested an empirical equation depending on RMi (Palmström, 1996) values for the prediction of deformation modulus. Kayabaşı et al. (2003) proposed the most recent empirical equation by considering the RQD, elasticity modulus of intact rock and weathering degree for estimating the deformation modulus of rock masses. Recently, with the study conducted by Gökçeoğlu et al. (2003), the prediction performance of the existing empirical equations was checked and some contributions to the work of Kayabaşı et al. (2003) was provided.

Mostly used empirical equations for the estimation of deformation modulus are given in Table 2.6.

Most resently, a prediction model, based on an approach which considers that modulus ratios of the rock mass and intact rock should be theoretically equal to each other when GSI is equal to 100, was developed by Sönmez et.al. (2004b).

Hoek presented a discussion paper, which is named as *estimates of rock mass strength and deformation modulus*, in the internet site www.rocscience.com (Hoek, 2004). In this paper, empirical estimates of rock mass strength and deformation modulus, which have beenpublished by several authors, together with available data from in situ measurements are summarized in Figures (Appendix A.III). These estimates are based on rock mass classification systems. All of the empirical relationships used in these studies are intended to provide initial estimates of the rock mass properties and they should be used with caution in engineering design. In critical cases it is strongly recommended that the estimates should be confirmed by in situ measurements or by back analysis of excavation behavior.

Table 2.6 List of empirical equations suggested for estimating the deformation modulus with required parameters and limitations

Originator of empirical equation	Required parameters	Limitations	Equation
Bieniawski (1978)	RMR	RMR > 50	E_m= 2RMR-100
Serafim and Pereira (1983)	RMR	RMR ≤ 50	$E_m=10^{[(RMR-10)/40]}$
Barton (2002)	Q, σ_c	σ_c ≤100MPa	$E_m= 10[(\sigma_c /100)Q]^{1/3}$
Hoek et al. (2002)	GSI, σ_c, D	σ_c≤100 MPa	$E_m= [1-(D/2)]\sqrt{(\sigma_c/100)}\, 10^{(GSI-10)/40}$
		σ_c>100 MPa	$E_m= [1-(D/2)]10^{(GSI-10)/40}$
σ_c : Uniaxial compressive strength, D : Disturbance factor (Appendix A II).			

CHAPTER III

GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS AT THE DİM TUNNEL PROJECT AREA

3.1 Introduction

In this chapter, general information about Dim Tunnel, previous geological studies, and geological and geotechnical studies carried out by the author around the tunnel project area are presented.

3.2 General Information about Dim Tunnel

The study area is located 6 km southeast of Alanya on the Alanya-Gazipaşa-5. Division Boundary Road along the Mediterranean Sea coast between Km 6+050 and 7+400 in southern Turkey (Figures 3.1, 3.2 and 3.3).

The proposed Dim Tunnel has a horse-shoe shape, with a diameter of 10 meters and maximum overburden thickness of 70 meters.

3.3 Previous Studies

The proposed tunneling area and its vicinity were examined mainly for geological and mining purposes by Blumental (1951), Okay and Özgül (1984), and Şengün (1986).

Figure 3.1 Location map of the study area.

Figure 3.2 General view of proposed Dim Tunnel route from Km 6+200.

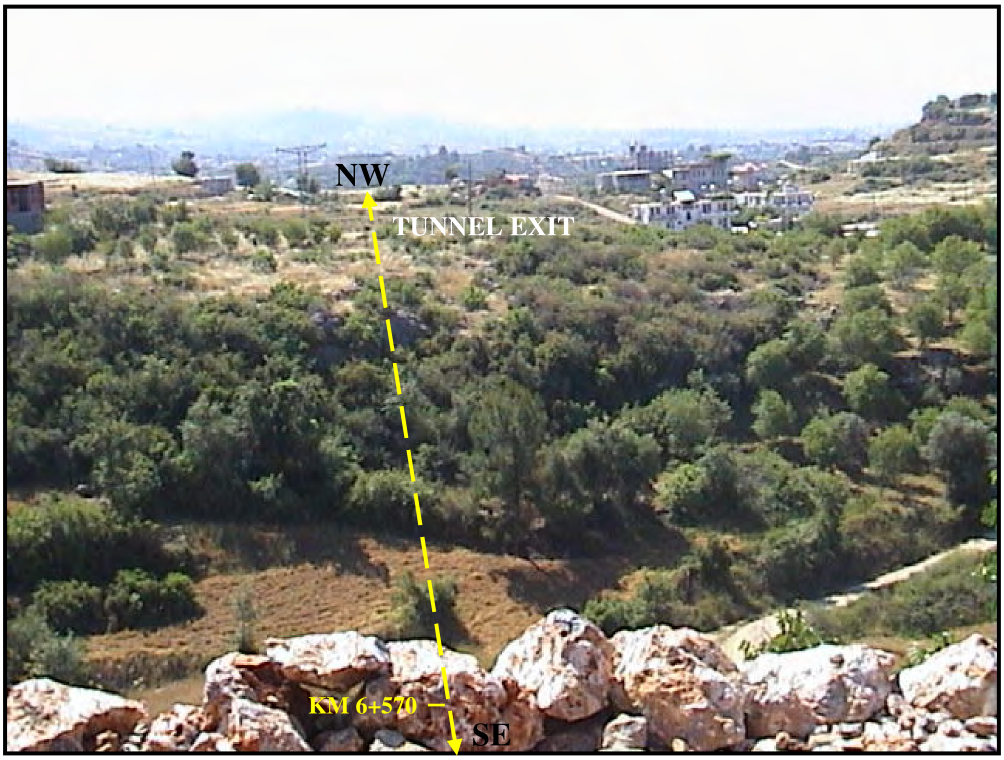


Figure 3.3 General view of proposed Dim Tunnel route from Km 6+570.

In regard to geotechnical investigations, Petra Engineering and Consulting Company, in 2002, carried out a detailed geotechnical investigation along the Dim Tunnel at the Alanya - Gazipaşa - 5. Division Boundary Road between Km 6+050 and Km 7+400. The preliminary geotechnical investigation report was completed and submitted to the General Directorate of Highways in January 2003 but the final geotechnical investigation report (including rock mass classifications, related support system, etc.) and design of the tunnel has not been prepared yet. The author of this thesis also involved in the project for Petra during the geological and geotechnical investigations.

3.3.1 Geology

In this section regional geology, site geology and structural geology of the study area and its vicinity are evaluated.

3.3.1.1 Regional Geology

The Alanya Massif is the name given to a large area of metamorphic rocks situated towards the east of Antalya Bay in the Eastern Mediterranean (Blumental, 1951).

The Mesozoic continental margin type lithologies of the Antalya unit crop out beneath the Alanya Massif in a large tectonic window.. In the east of the Antalya Bay between Alanya and Anamur, the largely sedimentary lithologies of the Antalya unit are in turn tectonically overlain by the metamorphic rocks of the Alanya Massif (Figure 3.4).

The southern part of the Alanya Massif is made up of three superimposed, relatively flat lying, crystalline nappes (Alanya Nappes). The Alanya Massif consists of the structurally lowest part of Mahmutlar Nappe, the intermediate part of the Sugözü Nappe, and the structurally highest unit of the Yumrudağ Nappe. Mahmutlar Nappe consists of heterogeneous series of shales, sandstones, dolomites, limestones and quartzites. These are metamorphosed under greenschist facies conditions, and at least part of the sequence is Permian in age. Sugözü Nappe made up of garnet-mica schists, eclogites and blue schist. Alanya nappe consists of a thick Permian carbonate sequence underlain by relatively thin schist metamorphosed under low-grade greenschist facies (Okay and Özgül, 1984).

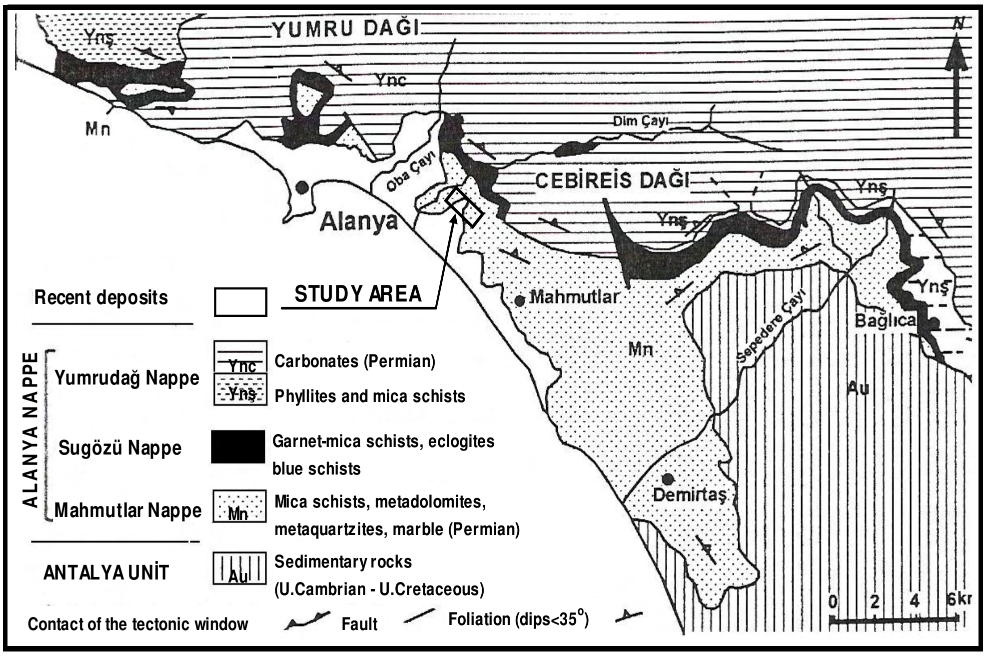


Figure 3.4 Simplified regional geological map of the Alanya region (Okay and Özgül, 1984).

3.3.1.2 Site Geology

In the study area and its close vicinity, Permian aged Alanya formation belongs to Mahmutlar Nappe, Miocene aged Mut formation and Quaternary deposits are distinguished. The simplified stratigraphical section of the study area is presented in Figure 3.5.

Alanya formation (Pza) consists of schists with recrystallized limestone intercalation (Şengün, 1986). The transition from the schists to the recrystallized limestone is gradational with schist and carbonate bands of several meters thick at the contact. The thickness of the schist is given as approximately 500 m (Okay and Özgül, 1984).

Mut formation (Tm) consists of alternation of conglomerates, sandstones, siltstones and shales, grading into limestone in the uppermost section. The thickness of the Mut formation is approximately 100 m (Şengün, 1986).

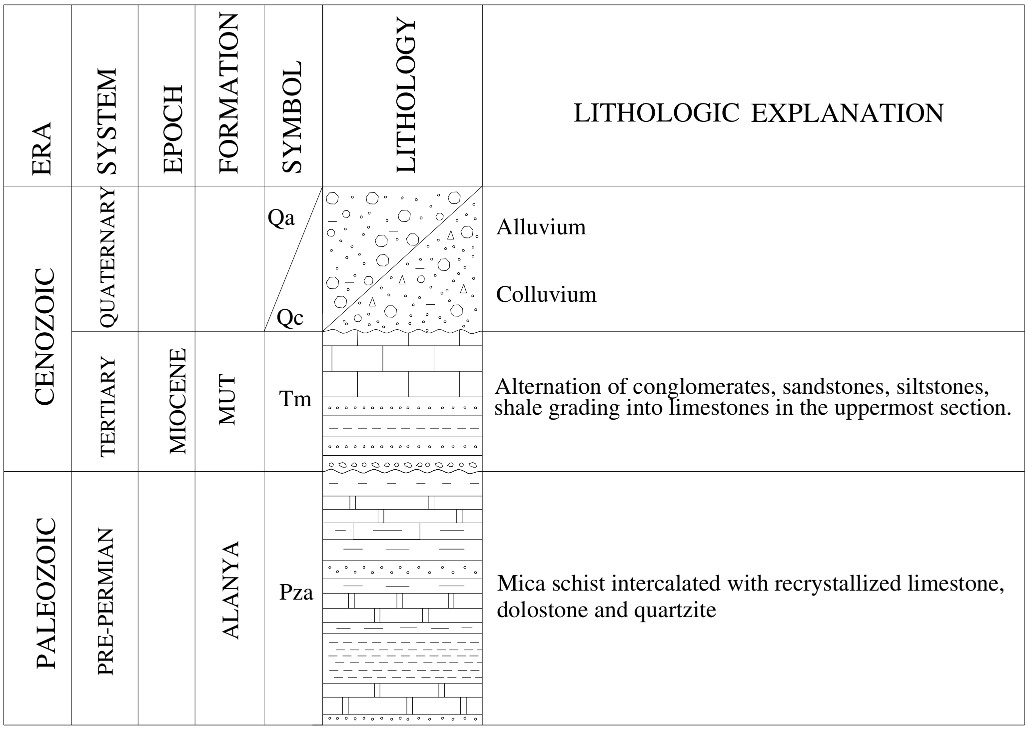


Figure 3.5 Simplified stratigaraphical section of the site vicinity (modified from Okay and Özgül, 1984; Şengün, 1986).

3.3.1.3 Structural Geology

Considering the size of project area, the effect of regional tectonic activity is not well observed. Therefore, some locally observed geologic structures such as folding, foliation and jointing could be described. In the project area and its surrounding, no fault is expected to cut the proposed tunnel axis.

Foliation is the product of regional metamorphism in schists. Minor folds and rarely developed joints are observed locally within schist unit.

3.3.2 Hydrogeology

In the study area, the schist units are accepted as impervious because of very poor water storage and conduit capacity of these rocks. The other units, limestone, conglomerate and intercalation of sandstone-shale units is also accepted as impervious, according to field and borehole observations.

There are no significant and permanently flowing springs at the study area. The groundwater table was observed at two of the boreholes (~50 m depth) along the tunnel route and the rock mass is generally dry and sometimes shows leakages according to the investigations carried out Petra Engineering and Consulting Company (2002).

3.3.3 Subsurface Investigations

In regards to geotechnical investigations, Petra Company, in 2002, carried out a detailed geotechnical investigation at the proposed Dim tunnel project area (between Km 6+050 and 7+400). In order to determine the geotechnical properties of the ground, along the 1350 m long Dim Tunnel, a total of 462 m of drilling was performed with 8 boreholes (Table 3.1).

3.3.4 Laboratory Tests

In order to determine the necessary geomechanical parameters for tunnel design, rock mechanics testing (uniaxial compressive strength, point load, slake durability, unit weight) was performed on samples taken from the core borings drilled in the study area. Laboratory tests were conducted by Rock Mechanics Laboratories of General Directorate of Highway Research Department and Mining Department of the Middle East Technical University (Appendix C).

Table 3.1 Numbers, kilometers, coordinates, elevations and depths of drillings

Borehole No.	Km	Coordinates		Elevation (m)	Depth (m)
		Northing	Southing		
SK-6+050	6+050	4045002.5	417106.4	21.00	15.00
SK-6+180	6+232	4045181.9	417082.2	94.00	85.00
SK-6+280	6+280	4045228.4	417065.3	73.00	63.00
SK-6+400	6+370	4045308.3	417027.2	88.00	76.00
SK-6+570	6+610	4045514.8	416912.2	95.50	80.00
SK-6+880	6+880	4045753.3	416779.1	74.00	52.00
SK-7+130	7+130	4045981.9	416692.6	72.00	45.00
SK-7+250	7+250	4046125.8	416686.1	77.00	46.00

3.4 Current Studies

After the review of the previous studies, a detailed geological and geotechnical field investigations were carried out in the project area to determine the rock mass conditions. These are:

a. Field geology (identification of lithological units, determination of discontinuity characteristics, etc.),

b. Core-box survey and geotechnical borehole logging (determination of lithological units, total core recovery (TCR), intact core recovery (ICR), rock quality designation (RQD), joint conditions such as weathering, roughness, persistency, aperture, filling for each successive structural domain).

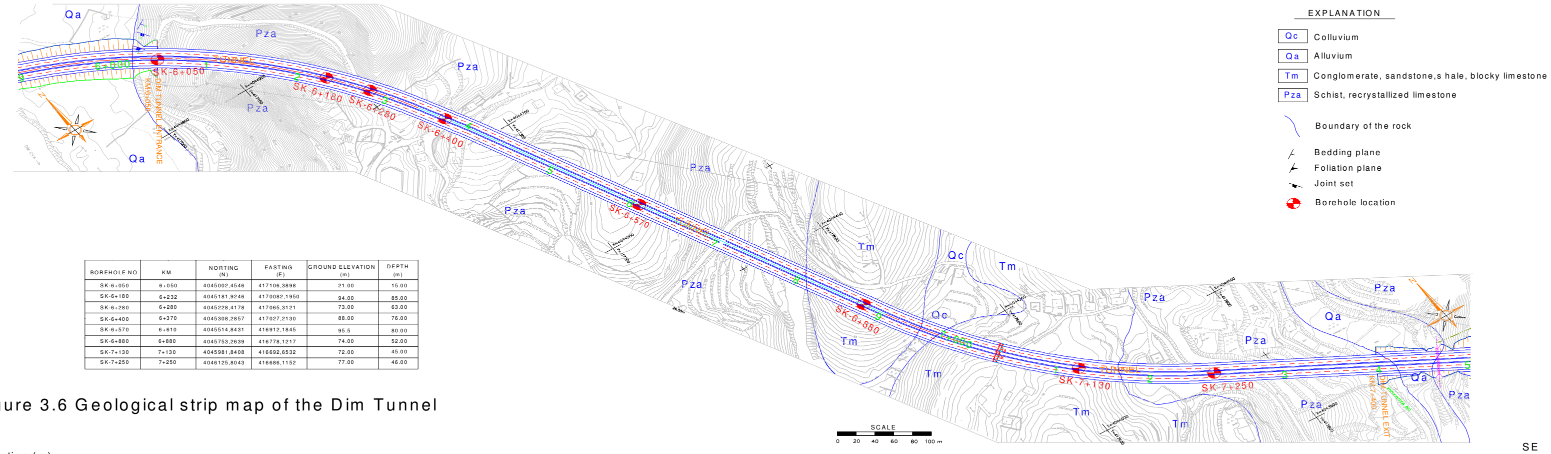
A strip geological map and cross-section showing borehole locations along the tunnel route were prepared based on field geology and core-box survey, and presented in Figures 3.6 and 3.7.

Geotechnical borehole logs were prepared considering the successive structural domains. Structural domains, in core boxes, are the zones where certain features of the rock (i.e., rock type, appearance and fracture frequency) are more or less the same. The geotechnical borehole logging was not carried out along the total length of the borehole drilling, but between the distance starting at approximately two width of tunnel span up from the estimated periphery of the tunnel to the end of the borehole. All of the logs including input-data required for rock mass classification systems are presented in Appendix B.

3.5 Engineering Geology

This chapter comprises the evaluation of engineering geological properties of the rocks exposed and cut along the tunnel route on the basis of field measurements, core-box survey and laboratory tests. The rock descriptions include both rock mass and rock material characteristics that based on ISRM (1981).

The rock types observed in the project area are predominantly schist with rarely recrystallized limestone intercalation, and blocky limestone, conglomerate and sandstone-shale alternation.



BOREHOLE NO	KM	NORTING (N)	EASTING (E)	GROUND ELEVATION (m)	DEPTH (m)
SK-6+050	6+050	4045002,4546	417106,3898	21.00	15.00
SK-6+180	6+232	4045181,9246	4170082,1950	94.00	85.00
SK-6+280	6+280	4045228,4178	417065,3121	73.00	63.00
SK-6+400	6+370	4045308,2857	417027,2130	88.00	76.00
SK-6+570	6+610	4045514,8431	416912,1845	95.5	80.00
SK-6+880	6+880	4045753,2639	416778,1217	74.00	52.00
SK-7+130	7+130	4045981,8408	416692,6532	72.00	45.00
SK-7+250	7+250	4046125,8043	416686,1152	77.00	46.00

Figure 3.6 Geological strip map of the Dim Tunnel

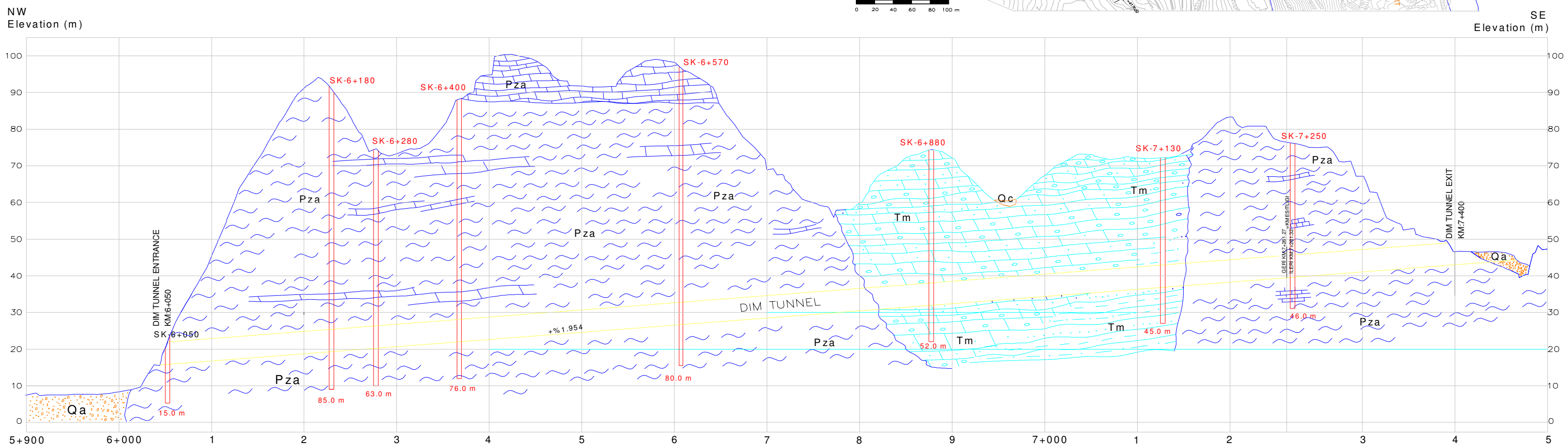


Figure 3.7 Exaggerated geological cross-section of the Dim Tunnel

3.5.1 Schist

Schist, which is rarely intercalated with recrystallized limestone, will be cut along the most part of the tunnel route (Figures 3.8, 3.9 and 3.10). Schist is greenish gray, moderately to highly weathered and mainly very weak to moderately weak, occasionally strong. It is easily separated along the foliation planes, which is highly persistent. Field and core-box observations show that thin foliation planes (5-15 cm) are tight (<1 mm). The joint walls are undulating and rough. Apertures are <1 to 5 mm wide and sometimes filled with calcite infilling. Average spacing of joints in the schist ranges between 0.5 to 1.5 m. Measurements of discontinuities were taken at two different stations along the tunnel route. The number of measurements is low, because the schists crop ot only in a few locations. Orientations of major discontinuity sets with pole plot, contour plot, rose diagram and discontinuity plane plots of schist unit are presented in Figure 3.11.

Figure 3.8 General view of schists from the entrance portal of the Dim Tunnel at Km 6+050.

Figure 3.9 A close view of schists from the entrance portal of the Dim Tunnel at Km 6+050.

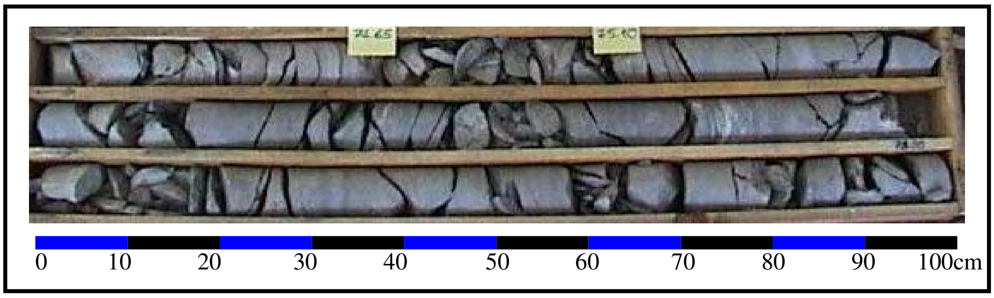
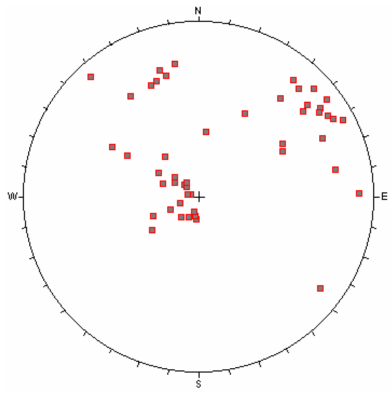
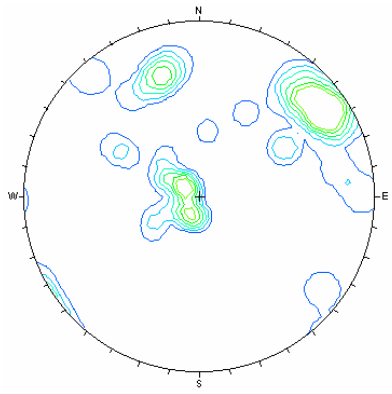


Figure 3.10 Cores of schists taken from borehole SK-6+180.

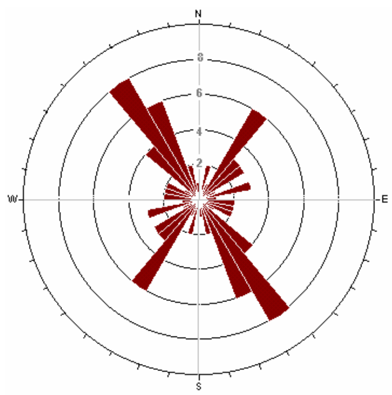
The uniaxial compressive strength and point load strength index of the schists with recrystallized limestone range between 10 and 95 MPa, and 1.94 and 5 MPa, respectively. The Rock Quality Designation (RQD) ranges from 0 % to 95 % and weighted mean RQD is approximately 11 %. Slake durability index is between 40 to 99 %.

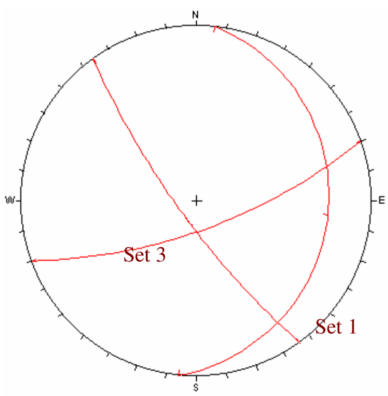
Discontinuity Set	Dip amount (°)	Dip direction (°)	Discontinuity Type
Set 1	16	096	foliation plane
Set 2	71	160	joint
Set 3	78	234	joint





(a) Pole Plot (b) Contour Plot





(c) Rose Diagram (b) Plane Plot

Figure 3.11 Pole plot (a), contour plot (b), rose diagram (c), and discontinuity plane plot (d) in discontinuities of schist unit.

3.5.2 Blocky Limestone

Blocky limestone will be along the tunnel route between Km 6+800 and 7+150, and at borehole SK-6+880. (Figures 3.12, 3.13 and 3.14).

Figure 3.12 A view of blocky limestone at the Dim tunnel route (Km 6+900).

Figure 3.13 Blocky limestone and schist boundary along the Dim Tunnel route.

It is light gray, moderately weathered, and moderately strong, and includes solution cavities (1-5 m in size). The joint walls are undulating, rough and surface-coated. The uniaxial compressive strength ranges between 10 and20 MPa. The Rock Quality Designation (RQD) ranges from 0 % to 40 % and weighted mean RQD is approximately 6 %. Slake durability index is between 22 to 77 %.

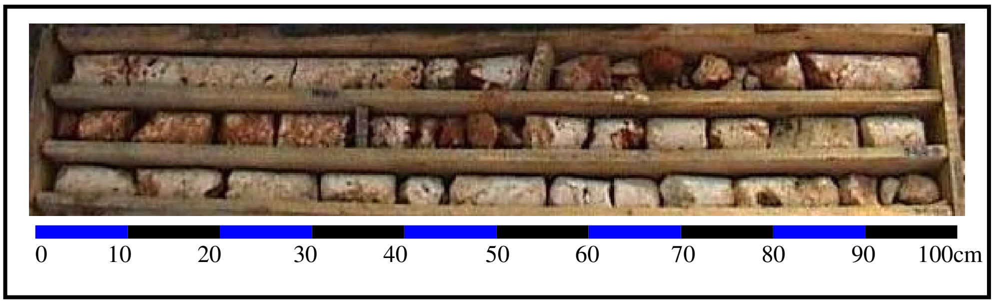


Figure 3.14 Cores of blocky limestone taken from from borehole SK-6+880.

3.5.3 Conglomerate

Conglomerate does not crop out at the surface but is encountered at borehole SK-7+130 at Km 7+130 along the Dim Tunnel route (Figure 3.15). It is light grayish-white, approximately horizontally bedded, slightly weathered and moderately strong to strong. Matrix is light brown, beige, moderately hard, fine to medium grained.

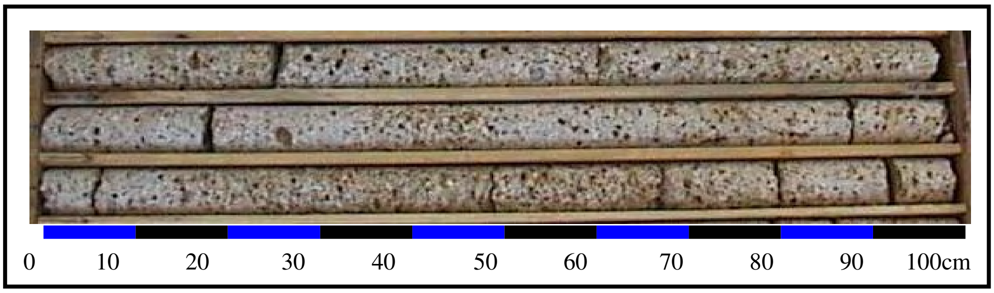


Figure 3.15 Cores of conglomerates taken from borehole SK-7+130.

The uniaxial compressive strength of conglomerate is approximately 15 MPa. The Rock Quality Designation (RQD) ranges from 93 % to 94 % and weighted mean RQD is approximately 94 %. Slake durability index is 99 %.

3.5.4 Sandstone-Shale Alternation

Shale-sandstone alternation does not crop out at the surface but it will be cut along the tunnel route at borehole SK-7+130 at Km 7+130 and its surroundings (Figure 6.16).

Based on the borehole data, shale-sandstone alternation is yellowish light brown to dark gray, approximately horizontally bedded, highly to moderately weathered, occasionally completely weathered, very weak to weak. The uniaxial compressive strength of the sandstone-shale alternation ranges between 5 and 10 MPa. The Rock Quality Designation (RQD) ranges from 0 % to 85 % and weighted mean RQD is approximately 62 %. Slake durability index is between 3 and 30 %.

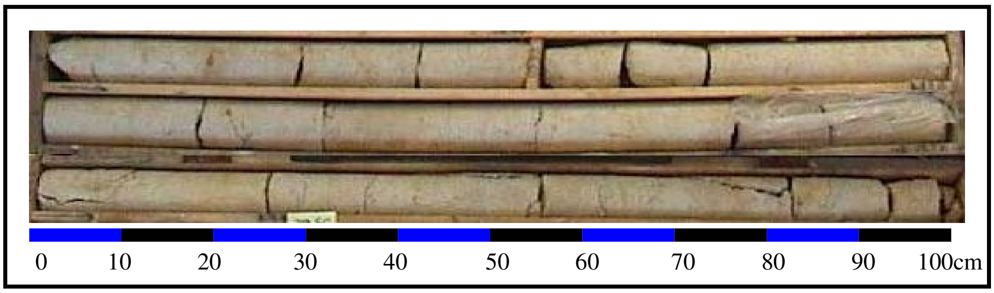


Figure 3.16 Cores of sandstone - shale alternation taken from borehole SK-7+130.

CHAPTER IV

ROCK MASS CLASSIFICATION SYSTEMS APPLIED TO DIM TUNNEL GROUND

4.1 Introduction

In this chapter, considering the geological and geotechnical data, which are discussed in the preceding chapter, rock mass classification systems for the Dim Tunnel ground have been applied.

4.2 Rock Mass Classification for the Dim Tunnel

For a preliminary tunnel design, at least two classification systems should be applied (Bieniawski, 1989). For the preliminary design of the Dim Tunnel, RMR, M-RMR, Q, GSI, and NATM classification systems were used.

4.2.1 Modified-Rock Mass Rating (M-RMR)

The M-RMR system is a powerful orderly process that can be used in characterizing all ranges of rock mass conditions including weak, stratified anisotropic and clay bearing rock masses.

The input parameters required for the M-RMR system have been extracted both from the geotechnical borehole logs and from the results of the laboratory tests (Appendix B). Then the collected input parameters have been tabulated on rock mass classification logs (input data forms) considering the successive structural domains. Structural domains, in core boxes, are the zones where certain features of the rock are more or less the same. The input data forms and core photographs of each structural domain are presented in Appendix C and Appendix D, respectively.

The M-RMR values were determined with the latest version (2002) of ROCKMASS computer program. During classification process 126 individual section (structural domain) from 8 boreholes with a total length of 282 m along the Dim tunnel route were evaluated. All ROCKMASS calculations and the results of these calculations with respect to M-RMR are given in Appendix E.I. and Figure 4.1, respectively.

Based on these calculations, the M-RMR value of schist with recrystallized limestone intercalation, which will be cut along the most part of the proposed tunnel route, changes between 6 and 61. Weighted mean M-RMR value is around 28, which corresponds to poor rock, based on the classification by Bieniawski (1989).

The M-RMR value of blocky limestone shows quality variations within a range changing between 15 and 53. Weighted mean value is around 40 and this corresponds to poor rock.

The M-RMR value for conglomerate is found to be 63. This corresponds to good rock.

The M-RMR value of sandstone-shale alternation changes between 25 and 46. Weighted mean value is around 40 and this corresponds to poor rock.

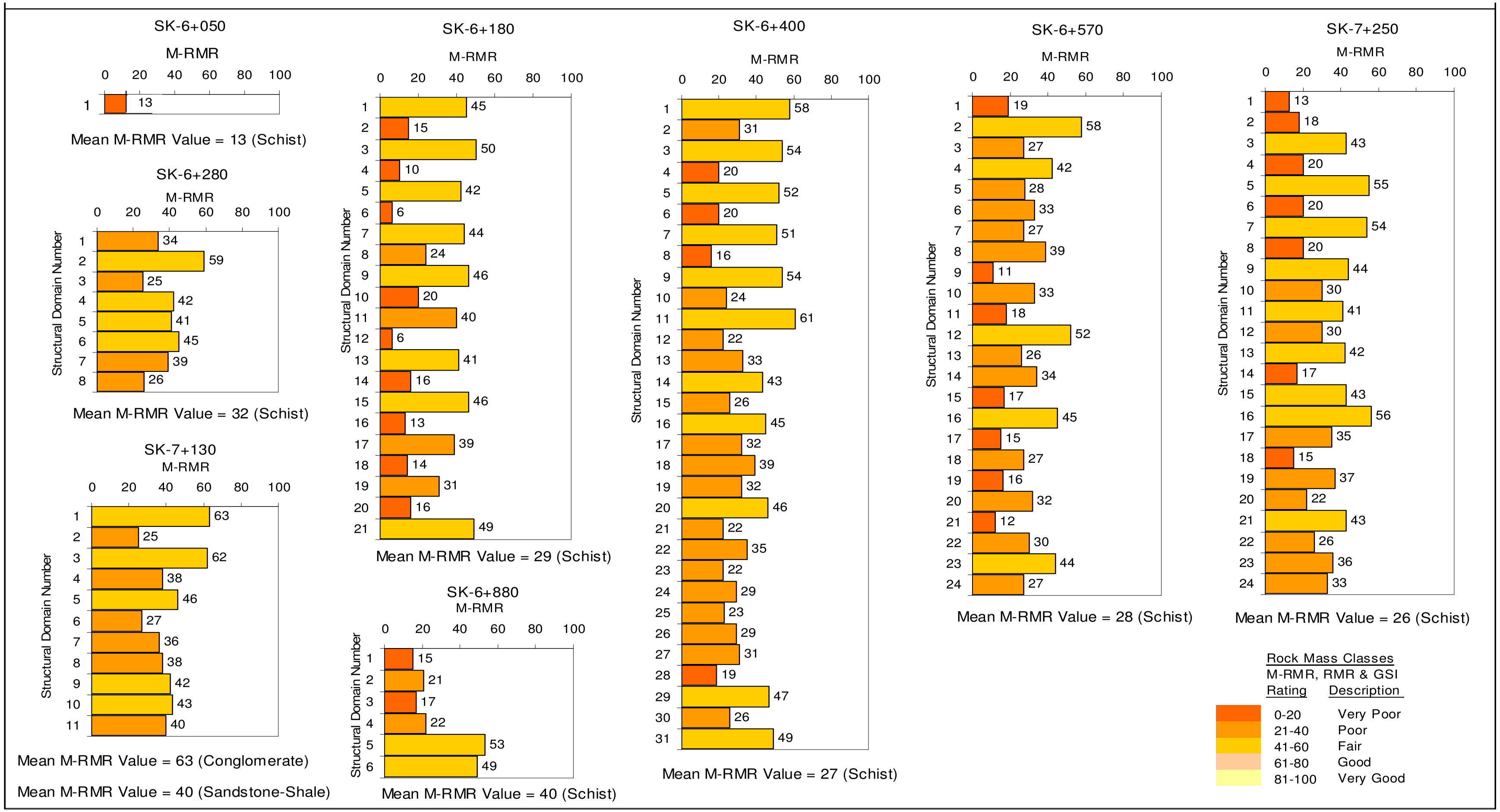


Figure 4.1 M-RMR values of each successive structural domain for the study area.

4.2.2 Rock Mass Rating (RMR)

In order to determine the rock mass rating (RMR), Bieniawski's 1989 version rock mass rating system was used. The six parameters were determined and by summing these parameters rock mass ratings for each successive structural domain of borehole locations were computed (Appendix E.II).

One of the basic differences between the RMR and M-RMR system appears in characterization of extreme ends in rock mass quality spectrum, namely, the very poor / poor and good / very good rock mass conditions (Ünal,1996). In this study, both RMR and M-RMR were used to see the quality rating changes of rock mass.

According to the RMR calculations, rating of schist with recrystallized limestone intercalation changes between 26 and 62. Weighted mean M-RMR value is around 38, which corresponds to poor rock, based on the classification by Bieniawski (1989).

The RMR value of blocky limestone shows quality variations within a range changing between 35 and 54. Weighted mean value is around 36 and this corresponds to poor rock.

The RMR value for conglomerate is found to be 58. This corresponds to fair rock.

The RMR value of sandstone-shale alternation changes between 35 and 55. Weighted mean value is around 49 and this corresponds to fair rock.

The results of rock mass rating determinations are given in Figure 4.2.

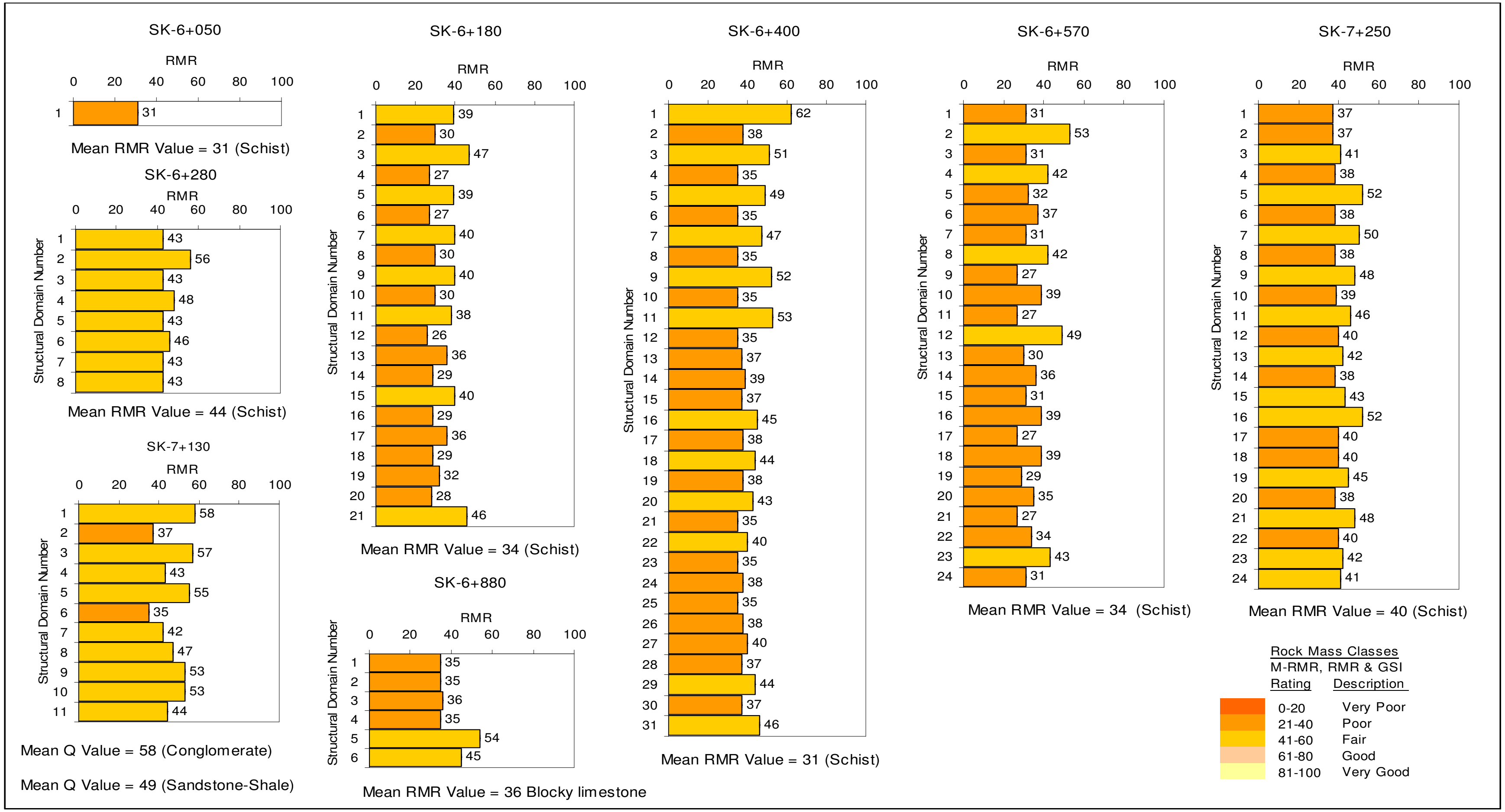


Figure 4.2 RMR values of each successive structural domain for the study area

4.2.3 Rock Mass quality (Q)

Q values for each succesive structural domain of each borehole location along the Dim Tunnel were calculated with ROCKMASS software. These calculations and results of the calculations are presented in Appendix E.I and Figure 4.3, respectively.

According to the Q calculations, rating of schist with recrystallized limestone intercalation changes between 0.01 and 4.53. Weighted mean Q value is around 0.36, which corresponds to very poor rock, based on the classification by Barton (2002).

The Q value of blocky limestone shows quality variations within a range changing between 0.01 and 6. Weighted mean value is around 0.18 and this corresponds to very poor rock.

The Q value for conglomerate is found to be 18.75. This corresponds to good rock.

The Q value of sandstone-shale alternation changes between 0.01 and 7.56. Weighted mean value is around 5.10 and this corresponds to fair rock.

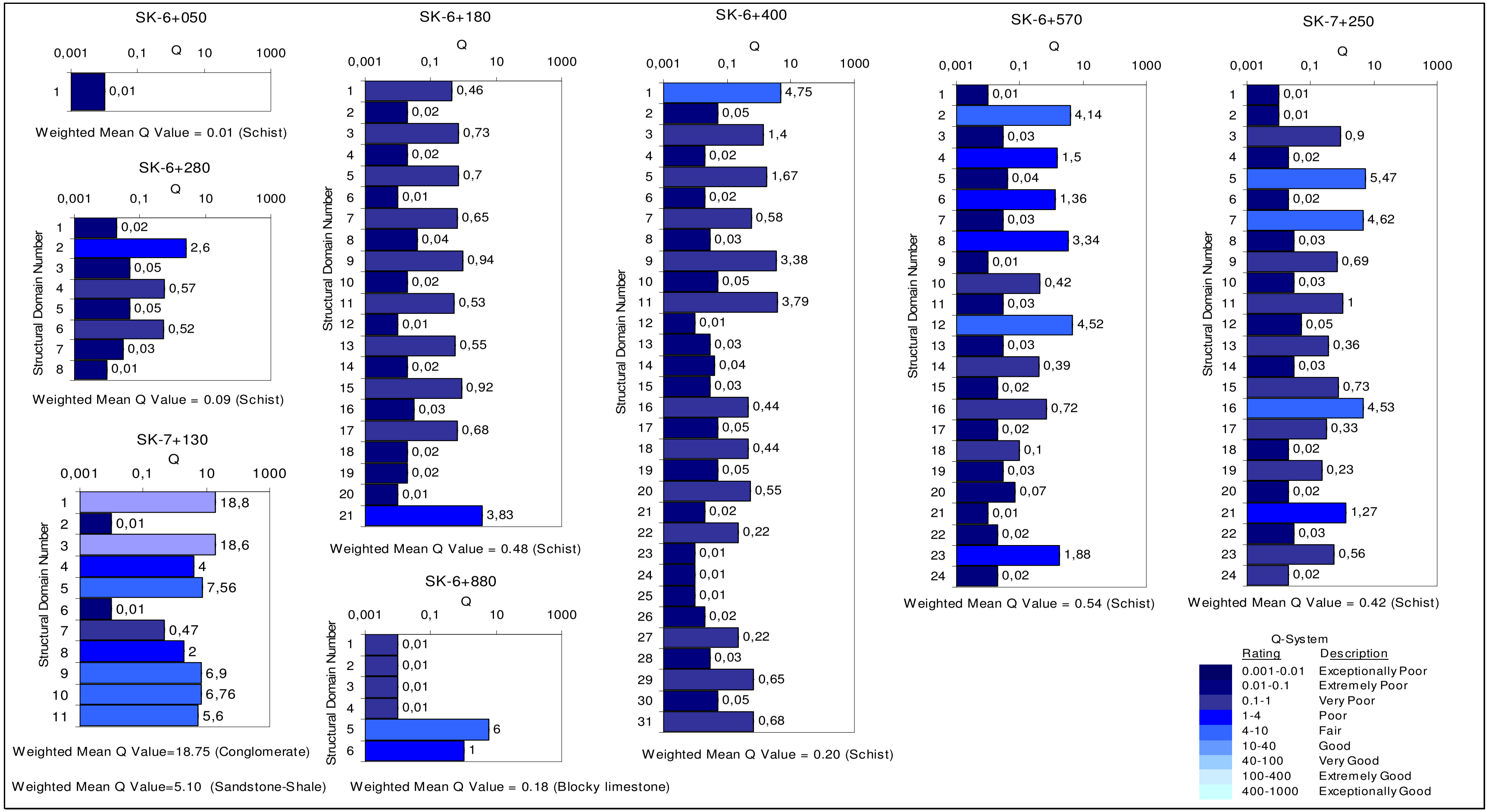


Figure 4.3 Q values of each successive structural domain for the sudy area

4.2.4 Geological Strength Index (GSI)

Geological strength index of the rock masses for the study area were determined by using the modified GSI chart of Sönmez and Ulusay (2002). Structural rating (SR), which are based on volumetric joint count (J_v), and surface condition rating (SCR) were estimated from the input parameters of RMR scheme (e.g. RQD, roughness, weathering and infilling). The GSI calculations and the result of these calculations for each borehole location were given in Appendix E.III and Figure 4.4, respectively.

According to the GSI calculations, rating of schist with recrystallized limestone intercalation ranges between 19 and 51. Weighted mean value is around 38, which corresponds to poor rock class.

The GSI value of blocky limestone shows quality variations within a range changing between 36 and 46. Weighted mean value is around 38, which corresponds to poor rock, based on the classification by Bieniawski (1989).

The GSI value for conglomerate is found to be 52. This corresponds to fair rock.

The GSI value of sandstone-shale alternation changes between 36 and 48. Weighted mean value is around 45 and this corresponds to fair rock.

The results of GSI determinations for each borehole location in the study area are given in Figure 4.4.

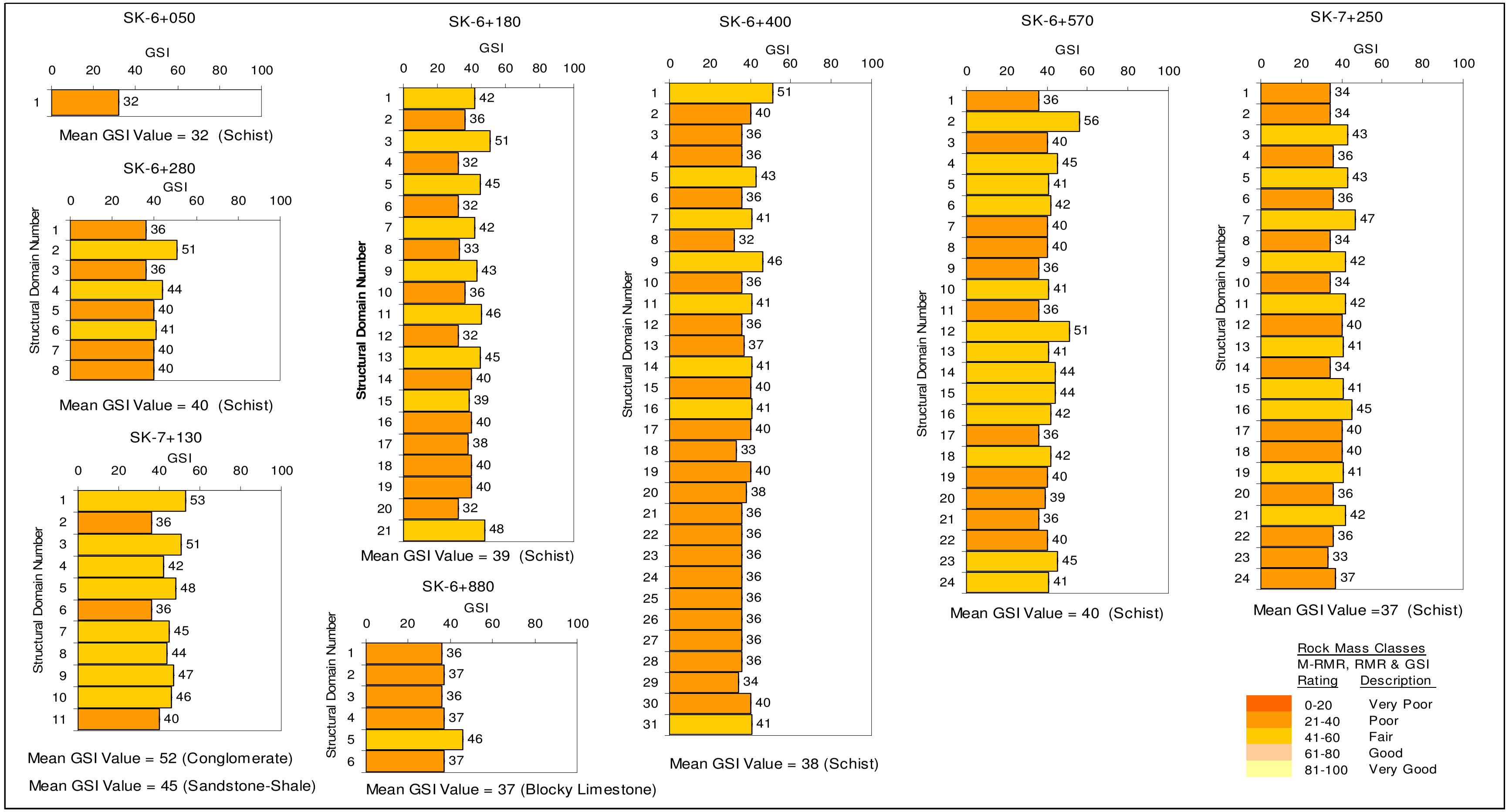


Figure 4.4 GSI values of each successive structural domain for the study area

4.2.5 New Austrian Tunneling Method (NATM)

Each borehole location along the tunnel route is also classified according to the qualitative NATM classification as given in Table 4.1.

Table 4.1 NATM rock mass classes for the project area.

Borehole No	Rock Type	NATM Rock Mass Class	Behavior of Rock Mass
SK-6+050	Schist	B3	Rolling
SK-6+180	Schist	B3	Rolling
SK-6+280	Schist	B3	Rolling
SK-6+400	Schist	B3	Rolling
SK-6+570	Schist	B3	Rolling
SK-6+880	Blocky limestone	B3	Rolling
SK-7+130	Conglomerate	B1-B2	Friable-Very Friable
	Sandstone-shale	B2	Friable
SK-7+250	Schist	B3	Rolling

4.3 Correlations between RMR, M-RMR, Q, GSI and NATM

RMR, M-RMR, Q and GSI classification systems are based on the principal properties of a rock mass such as intact rock strength, discontinuity conditions (roughness, filling, weathering etc.), and geometry of intact rock block, and various empirical correlations have been developed between these classification systems as mentioned in Chapter 2.

For each borehole location in this study, rock masses are classified according to quantitative classification systems such as M-RMR, RMR, Q and GSI; and qualitative NATM classification. The results of these quantitative classifications for all borehole locations are presented comparatively in Appendix F. Also the summary results of the rock mass classifications for the Dim Tunnel are given in Table 4.2.

Table 4.2 Summary of the rock mass classification results of the study area

Borehole No	Rock Type	Rock Mass Ratings				
		RMR	M-RMR	Q	GSI	NATM
SK-6+050	Schist	31	13	0.01	32	B3
SK-6+180	Schist	34	29	0.48	39	B3
SK-6+280	Schist	44	32	0.09	40	B3
SK-6+400	Schist	31	27	0.20	38	B3
SK-6+570	Schist	34	28	0.54	40	B3
SK-6+880	Blocky limestone	36	40	0.18	37	B3
SK-7+130	Conglomerate	58	63	18.75	52	B1-B2
	Sandstone-shale	49	40	5.10	45	B2
SK-7+250	Schist	40	26	0.42	37	B3

The results of rock mass classifications systems for the Dim Tunnel study area were compared and relationships between

a. RMR and Q,
b. M-RMR and Q,
c. RMR and GSI,
d. M-RMR and GSI, and
e. Q and GSI,
f. RMR and M-RMR were made by carrying out statistical analyses and the regression equations given below were obtained.

The empirical relation between RMR and Q that is proposed by Bieniawski (1976) is in the form of RMR = 9 lnQ + 44. For the Dim Tunnel study area the empirical equation can be expressed by RMR = 2.80 lnQ + 45.19 (R^2=0.67) as seen in Figure 4.5. This equation was obtained from 126 data which relate the structural domains.

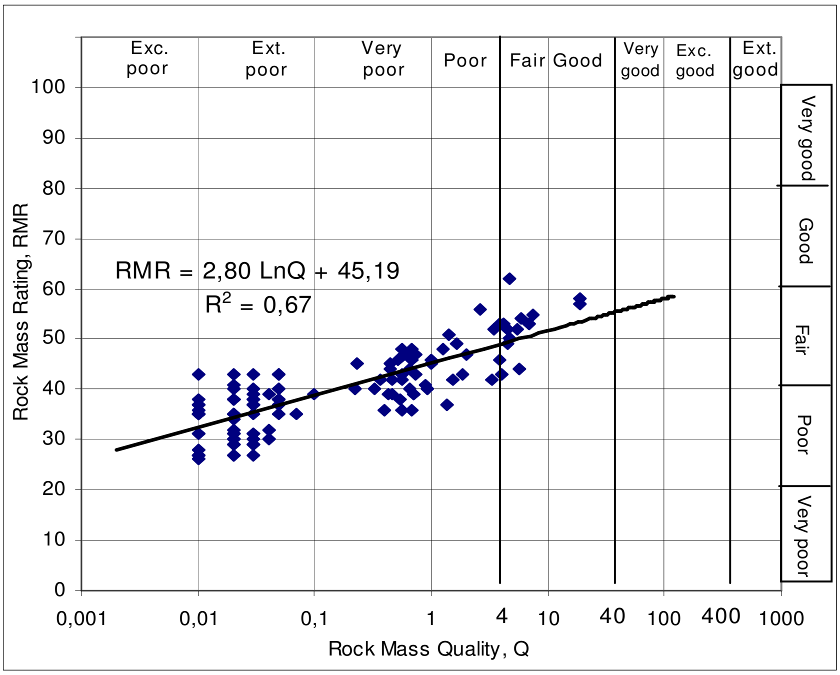


Figure 4.5 Relationship between the RMR and Q values for the study area.

The empirical relation between M-RMR and Q that is proposed by Ünal (1996) is in the form of M-RMR = 9.66 lnQ + 37.9. For the Dim Tunnel study area the empirical equation can be expressed by M-RMR = 5.43 lnQ + 43.69 (R^2=0.78) as seen in Figure 4.6.

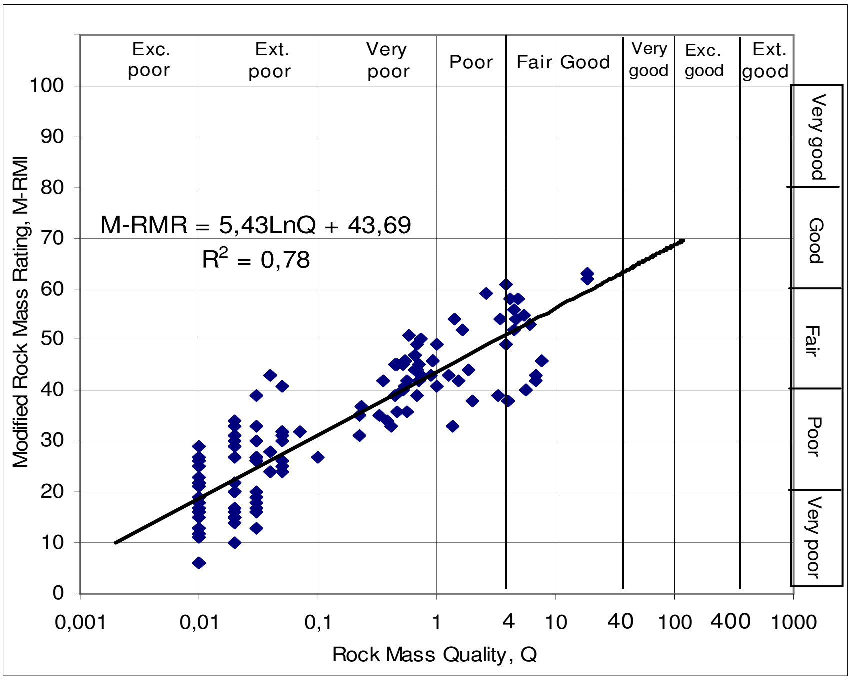


Figure 4.6 Relationship between M-RMR and Q values for the study area.

The correlations between RMR and GSI, M-RMR and GSI, and Q and GSI values were performed (Figures 4.7, 4.8 and 4.9) and the regression equations given below were obtained. GSI=0.42RMR+23.07 (R^2=0.44) between GSI and RMR, GSI=0.26 M-RMR+31.32 (R^2=0.53) between GSI and M-RMR, and GSI=1.61 LnQ+42.99 (R^2=0.54) between GSI and Q.

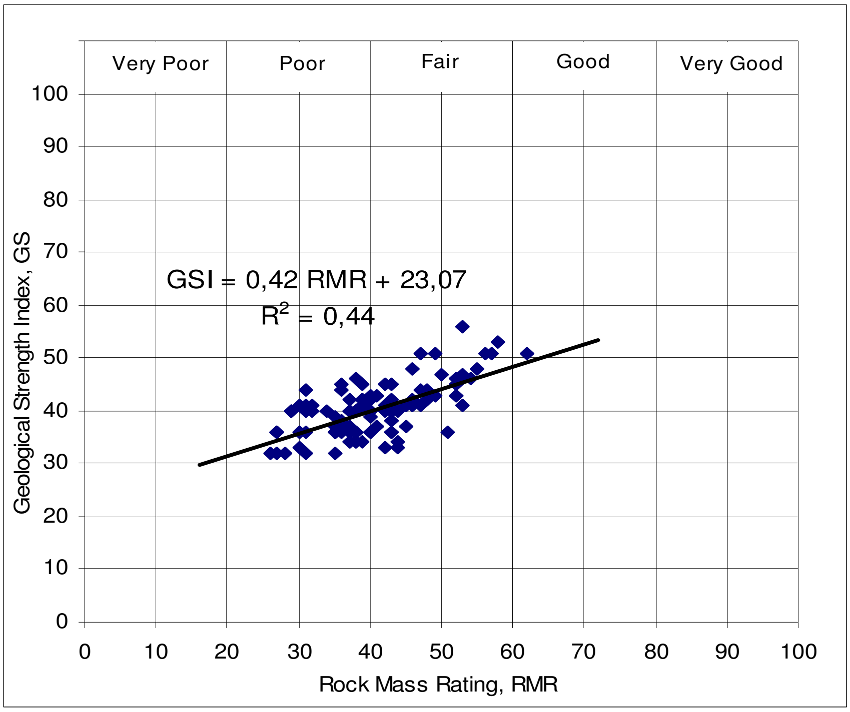


Figure 4.7 Relationship between RMR and GSI values for the study area.

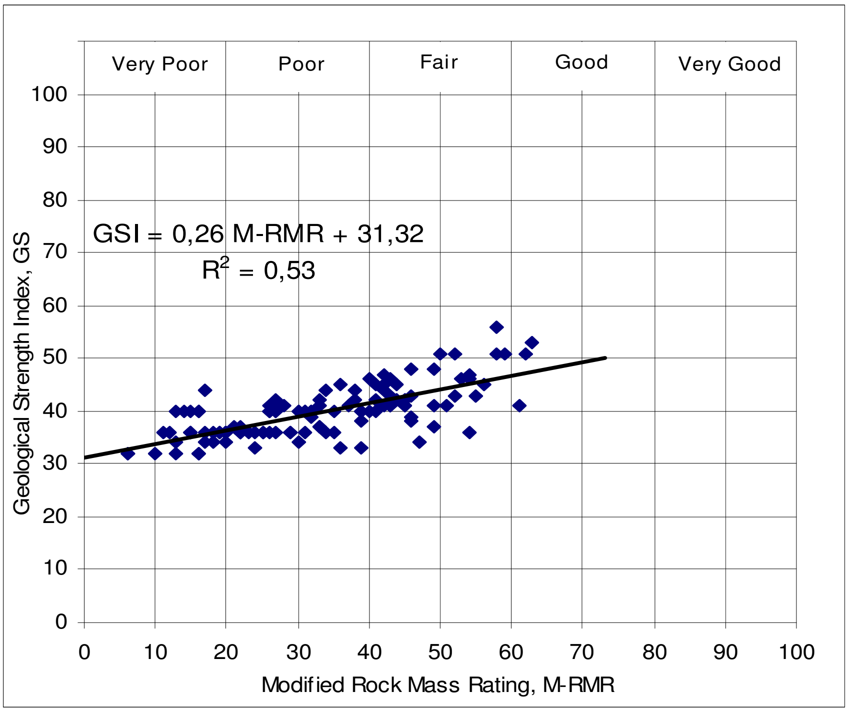


Figure 4.8 Relationship between M-RMR and GSI values for the study area.

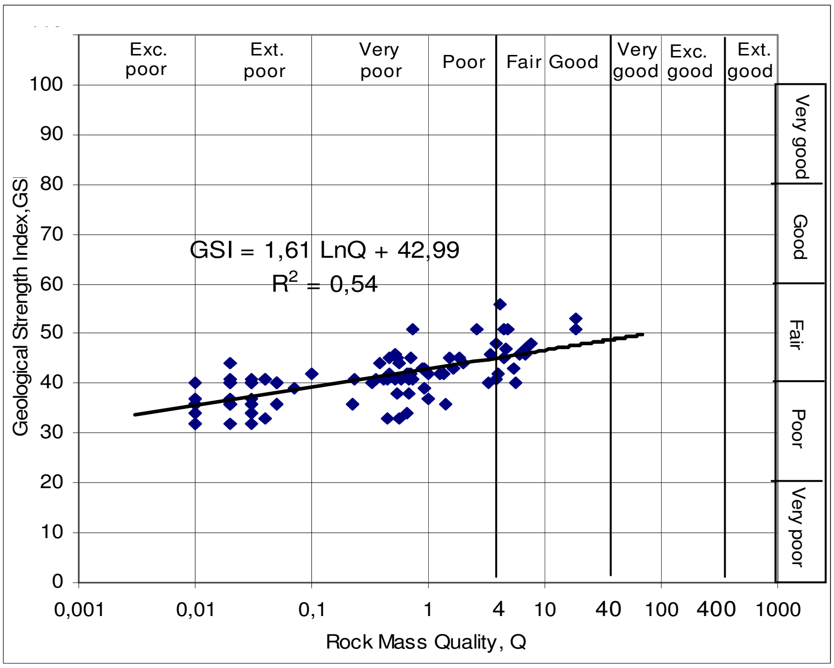


Figure 4.9 Relationship between Q and GSI values for the study area.

The M-RMR and RMR values were correlated and an empirical relation were found for the study area. The regression equation can be expressed by M-RMR = 1.56 RMR - 28.91 (R^2=0.76) for 126 data as seen in Figure 4.10.

M-RMR values are quite worse than RMR values at the lower bounds (RMR < 40), therefore, the correlation between M-RMR and RMR for RMR < 40 (68 data) were also carried out and the regression equation M-RMR = 0.0046 $RMR^{2.40}$ (R^2=0.48) was obtained (Figure 4.11).

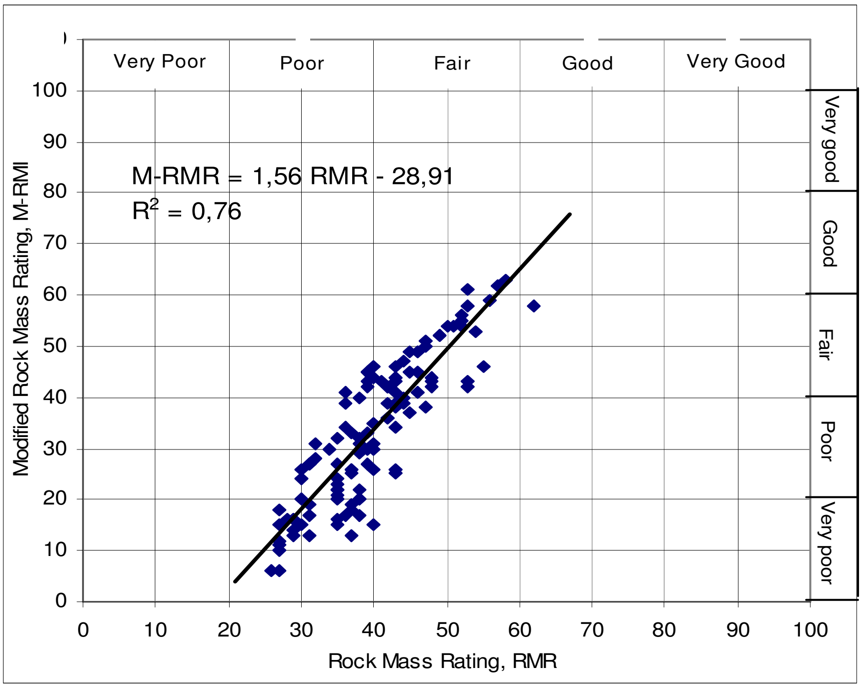


Figure 4.10 Relationship between M-RMR and RMR values for the study area.

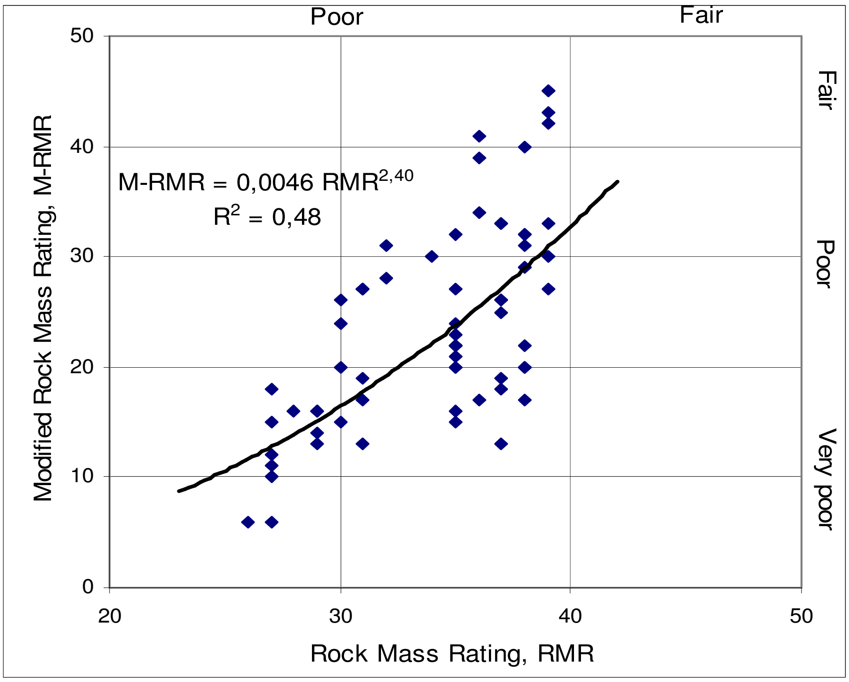


Figure 4.11 Relationship between M-RMR and RMR values considering RMR < 40 for the study area.

Relatively low correlation coefficient may also indicate deficiency of the RMR system in characterizing poor and very poor (RMR > 40) rock mass.

4.4. Discussion

According to Ulusay (1991), Ünal et al. (1992), Ulusay et al. (1995), and Ünal (1996), the results obtained from the RMR and M-RMR systems are very close to each other in the range 20 < RMR < 40. However, one of the basic differences between the RMR and M-RMR system appears in characterization of extreme ends in rock mass quality spectrum, namely, very poor / poor (RMR < 40) and good / very good (RMR > 70) rock mass conditions.

All RMR, M-RMR and GSI values for each structural domain were plotted in Figure 4.12. This figure shows the total range of index values obtained from each borehole drilled in the Dim Tunnel route. During analyses the lowest and the highest M-RMR values were selected for each borehole and corresponding RMR and GSI values were considered in preparing Table 4.3 and in drawing Figure 4.13. The results indicate that the rock mass shows a wider quality-rating range (6 to 63) with M-RMR system. However, the same rock mass shows quality variation within a range changing between 27 and 58 based on the RMR system. In conclusion, the M-RMR system estimates better rock mass quality ratings at the upper bounds (RMR > 50) of the rock mass condition, but worst ratings at the lower bounds (RMR < 40) for the study area. These results confirm the previous studies (Ulusay, 1991; Ünal et al., 1992; Ulusay et al., 1995; and Ünal, 1996). On the other hand, the GSI values for the same rock mass intensify in the range of 32 to 56.

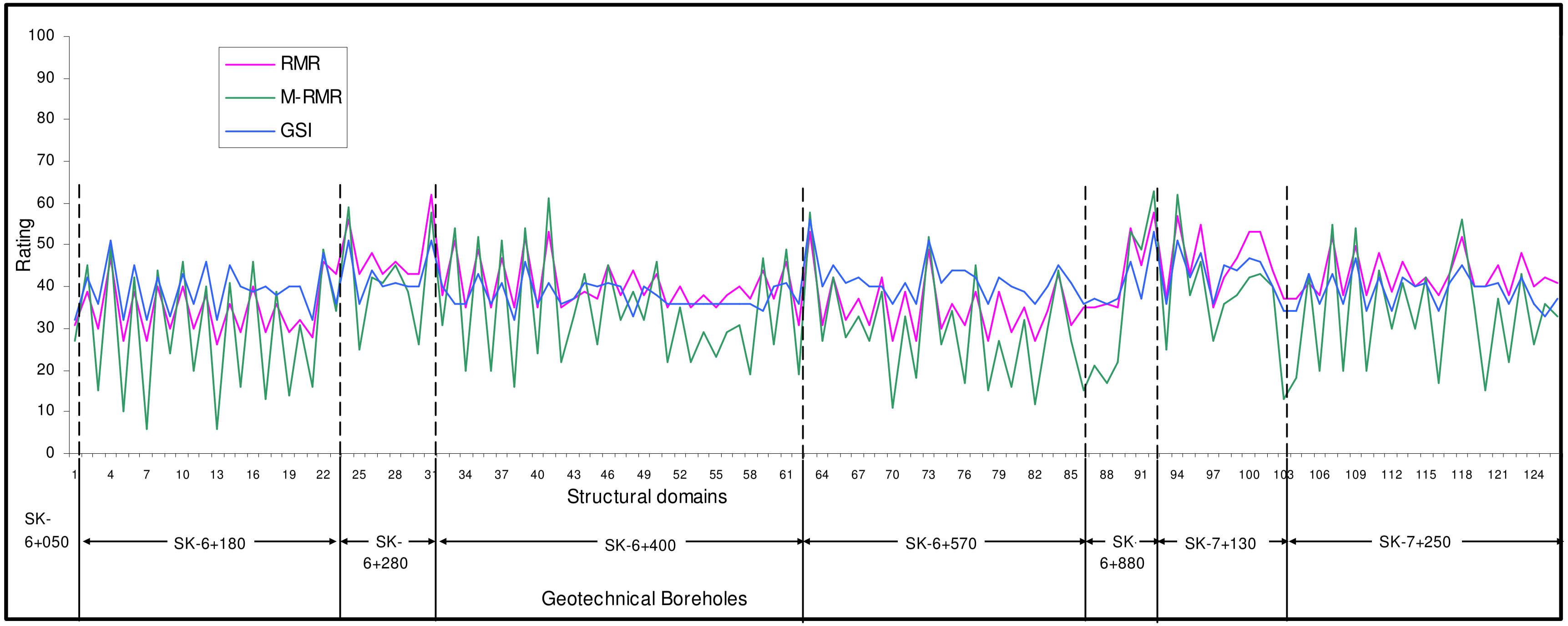


Figure 4.12 Total range of the RMR, M-RMR and GSI index values for each structural domain which obtained from each borehole drilled in the Dim Tunnel route.

Table 4.3 The minimum and maximum M-RMR values for each borehole and corresponding RMR and GSI values.

Borehole No.	Structural Domain No.	Minimum Values		
		M-RMR	RMR	GSI
SK-6+050	1	13	31	32
SK-6+180	6	6	27	32
SK-6+280	3	25	43	36
SK-6+400	8	16	35	32
SK-6+570	9	11	27	36
SK-6+880	1	15	35	36
SK-7+130	2	25	37	36
SK-7+250	1	13	37	34
Borehole No.	Structural Domain No.	Maximum Values		
		M-RMR	RMR	GSI
SK-6+050	1	13	31	32
SK-6+180	3	50	47	51
SK-6+280	2	59	56	51
SK-6+400	11	61	53	41
SK-6+570	2	58	53	56
SK-6+880	5	53	54	46
SK-7+130	1	63	58	53
SK-7+250	16	56	52	45

In the case of tunnels, the rock mass classification index values may be used to estimate the stand-up time and the maximum unsupported span for a given RMR, M-RMR or Q value as mentioned in Chapter 2. Considering Bieniawski's (1989) roof span vs stand-up time plot (Figure A.2 in Appandix A), Barton's (1974) maximum unsupported span equation (Equation 2.7 in Chapter 2), and the summary table (Table 4.2 given in page 65) showing the rock-mass-ratings in the study area, the maximum unsupported spans and the

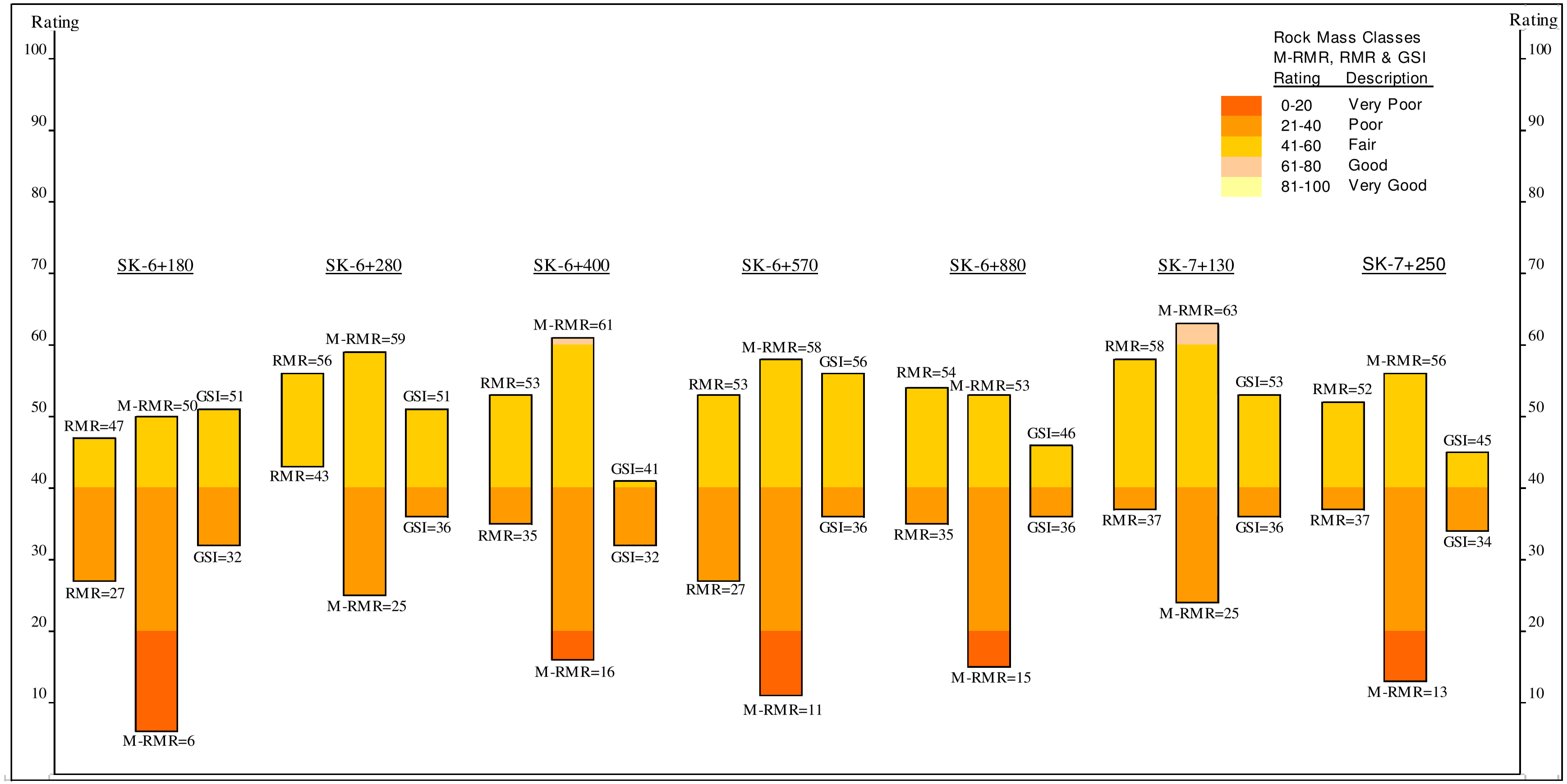


Figure 4.13 Graphical representation of the minimum and maximum M-RMR values for each borehole and corresponding RMR and GSI values.

stand-up times for 10 m span were determined for each borehole location, and the results are tabulated in Table 4.4.

Table 4.4 Maximum unsupported spans and their stand-up time based on RMR, M-RMR and Q values for the each borehole location.

Borehole No.	Rock Type	Maximum Unsupported Span (m)		Stand-up Time for 10 m Span
		RMR / M-RMR*	Q**	RMR / M-RMR*
SK-6+050	Schist	1.40 / 1.20	0.32	<10 / 20 min
SK-6+180	Schist	1.60 / 1.30	1.49	<10 / 48 min
SK-6+280	Schist	2.25 / 1.50	0.76	25 min / 12 hr
SK-6+400	Schist	1.40 / 1.20	1.05	<10 / 20 min
SK-6+570	Schist	1.60 / 1.25	1.56	<10 / 48 min
SK-6+880	Blocky limestone	1.70 / 1.90	1.01	4 / 1.5 hr
SK-7+130	Conglomerate	2.90 / 3.20	6. 46	2 mo / 21 day
	Sandstone-shale	2.40 / 1.90	3.84	4 hr / 1.6 day
SK-7+250	Schist	1.90 / 1.10	1.41	10 min / 4 hr

* Roof span vs stand-up time (Bieniawski, 1989)
**Maximum unsupported span= 2.ESR.$Q^{0.4}$ (Barton, 1974)

According to these results, it is interesting to notice the difference of “maximum unsupported spans” predicted by RMR, M-RMR and Q system. In addition, based on the RMR and M-RMR systems, it can be concluded that, except for conglomerate, all other classification index values belonging to other rock units fall into immediate collapse region for a span of 10 meters. Consequently, the tunnel should be excavated in two stages using the top heading and bench by drilling and blasting method the supports, such as rock bolt, wiremesh, shotcrete and steel arch should be used .

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The main objective of this study is to provide a complete data obtained from a number of rock mass classification systems carried out at the Dim Tunnel study area to utilize in the future excavation and support-design studies. Geological and geotechnical properties of the rock units exposed at the surface and cut along tunnel route in the study area were investigated both in the field and laboratory. During classification process 126 individual section (structural domain) from 8 boreholes with a total length of 282 m were evaluated.

5.1 Conclusions

Based on the investigations carried out in this study, the following conclusions and are drawn:

1. The rock masses were classified based on the RMR, M-RMR, Q, GSI and NATM classification systems and divided into three categories. i) Schist unit with recrystallized limestone intercalation and blocky limestone is very poor to poor according to the RMR, M-RMR, Q and GSI classes and it is classified as B3 (rolling) according to the NATM, ii) conglomerate is fair to good according to the RMR, M-RMR, Q and GSI classes and it is classified as B1 (friable) to B2 (very friable) according to the NATM, iii) sandstone-shale alternation is poor to fair

according to the RMR, M-RMR, Q and GSI classes and it is classified as B2 (very friable) according to the NATM.

2. The results of rock mass classifications systems for the Dim Tunnel study area were compared and relationships between RMR and Q, M-RMR and Q, RMR and GSI, M-RMR and GSI, Q and GSI, and RMR and M-RMR were made by carrying out statistical analyses. The regression equations given below were obtained:

    i. RMR=2.80 lnQ + 45.19 (R^2 =0.67) between RMR and Q,

    ii. M-RMR=5.43 lnQ + 43.69 (R^2 =0.78) between M-RMR and Q,

    iii. GSI=0.42 RMR+23.07 (R^2 =0.44) between GSI and RMR,

    iv. GSI=0.26 M-RMR+31.32 (R^2 =0.53) between GSI and M-RMR,

    v. GSI=1.61 lnQ + 42.99 (R^2 =0.54) between GSI and Q,

    vi. M-RMR=1.56RMR-28.91 (R^2=0.76) between M-RMR and RMR.

3. In the range where the RMR is less than 40 the following regression equation was obtained:

    M-RMR = 0.0046 $RMR^{2.40}$ (R^2 = 0.48).

    Relatively low correlation coefficient may indicate deficiency of the RMR system in characterizing poor and very poor (RMR > 40) rock mass.

4. The results obtained from the comparison of the RMR and M-RMR classification systems carried out in the study area indicate that the M-RMR system estimates better rock mass quality ratings at the upper bounds (RMR > 50) of the rock mass condition, but worst ratings at the lower bounds (RMR < 40), as also suggested by the previous studies.

5. Except for conglomerate, all other classification index values belonging to other rock units fall into immediate collapse region for a span of 10 meters. Consequently, the tunnel should be excavated in two stages using the top heading and bench by drilling and blasting method the supports, such as rock bolt, wiremesh, shotcrete and steel arch should be used.

5.2. Recommendations for Future Studies

1. Based on rock mass classifications carried out in this study, the tunnel ground was charaterized according to the RMR, M-RMR, Q, GSI and NATM systems. During future studies, excavation and support recommendations and strength parameters should be determined based on these classification studies with other empirical methods and, numerical studies.

2. During this study, correlations were made between the RMR, M-RMR, Q and GSI classification systems and, the related regression equations and regression coefficients were determined. However, further studies should be carried out in other locations in order to obtain more data and to iclude larger number of rock units.

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APPENDIX A

INFORMATION RELATED TO ROCK MASS CLASSIFICATION SYSTEMS USED IN THIS STUDY

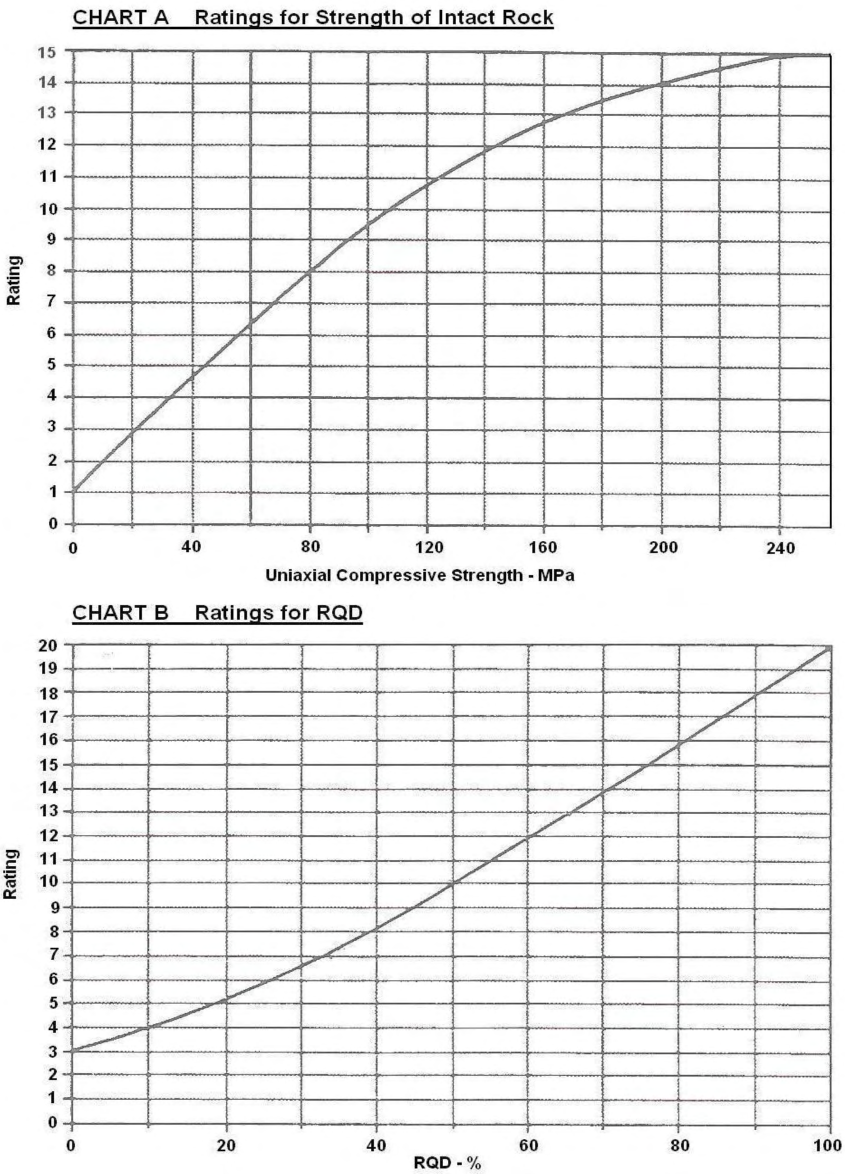
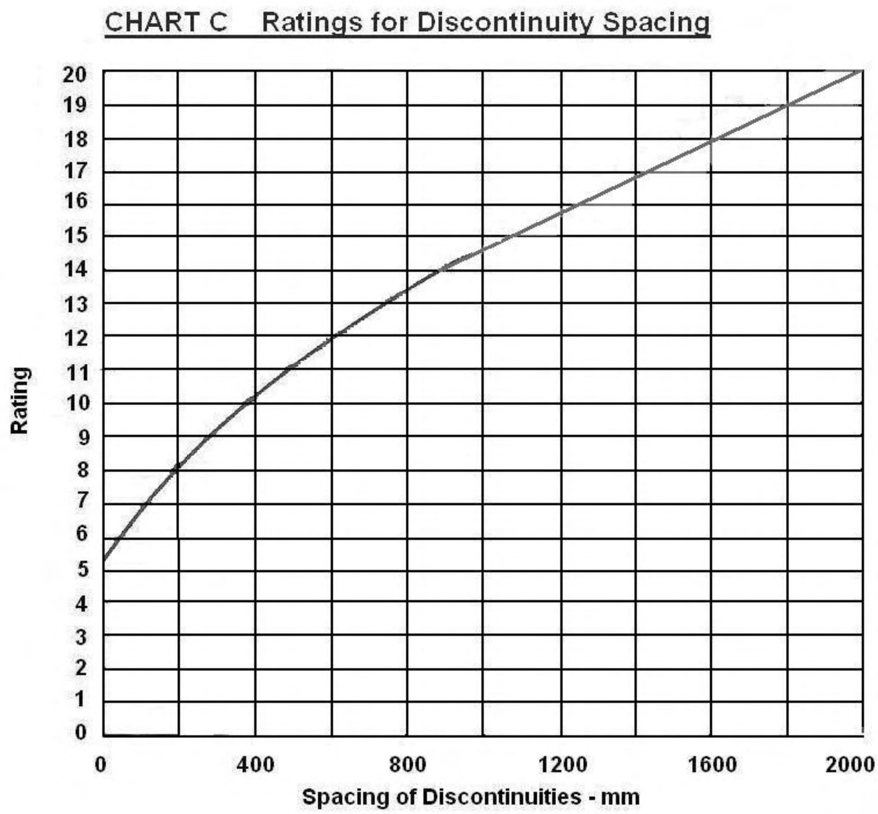


Figure A.1 Ratings of input parameters for RMR (After Bieniawski, 1989).



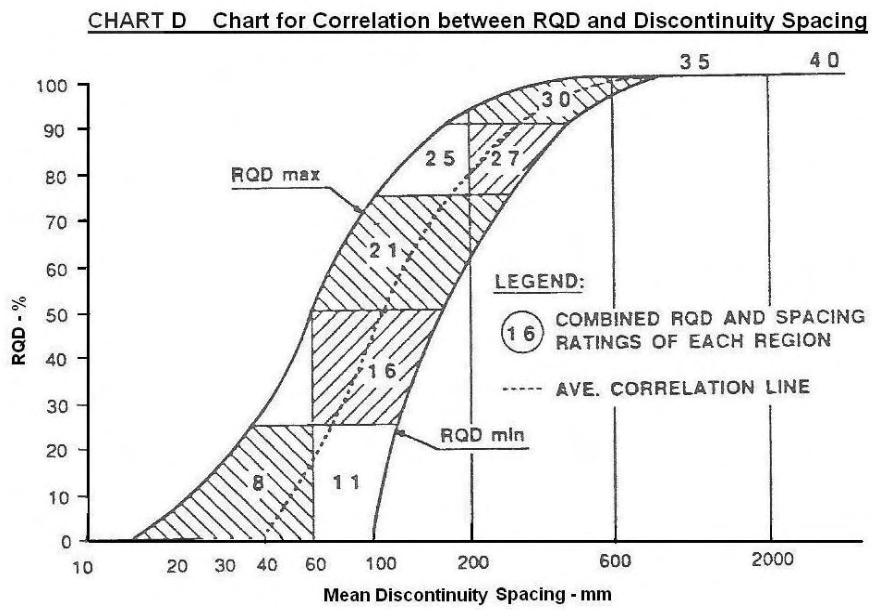


Figure A.1 (Continued).

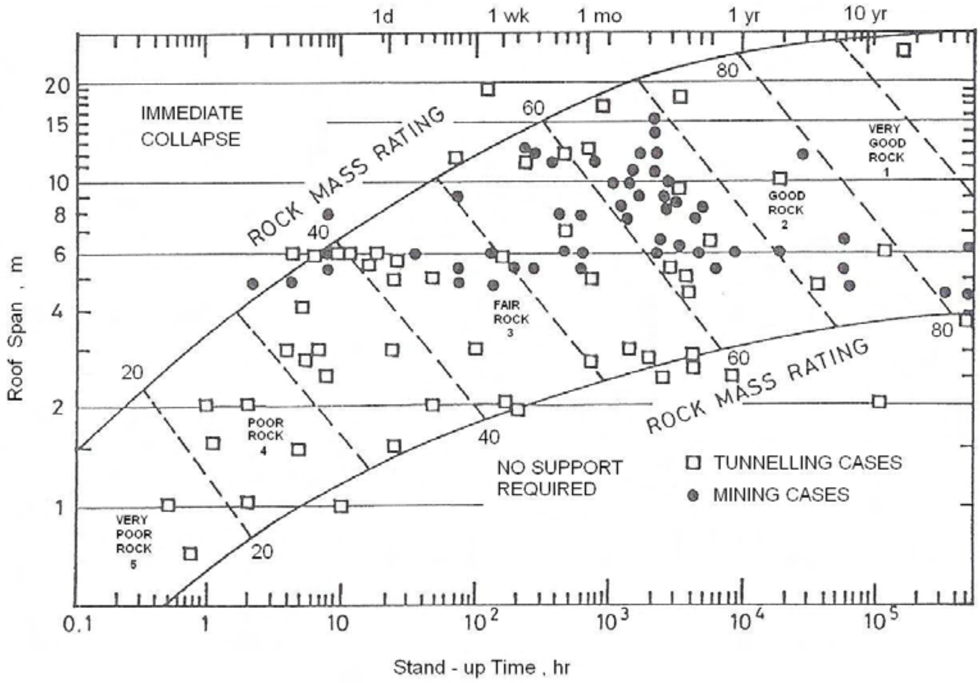


Figure A.2 Relationship between the RMR-value and stand-up time of an unsupported underground excavation (After Bieniawski, 1989).

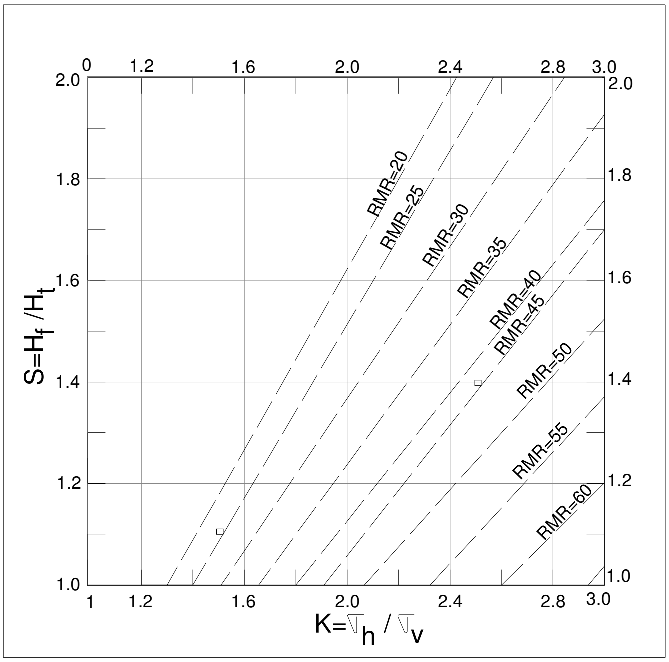


Figure A.3 The effect of horizontal-to-vertical stress ratio (K) to failure height to rock load height ratio (strength factor, S) for various RMR values (modified from Ünal and Ergür, 1990a).

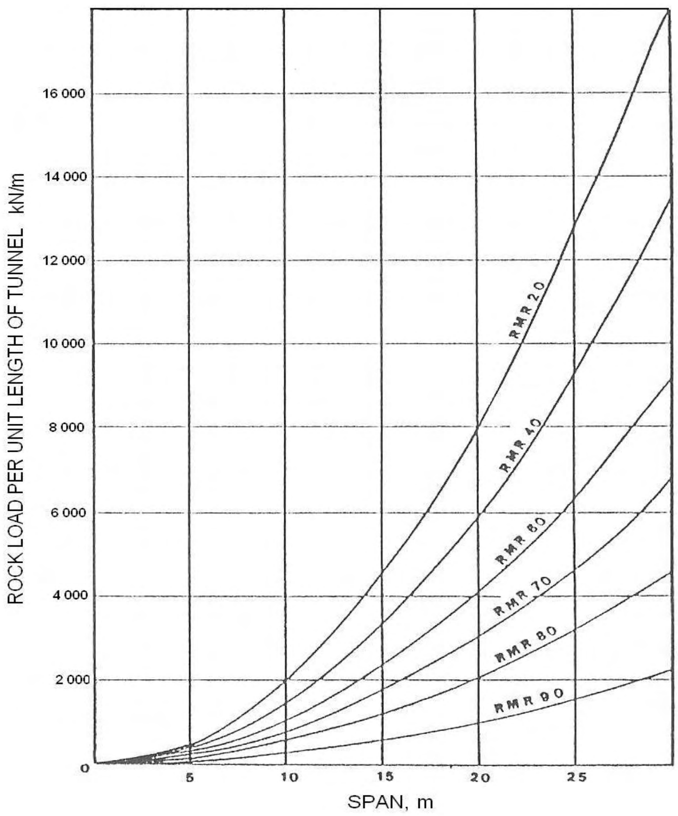


Figure A.4 Variation of rock-load as function of roof span in different rock classes in the Geomechanics Classification (after Ünal, 1983).

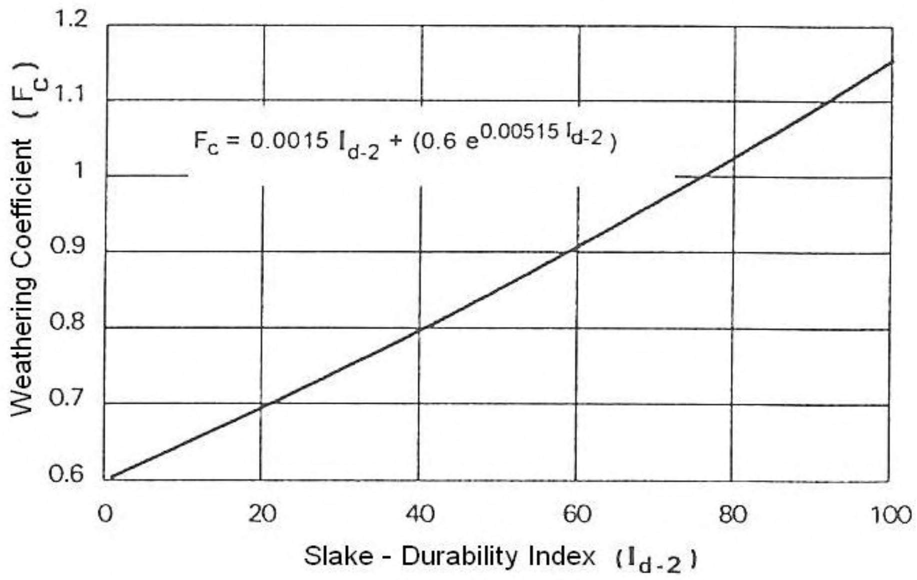


Figure A.5 Suggested adjustment for slaking effect of water (Ünal, 1996).

Table A.1 Guidelines for Excavation and Support of 10 m span rock tunnels in accordance with the RMR System (Bieniawski, 1989).

Rock mass class	**Excavation**	**Rock bolts (20 mm diameter, fully grouted)**	**Shotcrete**	**Steel sets**
I - Very good rock RMR: 81-100	Full face, 3 m advance	Generally no support required except spot bolting		
II - Good rock RMR: 61-80	Full face, 1 – 1.5 m advance. Complete support 20 m from face	Locally, bolts in crow 3 m long, spaced 2.5 m with occasional wire mesh	50 mm in crown where required	None
III - Fair rock RMR: 41-60	Top heading and bench 1.5 - 3 m advance in top heading. Commence support after each blast. Complete support 10 m from face	Systematic bolts 4 m long , spaced 1.5 - 2 m in crown and walls with wire mesh in crown	50 - 100 mm in crown and 30 mm in sides	None
IV - Poor rock RMR: 21-40	Top heading and bench 1.0 – 1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face	Systematic bolts 4-5 m long, spaced 1 – 1.5 m in crown and walls with wire mesh	100 - 150 mm in crown and 100 mm in sides	Light to medium ribs spaced 1.5 m where required
V - Very poor rock RMR : < 20	Multiple drifts 0,5 – 1.5 m advance in top heading. Install support concurrently with possible after blasting	Systematic bolts 5 - 6 m long, spaced 1 – 1.5 m in crown and walls with wire mesh. Bolt invert	150 - 200 mm in crown, 150 mm in sides, and 50 mm on face	Medium to heavy ribs spaced 0.75 m with steel lagging and fore poling if required. Close invert

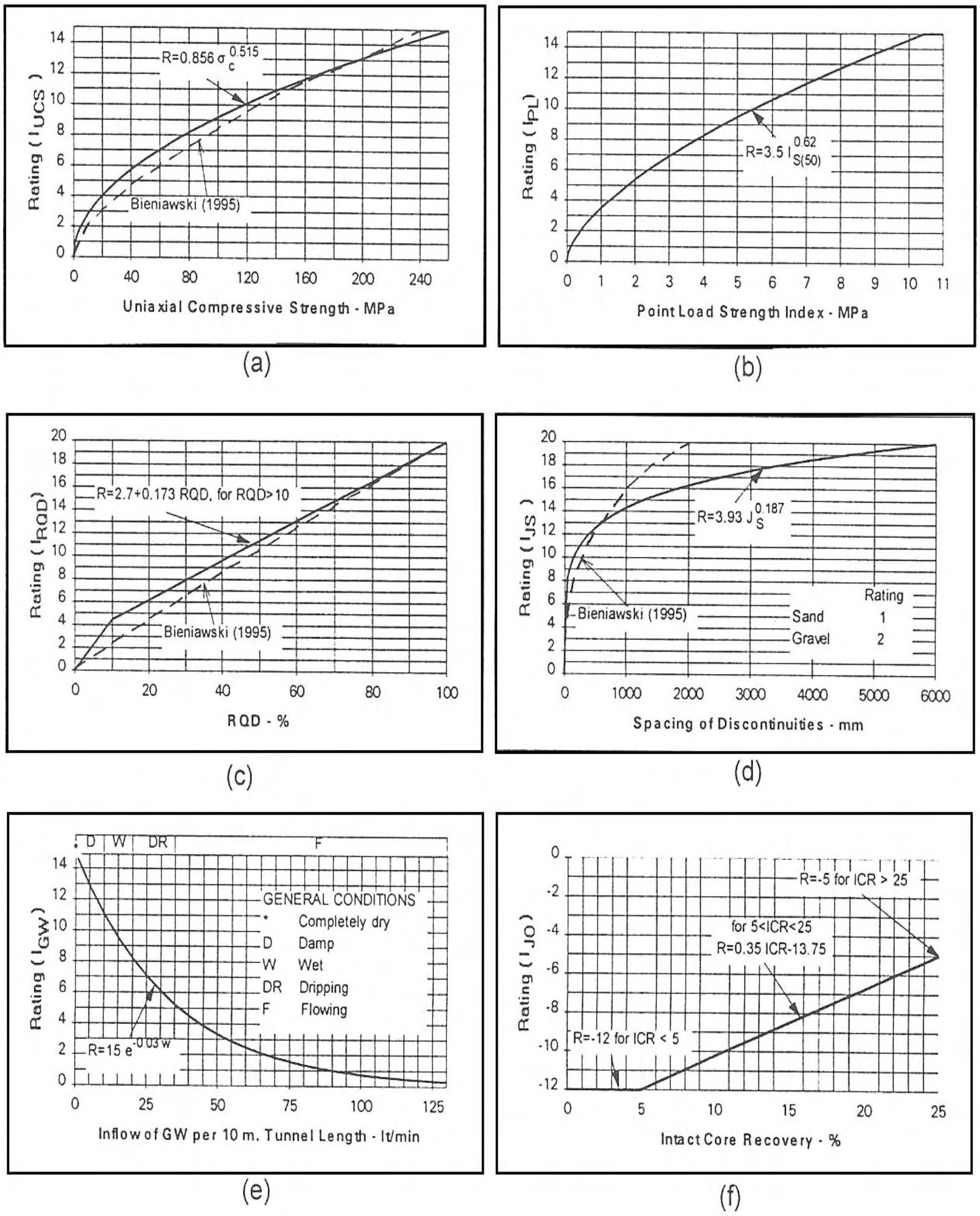


Figure A.6 Suggested intervals and ratings for various input parameters used in modified-rock mass rating classsification (after Ünal, 1996).

JOINT CONDITION INDEX (I_{JC})

PARAMETER	CONDITION		RATING
I. WEATHERING "W"	Unweathered		8
	Slightly weathered		7
	Moderately weathered		6
	Highly weathered		4
	Very highly weathered		2
	Decomposed		0
II. ROUGHNESS "R"	Ondulating	Very rough	8
		Rough	6
		Slightly rough	4
		Smooth	2
		Slickensided	1
	Planar	Very rough	4
		Rough	3
		Slightly rough	2
		Smooth	1
		Slickensided	0
III. CONTINUITY "C" (PERSISTENCY)	Very low		3,5
	Low		3
	Medium		2
	High		1,5
	Very high		1
IV. APERTURE "A"	0.0 - 0.01 mm		4
	0.01 - 1.0 mm		3
	1.0 - 5.0 mm		2
	> 5 mm		0
V. FILLING "D"	None		1
	0 - 1 mm		4
	1 - 5 mm (Hard)		3,5
	1 - 5 mm (Soft)		3
	> 5 mm (Hard)		2
	> 5 mm (Soft)		0

Figure A.7 Intervals and ratings for joint condition index, I_{JC} (After Ünal, 1996).

ICR ≤ 25

- Without Filling
  - BST 1: bs = 0
  - BST 2: bs = 2
  - BST 3: bs = 4
  - BST 4: bs = 6
  - BST 5: bs = 8
  - $I_{JC} = bs + W / 2 + 8$
- With Filling
  - $t_f \geq 5$ mm (t_f : filling thickness)
    - soft: 0
    - hard: 4
  - 1 mm < t_f < 5 mm
    - soft: $I_{JC} = bs / 2 + W / 2$
    - hard: $I_{JC} = bs / 2 + W / 2 + 4$
  - t_f < 1 mm: $I_{JC} = bs + W / 2 + 4$

ICR > 25

Use I_{JC} Rating Chart and
Calculate I_{JC} from the following equations :

- Without Filling
  - $I_{JC} = W + R + (C * A * D)$; D = 1
- With Filling
  - $t_f \geq 5$ mm
    - soft: $I_{JC} = 0$
    - hard: $I_{JC} = 1.00 * (C * D)$
  - 1 mm < t_f < 5 mm
    - soft: $I_{JC} = 0.67 * (C * D)$
    - hard: $I_{JC} = 1.33 * (C * D)$
  - t_f < 1 mm
    - soft: $I_{JC} = 1.50 * (C * D)$
    - hard: $I_{JC} = 1.67 * (C * D)$

Note : Ratings for the following parameters should be determined from I_{JC} Rating Chart (Table 4.4)
W : Alteration R : Roughness C : Persistence A : Aperture D : Filling

Figure A.8 Determination of Joint Condition Index, I_{JC} (After Ünal, 1996).

RUCTURAL DOMAIN TYPE	JOINT CONDITIONS	I_{JA} VALUE
BSTR 1 / 2	NO CLAY WITH CLAY	c , N => 5 b , H => 8
BSTR 3 / 4 / 5	NO FILLING	a, C } 2
	HARD FILLING – No Clay	b, F } 4
	HARD FILLING – With Clay	b, G } 6
	SOFT FILLING	b, H } 8

Figure A.9 Suggestions in Determining Joint Alteration Index (J_a) in Broken Structural Domains (Ünal, 2002).

	DESCRIPTION	I_{JA} VALUE
NO FILLING	**a) Rock Wall Contact**	
	A. Hard, tightly healed filling	0.75
	B. Ünaltered joint walls Surface staining only	1.0
COATING	C. Slightly altered joint walls Non-Softening mineral coatings (Hard) Clay-free, disintegrated rock	2.0
	D. Sandy clay coatings (Hard)	3.0
	E. Softening clay coatings (Soft)	4.0
FILLING	**b) Rock Wall Contact When Sheared** **Filling thickness < 5 mm**	
	F. Clay-free sandy particles	4.0
	G. Hard filling with clay	6.0
	H. Soft Filling	8.0
	J. Swelling Clay	8 - 12

Figure A.10 Suggestions in Determining Joint Alteration Index (J_a) in Normal Structural Domains (Ünal, 2002).

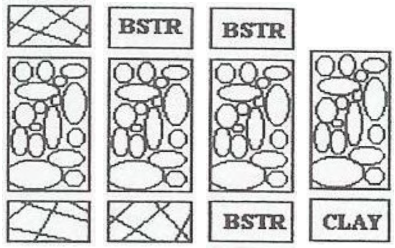
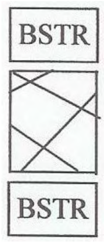
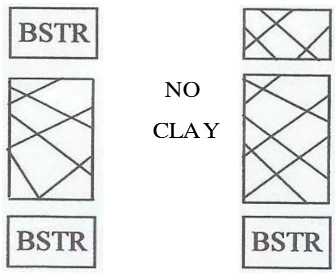
(a) Weakness zones intersecting excavation, which may cause loosening of rock mass		
DESCRIPTION	ISRF VALUE	NOTES
BSTR* 1 / 2 BSTR 3 / 4 / 5	(i) a,G => 5 (ii) a,D => 7,5 (iii) a,A => 10 (iv) a,A => 10	 (i) (ii) (iii) (iv)
Multiple weakness zones in competent rock; Very loose suronding rock and Containing clay	a, A } 10	 + Containing CLAY
Multiple Weakness Zones + Loose Surrounding Rock <u>NO CLAY</u>	(i) a, D } 7.5 (ii) a, G } 5.0	 (i) (ii)
Multiple Weakness Zones No Loose Surrounding Rock		
Containing Clay — Depth < 50 m.	a, B } 5	
Containing Clay — Depth > 50 m.	a, C } 2.5	
Clay Free — Depth < 50 m	a, E } 5	
Clay Free — Depth > 50 m	a, F } 2.5	
* Broken Structural Domain		

Figure A.11 Suggestions in Determining Stress Reduction Factor (SRF) in Evaluating Core Boxes (After Ünal, 2002).

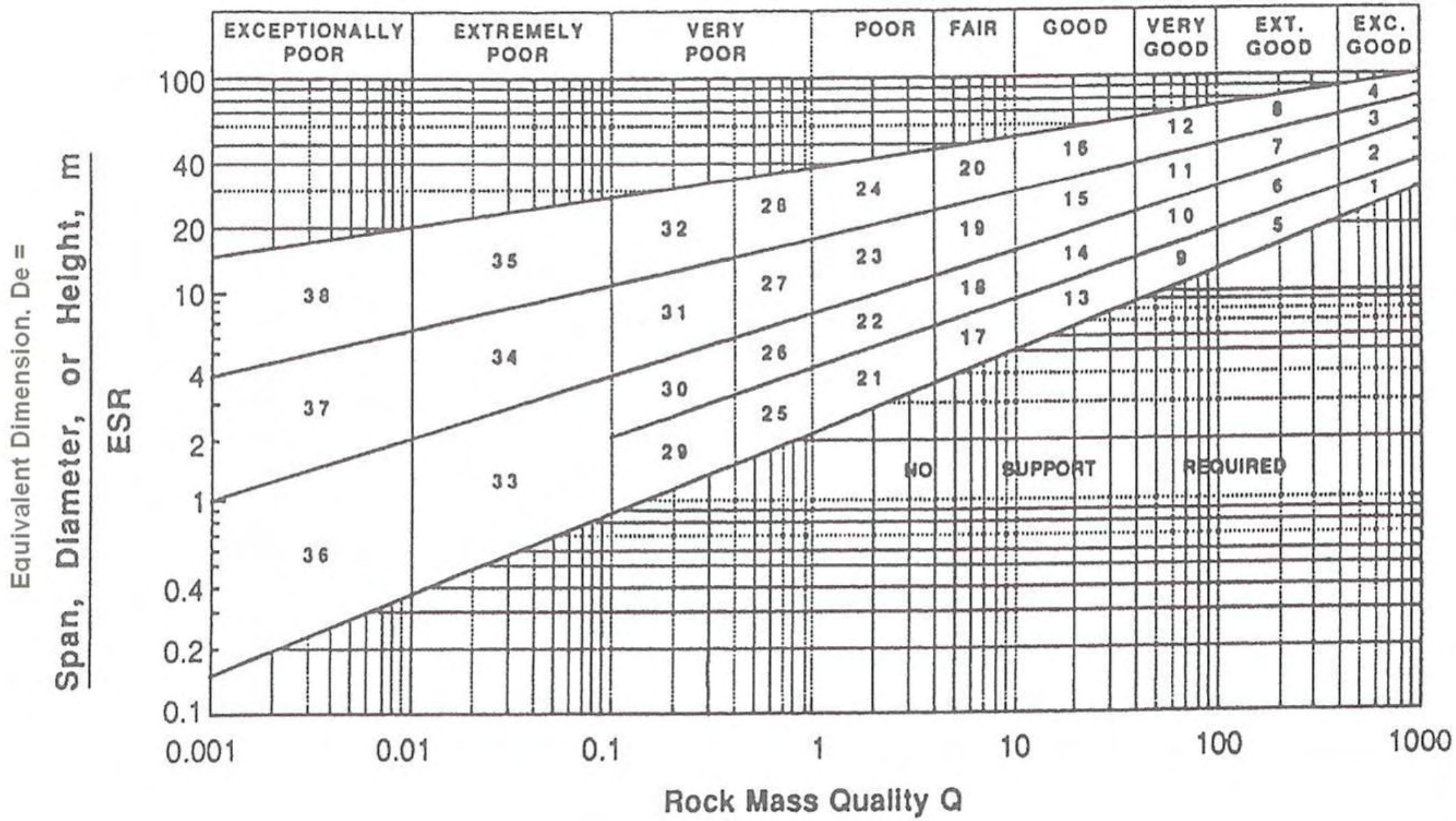


Figure A.12 Tunnel support chart showing 38 support categories (After Barton et al., 1974)

Table A.2 Q-System : Support Measures for Q Range 10 to 1000[a] (Barton et al., 1974).

Support Category	Q	Conditional Factors			P^b (kg/cm^2)	Span/ESR (m)	Type of Support	Notes
		RQD/J_n	J_r/J_n	Span/ESR (m)				
1[c]	1000-400	-	-	-	<0.01	20-40	sb (utg)	-
2[c]	1000-400	-	-	-	<0.01	30-60	sb (utg)	-
3[c]	1000-400	-	-	-	<0.01	46-80	sb (utg)	-
4[c]	1000-400	-	-	-	<0.01	65-100	sb (utg)	-
5[c]	400-100	-	-	-	0.05	12-30	sb (utg)	-
6[c]	400-100	-	-	-	0.05	19-45	sb (utg)	-
7[c]	400-100	-	-	-	0.05	30-65	sb (utg)	-
8[c]	400-100	-	-	-	0.05	48-88	sb (utg)	-
9	100-40	≥20	-	-	0.25	8.5-19	sb (utg)	-
	-	<20	-	-	-	-	B (utg) 2.5-3 m	-
10	100-40	≥30	-	-	0.25	14-30	B (utg) 2-3 m	-
		<30	-	-	-	-	B (utg) 1.5-2 m + clm	-
11[c]	100-40	≥30	-	-	0.25	23-48	B (tg) 2-3 m	-
	-	<30	-	-	-	-	B (tg) 1.5-2 m + clm	-
12[c]	100-40	≥30	-	-	0.25	40-72	B (tg) 2-3 m	-
	-	<30	-	-	-	-	B (tg) 1.5-2 m + clm	-
13	40-10	≥10	≥1.5	-	0.5	5-14	sb (utg)	I
	-	≥10	<1.5	-	-	-	B (utg) 1.5-2 m	I
	-	<10	≥1.5	-	-	-	B (utg) 1.5-2 m	I
	-	<10	<1.5	-	-	-	B (utg) 1.5-2 m + S 2-3 cm	I
14	40-10	≥10	-	≥15	0.5	9-23	B (tg) 1.5-2 m + clm	I, II
	-	<10	-	≥15	-	-	B (tg) 1.5-2 m + S (mr) 5-10 cm	I, II
	-	-	-	<15	-	-	B (utg) 1.5-2 m + clm	I, III

Table A.2 (Continued).

Support Category	Q	Conditional Factors			P^b (kg/cm^2)	Span/ESR (m)	Type of Support	Notes
		RQD/ J_n	J_r/J_n	Span/ESR (m)				
15	40-10	>10	-	-	0.5	15-40	B (tg) 1.5-2 m + clm	I, II, IV
	-	≤10	-	-	-	-	B (tg) 1.5-2 m + S (mr) 5-10 cm	I, II, IV
16[c,d]	40-10	>15	-	-	0.5	30-65	B (tg) 1.5-2 m + clm	I, V,VI
	-	≤15	-	-	-	-	B (tg) 1.5-2 m + S (mr) 10-15 cm	I, V, VI

[a] After Barton et al. (1974)
[b] Approx.
[c] Original authors' estimates of support. Insufficient case records avaliable for reliable estimation of support requirements. The type of support to be used in categories 1-8 will depend on the blasting technique. Smooth-wall blasting and thorough barring-down may remove the need for support. Rough-wall blasting may result in the need for single applications of shotcrete, especially where the excavation height is >25 m. Future case records should differentiate categories 1-8. Key: sb = spot bolting; B = systematic bolting; (utg) = untensioned, grouted; (tg) tensioned (expanding-shell type for competent rock masses, grouted post-tensioned in very poor quality rock masses); S = shotcrete; (mr) = mesh-reinforced; clm = chain-link mesh; CCA = cast concrete arch; (sr) steel-reinforced. Bolt spacings are given in meters (m). Shotcrete or cast concrete arch thickness is given centimeters (cm).

Table A.3 Q-System: Support Measures for Q Range 1 to 10[a] (After Barton et al., 1974).

Support Category	Q	Conditional Factors			P^b (kg/cm^2)	Span/ESR (m)	Type of Support	Notes
		RQD/J_n	J_r/J_n	Span/ESR (m)				
17	10-4	>30	-	-	1.0	3.5-9	sb (utg)	I
	-	≥10, ≤30	-	-	-	-	B (utg) 1-1.5 m	I
	-	<10	-	≥6	-	-	B (utg) 1-1.5 m + S 2-3 cm	I
	-	<10	-	<6	-	-	S 2-3 cm	I
18	10-4	>5	-	≥10	1.0	7-15	B (tg) 1-1.5 m + clm	I,III
	-	>5	-	<10	-	-	B (utg) 1-1.5 m + clm	I
	-	≤5	-	≥10	-	-	B (tg) 1-1.5 m + S 2-3 cm	I,III
	-	≤5	-	<10	-	-	B (utg) 1-1.5 m + S 2-3 cm	I
19	10-4	-	-	≥20	1.0	12-29	B (tg) 1-2 m + S (mr) 10-15 cm	I,II,IV
	-	-	-	<20	-	-	B (tg) 1-1.5 m + S (mr) 5-10 cm	I,II
20[c]	10-4	-	-	≥35	1.0	24-52	B (tg) 1-2 m + S (mr) 20-25 cm	I,V,VI
	-	-	-	<35	-	-	B (tg) 1-2 m + S (mr) 10-20 cm	I,II,IV
21	4-1	≥12.5	≤0.75	-	1.5	2.1-6.5	B (utg) 1 m + S 2-3 cm	I
	-	<12.5	<0.75	-	-	-	S 2.5-5 cm	I
	-	-	>0.75	-	-	-	B (utg) 1 m	I
22	4-1	>10, <30	>1.0	-	1.5	4.5-11.5	B (utg) 1 m + clm	I
	-	≤10	>1.0	-	-	-	S 2.5-7.5 cm	I
	-	<30	≤1.0	-	-	-	B (utg) 1 m + S (mr) 2.5-5 cm	I
	-	≥30	-	-	-	-	B (utg) 1m	I
23	4-1	-	-	≥15	1.5	8-24	B (tg) 1-1.5 m + S (mr) 10-15 cm	I,II,IV,VII
	-	-	-	<15	-	-	B (utg) 1-1.5 m + S (mr) 5-10 m	I
24[c,d]	4-1	-	-	≥30	1.5	18-46	B (tg) 1.5 m + S (mr) 15-30 cm	I,V,VI
	-	-	-	<30	-	-	B (tg) 1-1.5 m + S (mr) 10-15 cm	I,II,IV

[a] After Barton et al. (1974) [b] Approx.

[c] See note XII in Table 5.6. [d] See footnote c in Table 5.2.

Table A.4 Q-System: Support Measures for Q Range 0.1 to 1.0[a] (After Barton et. al., 1974).

Support Category	Q	Conditional Factors			P^b (kg/cm^2)	Span/ESR (m)	Type of Support	Notes
		RQD/J_n	J_r/J_n	Span/ESR (m)				
25	1.0-0.4	>10	>0.5	-	2.25	1.5-4.2	B (utg) 1 m + mr or clm	I
	-	≤10	>0.5	-	-	-	B (utg) 1 m + S (mr) 5 cm	I
	-	-	≤5	-	-	-	B (tg) 1 m + S (Mr) 5 cm	I
26	1.0-0.4	-	-	-	2.25	3.2-7.5	B (tg) 1 m + S (mr) 5-7.5 cm	VIII, X, XI
	-	-	-	-	-	-	B (utg) 1 m + S 2.5-5 cm	I,IX
27	1.0-0.4	-	-	≥12	2.25	6-18	B (tg) 1 m + S (mr) 7.5-10 cm	I,IX
	-	-	-	<12	-	-	B (utg) 1 m + S (mr) 5-7.5 cm	I,IX
	-	-	-	>12	-	-	CCA 20-40 cm + B (tg) 1 m	VIII, X, XI
	-	-	-	<12	-	-	S (mr) 10-20 cm + B (tg) 1 m	VIII, X, I
28[d]	1.0-0.4	-	-	≥30	2.5	15-38	B (tg) 1 m + S (mr) 30-40 cm	I,IV,V,IX
	-	-	-	≥20, <30	-	-	B (tg) 1 m + S (mr) 20-30 cm	I,II,IV,IX
	-	-	-	<20	-	-	B (tg) 1 m + S (mr) 15-20 cm	I,II,IX
	-	-	-	-	-	-	CCA (sr) 30-100 cm + B (tg) 1 m	IV,VIII,X,XI
29	0.4-0.1	>5	>0.25	-	3.0	1.0-3.1	B (utg) 1 m + S 2-3 cm	-
	-	≤5	>0.25	-	-	-	B (utg) 1 m + S (mr) 5 cm	-
	-	-	≤0.25	-	-	-	B (tg) 1 m + S (Mr) 5 cm	-
30	0.4-0.1	≥5	-	-	3.0	2.2-6	B (tg) 1 m + S 2.5-5 cm	IX
	-	<5	-	-	-	-	S (mr) 5-7.5 cm	IX
	-	-	-	-	-	-	B (tg) 1 m + S (mr) 5-7.5 cm	VIII,X,XI
31	0.4-0.1	>4	-	-	3.0	4-14.5	B (tg) 1 m + S (mr) 5-12.5 cm	IX
	-	≤4, ≥1.5	-	-	-	-	S (mr) 7.5-25 cm	IX
	-	<1.5	-	-	-	-	CCA 20- 40 cm + B (tg) 1 m	IX, XI
	-	-	-	-	-	-	CCA (sr) 30-50 cm + B (tg) 1 m	VII,X,XI
32[d]	0.4-0.1	-	-	≥20	3.0	11-34	B (tg) 1 m + S (mr) 40-60 cm	II,IV,IX,XI
	-	-	-	<20	-	-	B (tg) 1 m + S (mr) 20-40 cm	III,IV,IX,XI

[a] After Barton et al. (1974)   [b] Approx.   [c] For key, refer to Table 5.2, footnote c.   [d] See note XII in Table 5.6.

Table A.5 Q-System: Support Measures for Q Range 0.001 to 0.1[a] (After Barton et al., 1974)

Support Category	Q	Conditional Factors			P^b (kg/cm^2)	Span/ESR (m)	Type of Support	Notes
		RQD/J_n	J_r/J_n	Span/ESR (m)				
33	0.1-0.01	≥2	-	-	6	1.0-3.9	B (tg) 1 m + S(mr) 2.5-5 cm	IX
	-	<2	-	-	-	-	S (mr) 5-10 cm	IX
	-	-	-	-	-	-	S (mr) 7.5-15 cm	VIII,X
34	1.0-0.01	≥2	≥0.25	-	6	2.0-11	B (tg) 1 m + S (mr) 5-7.5 cm	IX
	-	<2	≥0.25	-	-	-	S (mr) 7.5-15 cm	IX
	-	-	<0.25	-	-	-	S (mr) 15-25 cm	IX
	-	-	-	-	-	-	CCA (sr) 20-60 cm + B (tg) 1 m	VIII, X, XI
35[d]	0.1-0.01	-	-	≥15	6	6.2-28	B (tg) 1 m + S (mr) 30-100 cm	II, IX, XI
	-	-	-	≥15	-	-	CCA (sr) 60-200 cm + B (tg) 1 m	VIII,X,XI,III
	-	-	-	<15	-	-	B (tg) 1 m + S (mr) 20-75 cm	IX, XI, III
	-	-	-	<15	-	-	CCA (sr) 40-150 cm + B (tg) 1 m	VIII,X,XI,III
36	0.01-0.001	-	-	-	12	1.0-2.0	S (mr) 10-20 cm	IX
	-	-	-	-	-	-	S (mr) 10-20 cm + B (tg) 0.5-1.0 m	VIII,X,XI
37	0.01-0.001	-	-	-	12	1.0-6.5	S (mr) 20-60 cm	IX
	-	-	-	-	-	-	S (mr) 20-60 cm + B (tg) 0.5-1.0 m	VIII, X, XI
38[e]	0.01-0.001	-	-	≥10	12	4.0-20	CCA (sr) 100-300 cm	IX
	-	-	-	≥10	-	-	CCA (sr) 100-300 cm + B (tg) 1 m	VIII, X,II,XI
	-	-	-	<10	-	-	S (mr) 70-200 cm	IX
	-	-	-	<10	-	-	S (mr) 70-200 cm	VIII,X,III,XI

[a] After Barton et al. (1974)
[b] Approx.
[c] For key, refer to Table 5.2, footnote c.
[d] See note XII in Table 5.6.
[e] See note XII in Table 5.6.

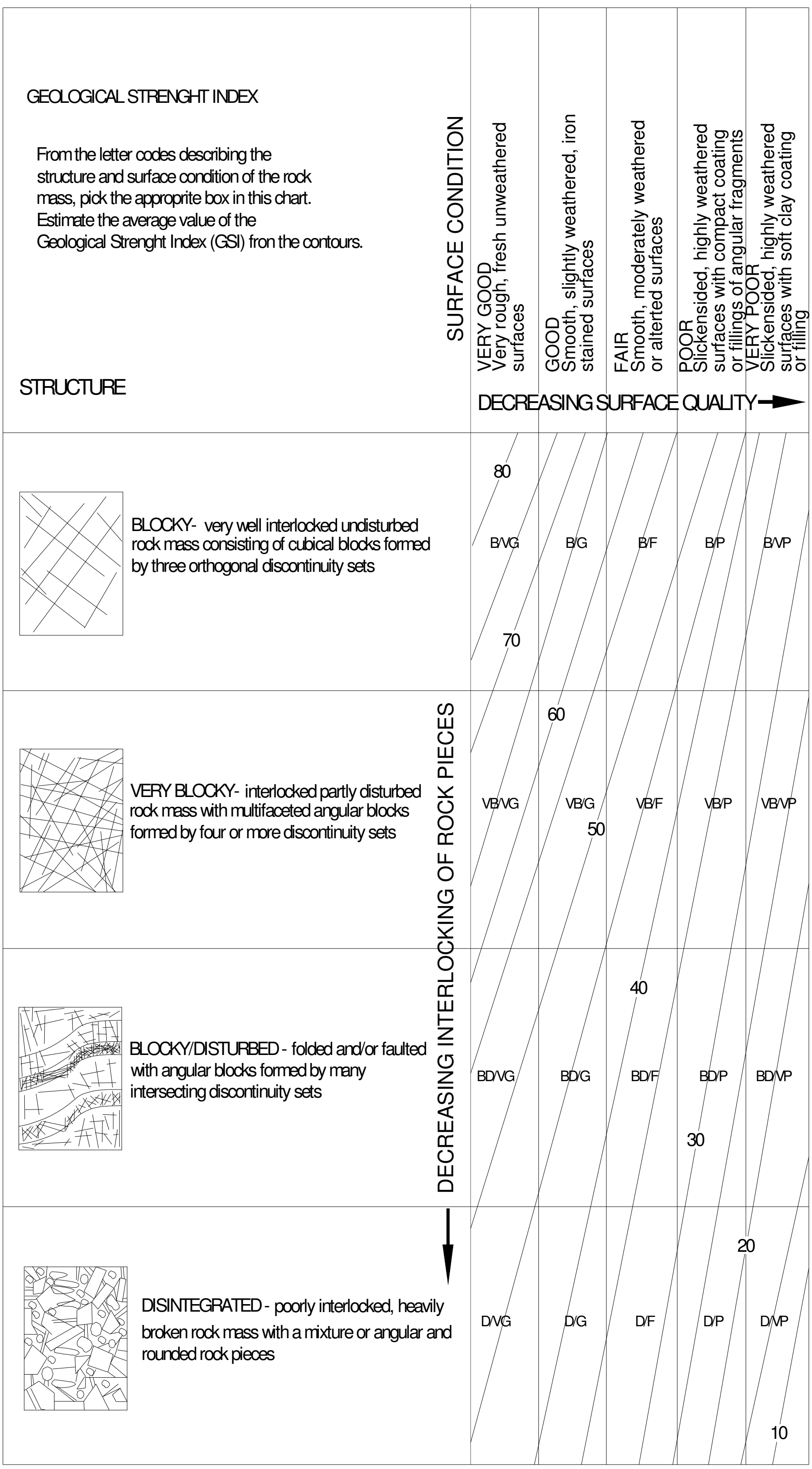


Figure A.13 GSI System (Hoek and Brown, 1997).

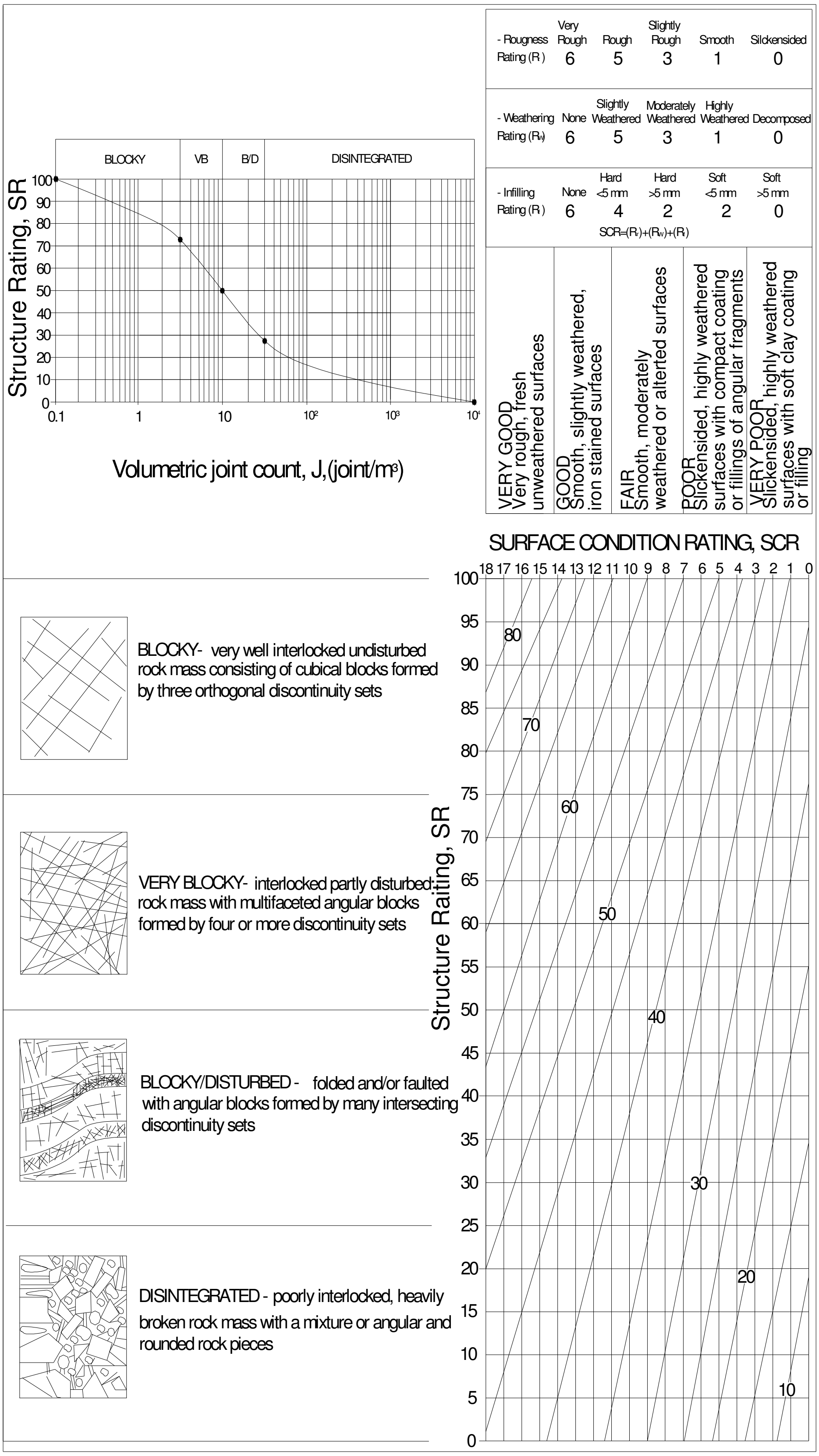


Figure A.14 Modification of GSI System by Sönmez and Ulusay (1999).

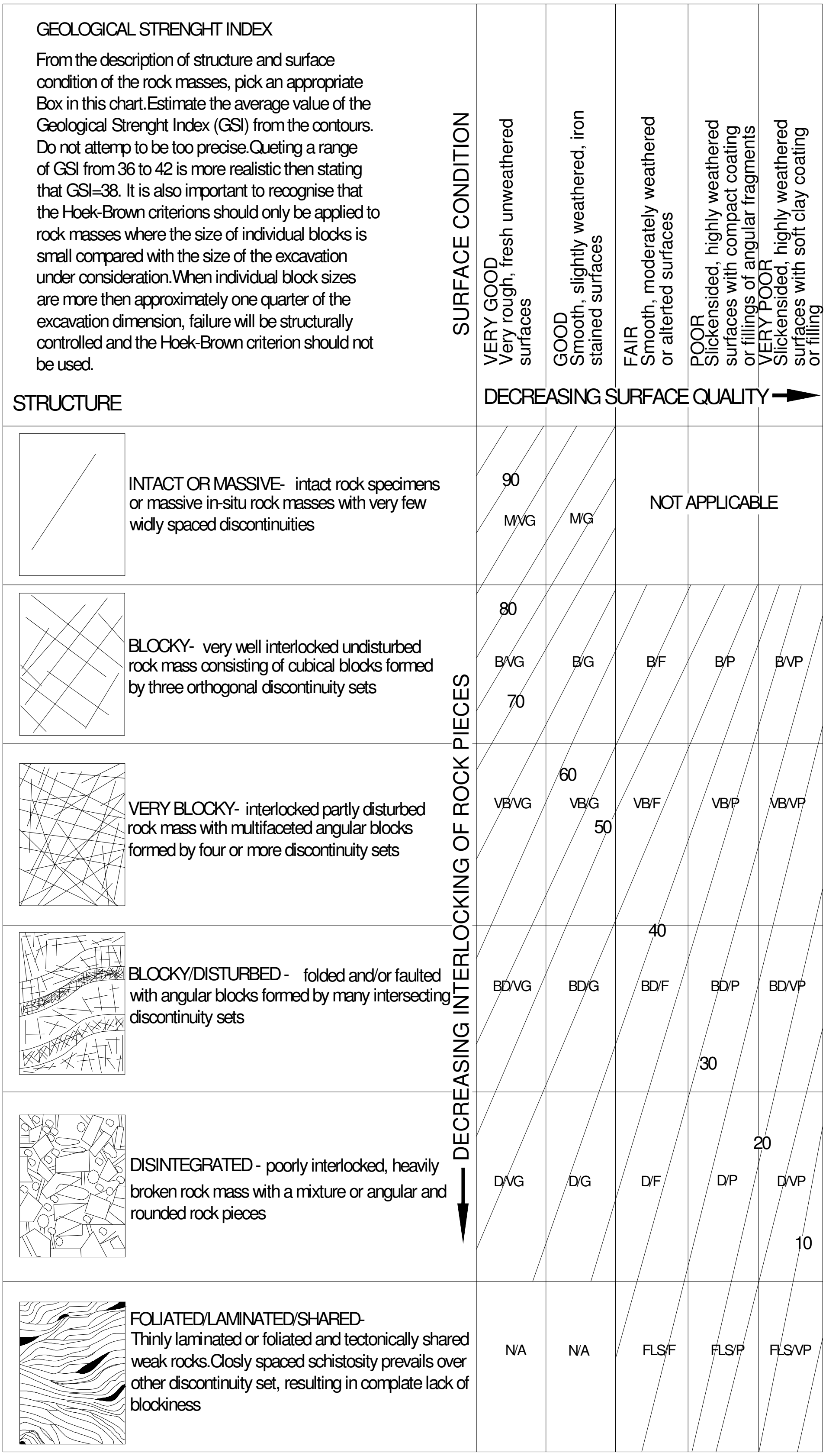


Figure A.15 GSI classification systems by Hoek (1999).

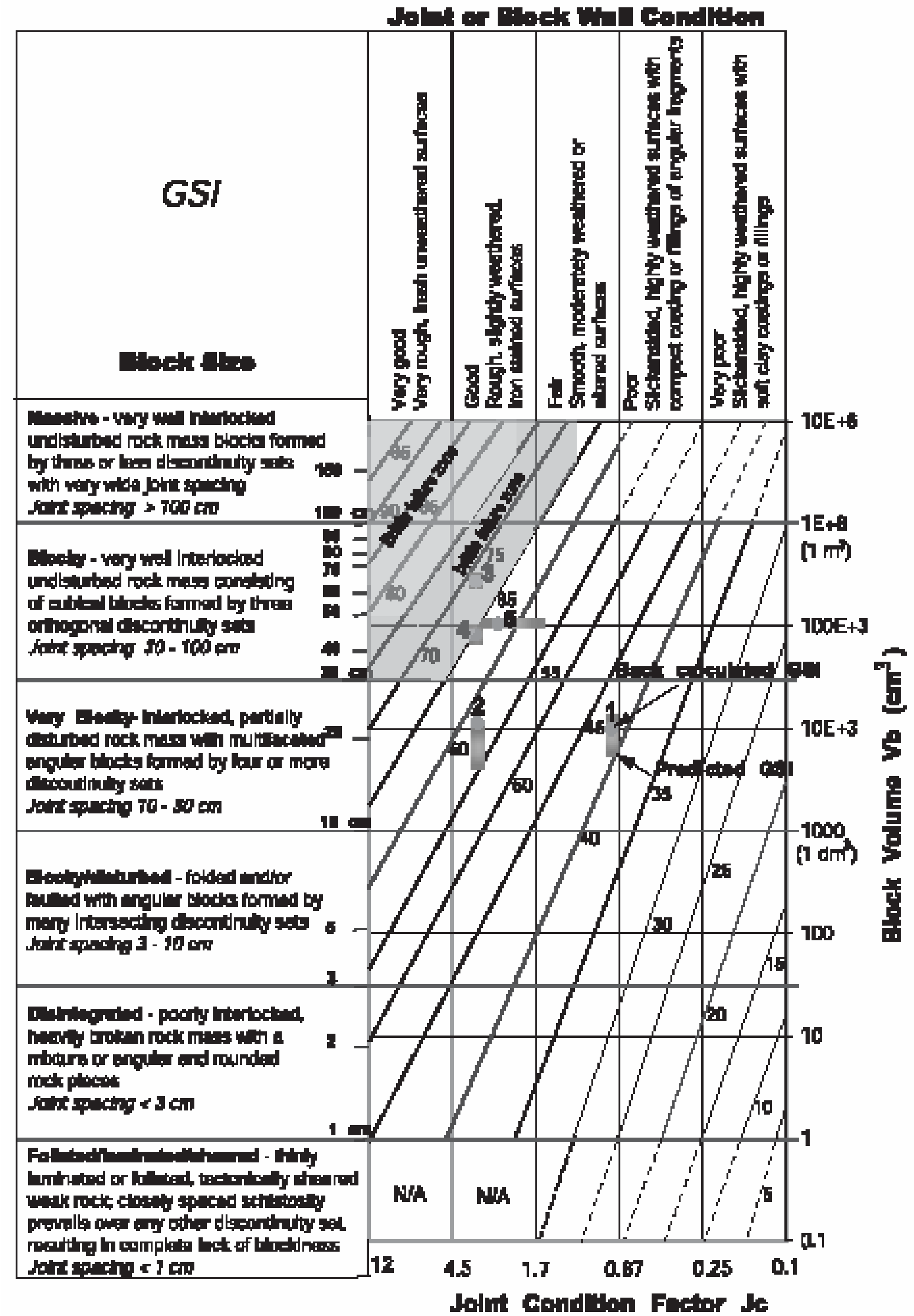


Figure A.16 Quantification of GSI chart (Cai, et al., 2004).

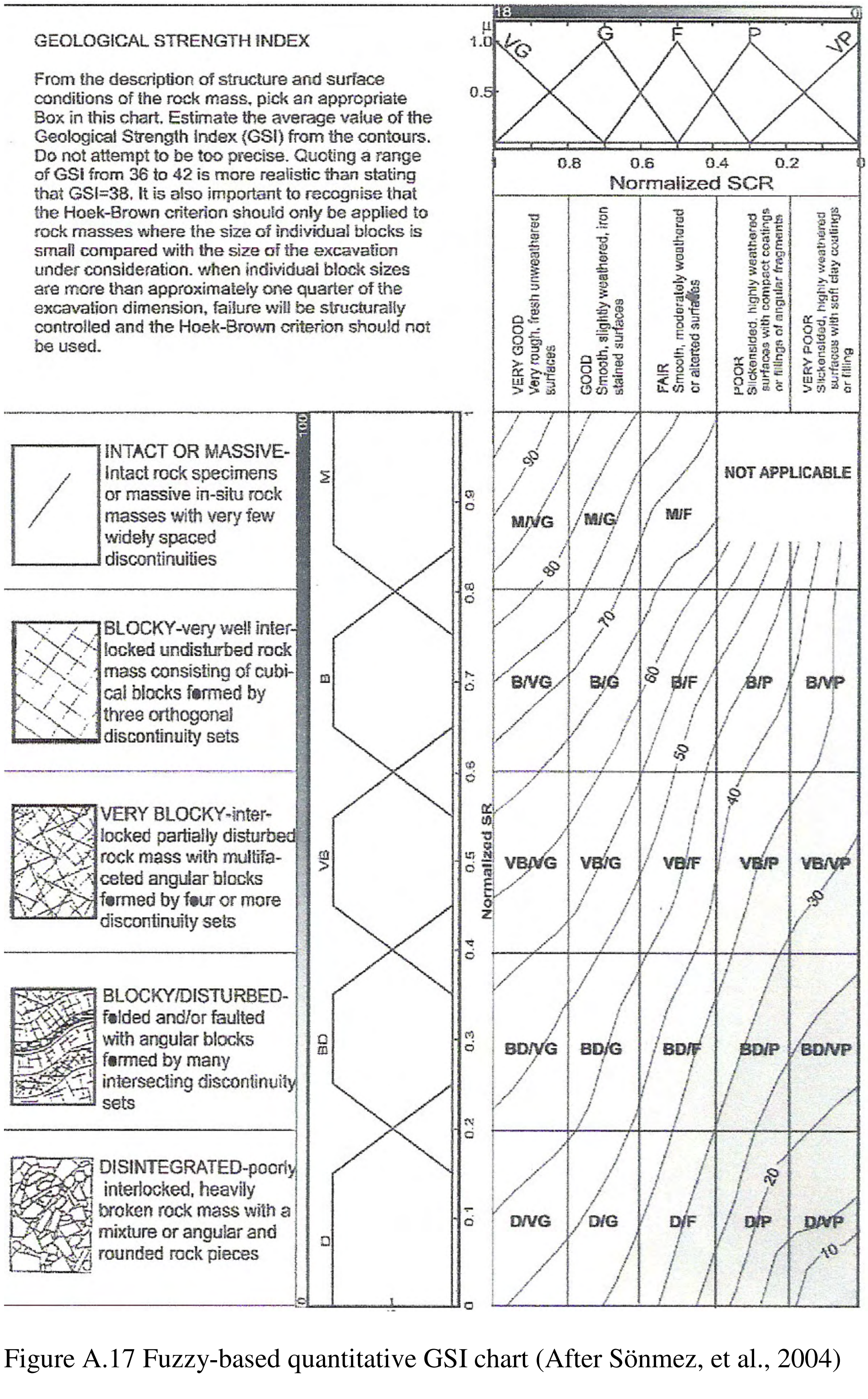


Figure A.17 Fuzzy-based quantitative GSI chart (After Sönmez, et al., 2004)

Table A.6 NATM rock mass classes (Geoconsult, 1993 and ONORM B 2203, 1994).

Rock Mass Class	Behavior of Rock Mass		Explanations
	ONORM B 2203 After Oct. 1994	ONORM B 2203 Before Oct. 1994	
A	A1 Stable	A1 Stable	The rock mass behaves elastically. Deformations are small and decrease rapidly. There is no tendency of overbreaking after scaling of the rock portions disturbed by blasting. The rock mass is permanently stable without support.
	A2 Slightly Overbreaking	A2 Slightly Overbreaking	The rock mass behaves elastically. Deformations are small and decrease rapidly. A slight tendency of shallow overbreaks in the tunnel roof and in the upper portions of the sidewalls caused by discontinuities and the dead weight of the rock mass exists.
B	B1 Friable	B1 Friable	Major parts of the rock mass behave elastically. Deformations are small and decrease rapidly. Low rock mass strength and limited stand-up times related to the prevailing discontinuity pattern yield overbreaks and loosening of the rock strata in tunnel roof and upper sidewalls if no support is installed in time.
	B2 Very Friable	B2 Very Friable	This type of rock mass is characterised by large areas of non-elastic zones extending far into the surrounding rock mass. Immediate installation of the tunnel support, will ensure deformations can be kept small and cease rapidly. In case of a delayed installation or an insufficient quantity of support elements, the low strength of the rock mass yields deep loosening and loading of the initial support. Stand-up time and unsupported span are short. The potential of deep and sudden failure from roof, sidewalls and face is high.
	B3 Rolling		

Table A.6 (Continued).

Rock Mass Class	Behavior of Rock Mass		Explanations
	ONORM B 2203 After Oct. 1994	ONORM B 2203 Before Oct. 1994	
C	C1 Rock Burstling	C1 Squeezing	C1 is characterized by plastic zones extending far into the surrounding rock mass and failure mechanisms such as spalling, buckling, shearing and rupture of the rock structure, by squeezing behaviour or by tendency rock burst. Subject rock mass shows a moderate, but distinct time depending squeezing behaviour; deformations calm down slowly except in case of rock bursts. Magnitude and velocity of deformations at the cavity boundary are moderate.
	C2 Squeezing		
	C3 Heavily Squeezing	C2 Heavily Squeezing	C2 is characterized by the development of deep failure zones and a rapid and significant movement of the rock mass into the cavity and deformations which decrease very slowly. Support elements may frequently be overstressed..
	C4 Flowing	L1 Short-term-stable with high cohesion	By limitation of the unsupported spans at arch and face, the rock mass remain stable for a limited time.
	C5 Swelling	L2 Short-term-stable with low cohesion	No stand up time without support by prior installation of forepolling or forepiling and shotcrete sealing of faces simultaneously with excavation. The low cohesion requires a number of subdivisions.

A.I A brief history of the development of the Hoek-Brown failure criterion (Hoek, 2004)

The original Hoek-Brown failure criterion was developed during the preparation of the book *Underground Excavations in Rock,* published in 1980. The criterion was required in order provide input information for the design of underground excavations. Since no suitable methods for estimating rock mass strength appeared to be available at that time, the efforts were focussed on developing a dimensionless equation that could be scaled in relation to geological information. The original Hoek-Brown equation was neither new nor unique – an identical equation had been used for describing the failure of concrete as early as 1936. The significant contribution that Hoek and Brown made was to link the equation to geological observations, initially in the form of Bieniawski's Rock Mass Rating and later to the Geological Strength Index GSI. The subsequent development of the criterion and the associated GSI system is described in these notes. Evert Hoek April 2004

A brief history of the development of the Hoek-Brown failure criterion

1980 Hoek E. and Brown E.T. 1980. *Underground Excavations in Rock* . London: Institution of Mining and Metallurgy 527 pages
Hoek, E. and Brown, E.T. 1980. Empirical strength criterion for rock masses. *J.Geotech. Engng Div.*, *ASCE* **106**(GT9), 1013-1035.

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

It was recognised very early in the development of the criterion that it would have no practical value unless the parameters could be estimated by simple geological observations in the field. The idea of developing a 'classification' for this specific purpose was discussed but, since Bieniawski's RMR had been published in 1974 and had gained popularity with the rock mechanics community; it was decided to use this as the basic vehicle for geological input. The original criterion was conceived for use under the confined conditions surrounding underground excavations. The data upon which some of the original relationships had been based came from tests on rock mass samples from the Bougainville mine in Papua New Guinea. The rock mass here is very strong andesite (uniaxial compressive strength about 270 MPa) with numerous clean, rough, unfilled joints. One of the most important sets of data was from a series of triaxial tests carried out by Professor John Jaeger at the Australian National University in Canberra. These tests were on 150 mm diameter samples of heavily jointed andesite recovered by triple-tube diamond drilling from one of the exploration adits at Bougainville.

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

1983 Hoek, E. 1983. Strength of jointed rock masses, 23rd. Rankine Lecture. *Géotechnique* **33**(3), 187-223.

One of the issues that had been troublesome throughout the development of the criterion has been the relationship between Hoek-Brown criterion, with the non-linear parameters *m* and *s*, and the Mohr-Coulomb criterion, with the parameters *c* and ϕ. Practically all software for soil and rock mechanics is written in terms of the Morh-Coulomb criterion and it was necessary to define the relationship between *m* and *s* and *c* and ϕ in order to allow the criterion to be used for to provide input for this software.

An exact theoretical solution to this problem (for the original Hoek-Brown criterion) was developed by Dr John. W. Bray at the Imperial College of Science and Technology and this solution was first published in the 1983 Rankine lecture. This publication also expanded on some of the concepts published by Hoek and Brown in 1980 and it represents the most comprehensive discussion on the original Hoek Brown criterion.

1988 Hoek E and Brown E.T. 1988. The Hoek-Brown failure criterion - a 1988 update. *Proc. 15th Canadian Rock Mech. Symp.* (ed. J.H. Curran), pp. 31-38. Toronto:Civil Engineering Dept., University of Toronto

By 1988 the criterion was being widely used for a variety of rock engineering problems, including slope stability analyses. As pointed out earlier, the criterion was originally developed for the confined conditions surrounding underground excavations and it was recognised that it gave optimistic results near surfaces in slopes. Consequently, in 1998, the idea of *undisturbed* and *disturbed* masses was introduced to provide a method for downgrading the properties for near surface rock masses.

This paper also defined a method of using Bieniawski's 1974 RMR classification for estimating the input parameters. In order to avoid double counting the effects of groundwater (an effective stress parameter in numerical analysis) and joint orientation (specific input for structural analysis), it was suggested that the rating for groundwater should always be set at 10 (completely dry) and the rating for joint orientation should always be set to zero (very favourable). Note that these ratings need to be adjusted in later versions of Bieniawski's RMR.

1990 Hoek, E. 1990. Estimating Mohr-Coulomb friction and cohesion values from the Hoek-Brown failure criterion. *Intnl. J. Rock Mech. & Mining Sci. & Geomechanics Abstracts.* **12**(3), 227-229.

This technical note addressed the on-going debate on the relationship between the Hoek-Brown and the Mohr-Coulomb criterion. Three different practical situations were described and it was demonstrated how Bray's solution could be applied in each case.

1992 Hoek, E., Wood, D. and Shah, S. 1992. A modified Hoek-Brown criterion for jointed rock masses. *Proc. rock characterization, symp. Int. Soc. Rock Mech.:Eurock '92*, (J. Hudson ed.). 209-213.

The use of the Hoek Brown criterion had now become widespread and, because of the lack of suitable alternatives, it was now being used on very poor quality rock masses. These rock masses differed significantly from the tightly interlocked hard rock mass model used in the development of the original criterion. In particular it was felt that the finite tensile strength predicted by the original Hoek Brown criterion was too optimistic and that it needed to be revised. Based upon work carried out br Dr Sandip Shah for his Ph.D thesis at the University of

Toronto, a modified criterion was proposed. This criterion contained a new parameter *a* that provided the means for changing the curvature of the failure envelope, particularly in the very low normal stress range. Basically, the modified Hoek Brown criterion forces the failure envelope to produce zero tensile strength.

1994 Hoek, E. 1994. Strength of rock and rock masses, *ISRM News Journal,* **2**(2), 4-16.

1995 Hoek, E., Kaiser, P.K. and Bawden. W.F. 1995. *Support of underground excavations in hard rock.* Rotterdam: Balkema

It soon became evident that the modified criterion was too conservative when used for better quality rock masses and a 'generalised' failure criterion was proposed in these two publications. This generalised criterion incorporated both the original and the modified criteria with a 'switch' at an RMR value of approximately 25. Hence, for excellent to fair quality rock masses, the original Hoek Brown criterion is used while, for poor and extremely poor rock masses, the modified criterion (published in 1992) with zero tensile strength is used.

These papers (which are practically identical) also introduced the concept of the Geological Strength Index (GSI) as a replacement for Bieniawski's RMR. It had become increasingly obvious that Bieniawski's RMR is difficult to apply to very poor quality rock masses and also that the relationship between RMR and *m* and *s* is no longer linear in these very low ranges. It was also felt that a system based more heavily on fundamental geological observations and less on 'numbers' was needed.

The idea of *undisturbed* and *disturbed* rock masses was dropped and it was left to the user to decide which GSI value best described the various rock types exposed on a site. The original *disturbed* parameters were derived by simply reducing the strength by one row in the classification table. It was felt that this was too arbitrary and it was decided that it would be preferable to allow the user to decide what sort of disturbance is involved and to allow this user to make their own judgement on how much to reduce the GSI value to account for the strength loss.

1997 Hoek, E. and Brown, E.T. 1997. Practical estimates or rock mass strength. *Intnl.J. Rock Mech. & Mining Sci. & Geomechanics Abstracts.* **34**(8), 1165-1186.

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

The most important aspect of this curve fitting process is to decide upon the stress range over which the hypothetical in situ 'tests' should be carried out. This was determined experimentally by carrying out a large number of comparative theoretical studies in which the results of both surface and underground excavation stability analyses, using both the Hoek Brown and Mohr Coulomb parameters, were compared.

1998 Hoek, E., Marinos, P. and Benissi, M. (1998) Applicability of the GeologicalStrength Index (GSI) classification for very weak and sheared rock masses. The case of the Athens Schist Formation. *Bull. Engg. Geol. Env.* 57(2), 151-160.

This paper extends the range of the Geological Strength Index (GSI) down to 5 to include extremely poor quality schistose rock masses such as the 'schist' encountered in the excavations for the Athens Metro and the graphitic phyllites encountered in some of the tunnels in Venezuela. This extension to GSI is based largely on the work of Maria Benissi on the Athens Metro. Note that there were now 2 GSI charts. The first of these, for better quality rock masses published in 1994 and the new chart for very poor quality rock masses published in this paper.

2000 Hoek, E. and Marinos, P. (2000) Predicting Tunnel Squeezing. *Tunnels and Tunnelling International.* Part 1 – November 2000, Part 2 – December, 2000.

This paper introduced an important application of the Hoek-Brown criterion in the prediction of conditions for tunnel squeezing, utilising a critical strain concept proposed by Sakurai in 1983.

2000 Marinos, P and Hoek, E. (2000) GSI – A geologically friendly tool for rock mass strength estimation. *Proc. GeoEng2000 Conference, Melbourne.*

2000 Marinos, P. & Hoek, E. 2000. From The Geological to the Rock Mass Model: Driving the Egnatia Highway through difficult geological conditions, Northern Greece, *Proc. 10th International Conference of Italian National Councilof Geologists, Rome*

These papers put more geology into the Hoek-Brown failure criterion than that which has been available previously. In particular, the properties of very weak rocks are addressed in detail for the first time. There is no change in the mathematical interpretation of the criterion in these papers.

2000 Hoek, E. and Karzulovic, A. (2000) Rock-Mass properties for surface mines. In *Slope Stability in Surface Mining* (Edited by W. A. Hustralid, M.K. McCarter and D.J.A. van Zyl), Littleton, CO: Society for Mining, Metallurgical and Exploration (SME), pages 59-70.

This paper repeats most of the material contained in Hoek and Brown, 1997, but adds a discussion on blast damage.

2000 Marinos, P and Hoek, E. (2000). GSI: a geologically friendly tool for rock mass strength estimation. *Proc. GeoEng2000*, Melbourne.

2001 Marinos. P, and Hoek, E. (2001) – Estimating the geotechnical properties of heterogeneous rock masses such as flysch. *Bulletin of the Engineering Geology & the Environment (IAEG),* 60, 85-92.

These papers does not add anything significant to the fundamental concepts of the Hoek-Brown criterion but they demonstrates how to choose appropriate ranges of GSI for different rock mass types. In particular, the 2001 paper on flysch discussed difficult materials such as flysch on the basis of the authors' experience in dealing with these rocks in major projects in northern Greece.

2002 Hoek, E., Carranza-Torres, C. and Corkum, B. (2002) Hoek-Brown criterion – 2002 edition. *Proc. NARMS-TAC Conference*, Toronto, 2002, **1**, 267-273.

This paper represents a major re-examination of the entire Hoek-Brown criterion and includes new derivations of the relationships between *m, s, a* and *GSI.* A new parameter D is introduced to deal with blast damage. The relationships between the Mohr Coulomb and the Hoek Brown criteria are examined for slopes and for underground excavations and a set of equations linking the two are presented. The final relationships were derived by comparing hundreds of tunnel and slope stability analyses in which both the Hoek-Brown and the Mohr Coulomb criteria were used and the best match was found by iteration. A Windows based program called *RocLab* was developed to include all of these new derivations and this program can be downloaded (free) from www.rocscience.com. A copy of the paper is included with the download.

2004 Chandler R. J., De Freitas M. H. and P. G. Marinos. Geotechnical Characterisation of Soils and Rocks: a Geological Perspective. Keynote paper in: *Advances in geotechnical engineering, The Skempton Conference*, v1, p. 67-102, Thomas Telford, ICE, London (2004)

A brief contribution on the Geological Strength Index within a more general paper on engineering geology of soils and rock.

2004 V. Marinos, P. Marinos and E. Hoek. Discussion on rock mass characterisation with special emphasis in the geological strength index and in tunnelling, *Proc. 32nd International Geological Congress, Florence*, 2004. (in press)

A discussion on some of the geological aspects of the Geological Strength Index applied to tunnelling.

Hoek, E., Marinos P, and Marinos V. 2004. Rock mass characterisation for molasses. Paper submitted to the International Journal of Rock Mechanics and Mining Science.

A significant paper in which a new GSI chart for molassic rock masses is introduced, Molasse consists of a series of tectonically undisturbed sediments of sandstones, conglomerates, siltstones and marls, produced by the erosion of mountain ranges after the final phase of an orogeny. They behave as continuous rock masses when they are confined at depth and, even if lithologically heterogeneous, the bedding planes do not appear as clearly defined discontinuity surfaces. The paper discusses the difference between these rock masses and the flysch type rocks, which have been severely disturbed by orogenic processes.

Summary equations for Hoek-Brown failure criteria (Hoek, 2004)

Publication	*Coverage*	*Equations*
Hoek & Brown 1980	Original criterion for heavily jointed rock masses with no fines. Mohr envelope was obtained by statistical curve fitting to a number of (σ_n', τ) pairs calculated by the method published by Balmer [28]. σ_1', σ_3' are major and minor effective principal stresses at failure, respectively σ_t is the tensile strength of the rock mass m and s are material constants σ_n', τ are effective normal and shear stresses, respectively.	$\sigma_1' = \sigma_3' + \sigma_{ci}\sqrt{m\sigma_3'/\sigma_{ci} + s}$ $\sigma_t = \frac{\sigma_{ci}}{2}\left(m - \sqrt{m^2+4s}\right)$ $\tau = A\sigma_{ci}\left((\sigma_n' - \sigma_t)/\sigma_{ci}\right)^B$ $\sigma_n' = \sigma_3' + \left((\sigma_1' - \sigma_3')/(1+\partial\sigma_1'/\partial\sigma_3')\right)$ $\tau = (\sigma_n' - \sigma_3')\sqrt{\partial\sigma_1'/\partial\sigma_3'}$ $\partial\sigma_1'/\partial\sigma_3' = m\sigma_{ci}/2(\sigma_1' - \sigma_3')$
Hoek 1983	Original criterion for heavily jointed rock masses with no fines with a discussion on anisotropic failure and an exact solution for the Mohr envelope by Dr J.W. Bray.	$\sigma_1' = \sigma_3' + \sigma_{ci}\sqrt{m\sigma_3'/\sigma_{ci} + s}$ $\tau = \left(Cot\phi_i' - Cos\phi_i'\right)m\sigma_{ci}/8$ $\phi_i' = \arctan\left(1/\sqrt{4h\cos^2\theta - 1}\right)$ $\theta = \left(90 + \arctan(1/\sqrt{h^3-1})\right)/3$ $h = 1 + \left(16(m\sigma_n' + s\sigma_{ci})/(3m^2\sigma_{ci})\right)$
Hoek & Brown 1988	As for Hoek 1983 but with the addition of relationships between constants m and s and a modified form of *RMR* (Bieniawski [15]) in which the Groundwater rating was assigned a fixed value of 10 and the Adjustment for Joint Orientation was set at 0. Also a distinction between *disturbed* and *undisturbed* rock masses was introduced together with means of estimating deformation modulus E (after Serafim and Pereira [18]).	*Disturbed rock masses:* $m_b/m_i = \exp\left((RMR - 100)/14\right)$ $s = \exp\left((RMR - 100)/6\right)$ *Undisturbed or interlocking rock masses* $m_b/m_i = \exp\left((RMR - 100)/28\right)$ $s = \exp\left((RMR - 100)/9\right)$ $E = 10^{((RMR-10)/40)}$ m_b, m_i are for broken and intact rock, respectively.
Hoek, Wood & Shah 1992	Modified criterion to account for the fact the heavily jointed rock masses have zero tensile strength. Balmer's technique for calculating shear and normal stress pairs was utilised	$\sigma_1' = \sigma_3' + \sigma_{ci}\left(m_b\sigma_3'/\sigma_{ci}\right)^\alpha$ $\sigma_n' = \sigma_3' + \left((\sigma_1' - \sigma_3')/(1+\partial\sigma_1'/\partial\sigma_3')\right)$ $\tau = (\sigma_n' - \sigma_3')\sqrt{\partial\sigma_1'/\partial\sigma_3'}$ $\partial\sigma_1'/\partial\sigma_3' = 1 + \alpha m_b^\alpha\left(\sigma_3'/\sigma_{ci}\right)^{(\alpha-1)}$
Hoek 1994 Hoek, Kaiser & Bawden 1995	Introduction of the Generalised Hoek-Brown criterion, incorporating both the original criterion for fair to very poor quality rock masses and the modified criterion for very poor quality rock masses with increasing fines content. The Geological Strength Index *GSI* was introduced to overcome the deficiencies in Bieniawski's *RMR* for very poor quality rock masses. The distinction between disturbed and undisturbed rock masses was dropped on the basis that disturbance is generally induced by engineering activities and should be allowed for by downgrading the value of *GSI*.	$\sigma_1' = \sigma_3' + \sigma_c\left(m\sigma_3'/\sigma_{ci} + s\right)^a$ for $GSI > 25$ $m_b/m_i = \exp\left((GSI - 100)/28\right)$ $s = \exp\left((GSI - 100)/9\right)$ $a = 0.5$ for $GSI < 25$ $s = 0$ $a = 0.65 - GSI/200$

Hoek, Carranza-Torres and Corkum, 2002	A new set of relationships between GSI, m_b, s and a is introduced to give a smoother transition between very poor quality rock masses (GSI < 25) and stronger rocks. A disturbance factor D to account for stress relaxation and blast damage is also introduced. Equations for the calculation of Mohr Coulomb parameters c and ϕ are introduced for specific ranges of the confining stress σ'_{3max} for tunnels and slopes. All of these equations are incorporated into the Windows program RocLab that can be downloaded from the Internet site www.rocscience.com. A copy of the full paper is included with the download.	$\sigma_1' = \sigma_3' + \sigma_{ci}\left(m_b \sigma_3'/\sigma_{ci} + s\right)^a$ $m_b = m_i \exp\left((GSI - 100)/(28 - 14D)\right)$ $s = \exp\left((GSI - 100)/(9 - 3D)\right)$ $a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$ $E_m(GPa) = \left(1 - \frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}} \cdot 10^{((GSI-10)/40)}$ $\phi' = \sin^{-1}\left[\frac{6am_b(s + m_b\sigma'_{3n})^{a-1}}{2(1+a)(2+a) + 6am_b(s + m_b\sigma'_{3n})^{a-1}}\right]$ $c' = \frac{\sigma_{ci}\left[(1+2a)s + (1-a)m_b\sigma'_{3n}\right](s + m_b\sigma'_{3n})^{a-1}}{(1+a)(2+a)\sqrt{1 + \left(6am_b(s + m_b\sigma'_{3n})^{a-1}\right)/((1+a)(2+a))}}$ where, for tunnels $\frac{\sigma'_{3max}}{\sigma'_{cm}} = 0.47\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.94}$ - H is the depth below surface for slopes $\frac{\sigma'_{3max}}{\sigma'_{cm}} = 0.72\left(\frac{\sigma'_{cm}}{\gamma H}\right)^{-0.91}$ - H is the slope height γ is the unit weight of the rock mass

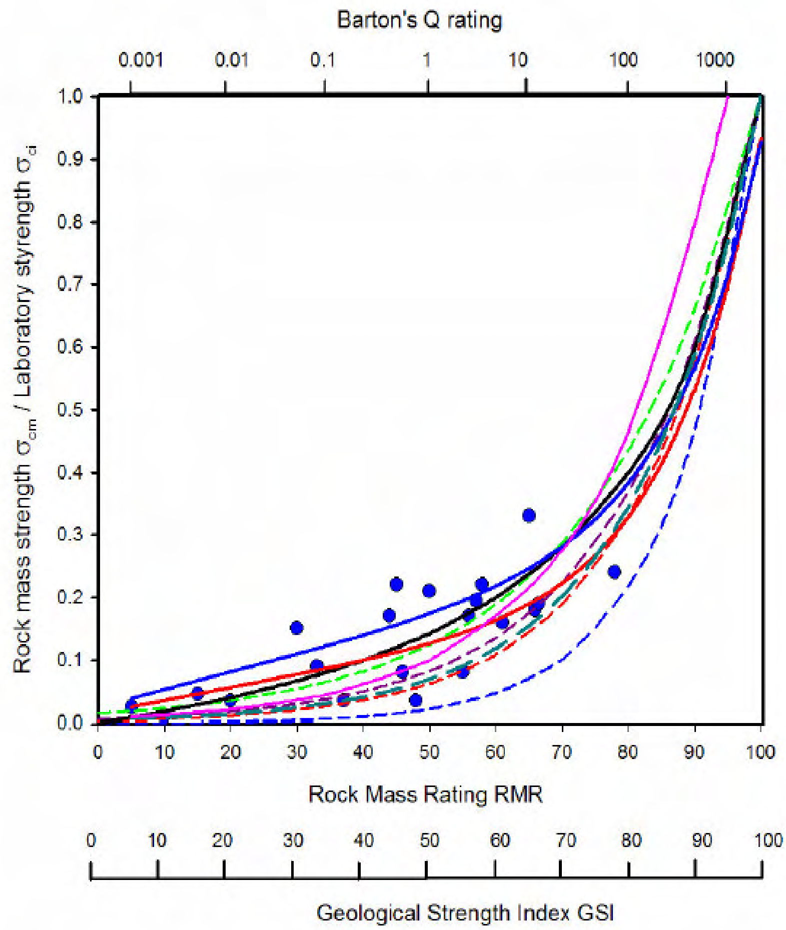
A.II Guidelince for estimeting disturbance factor D (Hoek, et al., 2002).

Appearance of rock mass	Description of rock mass	Suggested value of D
	Excellent quality controlled blasting or excavation by Tunnel Boring Machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	$D = 0$
	Mechanical or hand excavation in poor quality rock masses (no blasting) results in minimal disturbance to the surrounding rock mass. Where squeezing problems result in significant flor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	$D = 0$ $D = 0.5$ No invert
	Very poor quality blasting in a hard rock tunnel results in severe local damage, extending 2 or 3 m, in the surrounding rock mass.	$D = 0.8$
	Small scale blasting in civil engineering slopes results in modest rock mass damage, particularly if controlled blasting is used as shown on the left hand side of the photograph. However, stress relief results in some disturbance.	$D = 0.7$ Good blasting $D = 1.0$ Poor blasting
	Very large open pit mine slopes suffer significant disturbance due to heavy production blasting and also due to stress relief from overburden removal. In some softer rocks excavation can be carried out by ripping and dozing and the degree of damage to the slopes is less.	$D = 1.0$ Production blasting $D = 0.7$ Mechanical excavation

A.III Estimates of rock mass strength and deformation modulus (Hoek, 2004).

In the preliminary stages of a rock engineering design the need for approximate estimates of rock mass strength and deformation modulus frequently arises. Several authors have published empirical estimates of these properties, based on rock mass classification systems. These estimates, together with available data from in situ measurements, are summarized in Figures 1 and 3. Hoek et al (2002) and Barton (2000) have extended these empirical relationships to allow for different intact rock strength values and for disturbance due to blast damage and stres relaxation. These extended relationships are summarized in Figures 2 and 4. All of these relationships are intended to provide initial estimates of the rock mass properties and they should be used with caution in engineering design. In critical cases it is strongly recommended that the estimates should be confirmed by in situ measurements or by back analysis of excavation behaviour. The use of RMR values of less than 30 and Q values of less than 0.1 for making these estimates is not recommended because of the dominant role of RQD in these classifications and the difficulty of determining its value for very poor quality rock masses. It is recommended that only directly determined values of RMR, Q and GSI should be used for making these estimated and that equations relating these classification systems should not be used.

Evert Hoek April 2004



●	In situ tests from construction sites in Turkey	Aydan, O and Dalgic,S, 1998
red dashed	$\sigma_{cm}/\sigma_{ci} = \sqrt{\exp((RMR-100)/9)}$	Hoek, E and Brown, E.T., 1980
blue dashed	$\sigma_{cm}/\sigma_{ci} = \exp(7.65\,((RMR-100)/100))$	Yudhbir and Bieniawski, Z.T., 1983
green dashed	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/24)$	Kalamaris, G and Bieniawski, Z.T, 1993
teal dashed	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/20)$	Sheorey, P.R. 1997
purple dashed	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/18.75)$	Ramamurthy, T, 1986
black solid	$\sigma_{cm}/\sigma_{ci} = (RMR/(RMR+6(100-RMR)))$	Aydan, O and Dalgic,S, 1998
blue solid	m_i = 10, for confined conditions with D = 0	Hoek et al, 2002
magenta solid	$\sigma_{cm} = 5\gamma(Q\sigma_{ci}/100)^{(1/3)}$, γ = 2.6, σ_c = 100 MPa	Barton 2000, Singh 1993

Figure 1: Estimates of the ratio of rock mass strength to the strength of small laboratory samples based upon rock mass classifications.

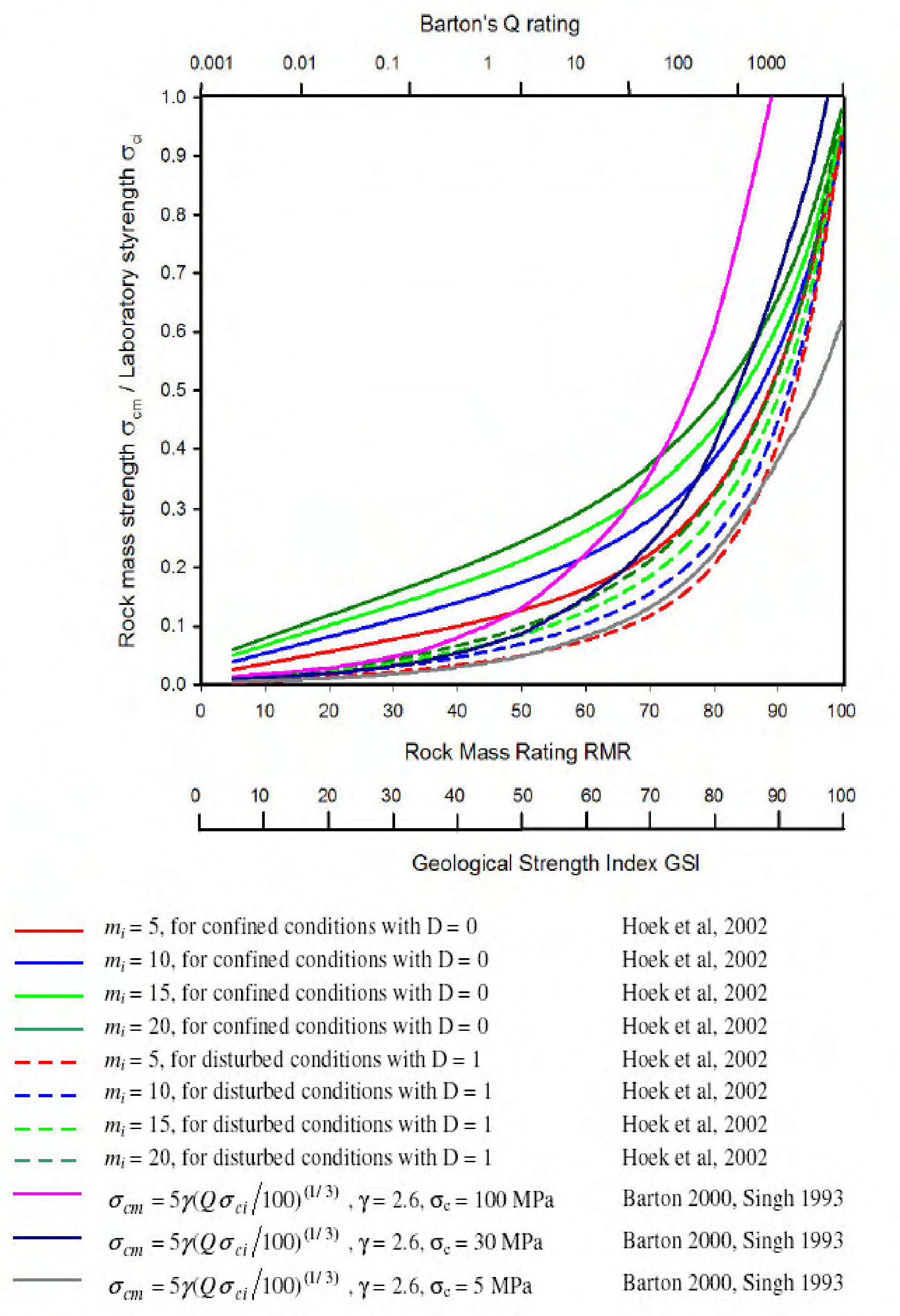


Figure 2: Rock mass strength predictions by Hoek at al, 2002, and Barton, 2000

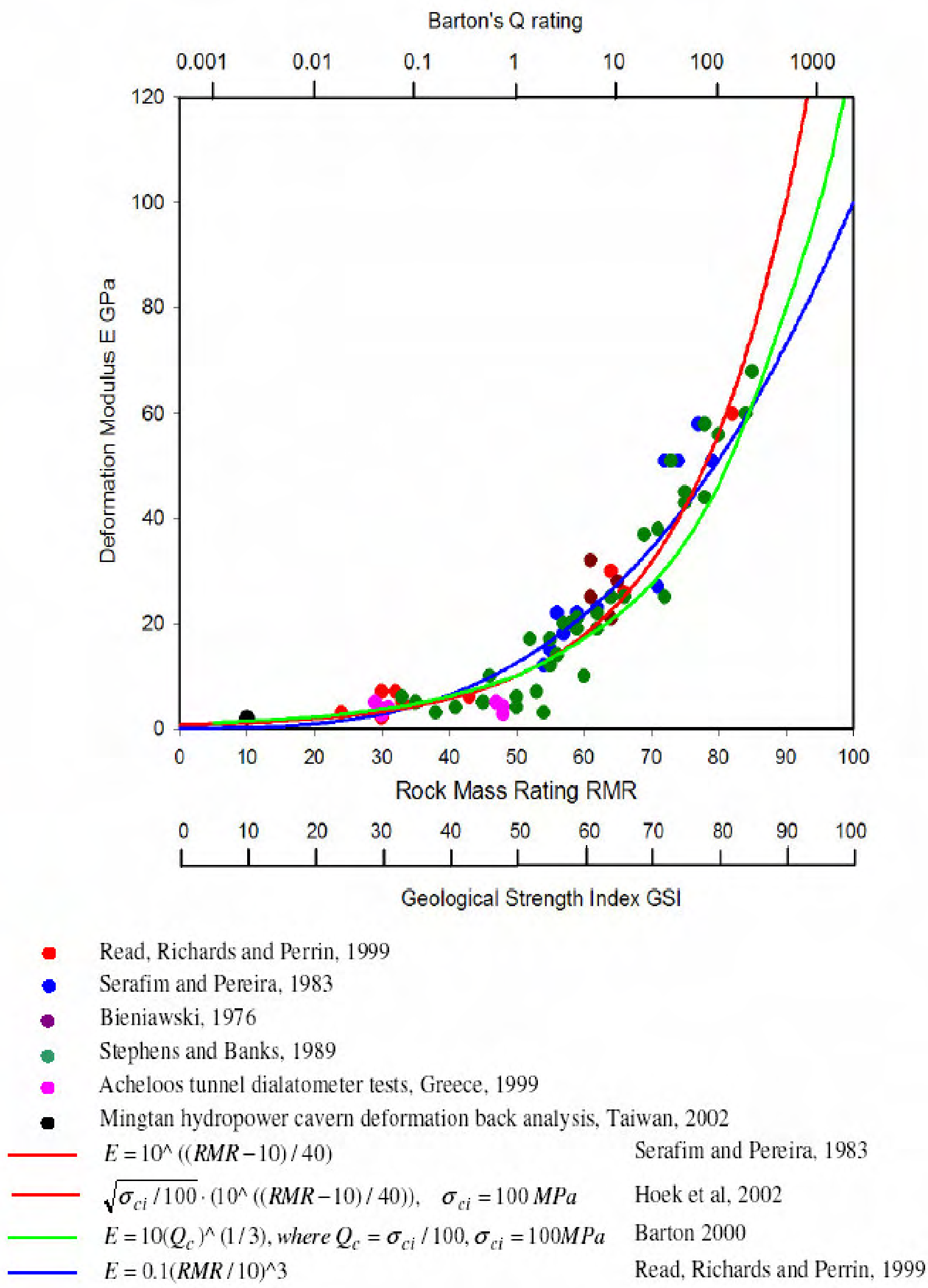


Figure 3: Deformation modulus field measurements and empirical estimates.

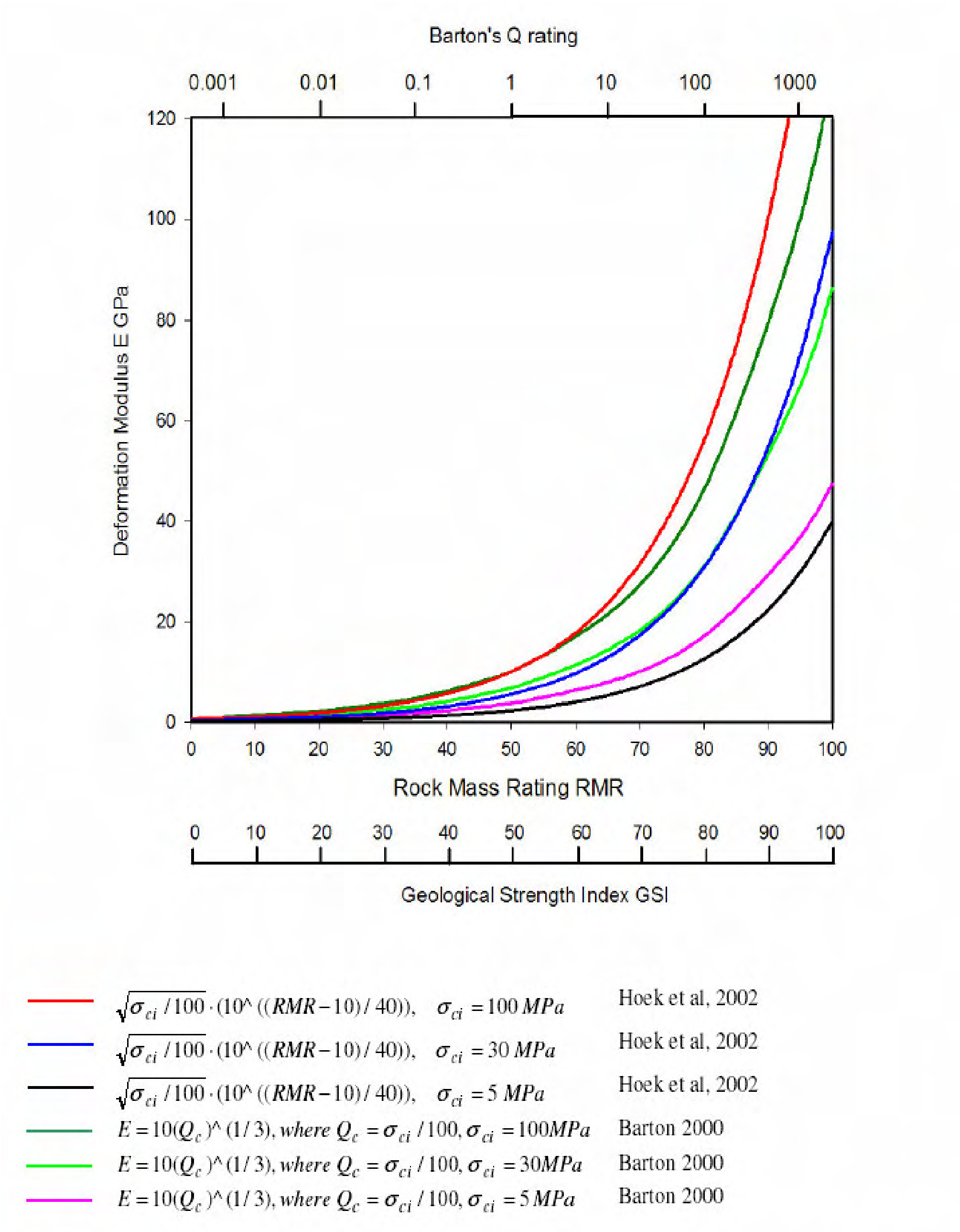


Figure 4: Estimates of rock mass deformation modulus by Hoek, Carranza-Torres and Corkum, 2002 and by Barton, 2000, for different values of the intact rock strength σ_{ci}.

Note: This paper together with the Windows program RocLab can be downloaded from www.rocscience.com.

APPENDIX B

GEOTECHNICAL BOREHOLE LOGS

Table B.1 Geotechnical borehole log for SK-6+050 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/1

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	15.0 m	RE- LOGGING DATE		
LOCATION	:	ALANYA-GAZİPAŞA ROAD	NORTHING	:	4045002.5	START	:	19.07.2003
BOREHOLE NO	:	SK -6+050	EASTING	:	417106.4	END	:	19.07.2003
TYPE OF MACHINE	:	0-900 Crellious	ELEVATION	:	21.0m			
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	22.09.2002	RE- LOGGED BY	:	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	23.09.2002	CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
1	1	0.00	15.00	15.00		5.55 (37)	2.06 (14)	0.24 (2)	BST 1 (2)	500	-	HW	-	-	0	6-S	c N (5)	a A (10)	SCHIST; 63 % core loss greenish gray, foliated, low to moderately hard; occasionally friable, weak- mod. weak, mod.- highly weathered, surface staining, clay-calcite filling						

Table B.2 Geotechnical borehole log for SK-6+180 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/4

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	85.0 m	RE- LOGGING DATE		
LOCATION	:	ALANYA -GAZİPAŞA ROAD	NORTHING	:	4045181.9	START	:	19.07.2003
BOREHOLE NO	:	SK -6+180	EASTING	:	417082.2	END	:	19.07.2003
TYPE OF MACHINE	:	D - 900 Crellious	ELEVATION	:	94.0 m			
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	24.08.2002	RE - LOGGED BY	:	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	28.08.2002	CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
8	1	50.00	51.00	1.0		0.98	0.92	0.42	W	2	-	SW	0-R	L	0.9	0	a C	a G	SCHIST ; light to dark gray, foliated,						
						(98)	(92)	(42)	J	3		SW	P-SR	L	0	3-H	(2)	(5)	friable to hard, very weak to						
									B	11		UW	P-SR	H	0.9	0			moderately weak, slighty weathered.						
8	2	51.00	54.70	3.7		3.10	0.43	0.00	BST	50	-	MW	-	-	-	3-H	b F	a G							
						(84)	(12)	(0)	1								(4)	(5)	51.50 -53.00m occasionally weak,						
									(4)										soft zone.						
8	3	54.70	55.95	1.25		1.20	1.16	0.83	W	3	-	SW	0-R	L	0.9	0	a C	a D		55.50 -56.00 m					
						(100)	(93)	(66)	J	2		SW	0-SR	L	0	3-H	(2)	(7.5)		x	x				
									B	9		UW	P-SR	H	0.9	0									
8	4	55.95	56.70	0.75		0.54	0.00	0.00	BST	50	-	HW	-	-	-	0.9-H	b F	a G							
						(72)	(0)	(0)	2								(4)	(5)							
									(3)																

Table B.2 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+180 Page: 2/4

PARAMETERS FOR M-RMR SYSTEM: STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY							PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
9	5	56.70	57.35	0.65		0.63 (97)	0.58 (89)	0.21 (32)	W J B	4 1 9	-	SW SW SW	0-R 0-R P-SR	M L H	0.9 0 0.9	0 0.9-H 0	a C (2)	a D (7.5)	SCHIST						
9	6	57.35	58.35	1.0		0.59 (59)	0.0 (0)	0.0 (0)	BST 3 (2)	500	-	HW	-	-	-	3-H	c N (5)	a G (5)	41 % core loss						
9	7	58.35	59.10	0.75		0.70 (93)	0.53 (71)	0.33 (44)	W B	2 13	-	MW MW	0-R 0-SR	L H	3 0.9	0 0	a C (2)	a D (7.5)							
9	8	59.10	64.15	5.05		3.84 (76)	1.88 (37)	0.50 (16)	BST 4 (4)	50	-	HW	-	-	-	3-H	b F (4)	a G (5)		2.00 m - 62.50 m X	X				
10	9	64.15	65.10	0.95		0.95 (100)	0.95 (100)	0.46 (48)	B	13	-	SW	P-SR	H	0.9	0	a C (2)	a D (7.5)	Unit weight : 27.25 Kn /m^3	64.20 -64.60 m X	XX				
10	10	65.10	65.70	0.60		0.47 (78)	0.16 (27)	0.0 (0)	BST 5 (4)	50	-	MW	-	-	-	3-H	b F (4)	a G (5)							

Table B.2 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+180 Page: 3/4

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
10	11	65.70	66.30	0.60		0.60 (100)	0.57 (95)	0.11 (18)	W B	3 7	-	SW SW	0-R P-R	L H	0.9 0.9	0 0	a C (2)	a D (7.5)	SCHIST						
10	12	66.30	67.15	0.85		0.55 (65)	0.0 (0)	0.0 (0)	BST 6 (2)	500	-	HW	-	-	-	0.9-H	c N (5)	a G (5)	66.30 -67.15 m soft - weak zone						
10	13	67.15	68.25	1.10		1.10 (100)	1.04 (95)	0.31 (28)	W J B	2 2 18	-	SW MW SW	0-R 0-R P-SR	L L H	0.9 0 0.9	0 3-H 0	a C (2)	a D (7.5)							
10	14	68.25	70.70	2.45		1.86 (65)	0.13 (5)	0.0 (0)	BST 7 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)							
10 11	15	70.70	73.55	2.85		2.78 (98)	2.61 (92)	1.31 (47)	W J B	3 1 11	-	MW MW MW	0-R 0-R P-S	L L H	3 0 0.9	0 0.9-H 0	a C (2)	a D (7.5)							
11	16	73.55	74.00	0.45		0.21 (47)	0.0 (0)	0.0 (0)	BST 8 (3)	50	-	MW	-	-	-	0	a C (2)	a G (5)		73.50 - 74.00 m X X					

Table B.2 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+180 Page: 4/4

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
11	17	74.00	74.65	0.65		0.60	0.60	0.20	W	6	-	MW	0-VR	H	0.9	0	a C	a D	SCHIST						
						(92)	(92)	(31)	J	1		MW	P-S	L	0.9	0	(2)	(7.5)							
									B	6		MW	P-S	H	0.9	0									
11	18	74.65	75.10	0.45		0.24	0.03	0.0	BST	50	-	MW	-	-	-	0	a C	a D	47 % core loss		74.95 - 75.10 m				
						(53)	(7)	(0)	9								(2)	(7.5)				X			
									(3)																
11	19	75.10	79.80	4.70		3.92	2.78	0.36	BST	50	-	MW	-	-	-	0	a C	a A							
12						(83)	(59)	(8)	10								(2)	(10)							
									(4)																
12	20	79.80	82.60	2.80		1.68	0.38	0.16	BST	50	-	HW	-	-	-	0.9-H	b F	a D	40 % core loss						
						(60)	(14)	(6)	11								(4)	(7.5)							
									(3)																
12	21	82.60	85.0	2.40		2.28	2.13	1.39	W	3	-	MW	0-VR	L	0.9	0	a C	a G							
						(95)	(89)	(58)	J	2		MW	P-R	L	0.9	0	(2)	(5)							
									B	16		MW	P-R	H	0.9	0									

Table B.3 Geotechnical borehole log for SK-6+280 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/2

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	63.0 m	RE - LOGGING DATE		
LOCATION	:	ALANYA - GAZİPAŞA ROAD	NORTHING	:	4045228.4	START	:	18.07.2003
BOREHOLE NO	:	SK -6+280	EASTING	:	417065.3	END	:	18.07.2003
TYPE OF MACHINE	:	D -900 Crellious	ELEVATION	:	73.0 m			
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	16.08.2002	RE - LOGGED BY	:	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	19.08.2002	CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																		PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY																
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
4	1	26.70	31.45	4.75		3.26 (77)	0.97 (20)	0.25 (5)	BST 1 (3)	50	-	MW	-	-	-	0.9-H	b F (4)	a D (7.5)	SCHIST ; gray, foliated, friable to moderately hard, very weak to mod. weak, lightly weathered, surface staining.						
4	2	31.45	31.95	0.50		0.50 (100)	0.48 (96)	0.26 (52)	B	7	-	SW	P-R	H	0.9	-	a C (2)	a D (7.5)							
4	3	31.95	32.50	0.55		0.24 (44)	0.22 (4)	0.00 (0)	BST 2 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)	% 56 core loss						
4	4	32.50	34.25	1.75		1.25 (71)	1.10 (63)	0.30 (17)	W J B	2 1 17	-	MW MW MW	0-R P-SR P-R	L M H	0.9 0 09	0 3-H 0	a C (2)	a D (7.5)			33.00 -33.50 m X				

Table B.3 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+280 Page: 2/2

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
4 5	5	34.25	36.80	2.55		1.91 (75)	0.64 (25)	0.18 (7)	BST 3 (4)	50	-	MW	-	-	-	-	a C (2)	a G (5)	SCHIST						
5	6	36.80	37.80	1.00		0.82 (82)	0.48 (48)	0.21 (21)	W J B	1 2 9	-	HW MW MW	0-R P-SR P-R	L M H	0.9 0 0.9	0 3-H 0	a C (2)	a D (7.5)							
5	7	37.80	42.50	4.70		3.41 (73)	1.63 (35)	0.16 (3)	BST 4 (4)	500	-	MW	-	-	-	-	a C (2)	a D (7.5)							
5 6 7	8	42.50	63.00	20.5		12.44 (61)	2.92 (14)	0.32 (2)	BST 5 (3)	500	-	MW	-	-	-	-	b F (4)	a A (10)			50.50-50.70 m X				

Table B.4 Geotechnical borehole log for SK-6+400 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/6

PROJECT	: DIM TUNNEL PROJECT	DEPTH	: 76.0 m	RE - LOGGING DATE			
LOCATION	: ALANYA - GAZİPAŞA ROAD	NORTHING	: 4045308.3	START	: 18.07.2003		
BOREHOLE NO	: SK - 6+400	EASTING	: 417027.2	END	: 18.07.2003		
TYPE OF MACHINE	: D - 900 Crellious	ELEVATION	: 88.0 m				
CORE BARREL	: Double Tube	B.H. DRILLING DATE / START	: 19.08.2002	RE - LOGGED BY	: SONGÜL COŞAR		
CIRCULATION FLUID	: Water	END	: 23.08.2002	CHECKED BY	: SONGÜL COŞAR		

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
6	1	41.50	42.05	0.55		0.53 (96)	0.52 (95)	0.52 (95)	B	4	-	SW	P-SR	H	0	3-H	a C (2)	a G (5)	SCHIST : gray, foliated, friable to mod. hard, very weak to weak, mod. Weathered	41.40 - 41.50m			X		
6	2	42.05	43.10	1.05		0.88 (84)	0.21 (20)	0.00 (0)	BST 1 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)							
6	3	43.10	43.50	0.40		0.40 (100)	0.33 (83)	0.25 (63)	W B	1 3	-	MW MW	0-R P-S	L H	0 0	0.9 0.9	a C (2)	a D (7.5)							
6	4	43.50	44.00	0.50		0.38 (76)	0.00 (0)	0.00 (0)	BST 2 (2)	500	-	HW	-	-	-	-	c N (5)	a G (5)							

Table B.4 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+400 Page: 2/6

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
6	5	44.00	44.30	0.30		0.27 (90)	0.24 (80)	0.15 (50)	J B	1 5	-	MW MW	P-R P-SR	L H	0.9 0.9	0 0	a C (2)	a D (7.5)	SCHIST; gray, foliated, friable to moderately hard, very weak to weak, moderately weathered.						
6	6	44.30	44.90	0.60		0.36 (60)	0.06 (10)	0.00 (0)	BST 3 (2)	500	-	HW	-	-	-	-	c N (5)	a G (5)							
6	7	44.90	46.80	1.90		1.87 (98)	1.80 (95)	0.50 (26)	W J B	1 2 28	-	MW MW MW	P-R P-R P-SR	L M H	0.9 0 0.9	0 0.9 0	a C (2)	a D (7.5)	Unit weight : 27.03 Kn/m^3 (45.00 -45.50m)	45.00 -45.50m X	X				
6 7	8	46.80	47.40	0.60		0.59 (98)	0.00 (0)	0.00 (0)	BST 4 (2)	500	-	HW	-	-	-	3-H	b F (4)	a G (5)							
7	9	47.40	47.90	0.50		0.47 (94)	0.47 (94)	0.19 (38)	B	6	-	SW	P-SR	H	0.9	0	a A (0.75)	a D (7.5)			47.50 - 47.75 m		X		
7	10	47.90	48.95	1.05		0.90 (86)	0.06 (6)	0.00 (0)	BST 5 (3)	50	-	HW	-	-	-	-	a C (2)	a G (5)							

Table B.4 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+400 Page: 3/6

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
7	11	48.95	49.80	0.85		0.83 (98)	0.66 (78)	0.54 (64)	W B	2 5	-	MW SW	0-R P-SR	L H	0.9 0.9	0 0	a A (0.75)	a D (7.5)	SCHIST						
7	12	49.80	50.50	0.70		0.70 (100)	0.03 (4)	0.00 (0)	BST 6 (2)	500	-	HW	-	-	-	-	c N (5)	a D (7.5)							
7	13	50.50	52.40	1.90		1.60 (84)	0.36 (19)	0.14 (7)	BST 7 (3)	50	-	HW	-	-	-	-	a C (2)	a A (10)							
7 8	14	52.40	54.20	1.80		1.80 (100)	0.64 (36)	0.26 (14)	BST 8 (4)	50	-	MW	-	-	-	-	a C (2)	a A (10)							
8	15	54.20	55.90	1.70		1.47 (86)	0.13 (8)	0.00 (0)	BST 9 (3)	50	-	MW	-	-	-	-	a C (2)	a D (7.5)							
8	16	55.90	57.40	1.50		1.46 (97)	1.28 (85)	0.30 (20)	W J B	7 1 19	-	MW MW MW	0-R P-SR P-SR	L M H	0.9 0 0.9	0 3-H 0	a C (2)	a D (7.5)			56.00 - 56.50 m X				

Table B.4 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+400 Page: 4/6

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
8 9	17	57.40	61.40	4.00		3.22 (81)	0.84 (21)	0.10 (3)	BST 10 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)	SCHIST						
9	18	61.40	62.40	1.00		0.96 (96)	0.88 (88)	0.20 (20)	W B	2 10	-	MW MW	0-R P-SR	L H	0.9 0	0 6-H	a C (2)	a D (7.5)							
9	19	62.40	63.90	1.50		1.16 (77)	0.42 (28)	0.00 (0)	BST 11 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)							
9	20	63.90	64.50	0.60		0.60 (100)	0.51 (85)	0.20 (33)	W JA JB B	4 1 1 3	-	MW MW HW MW	0-R 0-SR P-SR P-SR	L L L H	0 0.9 0.9 0	0.9-H 0 0 0.9-H	a C (2)	a D (7.5)		X	64.10 - 64.30 m				
9	21	64.50	64.80	0.30		0.30 (100)	0.00 (0)	0.00 (0)	BST 12 (2)	500	-	HW	-	-	-	-	c N (5)	a G (5)							
9	22	64.80	65.40	0.60		0.60 (100)	0.25 (42)	0.00 (0)	W J B	2 1 11	-	MW MW MW	0-R P-SR P-SR	L M H	0 0 0	3-H 3-H 0.9-H	a C (2)	a D (7.5)							

Table B.4 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK -6+400 Page: 5/6

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
9	23	65.40	65.90	0.50		0.48 (96)	0.00 (0)	0.00 (0)	BST 13 (2)	500	-	HW	-	-	-	-	c N (5)	a D (7.5)	SCHIST						
9 10	24	65.90	67.65	1.75		1.70 (97)	0.58 (25)	0.00 (0)	BST 14 (4)	50	-	MW	-	-	-	3-H	b F (4)	a A (10)							
10	25	67.65	69.00	1.35		1.03 (76)	0.18 (13)	0.00 (0)	BST 15 (2)	500	-	HW	-	-	-	-	c N (5)	a A (0)							
11	26	69.00	72.80	3.80		3.76 (99)	1.10 (25)	0.00 (0)	BST 16 (4)	50	-	MW	-	-	-	3-H	b F (4)	a D (7.5)							
11	27	72.80	73.10	0.30		0.30 (100)	0.30 (100)	0.00 (0)	W B	1 4	-	MW MW	0-R P-SR	L H	0 0	3-H 3-H	a C (2)	a D (7.5)							
11	28	73.10	73.50	0.40		0.40 (100)	0.00 (0)	0.00 (0)	BST 17 (3)	50	-	MW	-	-	-	3-H	b F (4)	a G (5)							

Table B.4 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)																									
																			SK -6+400	Page: 6/6					
PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
11	29	73.50	75.00	1.50		1.50 (100)	1.38 (92)	0.58 (39)	W J B	4 2 14	-	MW MW MW	0-R 0-SR P-S	L L H	0.9 0 0	0 0.9-H 0.9-H	a C (2)	a D (7.5)	SCHIST						
11	30	75.00	75.25	0.25		0.25 (100)	0.00 (0)	0.00 (0)	BST 18 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)							
11	31	75.25	76.00	0.75		0.75 (100)	0.68 (91)	0.20 (27)	W J B	2 2 12	-	MW MW MW	0-R P-SR 0-SR	L L H	0 0 0.9	3-H 3-H 0	a C (2)	a G (5)							

Table B.5 Geotechnical borehole log for SK-6+570 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/5

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	80.0 m	LOGGING DATE		
LOCATION	:	ALANYA-GAZİPAŞA ROAD	NORTHING	:	4045308.3	START	:	19.07.2003
BOREHOLE NO	:	SK-6+570	EASTING	:	417027.2	END	:	19.07.2003
TYPE OF MACHINE	:	D-900 Crellious	ELEVATION	:	95.50m			
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	29.08.2002	RE- LOGGED BY	:	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	02.09.2002	RE- CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
6	1	46.80	47.50	0.70		0.49 (70)	0.18 (26)	0.00 (0)	BST 1 (4)	50	-	MW	-	-	-	3-H	b F (4)	a D (7.5)	SCHIST						
6	2	47.50	48.00	0.50		0.50 (100)	0.50 (100)	0.47 (94)	W B	1 1	-	SW SW	0-VR 0-SR	L H	0.9 0.9	0 0	a C (2)	a D (7.5)			47.50-48.00m x				
6	3	48.00	48.80	0.80		0.62 (78)	0.24 (30)	0.00 (0)	BST 2 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)							
6	4	48.80	49.15	0.35		0.35 (100)	0.35 (100)	0.12 (34)	J B	1 4	-	MW SW	0-R 0-SR	L H	0 0.9	3-H 0	a C (2)	a D (7.5)							

Table B.5 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-6+570 Page: 2/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
6	5	49.15	50.00	0.85		0.57 (67)	0.28 (33)	0.10 (12)	BST 3 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)	SCHIST						
6	6	50.00	50.70	0.70		0.66 (94)	0.64 (91)	0.22 (31)	WB	1 8	-	MW SW	0-R 0-SR	L H	0.9 0	0 3-H	a C (2)	a D (7.5)							
6	7	50.70	52.90	2.20		1.71 (78)	0.42 19)	0.10 (5)	BST 4 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)			51.30-51.45m		X		
6 7	8	52.90	54.35	1.45		1.35 (93)	1.35 (93)	0.82 (57)	w J B	1 3 13	-	MW MW MW	0-VR 0-SR 0-SR	L L H	0.9 0.9 0	0 0 3-H	a C (2)	a D (7.5)							
7	9	54.35	55.10	0.75		0.38 (51)	0.06 (8)	0.00 (0)	BST 5 (2)	500	-	HW	-	-	-	0	c N (5)	a G (5)	schistosity planes partially with filling partially with only aperture						
7	10	55.10	58.10	3.00		2.88 (96)	2.44 (81)	0.56 (19)	W J B	7 3 35	-	MW MW MW	0-VR 0-R 0-R	L L H	0.9 0 0	0 3-H 3-H	a C (2)	a D (7.5)	Unit weight: 27.62 Kn/m^2	X	55.50-56.00 m X				

Table B.5 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-6+570 Page: 3/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
7	11	58.10	60.20	2.10		1.69 (80)	0.26 (12)	0.00 (0)	BST 6 (3)	50	-	HW	-	-	-	0	a C (2)	a G (5)	SCHIST						
7 8	12	60.20	61.50	1.30		1.28 (98)	1.20 (92)	1.00 (77)	J B	1 8	-	MW SW	0-SR P-SR	L H	0 0.9	3-H 0	a C (2)	a D (7.5)			60.90-61.20m X				
8	13	61.50	64.50	3.00		2.00 (67)	0.61 (20)	0.22 (7)	BST 7 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)							
8	14	64.50	65.20	0.70		0.64 (91)	0.60 (86)	0.00 (0)	W J B	2 1 8	-	MW MW SW	0-VR 0-R 0-SR	L L H	0.9 0 0.9	0 0.9-H 0	a C (2)	a D (7.5)							
8	15	65.20	66.70	1.50		1.02 (68)	0.06 (4)	0.00 (0)	BST 8 (4)	50	-	MW	-	-	-	0	a C (2)	a G (5)							
8	16	66.70	67.00	0.30		0.30 (100)	0.25 (83)	0.11 (37)	W B	1 5	-	MW MW	0-VR 0-SR	L H	0.9 0.9	0 0	a C (2)	a D (7.5)							

Table B.5 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-6+570 Page: 4/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
8	17	67.00	68.10	1.10		0.62 (56)	0.10 (9)	0.00 (0)	BST 9 (3)	50	-	HW	-	-	-	0	a C (2)	a G (5)	SCHIST						
8	18	68.10	68.70	0.60		0.55 (92)	0.45 (75)	0.17 (28)	W B	3 5	-	MW MW	0-R P-SR	L H	0.9 0.9	0 0	a C (2)	a A (0.75)							
8	19	68.70	69.10	0.40		0.21 (53)	0.05 (13)	0.00 (0)	BST 10 (3)	50	-	HW	-	-	-	0	a C (2)	a G (5)							
9	20	69.10	74.10	5.00		3.96 (79)	2.98 (60)	0.97 (19)	W J B	11 4 38	-	HW MW MW	0-VR P-SR P-SR	L L H	0 0 0	0.9-H 3-H 3-H	a C (2)	a D (7.5)			70.70-71.00m X		X 73.00-73.10m		
9	21	74.10	75.60	1.50		0.63 (42)	0.20 (13)	0.00 (0)	BST 11 (2)	500	-	HW	-	-	-	0	c N (5)	a D (7.5)	58 % core lass						

Table B.5 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-6+570 Page: 5/5

BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
	STRUCTURAL DOMAIN					**CORE RECOVERY**				**DISCONTINUITY**							**PARAMETERS FOR Q-SYSTEM**			**TEST SAMPLES TAKEN FOR**					
9	22	75.60	76.20	0.60		0.42 (84)	0.18 (36)	0.00 (0)	BST 12 (4)	50	-	MW	-	-	-	0	a C (2)	a D (7.5)	RECRISTALIZED LIMESTONE						
9	23	76.20	76.70	0.50		0.43 (86)	0.43 (86)	0.16 (32)	J B	1 7	-	SW SW	P-SR P-SR	L M	0.9 0.9	0 0	a B (1)	a D (7.5)							
9 10	24	76.70	80.00	3.30		1.90 (58)	0.76 (23)	0.31 (9)	BST 13 (3)	50	-	MW	-	-	-	0	a C (2)	a D (7.5)							

PARAMETERS FOR M-RMR SYSTEM

Table B.6 Geotechnical borehole log for SK-6+880 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/2

PROJECT	: DIM TUNNEL PROJECT	DEPTH	: 52.0 m	RE - LOGGING DATE			
LOCATION	: ALANYA -GAZİPAŞA ROAD	NORTHING	: 4045753.3		START	:	16.07.2003
BOREHOLE NO	: SK -6+880	EASTING	: 416779.1		END	:	16.07.2003
TYPE OF MACHINE	: D-900 Crellious	ELEVATION	: 74.0m				
CORE BARREL	: Double Tube	B.H. DRILLING DATE / START	: 02.09.2002	RE - LOGGED BY		:	SONGÜL COŞAR
CIRCULATION FLUID	: Water	END	: 04.09.2002		CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM		GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (M)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J/B/W)	# OF DISCONTINUITIES	ANGLE (°)	WEATHERING CONDITION	JOINT ROUGHNESS/CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)		UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANAL YSES
1	1	0.00	7.50	7.50		1.76 (23)	0.13 (2)	0.00 (0)	BST 1 (2)	500	-	HW	-	-	-	0	b H (8)	a A (10)	BLOCKY LIMESTONE 77 % core loss						
1	2	7.50	16.00	8.50		2.10 (25)	1.10 (13)	0.79 (9)	BST 2 (2)	500	-	HW	-	-	-	0	b H (8)	a A (10)	% 75 core loss						
1 2	3	16.00	33.50	17.50		5.18 (30)	0.16 (1)	0.10 (1)	BST 3 (2)	500	-	HW	-	-	-	0	b H (8)	a A (10)	70 % core loss	29.00-30.00m	X				
2	4	33.50	48.00	14.50		3.62 (25)	2.30 (16)	1.21 (8)	BST 4 (2)	500	-	HW	-	-	-	0	c N (5)	a D (7.5)	Unit weight : 22.21 KN/m^3 75 % core loss	42.00 -43.00 m X	X		40.80-41.20m X		

Table B.6 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-6+880 Page: 2/2

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
3	5	48.00	49.00	1.00		0.53 (53)	0.53 (53)	0.40 (40)	W	4	-	MW	0-R	L	3	0	a C (2)	a G (5)	BLOCKY LIMESTONE 47 % core loss						
3	6	49.00	52.00	3.00		2.40 (80)	1.74 (58)	0.45 (15)	W J	29 4	-	HW HW	0-R P-SR	L L	3 0.9	0 0	a C (2)	a C (2.5)							

Table B.7 Geotechnical borehole log for SK-7+130 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/2

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	45.0 m	RE- LOGGING DATE		
LOCATION	:	ALANYA-GAZİPAŞA ROAD	NORTHING	:	4045981.9	START	:	16.07.2003
BOREHOLE NO	:	SK -7+130	EASTING	:	416692.6	END	:	16.07.2003
TYPE OF MACHINE	:	D-900 Crellious	ELEVATION	:	72.00 m			
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	05.09.2002	RE- LOGGED BY	:	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	17.09.2002	CHECKED BY	:	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
3	1	15.30	21.10	5.80		5.72 (99)	5.72 (99)	5.48 (94)	JA JB	1 17	-	HW HW	P-R P-VR	L L	0 3	0.9-5 0	a A (0.75)	a G (5.0)	CONGLOMERATE:grayish white, hard, strong to mod. strong, slightly to mod. weathered.						
3	2	21.10	21.30	0.20		0.16 (80)	0.16 (80)	0.00 (0)	BST 1 (4)	50	-	HW	-	-	-	-	b H (8)	a G (5.0)	SHALE						
4	3	21.30	23.38	2.08		2.08 (100)	2.08 (100)	1.93 (93)	J B	6 1	-	HW MW	P-R P-SR	L H	3 0.9	0 0	a A (0.75)	a G (5.0)	CONGLOMERATE unit weight:20.80 KN /m^3	22.45 -23.00 m X			X 22.30 -22.45m		
4	4	23.38	26.05	2.67		1.90 (71)	1.88 (70)	1.21 (45)	W J B	5 1 12	-	HW HW MW	0-R P-R P-SR	L M H	0.9 0.9 0.9	0 0 0	a A (0.75)	a E (5.0)	SHALE-SANDSTONE INTERCLATION. (decomposet - clay like)	24.00 -25.00m	X				

Table B.7 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-7+130 Page: 2/2

PARAMETERS FOR M-RMR SYSTEM: STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY							PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
4-5	5	26.05	29.60	3.55		3.18 (90)	3.16 (89)	3.02 (85)	W B	2 11	-	HW MW	0-R P-SR	L H	0.9 0.9	0 0	a A (0.75)	a G (5.0)	SHALE -SANDSTONE INT.			27.95-28.20m	X		
5	6	29.60	31.00	1.40		1.03 (74)	0.78 (56)	0.00 (0)	BST 2 (4)	50	-	HW	-	-	-	-	b H (8.0)	a G (5.0)							
5	7	31.00	31.40	0.40		0.40 (100)	0.40 (100)	0.11 (28)	W B	2 4	-	HW MW	P-SR P-SR	L H	0.9 0.9	0 0	a E (4.0)	a G (50)							
5	8	31.40	35.00	3.60		3.13 (87)	2.96 (82)	2.17 (60)	W B	10 6	-	HW MW	0-R P-SR	L H	0.9 0.9	0. 0	a D (3.0)	a E (5.0)	SANDSTONE Unit weight:17.06 KN/m^3	32.00-32.20m X 34.60-34.90m	X		34.00-34.15m X		
6	9	35.00	41.00	6.00		5.96 (99)	5.82 (97)	4.68 (78)	W J B	15 1 8	-	MW MW MW	P-SR P-SR P-SR	L L H	0.9 0.9 0.9	0 0 0	a A (0.75)	a E (5.0)							
7	10	41.00	43.30	2.30		1.96 (85)	1.96 (85)	1.75 (76)	W B	2 10	-	MW MW	0-R P-SR	L H	0.9 0.9	0 0	a A (0.75)	a E (5.0)							
8	11	43.30	45.00	1.70		1.47 (86)	1.34 (79)	0.72 (42)	W B	7 7	-	HW MW	0-R P-SR	L H	0.9 0.9	0 0	a A (0.75)	a E (5.0)	SHALE - SANDSTONE INT.						

Table B.8 Geotechnical borehole log for SK-7+250 drilling

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

Page: 1/5

PROJECT	:	DIM TUNNEL PROJECT	DEPTH	:	46.0 m	RE- LOGGING DATE	
LOCATION	:	ALANYA-GAZİPAŞA ROAD	NORTHING	:	4046125.8	START :	17.07.2003
BOREHOLE NO	:	SK-7+250	EASTING	:	416686.1	END :	17.07.2003
TYPE OF MACHINE	:	D-900 Crellious	ELEVATION	:	77.0m		
CORE BARREL	:	Double Tube	B.H. DRILLING DATE / START	:	07.09.2002	RE- LOGGED BY :	SONGÜL COŞAR
CIRCULATION FLUID	:	Water	END	:	19.09.2002	CHECKED BY :	SONGÜL COŞAR

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
1	1	0.00	6.00	6.00		0.98 (16)	0.00 (0)	0.00 (0)	BST1 (1)	500	-	D	-	-	-	-	b H (8)	a A (10)	SCHIST; decomposed 84 % core loss						
1	2	6.00	20.95	14.95		3.42 (23)	0.98 (7)	0.26 (2)	BST2 (2)	500	-	VHW	-	-	-	-	b H (8)	a D (7.5)	77 % core lass		15.00-15.50 m X				
1	3	20.95	21.40	0.45		0.44 (98)	0.39 (87)	0.12 (27)	J B	1 9	-	HW MW	P-R P-SR	M H	0 0.9	3-H 0	a C (2)	a D (7.5)							
1	4	21.40	25.32	3.92		0.98 (25)	0.37 (9)	0.10 (3)	BST3 (2)	500	-	HW	-	-	-	-	c N (5)	a G (5)	75 %core lass						

Table B.8 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-7+250 Page: 2/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
1 2	5	25.32	26.20	0.88		0.87 (99)	0.85 (97)	0.72 (82)	J B	1 7	-	MW MW	P-SR 0-SR	M H	0 0.9	3-H 0	a C (2)	a D (7.5)	SCHIST unit weight : 28.35 KN/m3	 X	25.70-26.20 m				
2	6	26.20	26.70	0.50		0.20 (40)	0.00 (0)	0.00 (0)	BST4 (2)	50	-	HW	-	-	-	-	c N (5)	a G (5)	60 % core loss						
2	7	26.70	26.95	0.25		0.25 (100)	0.25 (100)	0.13 (52)	B	3	-	SW	P-SR	H	0.9	0	a A (0.75)	a D (7.5)							
2	8	26.95	27.25	0.30		0.26 (87)	0.00 (0)	0.00 (0)	BST 5 (3)	50	-	HW	-	-	-	3-H	b F (4)	a G (5)							
2	9	27.25	27.55	0.30		0.30 (100)	0.30 (100)	0.12 (40)	B	3	-	SW	P-SR	H	0	3-H	b F (4.0)	a D (7.5)							
2	10	27.55	27.90	0.35		0.30 (86)	0.04 (13)	0.00 (0)	BST 6 (3)	50	-	HW	-	-	-	3-H	b F (4.0)	a G (5)							

Table B.8 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-7+250 Page: 3/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
2	11	27.90	28.40	0.50		0.48 (96)	0.48 (96)	0.15 (30)	W J B	1 1 4	-	MW MW SW	0-R 0-SR P-SR	L M H	0.9 0 0	0 0.9-H 3-H	a C (2)	a G (5)	SCHIST:Light-dark gray, foliated, low hardness-hard, mod. weak-weak slightly to mod. weathered.						
2	12	28.40	30.50	2.10		1.23 (59)	0.43 (21)	0.00 (0)	BST 7 (3)	50	-	MW	-	-	-	-	a C (2)	a G (5)	41 % core loss						
2	13	30.50	33.00	2.50		1.78 (71)	1.58 (63)	0.41 (16)	W J B	6 1 15	-	MW MW MW	D-S P-SR P-SR	L L H	0.9 0 0.9	0 3-H 0	a C (2)	a D (7.5)							
2	14	33.00	33.60	0.60		0.48 (80)	0.06 (10)	0.00 (0)	BST 8 (3)	50	-	MW	-	-	-	6-H	b F (4)	a G (5)							
3	15	33.60	34.25	0.65		0.42 (65)	0.22 (34)	0.14 (22)	W J B	2 1 1	-	MW MW MW	0-R P-SR P-SR	L M H	0.9 0 0.9	0 0.9-H 0	a C (2)	a G (5)							
3	16	34.25	36.00	1.75		1.69 (97)	1.63 (93)	1.19 (68)	W J B	2 1 12	-	MW MW MW	0-R P-SR P-SR	L M H	0.9 0.9 0.9	0 0 0	a B (1.0)	a E (5)		34.80-35.20 m	X				

Table B.8 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)

SK-7+250 Page: 4/5

PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
3	17	36.00	36.40	0.40		0.29 (73)	0.29 (73)	0.00 (0)	J B	1 10	-	MW MW	P-SR P-SR	M H	0 0.9	0.S-H 0	a C (2)	a D (75)	SCHIST						
3	18	36.40	37.50	1.10		0.55 (50)	0.08 (7)	0.00 (0)	BST 9 (2)	500	-	VHW	-	-	-	-	C N (5)	a G (5)	50 % core loss						
3	19	37.50	40.80	3.30		2.14 (65)	1.76 (53)	0.70 (21)	W J B	6 2 19	-	HW MW MW	0-R 0-R P-SR	L L H	0 0.9 0	3-H 0 3-H	a C (2)	a D (7.75)							
3	20	40.80	41.30	0.50		0.36 (72)	0.00 (0)	0.00 (0)	BST 10 (2)	500	-	HW	-	-	-	-	C N (5)	a G (5)							
3	21	41.30	41.80	0.50		0.46 (92)	0.46 (92)	0.19 (38)	B	4	-	MW	P-R	H	0	3-H	a C (2)	a D (7.5)							
4	22	41.80	43.20	1.40		1.00 (71)	0.33 (24)	0.00 (0)	BST 11 (3)	50	-	MW	-	-	-	3-H	b F (4)	a G (5)							

Table B.8 Continued.

GEOTECHNICAL BOREHOLE LOG /FIELD DATA (METU-2003)																									
																			SK-7+250 Page: 5/5						
PARAMETERS FOR M-RMR SYSTEM																	PARAMETERS FOR Q-SYSTEM			TEST SAMPLES TAKEN FOR					
STRUCTURAL DOMAIN						CORE RECOVERY				DISCONTINUITY															
BOX #	STRUCTURAL DOMAIN NUMBER	FROM (m)	TO (m)	LENGTH (m)	CORE DIAMETER (mm.)	TOTAL, m. (%)	INTACT, m. (%)	TOTAL CORE LENGTH FOR RQD (m.) RQD %	TYPE (J /B / W)	# OF DISCONTINUITIES	ANGLE (o)	WEATHERING CONDITION	JOINT ROUGHNESS /CONDITION	PERSISTENCY	APERTURE THICKNESS (mm.) (IF NO FILLING EXISTS)	FILLING THICKNESS (mm.) and TYPE (IF EXIST)	JOINT ALTERATION NUMBER (Ja)	STRESS REDUCTION FACTOR (SRF)	GEOLOGICAL / GEOTECHNICAL DESCRIPTIONS AND NOTES	UCS TEST	POINT LOAD TEST	BLOCK PUNCH TEST	SLAKE DURABILITY TEST	X-RAY	PETROGRAPHIC ANALYSES
4	23	43.20	44.55	1.35		1.18 (87)	0.92 (68)	0.34 (25)	W J B	2 3 10	-	MW MW MW	0-R P-SR 0-SR	L M H	0.9 0 0	0 6-H 3-H	a C (2)	a D (7.5)	SCHIST						
4	24	44.55	46.00	1.45		1.16 (80)	0.36 (25)	0.17 (12)	BST 12 (4)	50	-	MW	-	-	-	-	b F (4)	a D (7.5)							

APPENDIX C

INPUT DATA FORMS FOR ROCK MASS CLASSIFICATION

Table C.1 Input data forms for rock mass classification for SK-6+050

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/1

PROJECT	:	DIM TUNNEL PROJECT	NORTHING	:	4045002.5	LOGGING DATE		
LOCATION	:	ALANYA -GAZİPAŞA ROAD	EASTING	:	417106.4	START / END	:	20.07.2003
BOREHOLE NO	:	SK -6+050	ELEVATION	:	21.0 m	LOGGED BY	:	SONGÜL COŞAR
						CHECKED BY	:	SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS	PLT	BPI	RQD	ICR	TCR											Jn	Jr	Ja	Jw	SRF
					(MPa)	(MPa)	(MPa)	(%)	(%)	(%)	(#/m)														
1	1	0.00	15.00	SCHIST	20	-	-	2	14	37	500	DRY	75	BST-2	-	HW	-	-	0	6-S	J	J	c K	A	a A

Table C.2 Input data forms for rock mass classification for SK-6+180 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/3

PROJECT	:	DIM TUNNEL PROJECT	NORTHING	:	4045181.9	LOGGING DATE	
LOCATION	:	ALANYA -GAZİPAŞA ROAD	EASTING	:	417082.2	START / END :	19.07.2003
BOREHOLE NO	:	SK -6+180	ELEVATION	:	94.0 m	LOGGED BY :	SONGÜL COŞAR
						CHECKED BY :	SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
8	1	50.00	51.00	SCHIST	-	2.5	-	42	92	98	16	WET	97	3	-	SW SW HW	0-R P-SR P-SR	L L H	0.9 0 0.9	0 3-H 0	E	F	a C	B	a G
8	2	51.00	54.70	SCHIST	25	-	-	0	12	84	50	WET	75	-	BST-4	MW	-	-	-	3-H	J	J	b F	B	a G
8	3	54.70	55.95	SCHIST	-	2.5	-	66	93	100	11	WET	99	3	-	SW SW HW	0-R 0-SR P-SR	L L H	0.9 0 0.9	0 3-H 0	E	E	a C	B	a D
8	4	55.95	56.70	SCHIST	10	-	-	0	0	72	50	WET	71	-	BST-3	HW	-	-	-	0.9-H	J	J	b F	B	a G
9	5	56.70	57.35	SCHIST	-	2.5	-	32	89	97	21	WET	96	3	-	SW SW SW	0-R 0-R P-SR	M L H	0.9 0 0.9	0 0.9-H 0	C	E	a C	B	a D
9	6	57.35	58.35	SCHIST	10	-	-	0	0	59	500	WET	58	-	BST-2	HW	-	-	-	3-H	J	J	c N	B	a G
9	7	58.35	59.10	SCHIST	-	2.5	-	44	71	93	20	WET	92	2	-	MW MW	0-R 0-SR	L H	3 0.9	0 0	C	B	a C	B	a D

Table C.2 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+180 Page: 2/3

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	STRUCTURAL DOMAINS TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	PLT (MPa)	BPI (MPa)	CORE RECOVERY RQD (%)	ICR (%)	TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
9	8	59.10	64.15	SCHIST	25	-	-	16	37	76	50	WET	75	-	BST-4	HW	-	-	-	3-H	J	J	b F	B	a G
10	9	64.15	65.10	SCHIST	40	-	-	48	100	100	13	WET	99	1	-	SW	P-SR	H	0.9	0	B	F	a C	B	a D
10	10	65.10	65.70	SCHIST	25	-	-	0	27	78	50	WET	77	-	BST-4	MW	-	-	-	3-H	J	J	b F	B	a G
10	11	65.70	66.30	SCHIST	40	-	-	18	95	100	16	WET	99	2	-	SW SW	0-R P-R	L H	0.9 0.9	0 0	C	E	a C	B	a D
10	12	66.30	67.15	SCHIST	5	-	-	0	0	65	500	WET	64	-	BST-2	HW	-	-	-	0.9-H	J	J	c N	B	a G
10	13	67.15	68.25	SCHIST	40	-	-	28	95	100	20	WET	99	3	-	SW MW SW	0-R 0-R P-SR	L L H	0.9 0 0.9	0 3-H 0	C	F	a C	B	a D
10	14	68.25	70.70	SCHIST	10	-	-	0	5	65	50	WET	64	-	BST-4	MW	-	-	-	0	J	J	a C	B	a G
10 11	15	70.70	73.55	SCHIST	-	3	-	47	92	98	5	WET	97	3	-	MW MW MW	0-R 0-R P-S	L L H	3 0 0.9	0 0.9-H 0	C	F	a C	B	a D

Table C.2 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+180 Page: 3/3

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
11	16	73.55	74.00	SCHIST	10	-	-	0	0	47	50	WET	46	-	BST-3	MW	-	-	-	0	J	J	a C	B	a G
11	17	74.00	74.65	SCHIST	-	3	-	31	92	92	20	WET	91	3	-	MW MW MW	0-VR P-S P-S	H L H	0.9 0.9 0.9	0 0 0	C	E	a C	B	a D
11	18	74.65	75.10	SCHIST	10	-	-	0	7	53	50	WET	52	-	BST-3	MW	-	-	-	0	J	J	a C	B	a D
11 12	19	75.10	79.80	SCHIST	25	-	-	8	59	83	50	WET	82	-	BST-4	MW	-	-	-	0	J	J	a C	B	a A
12	20	79.80	82.60	SCHIST	20	-	-	6	14	60	50	WET	59	-	BST-3	HW	-	-	-	0.9-H	J	J	b F	B	a D
12	21	82.60	85.0	SCHIST	-	3	-	58	89	95	8	WET	94	3	-	MW MW MW	0-VR P-R P-R	L L H	0.9 0.9 0.9	0 0 0	C	E	a C	B	a G

Table C.3 Input data forms for rock mass classification for SK-6+280 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/1

PROJECT	:	DIM TUNNEL PROJECT	NORTHING	:	4045228.4	LOGGING DATE		
LOCATION	:	ALANYA -GAZİPAŞA ROAD	EASTING	:	417065.3	START / END	:	18.07.2003
BOREHOLE NO	:	SK -6+280	ELEVATION	:	73.00 m	LOGGED BY	:	SONGÜL COŞAR
						CHECKED BY	:	SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS	PLT	BPI	RQD	ICR	TCR											Jn	Jr	Ja	Jw	SRF
					(MPa)	(MPa)	(MPa)	(%)	(%)	(%)	(#/m)														
4	1	26.70	31.45	SCHIST	80	-	-	5	20	77	50	DRY	74	BST-4	-	MW	-	-	-	0.9-H	J	J	b F	A	a D
4	2	31.45	31.95	SCHIST	-	5	-	52	96	100	14	DRY	97	1	B	SW	P-R	H	0.9	-	B	E	a C	A	a D
4	3	31.95	32.50	SCHIST	75	-	-	0	4	44	50	DRY	42	BST-3	-	MW	-	-	-	0	J	J	b F	A	a G
4	4	32.50	34.25	SCHIST	-	5	-	17	63	71	11	DRY	68	3	W J B	MW MW MW	0-R P-SR P-R	L M H	0.9 0 9	0 3-H 0	C	E	a C	A	a D
4 5	5	34.25	36.80	SCHIST	80	-	-	7	25	75	50	DRY	72	BST-4	-	MW	-	-	-	0	J	J	b F	A	a G
5	6	36.80	37.80	SCHIST	-	5	-	21	48	82	12	DRY	79	3	W J B	HW MW MW	0-R P-SR P-R	L M H	0.9 0 0.9	0 3-H 0	D	E	a C	A	a D
5	7	37.80	42.50	SCHIST	80	-	-	3	35	73	50	DRY	70	BST-4	-	MW	-	-	-	0	J	J	b F	A	a D
5 6 7	8	42.50	63.00	SCHIST	-	4	-	2	14	61	50	DRY	59	BST-3	-	MW	-	-	-	0	J	J	b F	A	a A

Table C.4 Input data forms for rock mass classification for SK-6+400 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/4

PROJECT	: DIM TUNNEL PROJECT	NORTHING	: 4045308.3	LOGGING DATE	
LOCATION	: ALANYA -GAZİPAŞA ROAD	EASTING	: 417027.2	START / END	: 20.07.2003
BOREHOLE NO	: SK -6+400	ELEVATION	: 88.0 m	RE- LOGGED BY	: SONGÜL COŞAR
				RE- CHECKED BY	: SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
6	1	41.50	42.05	SCHIST	-	3	-	95	95	96	7	DRY	99	1	B	SW	P-SR	H	0	3-H	B	F	a C	A	a G
6	2	42.05	43.10	SCHIST	20	-	-	0	20	84	50	DRY	83	BST-3	-	MW	-	-	-	0	J	J	a C	A	a G
6	3	43.10	43.50	SCHIST	-	3	-	63	83	100	10	DRY	99	2	W B	MW MW	0-R P-S	L H	0 0	0.9 0.9	C	F	a C	A	a D
6	4	43.50	44.00	SCHIST	10	-	-	0	0	76	500	DRY	75	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
6	5	44.00	44.30	SCHIST	-	3	-	50	80	90	20	DRY	90	2	J B	MW MW	P-R P-SR	L H	0.9 0.9	0 0	B	F	a C	A	a D
6	6	44.30	44.90	SCHIST	10	-	-	0	10	60	500	DRY	60	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
6	7	44.90	46.80	SCHIST	95	-	-	26	95	98	16	DRY	98	3	W J B	MW MW MW	P-R P-R P-R	L M H	0.9 0 0.9	0 0.9 0	C	F	a C	A	a D

Table C.4 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+400 Page: 2/4

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	STRUCTURAL DOMAINS TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	STRENGHT PARAMETERS PLT (MPa)	STRENGHT PARAMETERS BPI (MPa)	CORE RECOVERY RQD (%)	CORE RECOVERY ICR (%)	CORE RECOVERY TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
6 7	8	46.80	47.40	SCHIST	10	-	-	0	0	98	500	DRY	97	BST-2	-	HW	-	-	-	3-H	J	J	b F	A	a D
7	9	47.40	47.90	SCHIST	95	-		38	94	94	12	DRY	93	1	B	SW	P-SR	H	0.9	0	B	F	a A	A	a D
7	10	47.90	48.95	SCHIST	10	-	-	0	6	86	50	DRY	85	BST-3	-	HW	-	-	-	0	J	J	a C	A	a G
7	11	48.95	49.80	SCHIST	95	-	-	64	78	98	8	DRY	97	2	W B	MW SW	0-R P-SR	L H	0.9 0.9	0 0	C	F	a A	A	a D
7	12	49.80	50.50	SCHIST	10	-	-	0	4	100	500	DRY	99	BST-2	-	HW	-	-	-	0	J	J	a C	A	a D
7	13	50.50	52.40	SCHIST	20	-	-	7	19	84	50	DRY	83	BST-3	-	HW	-	-	-	0	J	J	a C	A	a A
7 8	14	52.40	54.20	SCHIST	20	-	-	14	36	100	50	DRY	99	BST-4	-	MW	-	-	-	0	J	J	a C	A	a A
8	15	54.20	55.90	SCHIST	10	-	-	0	8	86	50	DRY	85	BST-3	-	MW	-	-	-	0	J	J	a C	A	a D

Table C.4 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+400 Page: 3/4

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS	PLT	BPI	RQD	ICR	TCR											Jn	Jr	Ja	Jw	SRF
					(MPa)	(MPa)	(MPa)	(%)	(%)	(%)	(#/m)														
8	16	55.90	57.40	SCHIST	85	-	-	20	85	97	18	DRY	96	3	W J B	HW MW MW	0-R P-SR P-SR	L M H	0.9 0 0.9	0 3-H 0	C	F	a C	A	a D
8 9	17	57.40	61.40	SCHIST	20	-	-	3	21	81	50	DRY	80	BST-3	-	MW	-	-	-	0	J	J	a C	A	a G
9	18	61.40	62.40	SCHIST	85	-	-	20	88	96	12	DRY	95		W B	MW MW	0-R P-SR	L H	0.9 0	0 6-H	C	F	a C	A	a D
9	19	62.40	63.90	SCHIST	20	-	-	0	28	77	50	DRY	76	BST-3	-	MW	-	-	-	0	J	J	a C	A	a G
9	20	63.90	64.50	SCHIST		2	-	33	85	100	15	DRY	99	4	W JA JB B	MW MW HW MW	0-R 0-SR P-SR P-SR	L L L H	0 0.9 0.9 0	0.9-H 0 0 0.9-H	E	E	a C	A	a D
9	21	64.50	64.80	SCHIST	10	-	-	0	0	100	500	DRY	95	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
9	22	64.80	65.40	SCHIST	-	2	-	0	42	100	21	DRY	99	3	W J B	MW	-	-	-	-	C	F	a C	A	a D
9	23	65.40	65.90	SCHIST	10	-	-	0	0	96	500	DRY	95	BST-2	-	HW	-	-	-	0	J	J	c N	A	a D

Table C.4 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+400 Page: 4/4

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	STRUCTURAL DOMAINS TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	STRENGHT PARAMETERS PLT (MPa)	STRENGHT PARAMETERS BPI (MPa)	CORE RECOVERY RQD (%)	CORE RECOVERY ICR (%)	CORE RECOVERY TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
9 10	24	65.90	67.65	SCHIST	25	-	-	0	33	97	50	DRY	96	BST-4	-	MW	-	-	-	3-H	J	J	b F	A	a A
10	25	67.65	69.00	SCHIST	15	-	-	0	13	76	500	DRY	75	BST-2	-	HW	-	-	-	0	J	J	c N	A	a A
10	26	69.00	72.80	SCHIST	20	-	-	0	29	99	50	DRY	98	BST-4	-	MW	-	-	-	3-H	J	J	b F	A	a D
11	27	72.80	73.10	SCHIST	-	2	-	0	100	100	16	DRY	99	2	W B	MW MW	0-R P-SR	L H	0 0	3-H 3-H	C	F	a C	A	a D
11	28	73.10	73.50	SCHIST	10	-	-	0	0	100	50	DRY	98	BST-3	-	MW	-	-	-	3-H	J	J	b F	A	a G
11	29	73.50	75.00	SCHIST	-	2	-	39	92	100	13	DRY	99	3	W J B	MW MW MW	0-R 0-SR P-S	L L H	0.9 0 0	0 0.9-H 0.9-H	E	E	a C	A	a D
11	30	75.00	75.25	SCHIST	10	-	-	0	0	100	50	DRY	98	BST-3	-	MW	-	-	-	0	J	J	a C	A	a G
11	31	75.25	76.00	SCHIST	-	2	-	27	91	100	21	DRY	99	3	W J B	MW MW MW	0-R P-SR 0-SR	L L H	0 0 0.9	3-H 3-H 0	E	E	a C	A	a G

Table C.5 Input data forms for rock mass classification for SK-6+570 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/3

PROJECT	:	DIM TUNNEL PROJECT	NORTHING	:	4045308.3	LOGGING DATE	
LOCATION	:	ALANYA -GAZİPAŞA ROAD	EASTING	:	417027.2	START / END :	19.07.2003
BOREHOLE NO	:	SK -6+570	ELEVATION	:	95.50 m	LOGGED BY :	SONGÜL COŞAR
						CHECKED BY :	SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
6	1	46.80	47.50	SCHIST	30	-	-	0	26	70	50	WET	68	BST-4	-	MW	-	-	-	0	J	J	b F	B	a D
6	2	47.50	48.00	SCHIST	-	1.94	-	94	100	100	4	WET	98	2	W B	SW SW	0-VR 0-SR	L H	0.9 0.9	0 0	B	C	a C	B	a D
6	3	48.00	48.80	SCHIST	30	-	-	0	30	78	50	WET	76	BST-4	-	MW	-	-	-	0	J	J	a C	B	a G
6	4	48.80	49.15	SCHIST	-	1.94	-	34	100	100	14	WET	98	2	J B	MW SW	0-R 0-SR	L H	0 0.9	3-H 0	B	C	a C	B	a D
6	5	49.15	50.00	SCHIST	30	-	-	12	33	67	50	WET	65	BST-3	-	MW	-	-	-	0	J	J	a C	B	a G
6	6	50.00	50.70	SCHIST	-	1.94	-	31	91	94	12	WET	92	2	W B	MW SW	0-R 0-SR	L H	0.9 0	0 3-H	B	C	a C	B	a D
6	7	50.70	52.90	SCHIST	30	-	-	5	19	78	50	WET	76	BST-4	-	MW	-	-	-	0	J	J	a C	B	a G

Table C.5 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+570 Page: 2/3

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	PLT (MPa)	BPI (MPa)	CORE RECOVERY RQD (%)	ICR (%)	TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
6 7	8	52.90	54.35	SCHIST	-	2.50	-	57	93	93	11	WET	91	3	W J B	MW MW MW	0-VR 0-SR 0-SR	L L H	0.9 0.9 0	0 0 3-H	D	C	a C	B	a D
7	9	54.35	55.10	SCHIST	10	-	-	0	8	51	500	WET	50	BST-2	-	MW	-	-	-	0	J	J	c N	B	a G
7	10	55.10	58.10	SCHIST	66	-	-	19	81	96	15	WET	95	3	W J B	MW MW MW	0-VR 0-R 0-R	L L H	0.9 0 0	0 3-H 3-H	E	B	a C	B	a D
7	11	58.10	60.20	SCHIST	15	-	-	0	12	80	50	WET	78	BST-3	-	MW	-	-	-	0	J	J	a C	B	a G
7 8	12	60.20	61.50	SCHIST	-	"	-	77	92	98	6	WET	96	2	J B	MW SW	0-SR P-SR	L H	0 0.9	3-H 0	B	F	a C	B	a D
8	13	61.50	64.50	SCHIST	20	-	-	7	20	67	50	WET	65	BST-4	-	MW	-	-	-	0	J	J	a C	B	a G
8	14	64.50	65.20	SCHIST	-	2.36	-	0	86	91	15	WET	90	3	W J B	MW MW SW	0-VR 0-R 0-SR	L L H	0.9 0 0.9	0 0.9-H 0	C	C	a C	B	a D
8	15	65.20	66.70	SCHIST	15	-	-	0	4	68	50	WET	65	BST-4	-	MW	-	-	-	0	J	J	a C	B	a G
8	16	66.70	67.00	SCHIST	-	3	-	37	83	100	20	WET	98	2	W B	MW MW	0-VR 0-SR	L H	0.9 0.9	0 0	B	C	a C	B	a D

Table C.5 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -6+570 Page: 3/3

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	PLT (MPa)	BPI (MPa)	CORE RECOVERY RQD (%)	ICR (%)	TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
8	17	67.00	68.10	SCHIST	15	-	-	0	9	56	50	WET	55	BST-3	-	HW	-	-	-	0	J	J	a C	B	a G
8	18	68.10	68.70	SCHIST	-	3	-	28	75	92	13	WET	90	2	W B	MW MW	0-R P-SR	L H	0.9 0.9	0 0	C	F	a C	B	a A
8	19	68.70	69.10	SCHIST	15	-	-	0	13	53	50	WET	50	BST-3	-	HW	-	-	-	0	J	J	a C	B	a G
9	20	69.10	74.10	SCHIST	-	3.6	-	19	60	79	10	WET	77	3	W J B	HW MW MW	0-VR P-SR P-SR	L L H	0 0 0	0.9-H 3-H 3-H	E	F	a C	B	a D
9	21	74.10	75.60	SCHIST	10	-	-	0	13	42	500	WET	40	BST-2	-	HW	-	-	-	0	J	J	c N	B	a D
9	22	75.60	76.20	LIMESTONE	-	3	-	0	36	84	50	WET	85	BST-4	-	MW	-	-	-	0	J	J	a C	B	a D
9	23	76.20	76.70	LIMESTONE	-	4	-	32	86	86	16	WET	85	2	J B	SW SW	P-SR P-SR	L M	0.9 0.9	0 0	B	F	a B	B	a D
9 10	24	76.70	80.00	LIMESTONE	-	3	-	9	23	58	50	WET	57	BST-3	-	MW	-	-	-	0	J	J	a C	B	a D

Table C.6 Input data forms for rock mass classification for SK-6+880 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/1

PROJECT	: DIM TUNNEL PROJECT	NORTHING	: 4045753.3	LOGGING DATE	
LOCATION	: ALANYA -GAZİPAŞA ROAD	EASTING	: 416779.1	START / END	: 16.07.2003
BOREHOLE NO	: SK -6+880	ELEVATION	: 72.00 m	LOGGED BY	: SONGÜL COŞAR
				CHECKED BY	: SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
1	1	0.00	7.50	BLOCKY LST	10	-	-	0	2	23	500	DRY	22	BST-2	-	HW	-	-	-	0	J	J	b H	A	a A
1	2	7.50	16.00	BLOCKY LST	10	-	-	9	13	25	500	DRY	24	BST-2	-	HW	-	-	-	0	J	J	b H	A	a A
1 2	3	16.00	33.50	BLOCKY LST	20	-	-	1	1	30	500	DRY	29	BST-2	-	HW	-	-	-	0	J	J	b H	A	a A
2	4	33.50	48.00	BLOCKY LST	10	-	-	8	16	25	500	DRY	24	BST-2	-	HW	-	-	-	0	J	J	c N	A	a D
3	5	48.00	49.00	BLOCKY LST	-	5	-	40	53	53	4	DRY	51	1	W	MW	0-R	L	3	0	C	F	a A	A	a G
3	6	49.00	52.00	BLOCKY LST	-	5	-	15	58	80	11	DRY	77	2	W J	HW HW	0-R P-SR	L L	3 0.9	0 0	C	F	a A	A	a G

Table C.7 Input data forms for rock mass classification for SK-7+130 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/2

PROJECT	:	DIM TUNNEL PROJECT	NORTHING	:	4045981.9	LOGGING DATE		
LOCATION	:	ALANYA -GAZİPAŞA ROAD	EASTING	:	416692.6	START / END	:	16.07.2003
BOREHOLE NO	:	SK -7+130	ELEVATION	:	72.00 m	LOGGED BY	:	SONGÜL COŞAR
						CHECKED BY	:	SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS	PLT	BPI	RQD	ICR	TCR											Jn	Jr	Ja	Jw	SRF
					(MPa)	(MPa)	(MPa)	(%)	(%)	(%)	(#/m)														
3	1	15.30	21.10	CONGLO	15	-	-	94	99	99	3	DRY	99	2	JA JB	HW HW	P-R P-VR	L L	0 3	0.9-5 0	B	E	a A	A	a G
3	2	21.10	21.30	SHALE	5	-	-	0	80	80	50	DRY	20	BST-4	-	HW	-	-	-	0	J	J	b H	A	a G
4	3	21.30	23.38	CONGLO	15	-	-	93	100	100	3	DRY	99	2	J B	HW MW	P-R P-SR	L H	3 0.9	0 0	B	E	a A	A	a G
4	4	23.38	26.05	SHALE	5	-	-	45	70	71	6	DRY	25	2	W J B	HW MW	P-R P-SR	M H	3 0.9	0 0	C	F	a A	A	a E
4 5	5	26.05	29.60	SHALE- SST	10	-	-	85	89	90	3	DRY	30	3	W B	HW HW MW	0-R P-R P-SR	L M H	0.9 0.9 0.9	0 0 0	C	F	a A	A	a G
5	6	29.60	31.00	SHALE- SST	10	-	-	0	56	74	50	DRY	30	BST-4	-	HW	-	-	-	0	J	J	b H	A	a G
5	7	31.00	31.40	SHALE- SST	10	-	-	28	100	100	15	DRY	30	2	W B	HW MW	P-SR P-SR	L H	0.9 0.9	0 0	C	F	a E	A	a G

Table C.7 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -7+130 Page: 2/2

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	STRUCTURAL DOMAINS TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	PLT (MPa)	BPI (MPa)	CORE RECOVERY RQD (%)	ICR (%)	TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
5	8	31.40	35.00	SST	10	-	-	60	82	87	4	DRY	3	2	W B	HW MW	0-R P-SR	L H	0.9 0.9	0. 0	C	E	a D	A	a E
6	9	35.00	41.00	SST	10	-	-	78	97	99	4	DRY	10	3	W J	MW MW	P-SR P-SR	L L	0.9 0.9	0 0	C	F	a A	A	a E
7	10	41.00	43.30	SHALE-SST	10	-	-	76	85	85	5	DRY	20	2	W B	MW MW	0-R P-SR	L H	0.9 0.9	0 0	C	F	a C	A	a D
8	11	43.30	45.00	SHALE-SST	10	-	-	42	79	86	8	DRY	30	2	W B	HW MW	0-R P-SR	L H	0.9 0.9	0 0	C	F	a C	A	a D

Table C.8 Input data forms for rock mass classification for SK-7+250 drilling

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

Page: 1/3

PROJECT	: DIM TUNNEL PROJECT	NORTHING	: 4046125.8	LOGGING DATE	
LOCATION	: ALANYA -GAZİPAŞA ROAD	EASTING	: 416686.1	START / END	: 17.07.2003
BOREHOLE NO	: SK -7+250	ELEVATION	: 77.00 m	LOGGED BY	: SONGÜL COŞAR
				CHECKED BY	: SONGÜL COŞAR

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
1	1	0.00	6.00	SCHIST	-	2	-	0	0	16	1000	DRY	15	BST-1	-	D	-	-	-	0	J	J	b H	A	a A
1	2	6.00	20.95	SCHIST	-	2	-	2	7	23	500	DRY	20	BST-2	-	VHW	-	-	-	0	J	J	b H	A	a D
1	3	20.95	21.40	SCHIST	-	2	-	27	87	98	22	DRY	95	2	J B	HW MW	P-R P-SR	M H	0 0.9	3-H 0	B	F	a C	A	a D
1	4	21.40	25.32	SCHIST	-	2	-	3	9	25	500	DRY	25	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
1 2	5	25.32	26.20	SCHIST	-	2	-	82	97	99	9	DRY	95	2	J B	MW MW	P-SR 0-SR	M H	0 0.9	3-H 0	B	C	a C	A	a D
2	6	26.20	26.70	SCHIST	-	2	-	0	0	40	500	DRY	40	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
2	7	26.70	26.95	SCHIST	-	2	-	52	100	100	12	DRY	97	1	B	SW	P-SR	H	0.9	0	B	F	a A	A	a D

Table C.8 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -7+250 Page: 2/3

BOX #	STR #	STRUCTURAL DOMAINS FROM (m)	STRUCTURAL DOMAINS TO (m)	ROCK TYPE	STRENGHT PARAMETERS UCS (MPa)	STRENGHT PARAMETERS PLT (MPa)	STRENGHT PARAMETERS BPI (MPa)	CORE RECOVERY RQD (%)	CORE RECOVERY ICR (%)	CORE RECOVERY TCR (%)	FRACTURE DENSITY (#/m)	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS Jn	Jr	Ja	Jw	SRF
2	8	26.95	27.25	SCHIST	-	2	-	0	0	87	50	DRY	82	BST-3	-	HW	-	-	-	3-H	J	J	b F	A	a G
2	9	27.25	27.55	SCHIST	-	2	-	40	100	100	10	DRY	97	1	B	SW	P-SR	H	0	3-H	B	F	b F	A	a D
2	10	27.55	27.90	SCHIST	-	2	-	0	13	86	50	DRY	95	BST-3	-	HW	-	-	-	3-H	J	J	b F	A	a G
2	11	27.90	28.40	SCHIST	-	2	-	30	96	96	12	DRY	93	3	W J B	MW MW SW	0-R 0-SR 0-SR	L M H	0.9 0 0	0 0.9-H 3-H	C	F	a C	A	a G
2	12	28.40	30.50	SCHIST	-	2	-	0	21	59	50	DRY	57	BST-3	-	MW	-	-	-	0	J	J	a C	A	a G
2	13	30.50	33.00	SCHIST	-	2	-	16	63	71	8	DRY	68	3	W J B	MW MW MW	D-S P-SR P-SR	L L H	0.9 0 0.9	0 3-H 0	C	F	a C	A	a D
2	14	33.00	33.60	SCHIST	-	2	-	0	10	80	50	DRY	77	BST-3	-	MW	-	-	-	6-H	J	J	b F	A	a G
3	15	33.60	34.25	SCHIST	-	2	-	22	34	65	6	DRY	63	3	W J B	MW MW MW	0-R P-SR P-SR	L M H	0.9 0 0.9	0 0.9-H 0	C	F	a C	A	a G

Table C.8 Continued.

INPUT DATA-FORM FOR ROCK MASS CLASSIFICATION (METU-2004)

SK -7+250 Page: 3/3

BOX #	STR #	STRUCTURAL DOMAINS		ROCK TYPE	STRENGHT PARAMETERS			CORE RECOVERY			FRACTURE DENSITY	GROUND WATER CONDITION	SLAKE DURABILITY INDEX Id-2	# OF DISCONTINUITY SETS	DISCONTINUITY SET TYPE	WEATHERING	ROUGHNESS / JOINT CONDITION	PERSISTENCY	APPERTURE	FILLING THICKNESS & TYPE	Q-SYSTEM PARAMETERS				
		FROM (m)	TO (m)		UCS (MPa)	PLT (MPa)	BPI (MPa)	RQD (%)	ICR (%)	TCR (%)	(#/m)										Jn	Jr	Ja	Jw	SRF
3	16	34.25	36.00	SCHIST	-	2	-	68	93	97	8	DRY	94	3	W J B	MW MW MW	0-R P-SR P-SR	L M H	0.9 0.9 0.9	0 0 0	C	F	a B	A	a E
3	17	36.00	36.40	SCHIST	-	2	-	0	73	73	27	DRY	70	2	J B	MW MW	P-SR P-SR	M H	0 0.9	0.9-H 0	B	F	a C	A	a D
3	18	36.40	37.50	SCHIST	-	2	-	0	7	50	500	DRY	48	BST-2	-	VHW	-	-	-	3-H	J	J	c N	A	a G
3	19	37.50	40.80	SCHIST	-	2	-	21	53	65	8	DRY	63	3	W J B	HW MW MW	0-R 0-R P-SR	L L H	0 0.9 0	3-H 0 3-H	E	F	a C	A	a D
3	20	40.80	41.30	SCHIST	-	2	-	0	0	72	50	DRY	70	BST-2	-	HW	-	-	-	0	J	J	c N	A	a G
4	21	41.30	41.80	SCHIST	-	2	-	38	92	92	8	DRY	89	1	B	MW	P-R	H	0	3-H	B	F	a C	A	a G
4	22	41.80	43.20	SCHIST	-	2	-	0	24	71	50	DRY	68	BST-3	-	MW	-	-	-	3-H	J	J	b F	A	a G
4	23	43.20	44.55	SCHIST	-	2	-	25	68	87	11	DRY	84	3	W J B	MW MW MW	0-R P-SR 0-SR	L M H	0.9 0 0	0 6-H 3-H	E	C	a C	A	a D
4	24	44.55	46.00	SCHIST	-	2	-	12	25	80	50	DRY	77	BST-4	-	MW	-	-	-	3-H	J	J	b F	A	a D

APPENDIX D

CORE BOX PHOTOGRAPS AND ILLUSTRATION OF STRUCTURAL DOMAINS

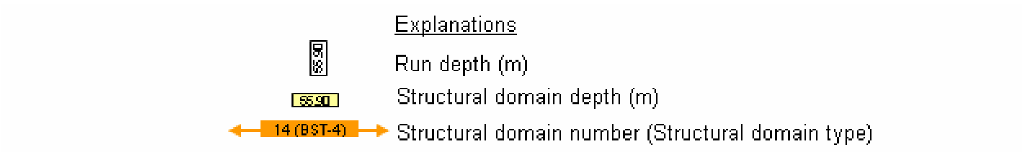


Figure D.1 Explanations of photograph illustrations

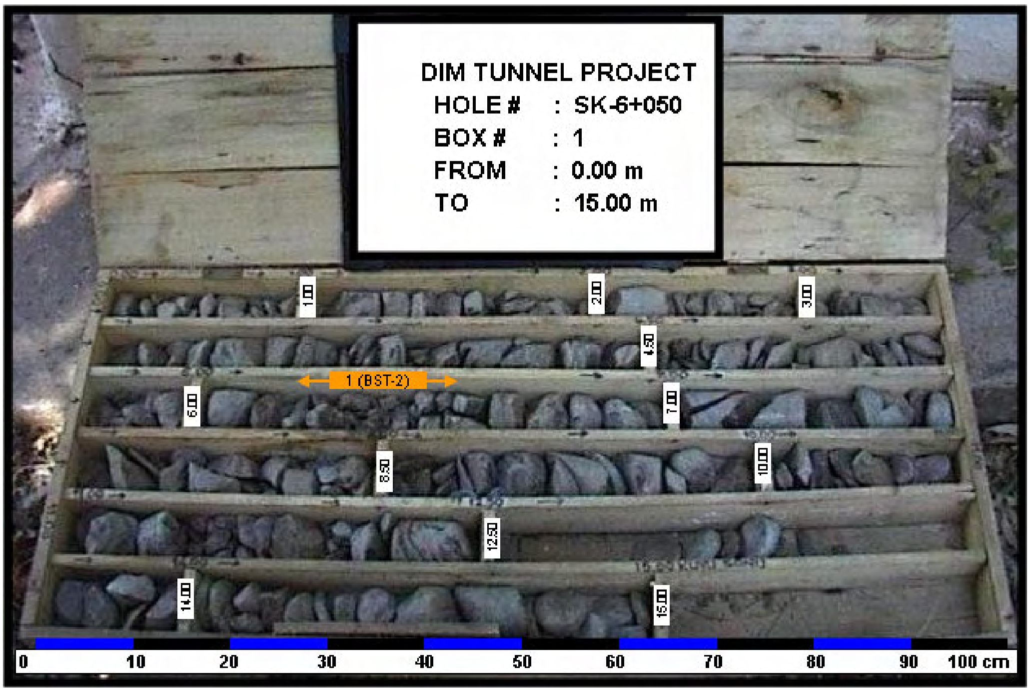


Figure D.2 Core box 1 photograph of borehole SK-6+050

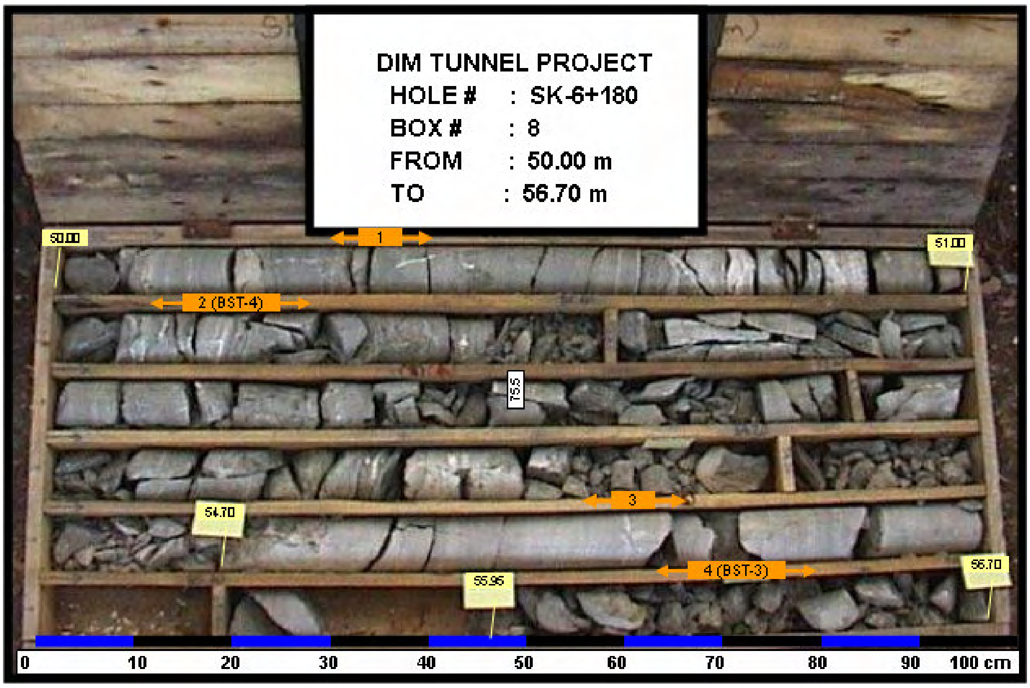


Figure D.3 Core box 8 photograph of borehole SK-6+180

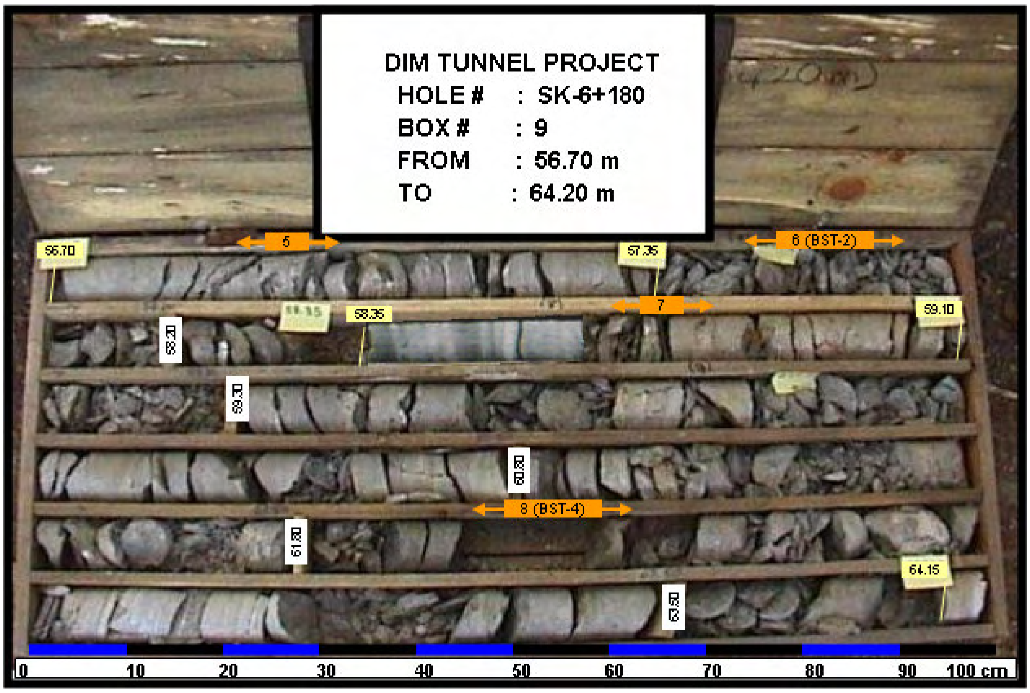


Figure D.4 Core box 9 photograph of borehole SK-6+180

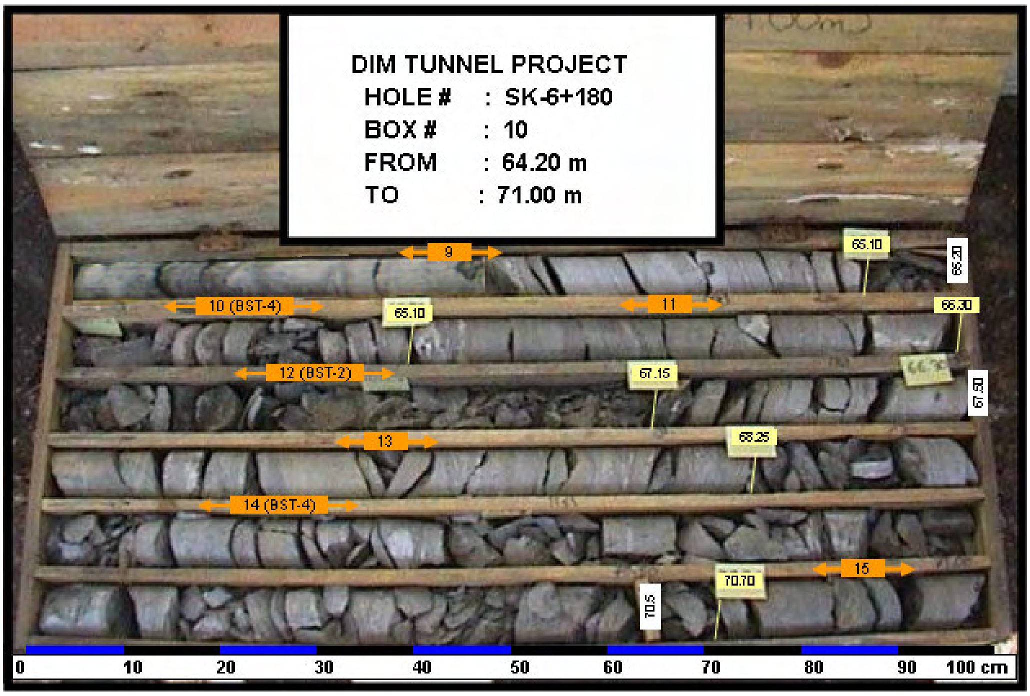


Figure D.5 Core box 10 photograph of borehole SK-6+180

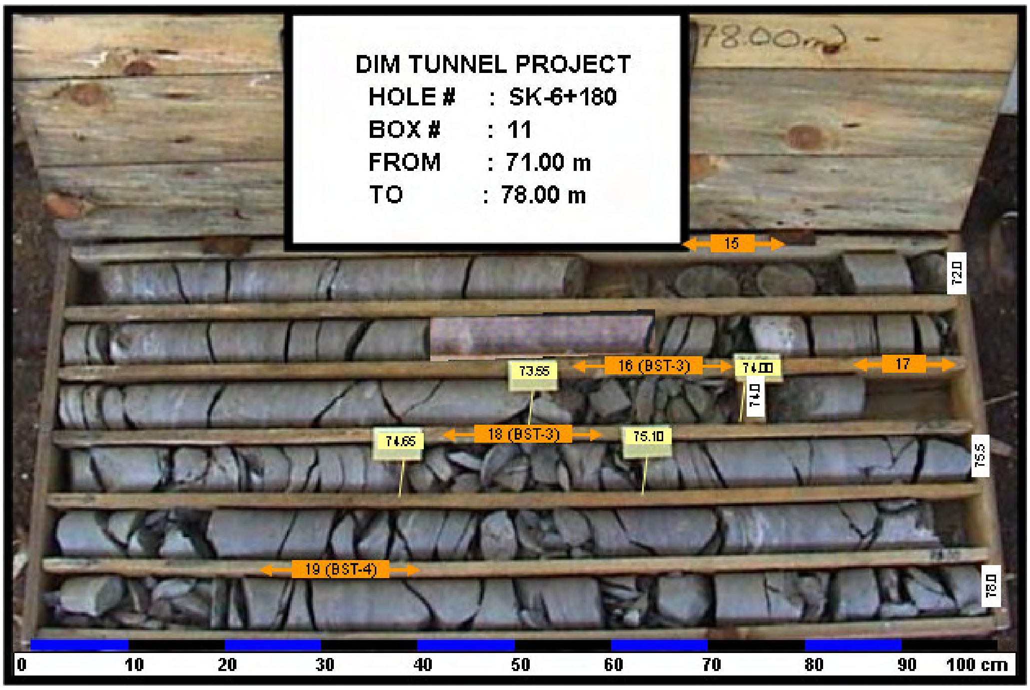


Figure D.6 Core box 11 photograph of borehole SK-6+180

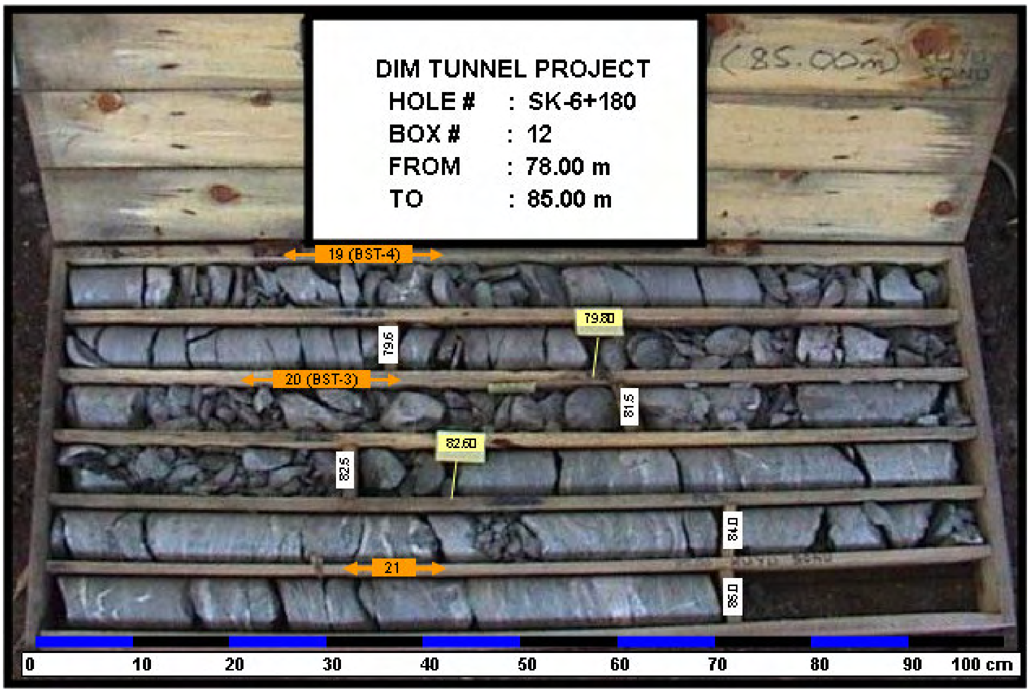


Figure D.7 Core box 12 photograph of borehole SK-6+180

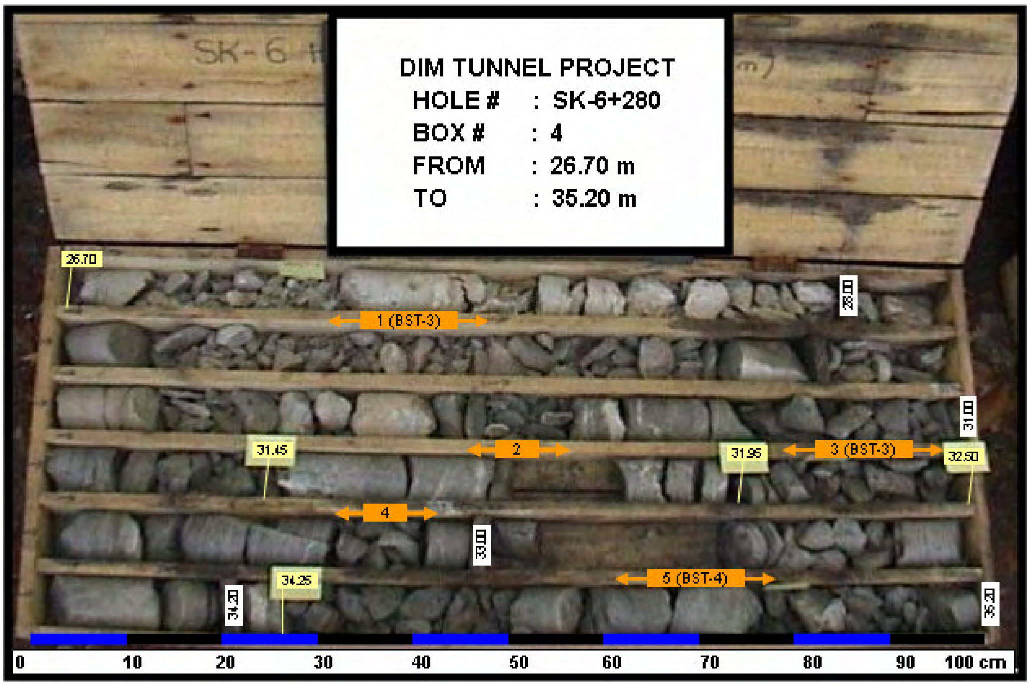


Figure D.8 Core box 4 photograph of borehole SK-6+280

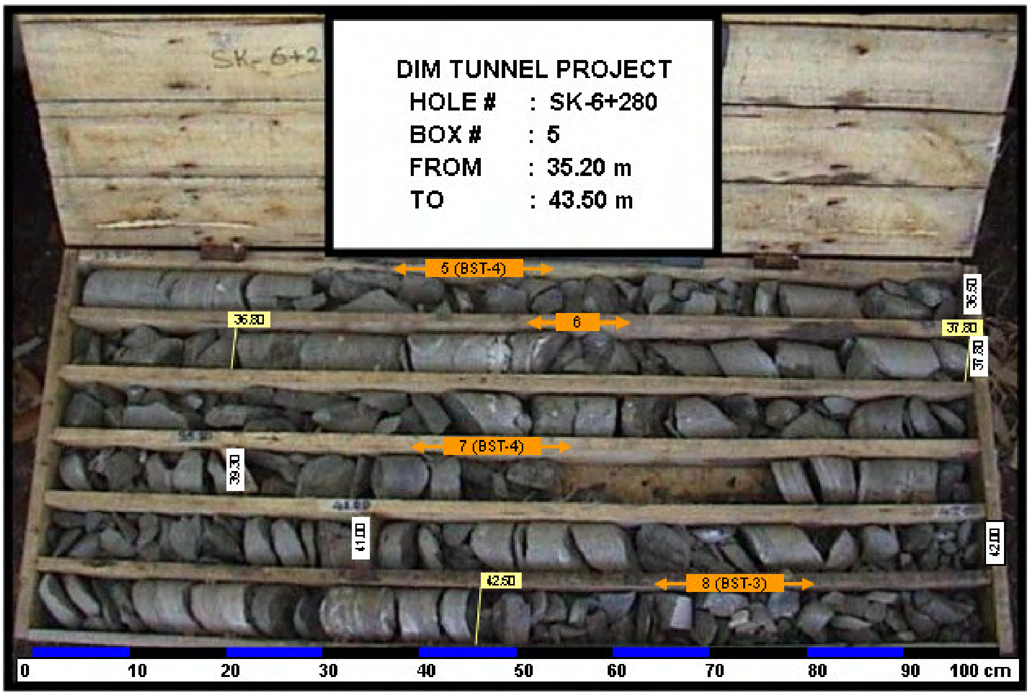


Figure D.9 Core box 5 photograph of borehole SK-6+280

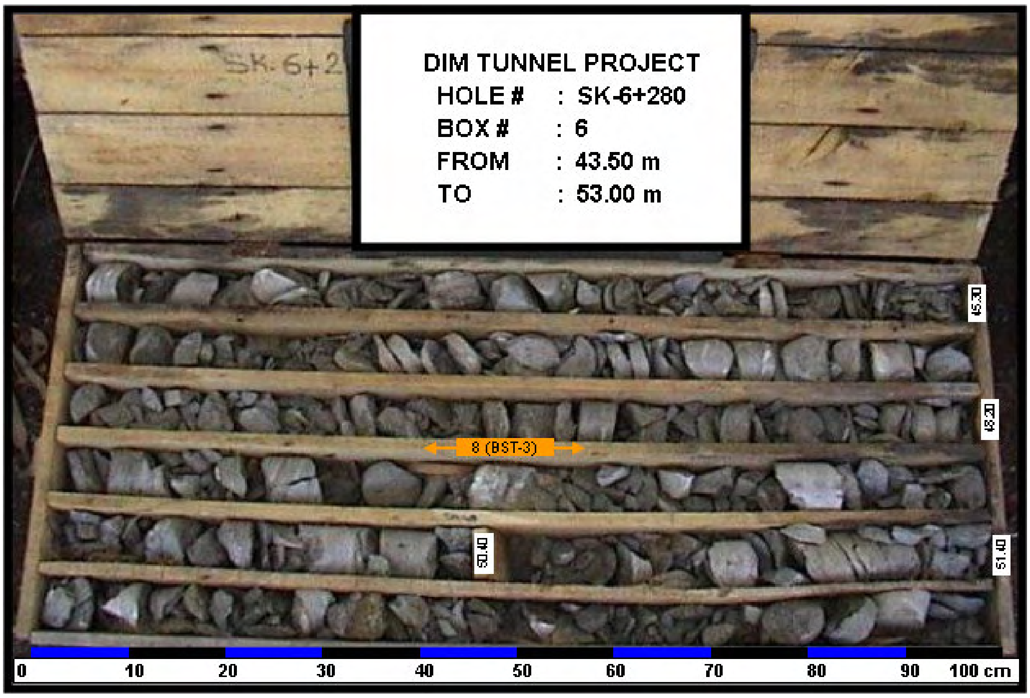


Figure D.10 Core box 6 photograph of borehole SK-6+280

Figure D.11 Core box 7 photograph of borehole SK-6+280

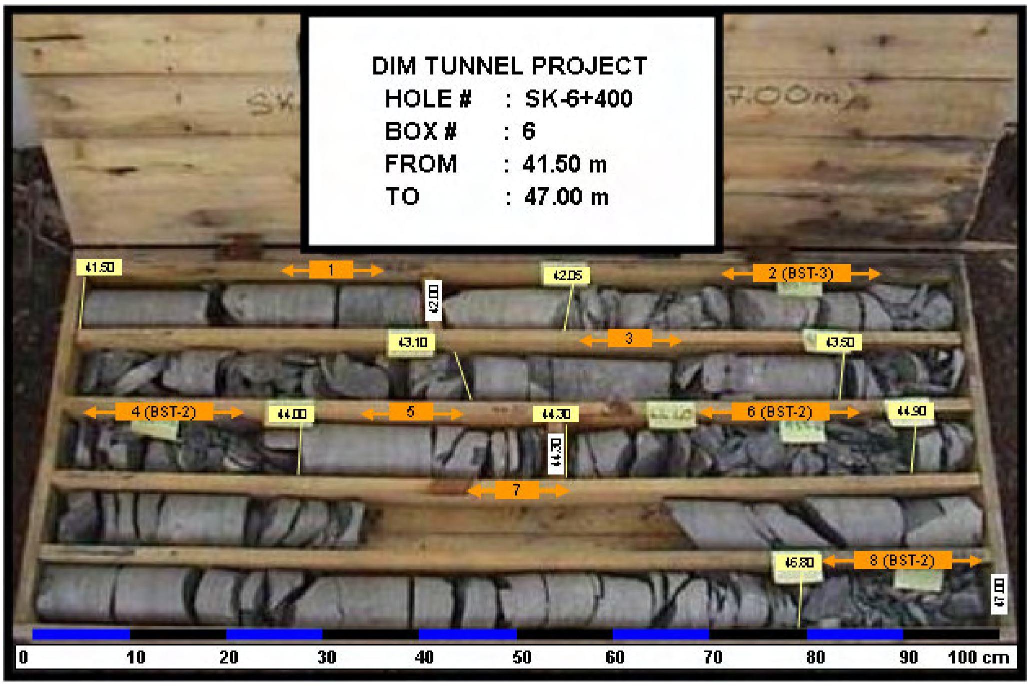


Figure D.12 Core box 6 photograph of borehole SK-6+400

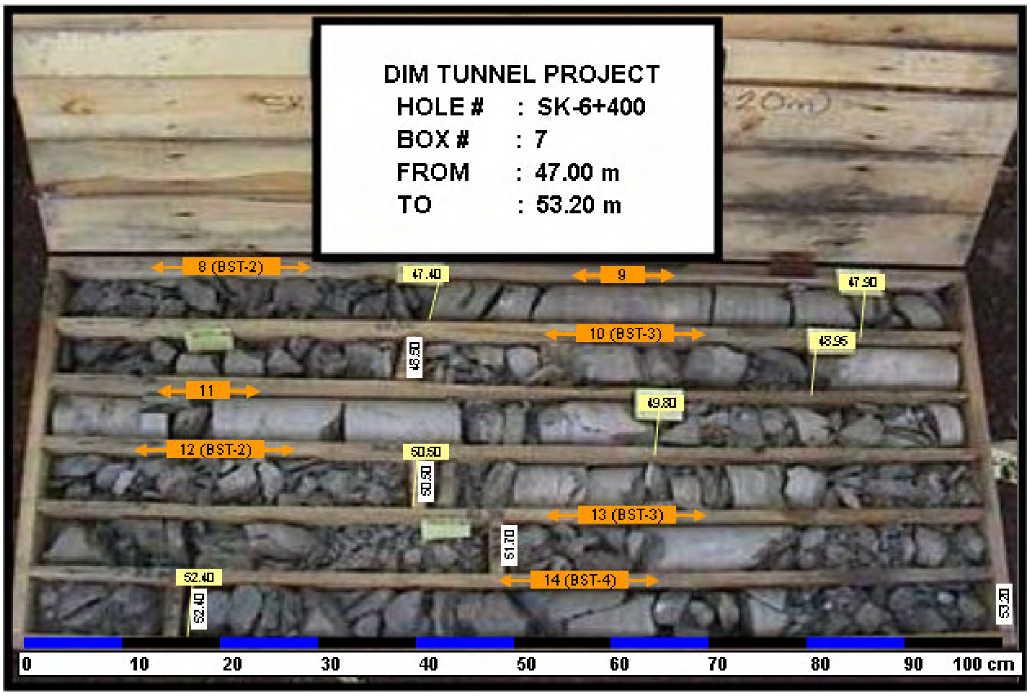


Figure D.13 Core box 7 photograph of borehole SK-6+400

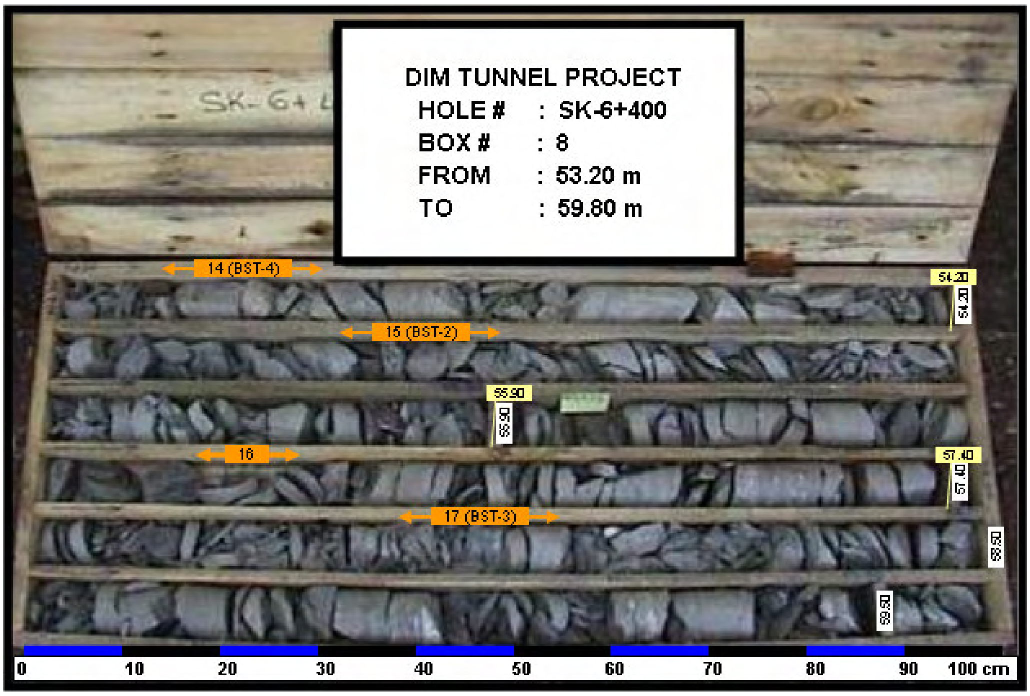


Figure D.14 Core box 8 photograph of borehole SK-6+400

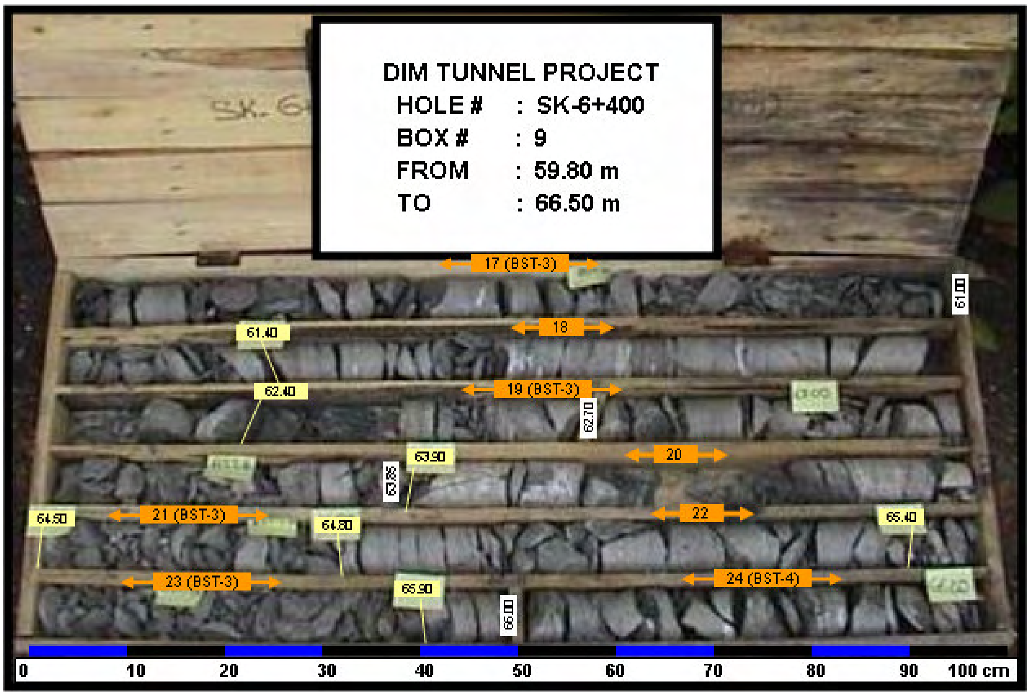


Figure D.15 Core box 9 photograph of borehole SK-6+400

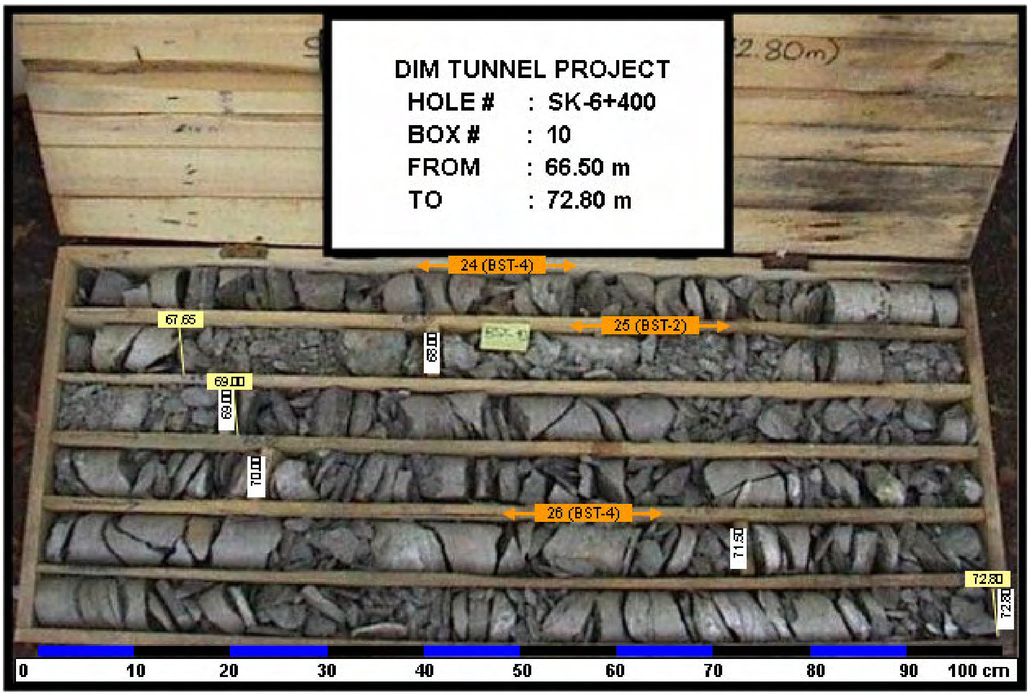


Figure D.16 Core box 10 photograph of borehole SK-6+400

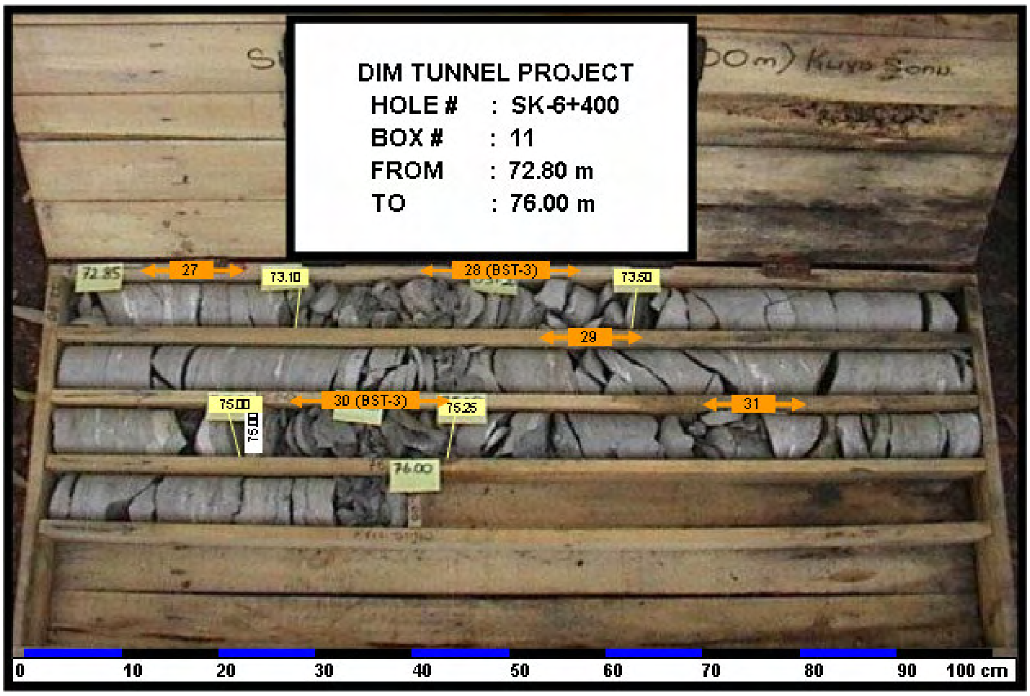


Figure D.17 Core box 11 photograph of borehole SK-6+400

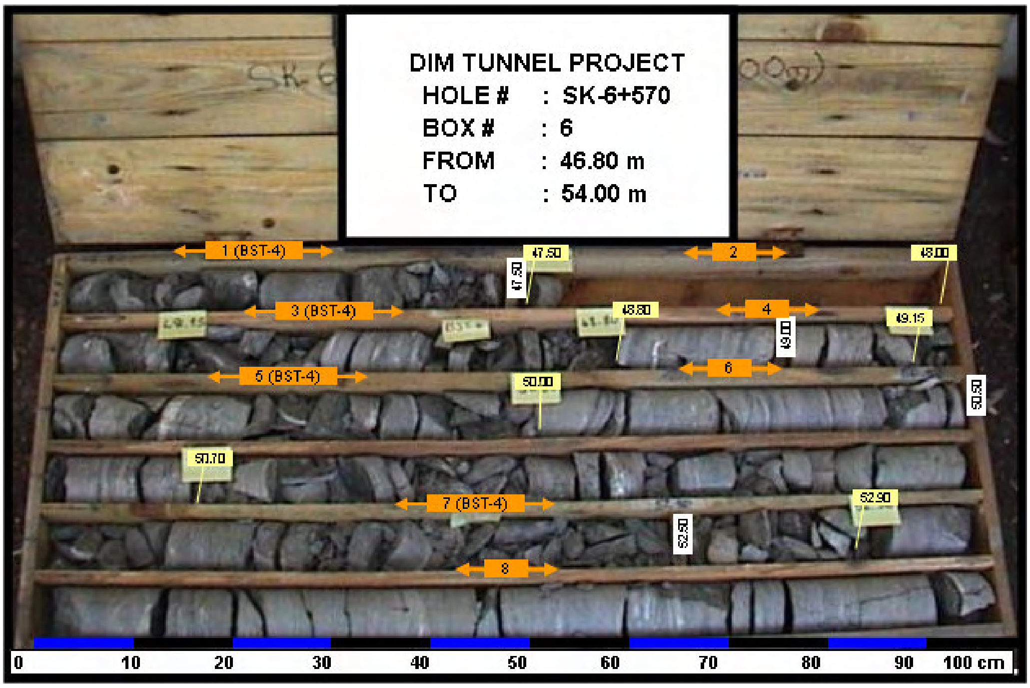


Figure D.18 Core box 6 photograph of borehole SK-6+570

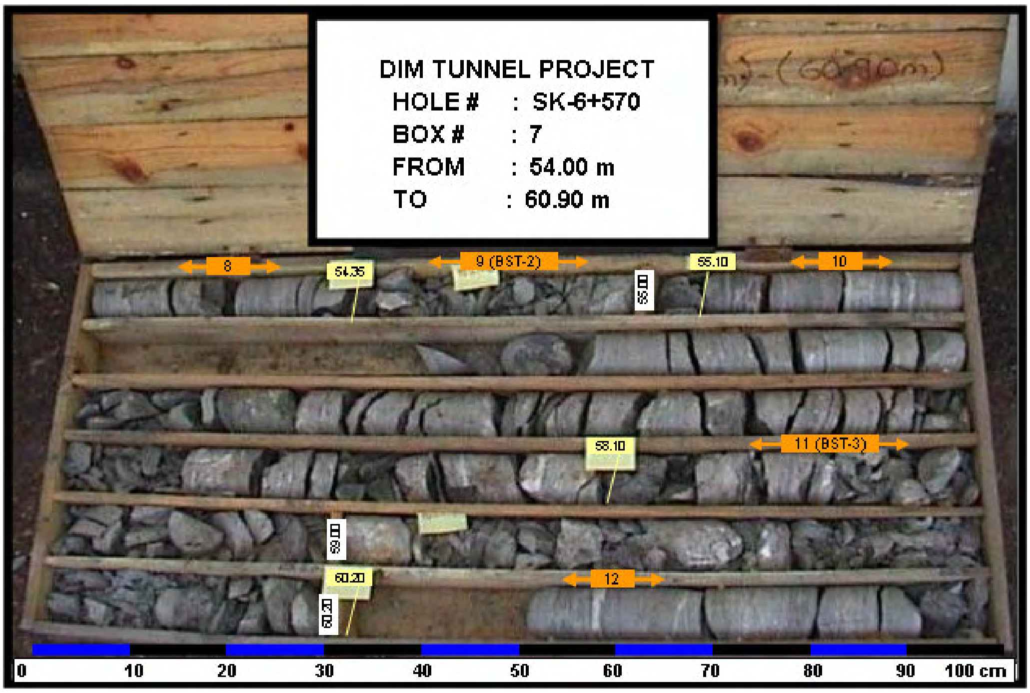


Figure D.19 Core box 7 photograph of borehole SK-6+570

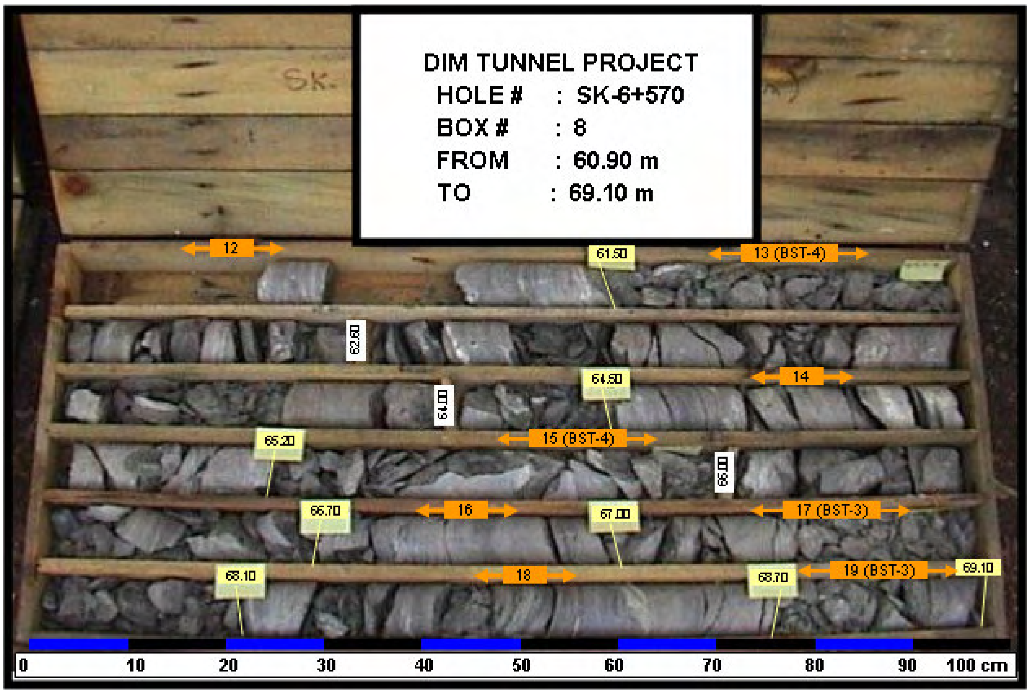


Figure D.20 Core box 8 photograph of borehole SK-6+570

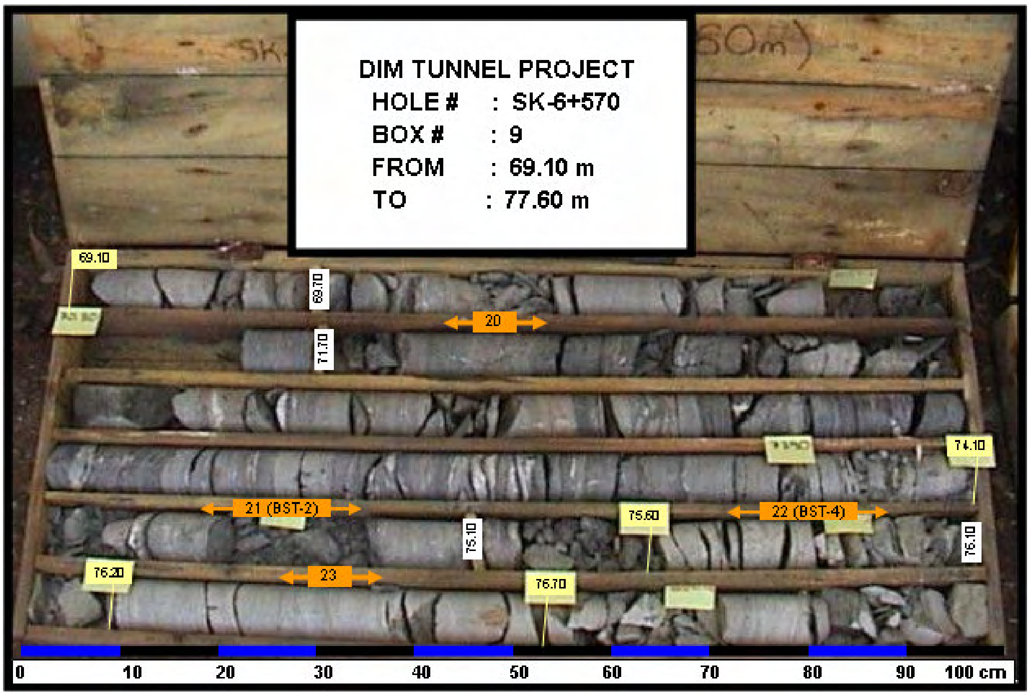


Figure D.21 Core box 9 photograph of borehole SK-6+570

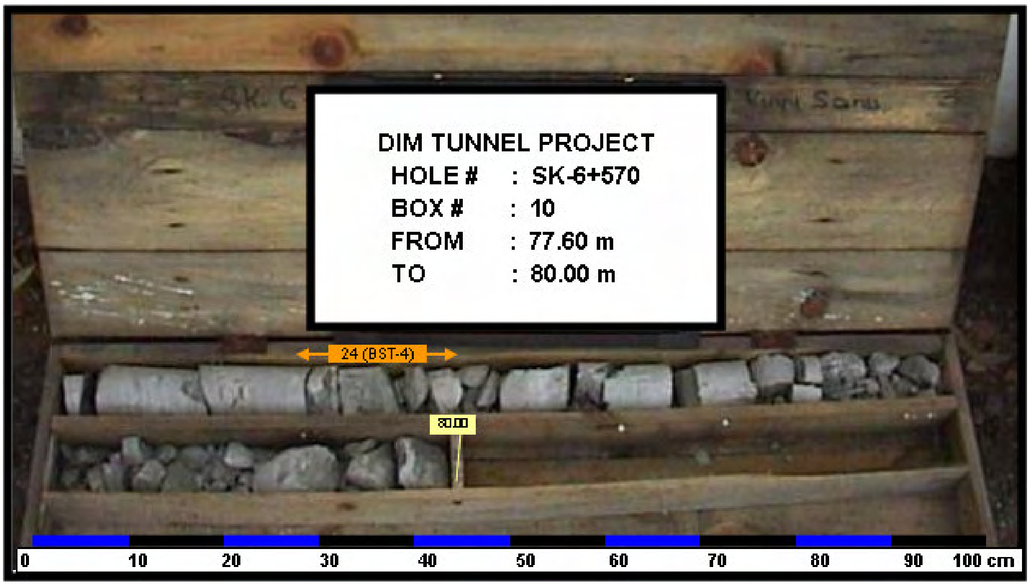


Figure D.22 Core box 10 photograph of borehole SK-6+570

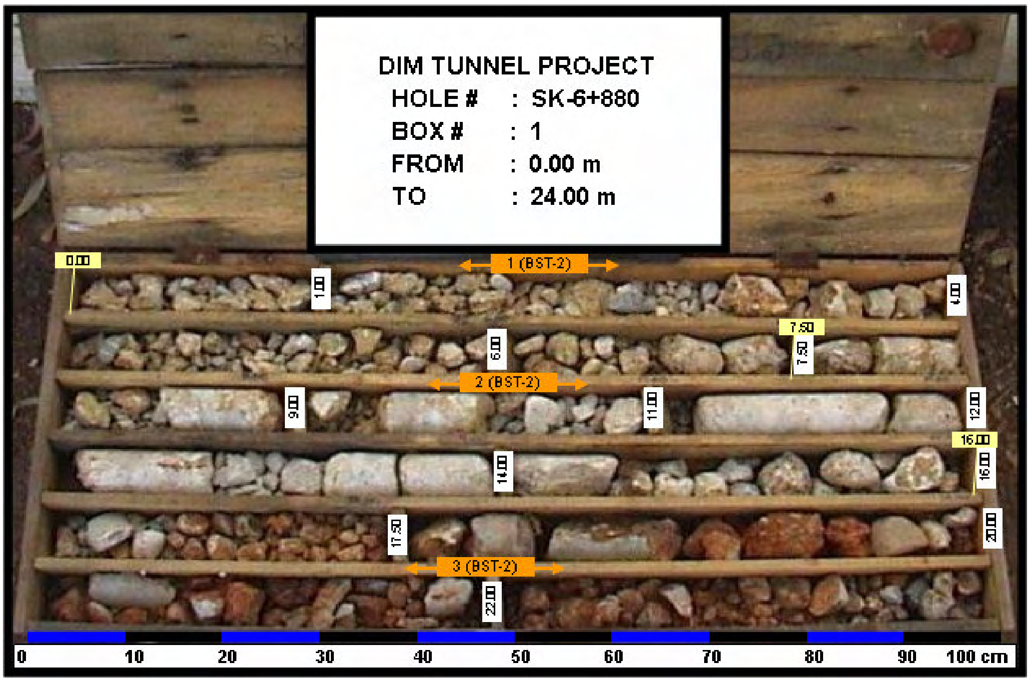


Figure D.23 Core box 1 photograph of borehole SK-6+880

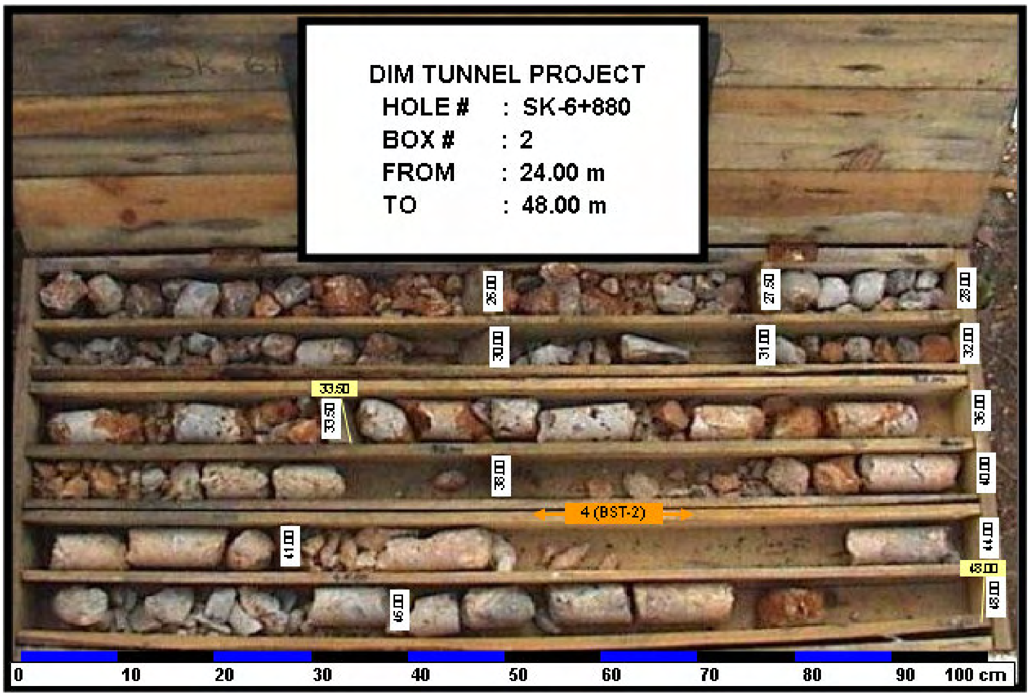


Figure D.24 Core box 2 photograph of borehole SK-6+880

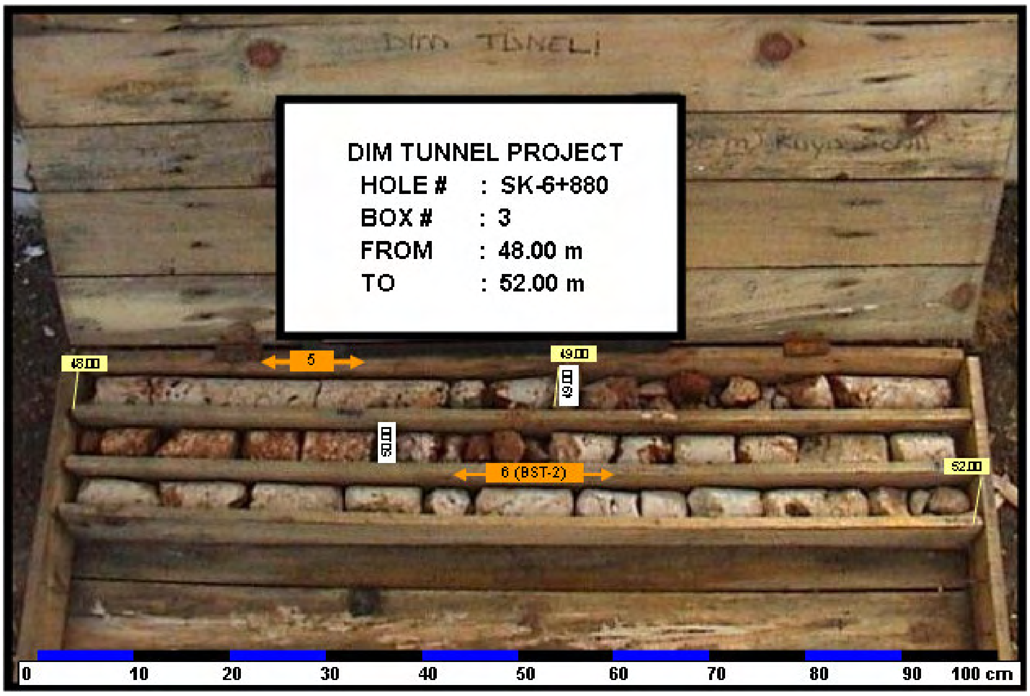


Figure D.25 Core box 3 photograph of borehole SK-6+880

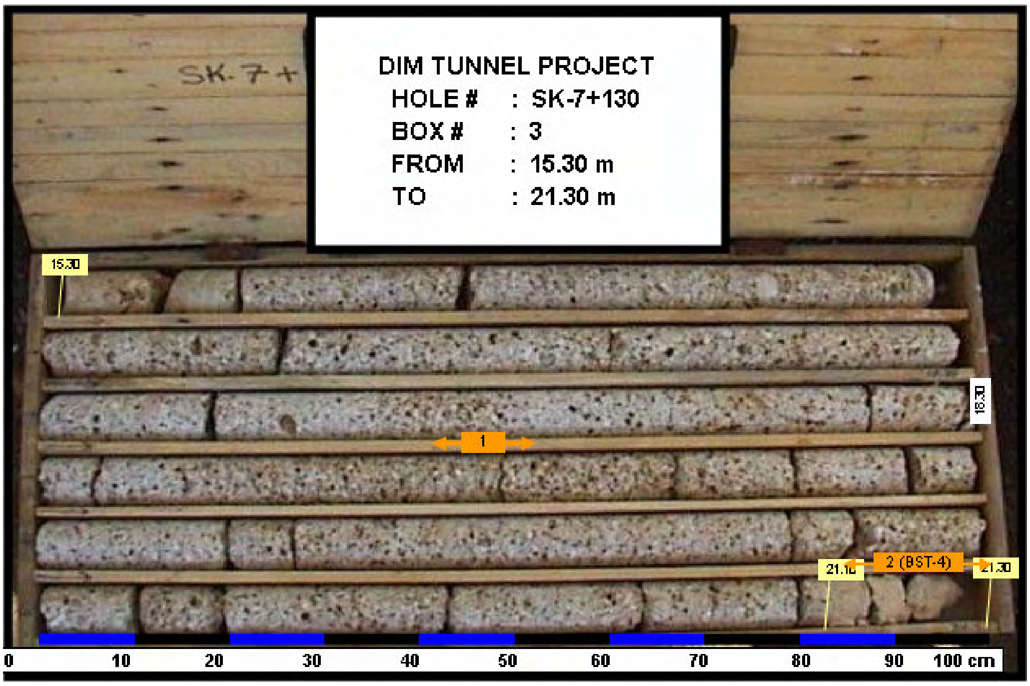


Figure D.26 Core box 3 photograph of borehole SK-7+130

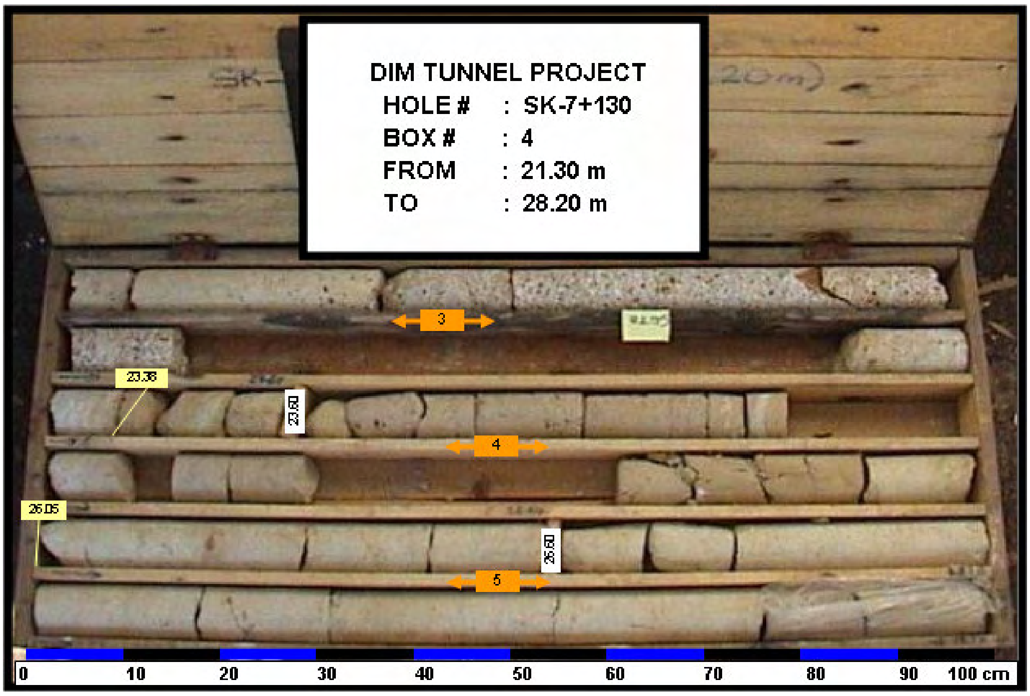


Figure D.27 Core box 4 photograph of borehole SK-7+130

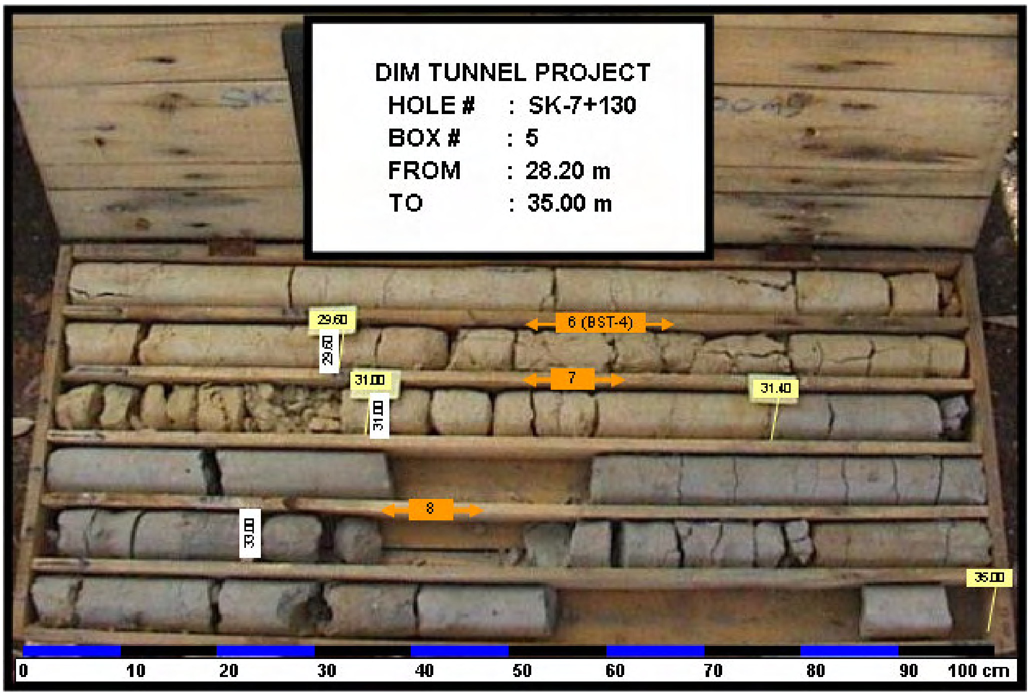


Figure D.28 Core box 5 photograph of borehole SK-7+130

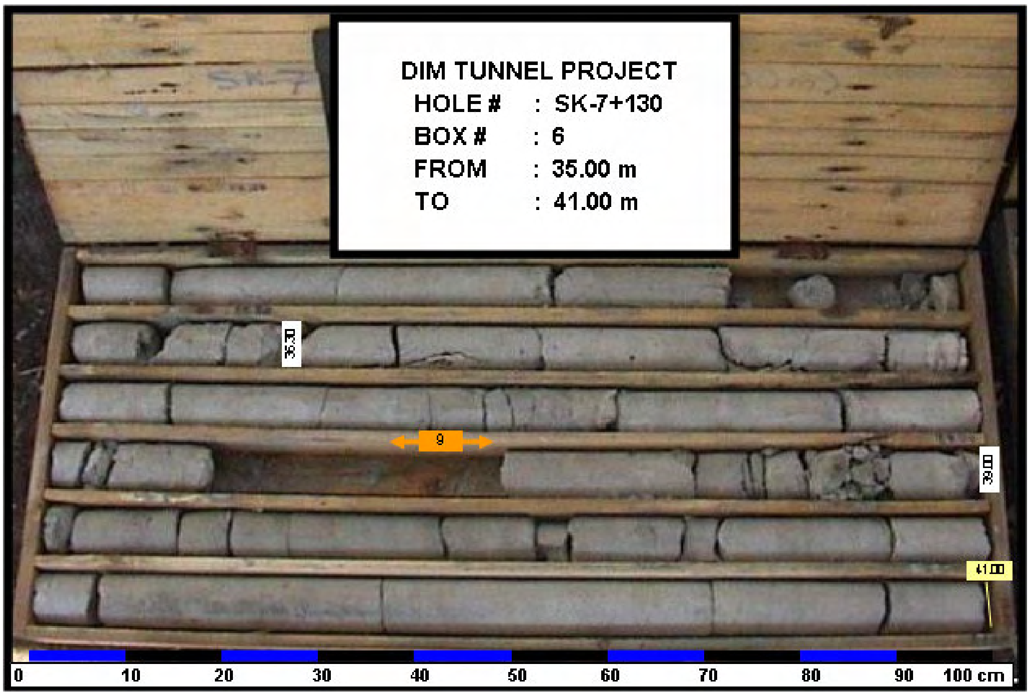


Figure D.29 Core box 6 photograph of borehole SK-7+130

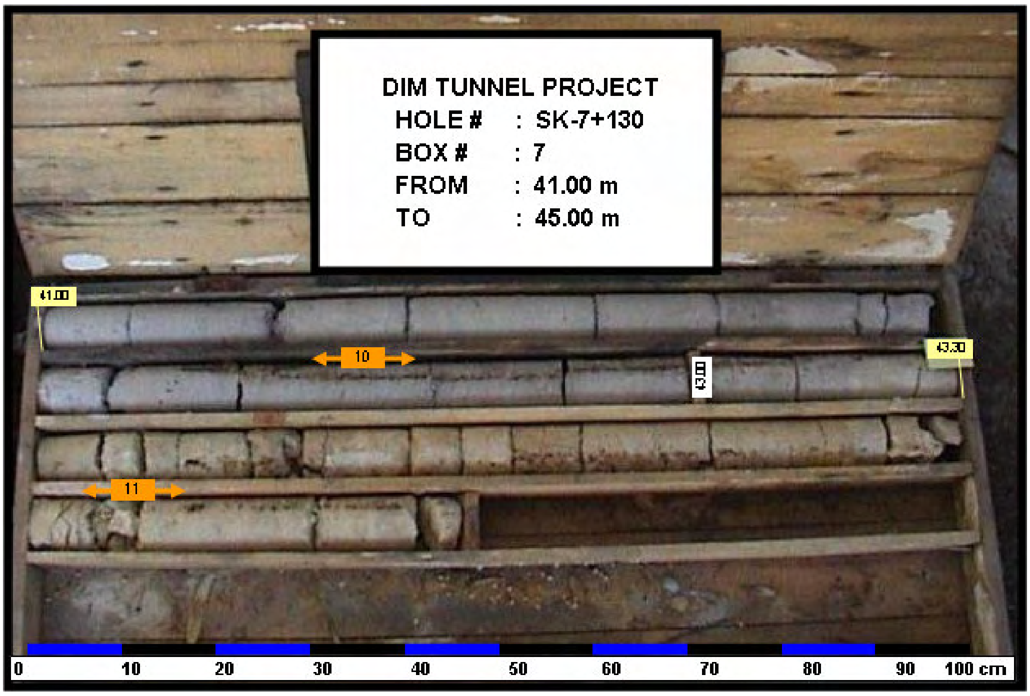


Figure D.30 Core box 7 photograph of borehole SK-7+130

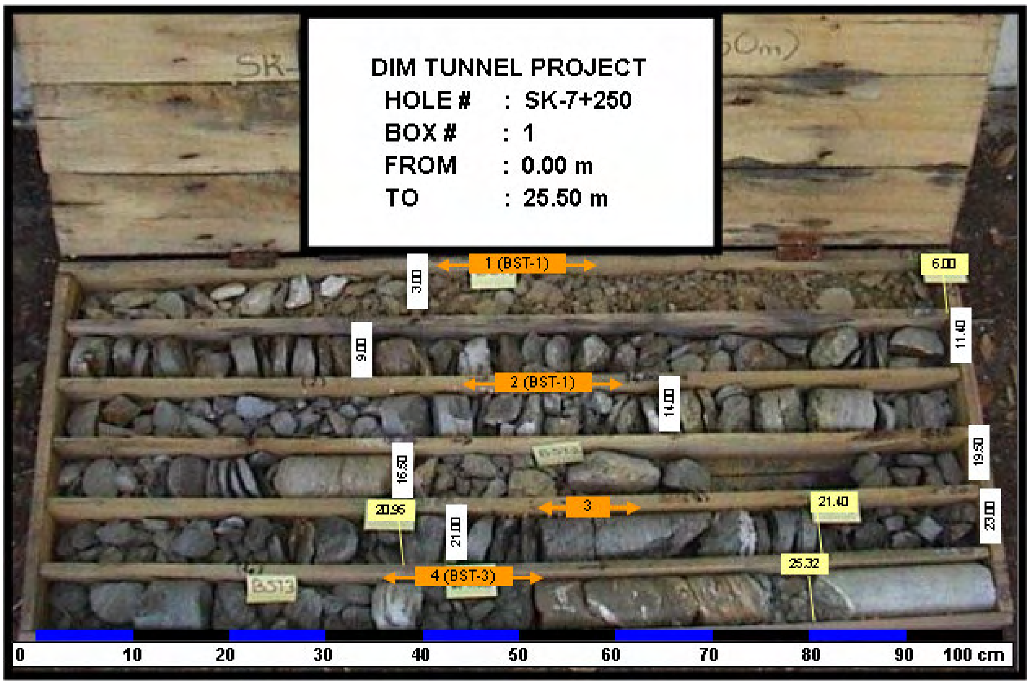


Figure D.31 Core box 1 photograph of borehole SK-7+250

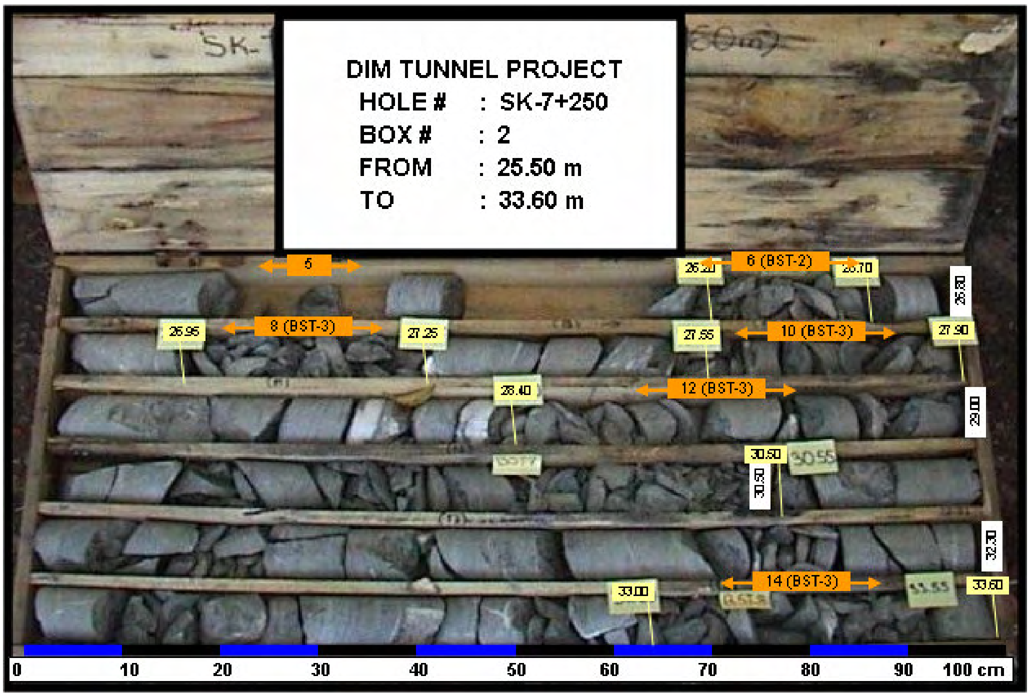


Figure D.32 Core box 2 photograph of borehole SK-7+250

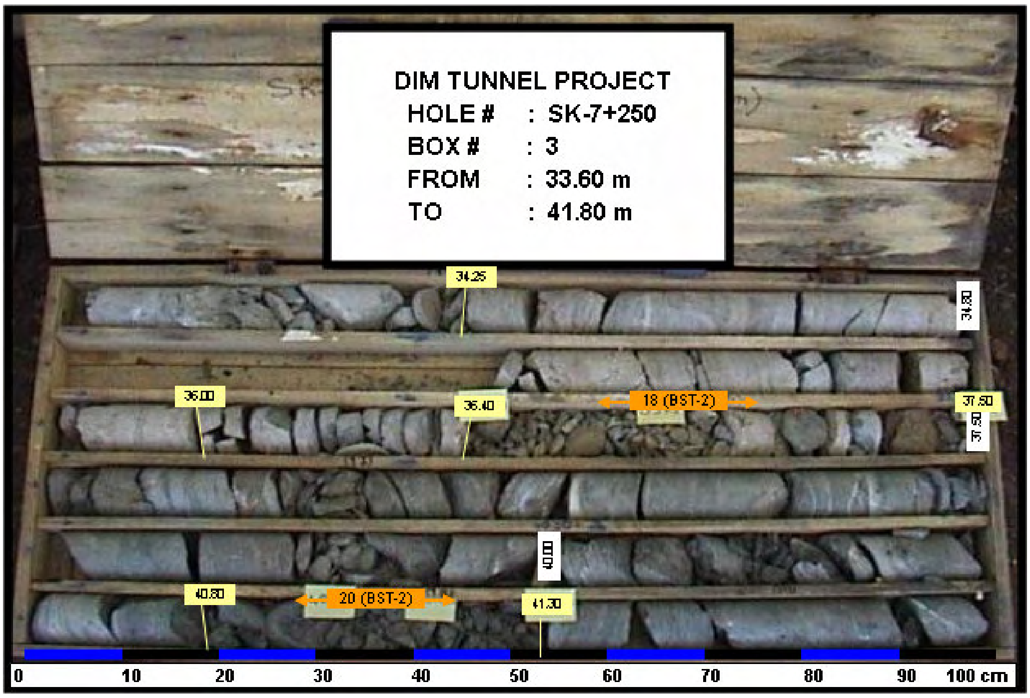


Figure D.33 Core box 3 photograph of borehole SK-7+250

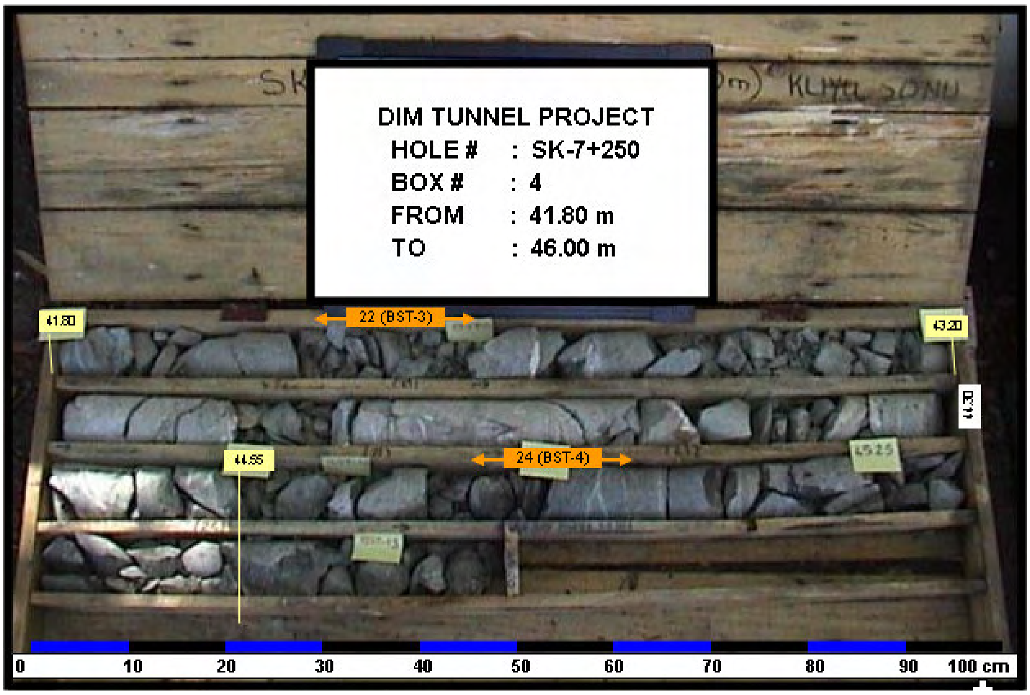


Figure D.34 Core box 4 photograph of borehole SK-7+250

APPENDIX E

ROCK MASS CLASSIFICATION CALCULATIONS FOR DIM TUNNEL

E.I ROCK MASS OUTPUTS

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
0 - 15	schist	20	2	14	500	bst2	0	75	hw	-	-	-	-	6	s

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
0 -15	schist	37	14	2	2

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
0 -15	schist	hw	-	-	-	6 |s

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
0 -15	schist	4	1	2	0	15	-9	1.00

Figure E.1 ROCKMASS outputs of the SK-6+050 borehole.

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM							
INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
0 -15	schist	10	20	1.0	6	1	10.0

FINAL CLASSIFICATION LOGS				
INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
0 -15	schist	2	13	0.01

Figure E.1 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
50.00 - 51.00	SCHIST	2.5	42	92	16	0	25	97	SW	P.	SR	L	0.0	3	H
51.00 - 54.70	SCHIST	25	0	12	50	BST4	25	75	MW	-	-	-	-	3	H
54.70 - 55.95	SCHIST	2.5	66	93	11	0	25	99	SW	U.	SR	L	0.0	3	H
55.95 - 56.70	SCHIST	10	0	0	50	BST3	25	71	HW	-	-	-	-	1	H
56.70 - 57.35	SCHIST	2.5	32	89	21	0	25	96	SW	P.	SR	H	0.5	0	-
57.35 - 58.35	SCHIST	10	0	0	500	BST2	25	58	HW	-	-	-	-	3	H
58.35 - 59.10	schìst	2.5	44	71	20	0	25	92	MW	U.	SR	H	0.5	0	-
59.10 - 64.15	SCHIST	25	16	25	50	BST4	25	75	HW	-	-	-	-	3	H
64.15 - 65.10	SCHIST	40	48	100	13	0	25	99	SW	P.	SR	H	0.5	0	-
65.10 - 65.70	SCHIST	25	0	25	50	BST4	25	77	MW	-	-	-	-	3	H
65.70 - 66.30	SCHIST	40	18	95	16	0	25	99	SW	P.	R	H	0.5	0	-
66.30 - 67.15	SCHIST	5.0	0	0	500	BST2	25	64	HW	-	-	-	-	1	H
67.15 - 68.25	SCHIST	40	28	95	20	0	25	99	SW	P.	SR	H	0.5	0	-
68.25 - 70.70	SCHIST	10	0	5	50	BST4	25	64	MW	-	-	-	-	0	-
70.70 - 73.55	SCHIST	3.0	47	92	5	0	25	97	MW	P.	S	H	0.5	0	-
73.55 - 74.00	SCHIST	10	0	0	50	BST3	25	46	MW	-	-	-	-	0	-
74.00 - 74.65	SCHIST	3.0	31	92	20	0	25	91	MW	P.	S	H	0.5	0	-
74.65 - 75.10	SCHIST	10	0	7	50	BST3	25	52	MW	-	-	-	-	0	-
75.10 - 79.80	SCHIST	25	8	25	50	BST4	25	82	MW	-	-	-	-	0	-
79.80 - 82.60	SCHIST	20	6	14	50	BST3	25	59	HW	-	-	-	-	1	H
82.60 - 85.00	SCHIST	3.0	58	89	8	0	25	94	MW	P.	R	H	0.5	0	-

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
50.00 -51.00	SCHIST	98	92	42	62
51.00 -54.70	SCHIST	84	12	0	20
54.70 -55.95	SCHIST	100	93	66	90
55.95 -56.70	SCHIST	72	0	0	20
56.70 -57.35	SCHIST	97	89	32	47
57.35 -58.35	SCHIST	59	0	0	2
58.35 -59.10	schìst	93	71	44	50
59.10 -64.15	SCHIST	76	25	16	20
64.15 -65.10	SCHIST	100	100	48	76
65.10 -65.70	SCHIST	78	25	0	20
65.70 -66.30	SCHIST	100	95	18	62
66.30 -67.15	SCHIST	65	0	0	2
67.15 -68.25	SCHIST	100	95	28	50
68.25 -70.70	SCHIST	65	5	0	20
70.70 -73.55	SCHIST	98	92	47	200
73.55 -74.00	SCHIST	47	0	0	20
74.00 -74.65	SCHIST	92	92	31	50
74.65 -75.10	SCHIST	53	7	0	20
75.10 -79.80	SCHIST	83	25	8	20
79.80 -82.60	SCHIST	60	14	6	20
82.60 -85.00	SCHIST	95	89	58	125

Figure E.2 ROCKMASS outputs of the SK-6+180 borehole.

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
50.00 -51.00	SCHIST	SW	P. SR	L	0.01	3 H
51.00 -54.70	SCHIST	MW	P. SR	L	-	3 H
54.70 -55.95	SCHIST	SW	U. SR	L	0.01	3 H
55.95 -56.70	SCHIST	HW	-	-	-	.9 H
56.70 -57.35	SCHIST	SW	P. SR	H	0.5	0 -
57.35 -58.35	SCHIST	HW	P. SR	H	-	3 H
58.35 -59.10	schìst	MW	U. SR	H	0.5	0 -
59.10 -64.15	SCHIST	HW	-	-	-	3 H
64.15 -65.10	SCHIST	SW	P. SR	H	0.5	0 -
65.10 -65.70	SCHIST	MW	P. SR	H	-	3 H
65.70 -66.30	SCHIST	SW	P. R	H	0.5	0 -
66.30 -67.15	SCHIST	HW	P. R	H	-	.9 H
67.15 -68.25	SCHIST	SW	P. SR	H	0.5	0 -
68.25 -70.70	SCHIST	MW	-	-	-	0 -
70.70 -73.55	SCHIST	MW	P. S	H	0.5	0 -
73.55 -74.00	SCHIST	MW	-	-	-	0 -
74.00 -74.65	SCHIST	MW	P. S	H	0.5	0 -
74.65 -75.10	SCHIST	MW	-	-	-	0 -
75.10 -79.80	SCHIST	MW	-	-	-	0 -
79.80 -82.60	SCHIST	HW	-	-	-	.9 H
82.60 -85.00	SCHIST	MW	P. R	H	0.5	0 -

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
50.00 -51.00	SCHIST	6	10	9	14	7	-5	1.13
51.00 -54.70	SCHIST	4	0	3	10	7	%-10	1.00
54.70 -55.95	SCHIST	6	14	9	14	7	-5	1.15
55.95 -56.70	SCHIST	3	0	3	10	7	-12	0.97
56.70 -57.35	SCHIST	6	8	8	14	7	-5	1.13
57.35 -58.35	SCHIST	3	0	2	7	7	-12	0.90
58.35 -59.10	schìst	6	10	8	15	7	-5	1.10
59.10 -64.15	SCHIST	4	5	3	9	7	-5	1.00
64.15 -65.10	SCHIST	6	11	9	14	7	-5	1.15
65.10 -65.70	SCHIST	4	0	3	10	7	-5	1.01
65.70 -66.30	SCHIST	6	6	9	15	7	-5	1.15
66.30 -67.15	SCHIST	2	0	2	8	7	-12	0.93
67.15 -68.25	SCHIST	6	8	8	14	7	-5	1.15
68.25 -70.70	SCHIST	3	0	3	17	7	-12	0.93
70.70 -73.55	SCHIST	7	11	11	12	7	-5	1.13
73.55 -74.00	SCHIST	3	0	3	15	7	-12	0.83
74.00 -74.65	SCHIST	7	8	8	12	7	-5	1.10
74.65 -75.10	SCHIST	3	0	3	15	7	-11	0.86
75.10 -79.80	SCHIST	4	4	3	17	7	-5	1.04
79.80 -82.60	SCHIST	4	3	3	10	7	-9	0.90
82.60 -85.00	SCHIST	7	13	10	14	7	-5	1.11

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
50.00 -51.00	SCHIST	42	6	1.0	2.00	.66	5.0
51.00 -54.70	SCHIST	10	20	1.0	4.00	.66	5.0
54.70 -55.95	SCHIST	66	6	1.5	2.00	.66	7.5
55.95 -56.70	SCHIST	10	20	1.0	4.00	.66	5.0
56.70 -57.35	SCHIST	32	3.0	1.5	2.00	.66	7.5
57.35 -58.35	SCHIST	10	20	1.0	5	.66	5.0
58.35 -59.10	schìst	44	3.0	3	2.00	.66	7.5
59.10 -64.15	SCHIST	10	20	1.0	4.00	.66	5.0
64.15 -65.10	SCHIST	48	2.0	1.0	2.00	.66	7.5
65.10 -65.70	SCHIST	10	20	1.0	4.00	.66	5.0
65.70 -66.30	SCHIST	10	3.0	1.5	2.00	.66	7.5
66.30 -67.15	SCHIST	10	20	1.0	5	.66	5.0
67.15 -68.25	SCHIST	28	3.0	1.0	2.00	.66	7.5
68.25 -70.70	SCHIST	10	20	1.0	2.00	.66	5.0
70.70 -73.55	SCHIST	47	3.0	1.0	2.00	.66	7.5
73.55 -74.00	SCHIST	10	20	1.0	2.00	.66	5.0
74.00 -74.65	SCHIST	31	3.0	1.5	2.00	.66	7.5
74.65 -75.10	SCHIST	10	20	1.0	2.00	.66	7.5
75.10 -79.80	SCHIST	10	20	1.0	2.00	.66	10.0
79.80 -82.60	SCHIST	10	20	1.0	4.00	.66	7.5
82.60 -85.00	SCHIST	58	3.0	1.5	2.00	.66	5.0

Figure E.2 (Continued).

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
50.00 -51.00	SCHIST	42	45	0.46
51.00 -54.70	SCHIST	0	15	0.02
54.70 -55.95	SCHIST	66	50	0.73
55.95 -56.70	SCHIST	0	10	0.02
56.70 -57.35	SCHIST	32	42	0.70
57.35 -58.35	SCHIST	0	6	0.01
58.35 -59.10	schist	44	44	1.94
59.10 -64.15	SCHIST	16	24	0.03
64.15 -65.10	SCHIST	48	46	1.06
65.10 -65.70	SCHIST	0	20	0.02
65.70 -66.30	SCHIST	18	40	0.40
66.30 -67.15	SCHIST	0	6	0.01
67.15 -68.25	SCHIST	28	41	0.41
68.25 -70.70	SCHIST	0	16	0.03
70.70 -73.55	SCHIST	47	46	0.69
73.55 -74.00	SCHIST	0	13	0.03
74.00 -74.65	SCHIST	31	39	0.68
74.65 -75.10	SCHIST	0	14	0.02
75.10 -79.80	SCHIST	8	31	0.02
79.80 -82.60	SCHIST	6	16	0.01
82.60 -85.00	SCHIST	58	49	1.91

Figure E.2 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
26.70 - 31.45	SCHIST	80	5	20	50	BST4	0	74	MW	-	-	-	-	1	H
31.45 - 31.95	SCHIST	5.0	52	96	14	0	0	97	SW	P.	R	H	0.5	0	-
31.95 - 32.50	SCHIST	75	0	4	50	BST3	0	42	MW	-	-	-	-	0	-
32.50 - 34.25	SCHIST	5.0	17	63	11	0	0	68	MW	P.	SR	M	0.0	3	H
34.25 - 36.80	SCHIST	80	7	25	50	BST4	0	72	MW	-	-	-	-	0	-
36.80 - 37.80	SCHIST	5.0	21	48	12	0	0	79	MW	P.	SR	M	0.0	3	H
37.80 - 42.50	SCHIST	80	3	25	50	BST4	0	70	MW	-	-	-	-	0	-
42.50 - 63.00	schist	4.0	2	14	50	BST3	0	59	MW	-	-	-	-	3	H

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
26.70 -31.45	SCHIST	77	20	5	20
31.45 -31.95	SCHIST	100	96	52	71
31.95 -32.50	SCHIST	44	4	0	20
32.50 -34.25	SCHIST	71	63	17	90
34.25 -36.80	SCHIST	75	25	7	20
36.80 -37.80	SCHIST	82	48	21	83
37.80 -42.50	SCHIST	73	25	3	20
42.50 -63.00	schist	61	14	2	20

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
26.70 -31.45	SCHIST	MW	-	-	-	.9 |H
31.45 -31.95	SCHIST	SW	P. R	H	0.5	0 -
31.95 -32.50	SCHIST	MW	P. R	H	-	0 -
32.50 -34.25	SCHIST	MW	P. SR	M	0.01	3 |H
34.25 -36.80	SCHIST	MW	-	-	-	0 -
36.80 -37.80	SCHIST	MW	P. SR	M	0.01	3 |H
37.80 -42.50	SCHIST	MW	-	-	-	0 -
42.50 -63.00	schist	MW	-	-	-	3 |H

Figure E.3 ROCKMASS outputs of the SK-6+280 borehole.

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
26.70 -31.45	SCHIST	8	2	3	13	15	-7	0.99
31.45 -31.95	SCHIST	9	12	9	15	15	-5	1.13
31.95 -32.50	SCHIST	8	0	3	15	15	-12	0.81
32.50 -34.25	SCHIST	9	6	9	9	15	-5	0.95
34.25 -36.80	SCHIST	8	3	3	17	15	-5	0.98
36.80 -37.80	SCHIST	9	6	9	9	15	-5	1.02
37.80 -42.50	SCHIST	8	1	3	17	15	-5	0.97
42.50 -63.00	schist	8	1	3	9	15	-9	0.90

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
26.70 -31.45	SCHIST	10	20	1.0	4.00	1	7.5
31.45 -31.95	SCHIST	52	2.0	1.5	2.00	1	7.5
31.95 -32.50	SCHIST	10	20	1.0	2.00	1	5.0
32.50 -34.25	SCHIST	10	3.0	1.5	2.00	1	7.5
34.25 -36.80	SCHIST	10	20	1.0	2.00	1	5.0
36.80 -37.80	SCHIST	10	4.0	1.5	2.00	1	7.5
37.80 -42.50	SCHIST	10	20	1.0	2.00	1	7.5
42.50 -63.00	schist	10	20	1.0	4.00	1	10.0

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
26.70 -31.45	SCHIST	5	34	0.02
31.45 -31.95	SCHIST	52	59	2.60
31.95 -32.50	SCHIST	0	25	0.05
32.50 -34.25	SCHIST	17	42	0.57
34.25 -36.80	SCHIST	7	41	0.05
36.80 -37.80	SCHIST	21	45	0.52
37.80 -42.50	SCHIST	3	39	0.03
42.50 -63.00	schist	2	26	0.01

Figure E.3 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM																
INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
41.50 - 42.05	SCHIST	3.0	95	95	7	0	0	99	SW	P.	SR	H	0.0	3	H
42.05 - 43.10	SCHIST	20	0	20	50	BST3	0	83	MW	-	-	-	-	0	-
43.10 - 43.50	SCHIST	3.0	63	83	10	0	0	99	MW	P.	S	H	0.0	1	H
43.50 - 44.00	SCHIST	10	0	0	500	BST2	0	75	HW	-	-	-	-	0	-
44.00 - 44.30	SCHIST	3.0	50	80	20	0	0	90	MW	P.	SR	H	0.5	0	-
44.30 - 44.90	SCHIST	10	0	10	500	BST2	0	60	HW	-	-	-	-	0	-
44.90 - 46.80	SCHIST	95	26	95	16	0	0	98	MW	P.	SR	H	0.5	0	-
46.80 - 47.40	SCHIST	10	0	0	500	BST2	0	97	HW	-	-	-	-	3	H
47.40 - 47.90	SCHIST	95	38	94	12	0	0	93	SW	P.	SR	H	0.5	0	-
47.90 - 48.95	SCHIST	10	0	6	50	BST3	0	85	HW	-	-	-	-	0	-
48.95 - 49.80	SCHIST	95	64	78	8	0	0	97	SW	P.	SR	H	0.5	0	-
49.80 - 50.50	SCHIST	10	0	4	500	BST2	0	99	HW	-	-	-	-	0	-
50.50 - 52.40	SCHIST	20	7	19	50	BST3	0	83	HW	-	-	-	-	0	-
52.40 - 54.20	SCHIST	20	14	25	50	BST4	0	99	MW	-	-	-	-	0	-
54.20 - 55.90	SCHIST	10	0	8	50	BST3	0	85	MW	-	-	-	-	0	-
55.90 - 57.40	SCHIST	85	20	85	18	0	0	96	MW	P.	SR	M	0.0	3	H
57.40 - 61.40	SCHIST	20	3	21	50	BST3	0	80	MW	-	-	-	-	0	-
61.40 - 62.40	SCHIST	85	20	88	12	0	0	95	MW	P.	SR	H	0.0	9	H
62.40 - 63.90	SCHIST	20	0	25	50	BST3	0	76	MW	-	-	-	-	0	-
63.90 - 64.50	SCHIST	2.0	33	85	15	0	0	99	MW	P.	SR	H	0.0	1	H
64.50 - 64.80	SCHIST	10	0	0	500	BST2	0	95	HW	-	-	-	-	0	-
64.80 - 65.40	SCHIST	2.0	0	42	21	0	0	99	MW	P.	SR	M	0.0	3	H
65.40 - 65.90	SCHIST	10	0	0	500	BST2	0	95	HW	-	-	-	-	0	-
66.90 - 67.65	SCHIST	25	0	25	50	BST4	0	96	MW	-	-	-	-	3	H
67.65 - 69.00	SCHIST	15	0	13	500	BST2	0	75	HW	-	-	-	-	0	-
69.00 - 72.80	SCHIST	20	0	25	50	BST4	0	98	MW	-	-	-	-	3	H
72.80 - 73.10	SCHIST	20	0	100	16	0	0	99	MW	P.	SR	H	0.0	3	H
73.10 - 73.50	SCHIST	10	0	0	50	BST3	0	98	MW	-	-	-	-	3	H
73.50 - 75.00	SCHIST	2.0	39	92	13	0	0	99	MW	P.	S	H	0.0	1	H
75.00 - 75.25	SCHIST	10	0	0	50	BST3	0	98	MW	-	-	-	-	0	-
75.25 - 76.00	SCHIST	2.0	27	91	21	0	0	99	MW	U.	R	L	0.0	3	H

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)					
INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
41.50 -42.05	SCHIST	96	95	95	142
42.05 -43.10	SCHIST	84	20	0	20
43.10 -43.50	SCHIST	100	83	63	100
43.50 -44.00	SCHIST	76	0	0	2
44.00 -44.30	SCHIST	90	80	50	50
44.30 -44.90	SCHIST	60	10	0	2
44.90 -46.80	SCHIST	98	95	26	62
46.80 -47.40	SCHIST	98	0	0	2
47.40 -47.90	SCHIST	94	94	38	83
47.90 -48.95	SCHIST	86	6	0	20
48.95 -49.80	SCHIST	98	78	64	125
49.80 -50.50	SCHIST	100	4	0	2
50.50 -52.40	SCHIST	84	19	7	20
52.40 -54.20	SCHIST	100	25	14	20
54.20 -55.90	SCHIST	86	8	0	20
55.90 -57.40	SCHIST	97	85	20	55
57.40 -61.40	SCHIST	81	21	3	20
61.40 -62.40	SCHIST	96	88	20	83
62.40 -63.90	SCHIST	77	25	0	20
63.90 -64.50	SCHIST	100	85	33	66
64.50 -64.80	SCHIST	100	0	0	2
64.80 -65.40	SCHIST	100	42	0	47
65.40 -65.90	SCHIST	96	0	0	2
66.90 -67.65	SCHIST	97	25	0	20
67.65 -69.00	SCHIST	76	13	0	2
69.00 -72.80	SCHIST	99	25	0	20
72.80 -73.10	SCHIST	100	100	0	62
73.10 -73.50	SCHIST	100	0	0	20
73.50 -75.00	SCHIST	100	92	39	76
75.00 -75.25	SCHIST	100	0	0	20
75.25 -76.00	SCHIST	100	91	27	47

Figure E.4 ROCKMASS outputs of the SK-6+400 borehole.

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
41.50 -42.05	SCHIST	SW	P. SR	H	0.01	3 H
42.05 -43.10	SCHIST	MW	-	-	-	0 -
43.10 -43.50	SCHIST	MW	P. S	H	0.01	.5 H
43.50 -44.00	SCHIST	HW	-	-	-	0 -
44.00 -44.30	SCHIST	MW	P. SR	H	0.5	0 -
44.30 -44.90	SCHIST	HW	-	-	-	0 -
44.90 -46.80	SCHIST	MW	P. SR	H	0.5	0 -
46.80 -47.40	SCHIST	HW	-	-	-	3 H
47.40 -47.90	SCHIST	SW	P. SR	H	0.5	0 -
47.90 -48.95	SCHIST	HW	-	-	-	0 -
48.95 -49.80	SCHIST	SW	P. SR	H	0.5	0 -
49.80 -50.50	SCHIST	HW	-	-	-	0 -
50.50 -52.40	SCHIST	HW	-	-	-	0 -
52.40 -54.20	SCHIST	MW	-	-	-	0 -
54.20 -55.90	SCHIST	MW	-	-	-	0 -
55.90 -57.40	SCHIST	MW	P. SR	M	0.01	3 H
57.40 -61.40	SCHIST	MW	-	-	-	0 -
61.40 -62.40	SCHIST	MW	P. SR	H	0.01	9 H
62.40 -63.90	SCHIST	MW	-	-	-	0 -
63.90 -64.50	SCHIST	MW	P. SR	H	0.01	.5 H
64.50 -64.80	SCHIST	HW	-	-	-	0 -
64.80 -65.40	SCHIST	MW	P. SR	M	0.01	3 H
65.40 -65.90	SCHIST	HW	-	-	-	0 -
66.90 -67.65	SCHIST	MW	-	-	-	3 H
67.65 -69.00	SCHIST	HW	-	-	-	0 -
69.00 -72.80	SCHIST	MW	-	-	-	3 H
72.80 -73.10	SCHIST	MW	P. SR	H	0.01	3 H
73.10 -73.50	SCHIST	MW	-	-	-	3 H
73.50 -75.00	SCHIST	MW	P. S	H	0.01	.5 H
75.00 -75.25	SCHIST	MW	-	-	-	0 -
75.25 -76.00	SCHIST	MW	U. R	L	0.01	3 H

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
41.50 -42.05	SCHIST	7	19	10	7	15	-5	1.15
42.05 -43.10	SCHIST	4	0	3	15	15	-7	1.04
43.10 -43.50	SCHIST	7	14	9	10	15	-5	1.15
43.50 -44.00	SCHIST	3	0	2	12	15	-12	1.00
44.00 -44.30	SCHIST	7	11	8	13	15	-5	1.09
44.30 -44.90	SCHIST	3	0	2	12	15	-10	0.91
44.90 -46.80	SCHIST	9	7	9	13	15	-5	1.14
46.80 -47.40	SCHIST	3	0	2	7	15	-12	1.13
47.40 -47.90	SCHIST	9	9	9	14	15	-5	1.11
47.90 -48.95	SCHIST	3	0	3	14	15	-12	1.06
48.95 -49.80	SCHIST	9	14	10	14	15	-5	1.13
49.80 -50.50	SCHIST	3	0	2	12	15	-12	1.15
50.50 -52.40	SCHIST	4	3	3	14	15	-7	1.04
52.40 -54.20	SCHIST	4	5	3	17	15	-5	1.15
54.20 -55.90	SCHIST	3	0	3	15	15	-11	1.06
55.90 -57.40	SCHIST	8	6	8	9	15	-5	1.13
57.40 -61.40	SCHIST	4	1	3	15	15	-6	1.03
61.40 -62.40	SCHIST	8	6	9	3	15	-5	1.12
62.40 -63.90	SCHIST	4	0	3	15	15	-5	1.00
63.90 -64.50	SCHIST	5	8	9	10	15	-5	1.15
64.50 -64.80	SCHIST	3	0	2	12	15	-12	1.12
64.80 -65.40	SCHIST	5	0	8	9	15	-5	1.15
65.40 -65.90	SCHIST	3	0	2	12	15	-12	1.12
66.90 -67.65	SCHIST	4	0	3	10	15	-5	1.13
67.65 -69.00	SCHIST	3	0	2	12	15	-9	1.00
69.00 -72.80	SCHIST	4	0	3	10	15	-5	1.14
72.80 -73.10	SCHIST	4	0	9	7	15	-5	1.15
73.10 -73.50	SCHIST	3	0	3	9	15	-12	1.14
73.50 -75.00	SCHIST	5	9	9	10	15	-5	1.15
75.00 -75.25	SCHIST	3	0	3	15	15	-12	1.14
75.25 -76.00	SCHIST	5	7	8	14	15	-5	1.15

Figure E.4 (Continued).

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
41.50 -42.05	SCHIST	95	2.0	1.0	2.00	1	5.0
42.05 -43.10	SCHIST	10	20	1.0	2.00	1	5.0
43.10 -43.50	SCHIST	63	3.0	1.0	2.00	1	7.5
43.50 -44.00	SCHIST	10	20	1.0	5	1	5.0
44.00 -44.30	SCHIST	50	2.0	1.0	2.00	1	7.5
44.30 -44.90	SCHIST	10	20	1.0	5	1	5.0
44.90 -46.80	SCHIST	26	3.0	1.0	2.00	1	7.5
46.80 -47.40	SCHIST	10	20	1.0	4.00	1	5.0
47.40 -47.90	SCHIST	38	2.0	1.0	0.75	1	7.5
47.90 -48.95	SCHIST	10	20	1.0	2.00	1	5.0
48.95 -49.80	SCHIST	64	3.0	1.0	0.75	1	7.5
49.80 -50.50	SCHIST	10	20	1.0	5	1	7.5
50.50 -52.40	SCHIST	10	20	1.0	2.00	1	10.0
52.40 -54.20	SCHIST	10	20	1.0	2.00	1	10.0
54.20 -55.90	SCHIST	10	20	1.0	2.00	1	7.5
55.90 -57.40	SCHIST	10	3.0	1.0	2.00	1	7.5
57.40 -61.40	SCHIST	10	20	1.0	2.00	1	5.0
61.40 -62.40	SCHIST	10	3.0	1.0	2.00	1	7.5
62.40 -63.90	SCHIST	10	20	1.0	2.00	1	5.0
63.90 -64.50	SCHIST	33	6	1.5	2.00	1	7.5
64.50 -64.80	SCHIST	10	20	1.0	5	1	5.0
64.80 -65.40	SCHIST	10	3.0	1.0	2.00	1	7.5
65.40 -65.90	SCHIST	10	20	1.0	5	1	7.5
66.90 -67.65	SCHIST	10	20	1.0	4.00	1	10.0
67.65 -69.00	SCHIST	10	20	1.0	5	1	10.0
69.00 -72.80	SCHIST	10	20	1.0	4.00	1	7.5
72.80 -73.10	SCHIST	10	3.0	1.0	2.00	1	7.5
73.10 -73.50	SCHIST	10	20	1.0	4.00	1	5.0
73.50 -75.00	SCHIST	39	6	1.5	2.00	1	7.5
75.00 -75.25	SCHIST	10	20	1.0	2.00	1	5.0
75.25 -76.00	SCHIST	27	6	1.5	2.00	1	5.0

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
41.50 -42.05	SCHIST	95	58	4.75
42.05 -43.10	SCHIST	0	31	0.05
43.10 -43.50	SCHIST	63	54	1.40
43.50 -44.00	SCHIST	0	20	0.02
44.00 -44.30	SCHIST	50	52	1.67
44.30 -44.90	SCHIST	0	20	0.02
44.90 -46.80	SCHIST	26	51	0.58
46.80 -47.40	SCHIST	0	16	0.03
47.40 -47.90	SCHIST	38	54	3.38
47.90 -48.95	SCHIST	0	24	0.05
48.95 -49.80	SCHIST	64	61	3.79
49.80 -50.50	SCHIST	0	22	0.01
50.50 -52.40	SCHIST	7	33	0.03
52.40 -54.20	SCHIST	14	43	0.04
54.20 -55.90	SCHIST	0	26	0.03
55.90 -57.40	SCHIST	20	45	0.44
57.40 -61.40	SCHIST	3	32	0.05
61.40 -62.40	SCHIST	20	39	0.44
62.40 -63.90	SCHIST	0	32	0.05
63.90 -64.50	SCHIST	33	46	0.55
64.50 -64.80	SCHIST	0	22	0.02
64.80 -65.40	SCHIST	0	35	0.22
65.40 -65.90	SCHIST	0	22	0.01
66.90 -67.65	SCHIST	0	29	0.01
67.65 -69.00	SCHIST	0	23	0.01
69.00 -72.80	SCHIST	0	29	0.02
72.80 -73.10	SCHIST	0	31	0.22
73.10 -73.50	SCHIST	0	19	0.03
73.50 -75.00	SCHIST	39	47	0.65
75.00 -75.25	SCHIST	0	26	0.05
75.25 -76.00	SCHIST	27	49	0.68

Figure E.4 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
46.80 - 47.50	SCHIST	30	0	25	50	BST4	25	68	MW	-	-	-	-	3	H
47.50 - 48.00	SCHIST	1.9	94	100	4	0	25	98	SW	U.	SR	H	0.5	0	-
48.00 - 48.80	SCHIST	30	0	25	50	BST4	25	76	MW	-	-	-	-	0	-
48.80 - 49.15	SCHIST	1.9	34	100	14	0	25	98	MW	U.	R	L	0.0	3	H
49.15 - 50.00	SCHIST	30	12	25	50	BST3	25	65	MW	-	-	-	-	0	-
50.00 - 50.70	SCHIST	1.9	31	91	12	0	25	92	SW	U.	SR	H	0.0	3	H
50.70 - 52.90	SCHIST	30	5	19	50	BST4	25	76	MW	-	-	-	-	0	-
52.90 - 54.35	SCHIST	2.5	57	93	11	0	25	91	MW	U.	SR	H	0.0	3	H
54.35 - 55.10	SCHIST	10	0	8	500	BST2	25	50	HW	-	-	-	-	0	-
55.10 - 58.10	SCHIST	66	19	81	15	0	25	95	MW	U.	R	H	0.0	3	H
58.10 - 60.20	SCHIST	15	0	12	50	BST3	25	78	HW	-	-	-	-	0	-
60.20 - 61.50	SCHIST	2.4	77	92	6	0	25	96	SW	P.	SR	H	0.5	0	-
61.50 - 64.50	SCHIST	20	7	20	50	BST4	25	65	MW	-	-	-	-	0	-
64.50 - 65.20	SCHIST	2.4	0	86	15	0	25	90	SW	U.	SR	H	0.5	0	-
65.20 - 66.70	SCHIST	15	0	4	50	BST4	25	65	MW	-	-	-	-	0	-
66.70 - 67.00	SCHIST	3.0	37	83	20	0	25	98	MW	U.	SR	H	0.5	0	-
67.00 - 68.10	schist	15	0	9	50	BST3	25	55	HW	-	-	-	-	0	-
68.10 - 68.70	SCHIST	3.0	28	75	13	0	25	0	MW	P.	SR	H	0.5	0	-
68.70 - 69.10	SCHIST	15	0	13	50	BST3	25	50	HW	-	-	-	-	0	-
69.10 - 74.10	SCHIST	3.6	19	60	10	0	25	77	MW	P.	SR	H	0.0	3	H
74.10 - 75.60	SCHIST	10	0	13	500	BST2	25	40	HW	-	-	-	-	0	-
75.60 - 76.20	RE-LST	3.0	0	25	50	BST4	25	85	MW	-	-	-	-	0	-
76.20 - 76.70	RE-LST	4.0	32	86	16	0	25	85	SW	P.	SR	M	0.5	0	-
76.70 - 80.00	RE-LST	3.0	9	23	50	BST3	25	57	MW	-	-	-	-	0	-

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
46.80 -47.50	SCHIST	70	25	0	20
47.50 -48.00	SCHIST	100	100	94	250
48.00 -48.80	SCHIST	78	25	0	20
48.80 -49.15	SCHIST	100	100	34	71
49.15 -50.00	SCHIST	67	25	12	20
50.00 -50.70	SCHIST	94	91	31	83
50.70 -52.90	SCHIST	78	19	5	20
52.90 -54.35	SCHIST	93	93	57	90
54.35 -55.10	SCHIST	51	8	0	2
55.10 -58.10	SCHIST	96	81	19	66
58.10 -60.20	SCHIST	80	12	0	20
60.20 -61.50	SCHIST	98	92	77	166
61.50 -64.50	SCHIST	67	20	7	20
64.50 -65.20	SCHIST	91	86	0	66
65.20 -66.70	SCHIST	68	4	0	20
66.70 -67.00	SCHIST	100	83	37	50
67.00 -68.10	schist	56	9	0	20
68.10 -68.70	SCHIST	92	75	28	76
68.70 -69.10	SCHIST	53	13	0	20
69.10 -74.10	SCHIST	79	60	19	100
74.10 -75.60	SCHIST	42	13	0	2
75.60 -76.20	RE-LST	84	25	0	20
76.20 -76.70	RE-LST	86	86	32	62
76.70 -80.00	RE-LST	58	23	9	20

Figure E.5 ROCKMASS outputs of the SK-6+570 borehole.

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
46.80 -47.50	SCHIST	MW	-	-	-	3 H
47.50 -48.00	SCHIST	SW	U. SR	H	0.5	0 -
48.00 -48.80	SCHIST	MW	-	-	-	0 -
48.80 -49.15	SCHIST	MW	U. R	L	0.01	3 H
49.15 -50.00	SCHIST	MW	U. R	L	-	0 -
50.00 -50.70	SCHIST	SW	U. SR	H	0.01	3 H
50.70 -52.90	SCHIST	MW	-	-	-	0 -
52.90 -54.35	SCHIST	MW	U. SR	H	0.01	3 H
54.35 -55.10	SCHIST	HW	-	-	-	0 -
55.10 -58.10	SCHIST	MW	U. R	H	0.01	3 H
58.10 -60.20	SCHIST	HW	-	-	-	0 -
60.20 -61.50	SCHIST	SW	P. SR	H	0.5	0 -
61.50 -64.50	SCHIST	MW	-	-	-	0 -
64.50 -65.20	SCHIST	SW	U. SR	H	0.5	0 -
65.20 -66.70	SCHIST	MW	-	-	-	0 -
66.70 -67.00	SCHIST	MW	U. SR	H	0.5	0 -
67.00 -68.10	schìst	HW	-	-	-	0 -
68.10 -68.70	SCHIST	MW	P. SR	H	0.5	0 -
68.70 -69.10	SCHIST	HW	-	-	-	0 -
69.10 -74.10	SCHIST	MW	P. SR	H	0.01	3 H
74.10 -75.60	SCHIST	HW	-	-	-	0 -
75.60 -76.20	RE-LST	MW	-	-	-	0 -
76.20 -76.70	RE-LST	SW	P. SR	M	0.5	0 -
76.70 -80.00	RE-LST	MW	-	-	-	0 -

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
46.80 -47.50	SCHIST	5	0	3	10	7	-5	0.95
47.50 -48.00	SCHIST	5	19	11	16	7	-5	1.14
48.00 -48.80	SCHIST	5	0	3	17	7	-5	1.00
48.80 -49.15	SCHIST	5	9	9	14	7	-5	1.14
49.15 -50.00	SCHIST	5	5	3	15	7	-5	0.94
50.00 -50.70	SCHIST	5	8	9	7	7	-5	1.10
50.70 -52.90	SCHIST	5	2	3	17	7	-7	1.00
52.90 -54.35	SCHIST	6	13	9	7	7	-5	1.10
54.35 -55.10	SCHIST	3	0	2	12	7	-11	0.85
55.10 -58.10	SCHIST	7	6	9	7	7	-5	1.12
58.10 -60.20	SCHIST	3	0	3	14	7	%-10	1.01
60.20 -61.50	SCHIST	6	16	10	14	7	-5	1.13
61.50 -64.50	SCHIST	4	3	3	17	7	-7	0.94
64.50 -65.20	SCHIST	6	0	9	16	7	-5	1.09
65.20 -66.70	SCHIST	3	0	3	17	7	-12	0.94
66.70 -67.00	SCHIST	7	9	8	15	7	-5	1.14
67.00 -68.10	schìst	3	0	3	14	7	-11	0.88
68.10 -68.70	SCHIST	7	8	9	13	7	-5	0.60
68.70 -69.10	SCHIST	3	0	3	14	7	-9	0.85
69.10 -74.10	SCHIST	8	6	9	7	7	-5	1.01
74.10 -75.60	SCHIST	3	0	2	12	7	-9	0.80
75.60 -76.20	RE-LST	7	0	3	17	7	-5	1.06
76.20 -76.70	RE-LST	8	8	9	15	7	-5	1.06
76.70 -80.00	RE-LST	7	4	3	15	7	-6	0.89

Figure E.5 (Continued).

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
46.80 -47.50	SCHIST	10	20	1.0	4.00	.66	7.5
47.50 -48.00	SCHIST	94	2.0	2	2.00	.66	7.5
48.00 -48.80	SCHIST	10	20	1.0	2.00	.66	5.0
48.80 -49.15	SCHIST	34	2.0	2	2.00	.66	7.5
49.15 -50.00	SCHIST	10	20	1.0	2.00	.66	5.0
50.00 -50.70	SCHIST	31	2.0	2	2.00	.66	7.5
50.70 -52.90	SCHIST	10	20	1.0	2.00	.66	5.0
52.90 -54.35	SCHIST	57	4.0	2	2.00	.66	7.5
54.35 -55.10	SCHIST	10	20	1.0	5	.66	5.0
55.10 -58.10	SCHIST	10	6	3	2.00	.66	7.5
58.10 -60.20	SCHIST	10	20	1.0	2.00	.66	5.0
60.20 -61.50	SCHIST	77	2.0	1.0	2.00	.66	7.5
61.50 -64.50	SCHIST	10	20	1.0	2.00	.66	5.0
64.50 -65.20	SCHIST	10	3.0	2	2.00	.66	7.5
65.20 -66.70	SCHIST	10	20	1.0	2.00	.66	5.0
66.70 -67.00	SCHIST	37	2.0	2	2.00	.66	7.5
67.00 -68.10	schist	10	20	1.0	2.00	.66	5.0
68.10 -68.70	SCHIST	28	3.0	1.0	2.00	.66	10.0
68.70 -69.10	SCHIST	10	20	1.0	2.00	.66	5.0
69.10 -74.10	SCHIST	10	6	1.0	2.00	.66	7.5
74.10 -75.60	SCHIST	10	20	1.0	5	.66	7.5
75.60 -76.20	RE-LST	10	20	1.0	2.00	.66	7.5
76.20 -76.70	RE-LST	32	2.0	1.0	1.00	.66	7.5
76.70 -80.00	RE-LST	10	20	1.0	2.00	.66	7.5

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
46.80 -47.50	SCHIST	0	19	0.01
47.50 -48.00	SCHIST	94	58	4.14
48.00 -48.80	SCHIST	0	27	0.03
48.80 -49.15	SCHIST	34	42	1.50
49.15 -50.00	SCHIST	12	28	0.04
50.00 -50.70	SCHIST	31	33	1.36
50.70 -52.90	SCHIST	5	27	0.03
52.90 -54.35	SCHIST	57	39	1.25
54.35 -55.10	SCHIST	0	11	0.01
55.10 -58.10	SCHIST	19	33	0.42
58.10 -60.20	SCHIST	0	18	0.03
60.20 -61.50	SCHIST	77	52	1.69
61.50 -64.50	SCHIST	7	26	0.03
64.50 -65.20	SCHIST	0	34	0.29
65.20 -66.70	SCHIST	0	17	0.03
66.70 -67.00	SCHIST	37	45	1.63
67.00 -68.10	schist	0	15	0.03
68.10 -68.70	SCHIST	28	27	0.31
68.70 -69.10	SCHIST	0	16	0.03
69.10 -74.10	SCHIST	19	32	0.14
74.10 -75.60	SCHIST	0	12	0.01
75.60 -76.20	RE-LST	0	30	0.02
76.20 -76.70	RE-LST	32	44	1.41
76.70 -80.00	RE-LST	9	27	0.02

Figure E.5 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
0.00 - 7.50	LIMEST	10	0	2	500	BST2	0	22	HW	-	-	-	-	0	-
7.50 - 16.00	LIMEST	10	9	13	500	BST2	0	24	HW	-	-	-	-	0	-
16.00 - 33.50	LIMEST	20	1	1	500	BST2	0	29	HW	-	-	-	-	0	-
33.50 - 48.00	LIMEST	10	8	16	500	BST2	0	24	HW	-	-	-	-	0	-
48.00 - 49.00	LIMEST	5.0	40	53	4	0	0	51	MW	U.	R	L	3.0	0	-
49.00 - 52.00	LIMEST	5.0	15	58	11	0	0	77	HW	P.	SR	L	0.5	0	-

Figure E.6 ROCKMASS outputs of the SK-6+880 borehole.

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
0.00 -7.50	LIMEST	23	2	0	2
7.50 -16.00	LIMEST	25	13	9	2
16.00 -33.50	LIMEST	30	1	1	2
33.50 -48.00	LIMEST	25	16	8	2
48.00 -49.00	LIMEST	53	53	40	250
49.00 -52.00	LIMEST	80	58	15	90

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
0.00 -7.50	LIMEST	HW	-	-	-	0 -
7.50 -16.00	LIMEST	HW	-	-	-	0 -
16.00 -33.50	LIMEST	HW	-	-	-	0 -
33.50 -48.00	LIMEST	HW	-	-	-	0 -
48.00 -49.00	LIMEST	MW	U. R	L	3.0	0 -
49.00 -52.00	LIMEST	HW	P. SR	L	0.5	0 -

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
0.00 -7.50	LIMEST	3	0	2	12	15	-12	0.70
7.50 -16.00	LIMEST	3	4	2	12	15	-9	0.71
16.00 -33.50	LIMEST	4	0	2	12	15	-12	0.74
33.50 -48.00	LIMEST	3	4	2	12	15	-8	0.71
48.00 -49.00	LIMEST	9	10	11	18	15	-5	0.86
49.00 -52.00	LIMEST	9	5	9	15	15	-5	1.01

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
0.00 -7.50	LIMEST	10	20	1.0	8	1	10.0
7.50 -16.00	LIMEST	10	20	1.0	8	1	10.0
16.00 -33.50	LIMEST	10	20	1.0	8	1	10.0
33.50 -48.00	LIMEST	10	20	1.0	5	1	7.5
48.00 -49.00	LIMEST	40	2.0	3	2.00	1	5.0
49.00 -52.00	LIMEST	10	3.0	1.0	2.00	1	2.5

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
0.00 -7.50	LIMEST	0	15	0.01
7.50 -16.00	LIMEST	9	21	0.01
16.00 -33.50	LIMEST	1	17	0.01
33.50 -48.00	LIMEST	8	22	0.01
48.00 -49.00	LIMEST	40	53	6.0
49.00 -52.00	LIMEST	15	49	1.00

Figure E.6 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM

INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
15.30 - 21.10	CONGLO	15	94	99	3	0	0	99	HW	P.	VR	L	3.0	0	-
21.10 - 21.30	SHALE	5.0	0	25	50	BST4	0	20	HW	-	-	-	-	0	-
21.30 - 23.38	CONGLO	15	93	100	3	0	0	99	MW	P.	SR	H	0.5	0	-
23.38 - 26.05	SHALE	5.0	45	70	6	0	0	25	MW	P.	SR	H	0.5	0	-
26.05 - 29.60	SH-SST	10	85	89	3	0	0	30	MW	P.	SR	H	0.5	0	-
29.60 - 31.00	SH-SST	10	0	25	50	BST4	0	30	HW	-	-	-	-	0	-
31.00 - 31.40	SH-SST	10	28	100	15	0	0	30	SW	P.	SR	H	0.5	0	-
31.40 - 35.00	SST	10	60	82	4	0	0	3	MW	P.	SR	H	0.5	0	-
35.00 - 41.00	SST	10	78	97	4	0	0	10	MW	P.	SR	M	0.5	0	-
41.00 - 43.30	SST	10	76	85	5	0	0	20	MW	P.	SR	M	0.5	0	-
43.30 - 45.00	SH-SST	10	42	79	8	0	0	30	MW	P.	SR	M	0.5	0	-

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)

INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
15.30 -21.10	CONGLO	99	99	94	333
21.10 -21.30	SHALE	80	25	0	20
21.30 -23.38	CONGLO	100	100	93	333
23.38 -26.05	SHALE	71	70	45	166
26.05 -29.60	SH-SST	90	89	85	333
29.60 -31.00	SH-SST	74	25	0	20
31.00 -31.40	SH-SST	100	100	28	66
31.40 -35.00	SST	87	82	60	250
35.00 -41.00	SST	99	97	78	250
41.00 -43.30	SST	85	85	76	200
43.30 -45.00	SH-SST	86	79	42	125

GEOTECHNICAL LOG (JOINT CONDITION)

INTERVAL	ROCK TYPE	WEATH.	ROUGHNESS		PERSIST.	APERT.	FILLING	
15.30 -21.10	CONGLO	HW	P.	VR	L	3.0	0	-
21.10 -21.30	SHALE	HW	P.	VR	L	-	0	-
21.30 -23.38	CONGLO	MW	P.	SR	H	0.5	0	-
23.38 -26.05	SHALE	MW	P.	SR	H	0.5	0	-
26.05 -29.60	SH-SST	MW	P.	SR	H	0.5	0	-
29.60 -31.00	SH-SST	HW	-		-	-	0	-
31.00 -31.40	SH-SST	SW	P.	SR	H	0.5	0	-
31.40 -35.00	SST	MW	P.	SR	H	0.5	0	-
35.00 -41.00	SST	MW	P.	SR	M	0.5	0	-
41.00 -43.30	SST	MW	P.	SR	M	0.5	0	-
43.30 -45.00	SH-SST	MW	P.	SR	M	0.5	0	-

Figure E.7 ROCKMASS outputs of the SK-7+130 borehole.

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM

INTERVAL	ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
15.30 -21.10	CONGLO	3	19	12	14	15	-5	1.15
21.10 -21.30	SHALE	2	0	3	16	15	-5	0.70
21.30 -23.38	CONGLO	3	19	12	13	15	-5	1.15
23.38 -26.05	SHALE	2	10	10	13	15	-5	0.72
26.05 -29.60	SH-SST	3	17	12	13	15	-5	0.75
29.60 -31.00	SH-SST	3	0	3	16	15	-5	0.75
31.00 -31.40	SH-SST	3	8	9	14	15	-5	0.75
31.40 -35.00	SST	3	13	11	13	15	-5	0.61
35.00 -41.00	SST	3	16	11	14	15	-5	0.65
41.00 -43.30	SST	3	16	11	14	15	-5	0.70
43.30 -45.00	SH-SST	3	10	10	14	15	-5	0.75

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
15.30 -21.10	CONGLO	94	2.0	1.5	0.75	1	5.0
21.10 -21.30	SHALE	10	20	1.0	8	1	5.0
21.30 -23.38	CONGLO	93	2.0	1.5	0.75	1	5.0
23.38 -26.05	SHALE	45	3.0	1.0	0.75	1	5.0
26.05 -29.60	SH-SST	85	3.0	1.0	0.75	1	5.0
29.60 -31.00	SH-SST	10	20	1.0	8	1	5.0
31.00 -31.40	SH-SST	28	3.0	1.0	4.00	1	5.0
31.40 -35.00	SST	60	3.0	1.5	3.00	1	5.0
35.00 -41.00	SST	78	3.0	1.0	0.75	1	5.0
41.00 -43.30	SST	76	3.0	1.0	0.75	1	5.0
43.30 -45.00	SH-SST	42	3.0	1.5	0.75	1	5.0

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
15.30 -21.10	CONGLO	94	63	18.8
21.10 -21.30	SHALE	0	25	0.01
21.30 -23.38	CONGLO	93	62	18.6
23.38 -26.05	SHALE	45	38	4.00
26.05 -29.60	SH-SST	85	46	7.6
29.60 -31.00	SH-SST	0	27	0.01
31.00 -31.40	SH-SST	28	36	0.47
31.40 -35.00	SST	60	38	2.00
35.00 -41.00	SST	78	42	6.9
41.00 -43.30	SST	76	43	6.8
43.30 -45.00	SH-SST	42	40	5.6

Figure E.7 (Continued).

INPUT PARAMETERS USED IN M-RMR SYSTEM																
INTERVAL	ROCK TYPE	STR	RQD	ICR	#/m	DSOR	GW	Id2	W	RD	RP	PRS	Ap	FT	FS
0.00 - 6.00	SCHIST	2.0	0	0	999	BST1	0	15	D	-	-	-	-	0	-
6.00 - 20.95	SCHIST	2.0	2	7	500	BST2	0	20	VH	-	-	-	-	0	-
20.95 - 21.40	SCHIST	2.0	27	87	22	0	0	95	HW	P.	R	M	0.0	3	H
21.40 - 25.32	SCHIST	2.0	3	9	500	BST2	0	25	HW	-	-	-	-	0	-
25.32 - 26.20	SCHIST	2.0	82	97	9	0	0	95	MW	P.	SR	M	0.0	3	H
26.20 - 26.70	SCHIST	2.0	0	0	50	BST2	0	40	HW	-	-	-	-	0	-
26.70 - 26.95	SCHIST	2.0	52	100	12	0	0	97	SW	P.	SR	H	0.5	0	-
26.95 - 27.25	SCHIST	2.0	0	0	50	BST3	0	82	HW	-	-	-	-	3	H
27.25 - 27.55	SCHIST	2.0	40	100	10	0	0	97	SW	P.	SR	H	0.0	3	H
27.55 - 27.90	SCHIST	2.0	0	13	10	BST3	0	97	HW	-	-	-	-	3	H
27.90 - 28.40	SCHIST	2.0	30	96	12	0	0	93	SW	P.	SR	H	0.0	3	H
28.40 - 30.50	SCHIST	2.0	0	21	50	BST3	0	57	MW	-	-	-	-	0	-
30.50 - 33.00	SCHIST	2.0	16	63	8	0	0	68	MW	P.	SR	H	0.5	0	-
33.00 - 33.60	SCHIST	2.0	0	10	50	BST3	0	77	MW	-	-	-	-	6	H
33.60 - 34.25	SCHIST	2.0	22	34	6	0	0	63	MW	P.	SR	H	0.5	0	-
34.25 - 36.00	SCHIST	2.0	68	93	8	0	0	94	MW	P.	SR	H	0.5	0	-
36.00 - 36.40	SCHIST	2.0	0	73	27	0	0	70	MW	P.	SR	H	0.5	0	-
36.40 - 37.50	SCHIST	2.0	0	7	500	BST2	0	48	VH	-	-	-	-	3	H
37.50 - 40.80	SCHIST	2.0	21	53	8	0	0	63	MW	P.	SR	H	0.0	3	H
40.80 - 41.30	SCHIST	2.0	0	0	500	BST2	0	70	HW	-	-	-	-	0	-
41.30 - 41.80	SCHIST	2.0	38	92	8	0	0	89	MW	P.	R	H	0.0	3	H
41.80 - 43.20	SCHIST	2.0	0	24	50	BST3	0	68	MW	-	-	-	-	3	H
43.20 - 44.55	SCHIST	2.0	25	68	11	0	0	84	MW	P.	SR	M	0.0	9	H
44.55 - 46.00	SCHIST	2.0	12	25	50	BST4	0	77	MW	-	-	-	-	3	H

GEOTECHNICAL LOG (CORE RECOVERY AND JOINT SPACING)					
INTERVAL	ROCK TYPE	T.C.R. (%)	I.C.R. (%)	RQD (%)	SPACING (mm)
0.00 -6.00	SCHIST	16	0	0	1
6.00 -20.95	SCHIST	23	7	2	2
20.95 -21.40	SCHIST	98	87	27	45
21.40 -25.32	SCHIST	25	9	3	2
25.32 -26.20	SCHIST	99	97	82	111
26.20 -26.70	SCHIST	40	0	0	20
26.70 -26.95	SCHIST	100	100	52	83
26.95 -27.25	SCHIST	87	0	0	20
27.25 -27.55	SCHIST	100	100	40	100
27.55 -27.90	SCHIST	86	13	0	100
27.90 -28.40	SCHIST	96	96	30	83
28.40 -30.50	SCHIST	59	21	0	20
30.50 -33.00	SCHIST	71	63	16	125
33.00 -33.60	SCHIST	80	10	0	20
33.60 -34.25	SCHIST	65	34	22	166
34.25 -36.00	SCHIST	97	93	68	125
36.00 -36.40	SCHIST	73	73	0	37
36.40 -37.50	SCHIST	50	7	0	2
37.50 -40.80	SCHIST	65	53	21	125
40.80 -41.30	SCHIST	72	0	0	2
41.30 -41.80	SCHIST	92	92	38	125
41.80 -43.20	SCHIST	71	24	0	20
43.20 -44.55	SCHIST	87	68	25	90
44.55 -46.00	SCHIST	80	25	12	20

Figure E.8 ROCKMASS outputs of the SK-7+250 borehole.

GEOTECHNICAL LOG (JOINT CONDITION)							
INTERVAL		ROCK TYPE	WEATH.	ROUGHNESS	PERSIST.	APERT.	FILLING
0.00	-6.00	SCHIST	D	-	-	-	0 -
6.00	-20.95	SCHIST	VHW	-	-	-	0 -
20.95	-21.40	SCHIST	HW	P. R	M	0.01	3 H
21.40	-25.32	SCHIST	HW	-	-	-	0 -
25.32	-26.20	SCHIST	MW	P. SR	M	0.01	3 H
26.20	-26.70	SCHIST	HW	-	-	-	0 -
26.70	-26.95	SCHIST	SW	P. SR	H	0.5	0 -
26.95	-27.25	SCHIST	HW	-	-	-	3 H
27.25	-27.55	SCHIST	SW	P. SR	H	0.01	3 H
27.55	-27.90	SCHIST	HW	-	-	-	3 H
27.90	-28.40	SCHIST	SW	P. SR	H	0.01	3 H
28.40	-30.50	SCHIST	MW	-	-	-	0 -
30.50	-33.00	SCHIST	MW	P. SR	H	0.5	0 -
33.00	-33.60	SCHIST	MW	P. SR	H	-	6 H
33.60	-34.25	SCHIST	MW	P. SR	H	0.5	0 -
34.25	-36.00	SCHIST	MW	P. SR	H	0.5	0 -
36.00	-36.40	SCHIST	MW	P. SR	H	0.5	0 -
36.40	-37.50	SCHIST	VHW	-	-	-	3 H
37.50	-40.80	SCHIST	MW	P. SR	H	0.01	3 H
40.80	-41.30	SCHIST	HW	-	-	-	0 -
41.30	-41.80	SCHIST	MW	P. R	H	0.01	3 H
41.80	-43.20	SCHIST	MW	-	-	-	3 H
43.20	-44.55	SCHIST	MW	P. SR	M	0.01	9 H
44.55	-46.00	SCHIST	MW	-	-	-	3 H

PARAMETERS AND RATINGS USED IN M-RMR SYSTEM									
INTERVAL		ROCK	STRI	RQDI	JSI	JCI	GWI	JOI	Fc
0.00	-6.00	SCHIST	5	0	1	8	15	-12	0.67
6.00	-20.95	SCHIST	5	1	2	11	15	-11	0.70
20.95	-21.40	SCHIST	5	7	8	9	15	-5	1.12
21.40	-25.32	SCHIST	5	1	2	12	15	-11	0.72
25.32	-26.20	SCHIST	5	17	9	9	15	-5	1.12
26.20	-26.70	SCHIST	5	0	3	12	15	-12	0.80
26.70	-26.95	SCHIST	5	12	9	14	15	-5	1.13
26.95	-27.25	SCHIST	5	0	3	8	15	-12	1.04
27.25	-27.55	SCHIST	5	10	9	7	15	-5	1.13
27.55	-27.90	SCHIST	5	0	9	8	15	-9	1.13
27.90	-28.40	SCHIST	5	8	9	7	15	-5	1.11
28.40	-30.50	SCHIST	5	0	3	15	15	-6	0.89
30.50	-33.00	SCHIST	5	5	10	13	15	-5	0.95
33.00	-33.60	SCHIST	5	0	3	4	15	-10	1.01
33.60	-34.25	SCHIST	5	7	10	13	15	-5	0.92
34.25	-36.00	SCHIST	5	14	10	13	15	-5	1.11
36.00	-36.40	SCHIST	5	0	8	13	15	-5	0.97
36.40	-37.50	SCHIST	5	0	2	6	15	-11	0.84
37.50	-40.80	SCHIST	5	6	10	7	15	-5	0.92
40.80	-41.30	SCHIST	5	0	2	12	15	-12	0.97
41.30	-41.80	SCHIST	5	9	10	7	15	-5	1.08
41.80	-43.20	SCHIST	5	0	3	9	15	-5	0.95
43.20	-44.55	SCHIST	5	7	9	4	15	-5	1.05
44.55	-46.00	SCHIST	5	5	3	10	15	-5	1.01

Figure E.8 (Continued).

PARAMETERS AND RATINGS USED IN BARTON Q SYSTEM

INTERVAL	ROCK	RQD	Jn	Jr	Ja	Jw	SRF
0.00 -6.00	SCHIST	10	20	1.0	8	1	10.0
6.00 -20.95	SCHIST	10	20	1.0	8	1	7.5
20.95 -21.40	SCHIST	27	2.0	1.0	2.00	1	7.5
21.40 -25.32	SCHIST	10	20	1.0	5	1	5.0
25.32 -26.20	SCHIST	82	2.0	2	2.00	1	7.5
26.20 -26.70	SCHIST	10	20	1.0	5	1	5.0
26.70 -26.95	SCHIST	52	2.0	1.0	0.75	1	7.5
26.95 -27.25	SCHIST	10	20	1.0	4.00	1	5.0
27.25 -27.55	SCHIST	40	2.0	1.0	4.00	1	7.5
27.55 -27.90	SCHIST	10	20	1.0	4.00	1	5.0
27.90 -28.40	SCHIST	30	3.0	1.0	2.00	1	5.0
28.40 -30.50	SCHIST	10	20	1.0	2.00	1	5.0
30.50 -33.00	SCHIST	10	3.0	1.0	2.00	1	7.5
33.00 -33.60	SCHIST	10	20	1.0	4.00	1	5.0
33.60 -34.25	SCHIST	10	3.0	1.0	2.00	1	5.0
34.25 -36.00	SCHIST	68	3.0	1.0	1.00	1	5.0
36.00 -36.40	SCHIST	10	2.0	1.0	2.00	1	7.5
36.40 -37.50	SCHIST	10	20	1.0	5	1	5.0
37.50 -40.80	SCHIST	10	6	1.0	2.00	1	7.5
40.80 -41.30	SCHIST	10	20	1.0	5	1	5.0
41.30 -41.80	SCHIST	38	2.0	1.0	2.00	1	7.5
41.80 -43.20	SCHIST	10	20	1.0	4.00	1	5.0
43.20 -44.55	SCHIST	10	6	2	2.00	1	7.5
44.55 -46.00	SCHIST	10	20	1.0	4.00	1	7.5

FINAL CLASSIFICATION LOGS

INTERVAL	ROCK TYPE	R Q D	M-RMR	BARTON-Q
0.00 -6.00	SCHIST	0	13	0.01
6.00 -20.95	SCHIST	2	18	0.01
20.95 -21.40	SCHIST	27	43	0.90
21.40 -25.32	SCHIST	3	20	0.02
25.32 -26.20	SCHIST	82	55	5.5
26.20 -26.70	SCHIST	0	20	0.02
26.70 -26.95	SCHIST	52	54	4.62
26.95 -27.25	SCHIST	0	20	0.03
27.25 -27.55	SCHIST	40	44	0.67
27.55 -27.90	SCHIST	0	30	0.03
27.90 -28.40	SCHIST	30	41	1.00
28.40 -30.50	SCHIST	0	30	0.05
30.50 -33.00	SCHIST	16	42	0.36
33.00 -33.60	SCHIST	0	17	0.03
33.60 -34.25	SCHIST	22	43	0.73
34.25 -36.00	SCHIST	68	56	4.53
36.00 -36.40	SCHIST	0	35	0.33
36.40 -37.50	SCHIST	0	15	0.02
37.50 -40.80	SCHIST	21	37	0.23
40.80 -41.30	SCHIST	0	22	0.02
41.30 -41.80	SCHIST	38	43	1.27
41.80 -43.20	SCHIST	0	26	0.03
43.20 -44.55	SCHIST	25	36	0.56
44.55 -46.00	SCHIST	12	33	0.02

Figure E.8 (Continued).

APPENDIX E II

ROCK MASS RATING (RMR) CALCULATIONS

Table E.II.1 Rock Mass Rating (RMR) calculations for SK-6+050, SK-6+180, SK-6+280 and SK-7+400 boreholes

	Borehole No	SK-6+050
	Structural Domain Number	1
	Parameters	Rating
1	PL/UCS	3
2	RQD	3
3	SPACING	5
4	DISCONTINUITY	
	persistence	1
	separation	1
	rougness	5
	infilling	2
	weathering	1
5	GROUNDWATER	15
6	ORIENTATION	-5
	RMR-Basic	36
	RMRo	31

	Borehole No	SK-6+180																				
	Structural Domain Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Parameters	Rating																				
1	PL/UCS	6	3	6	2	6	2	6	3	5	3	5	1	3	2	7	2	7	2	3	3	7
2	RQD	9	3	13	3	7	3	9	5	10	3	5	3	7	3	10	3	7	3	3	3	12
3	SPACING	5	5	6	5	5	5	6	5	6	5	5	5	5	5	6	5	5	5	5	5	6
4	DISCONTINUITY																					
	persistence	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	separation	4	6	4	6	4	6	4	6	4	6	4	6	4	4	4	4	4	4	6	6	4
	rougness	3	3	3	3	3	3	3	3	3	3	5	3	3	3	1	3	1	3	3	3	5
	infilling	4	4	6	4	6	4	6	4	4	4	6	4	6	6	6	6	6	6	6	4	6
	weathering	5	3	6	1	5	1	3	1	5	3	5	1	5	3	3	3	3	3	3	1	3
5	GROUNDWATER	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	44	35	52	32	44	32	45	35	45	35	43	31	41	34	45	34	41	34	37	33	51
	RMRo	39	30	47	27	39	27	40	30	40	30	38	26	36	29	40	29	36	29	32	28	46

	Borehole No	SK-6+280							
	Structural Domain Number	1	2	3	4	5	6	7	8
	Parameters	Rating							
1	PL/UCS	8	9	8	9	8	9	8	8
2	RQD	3	10	3	5	3	5	3	3
3	SPACING	5	6	5	5	5	5	5	5
4	DISCONTINUITY								
	persistence	1	1	1	1	1	1	1	1
	separation	6	4	6	4	4	4	4	4
	rougness	4	6	4	6	6	4	6	6
	infilling	3	5	3	5	3	5	3	3
	weathering	3	5	3	3	3	3	3	3
5	GROUNDWATER	15	15	15	15	15	15	15	15
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	48	61	48	53	48	51	48	48
	RMRo	43	56	43	48	43	46	43	43

	Borehole No	SK-6+400																														
	Structural Domain Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Parameters	Rating																														
1	PL/UCS	7	3	7	2	7	2	9	2	9	2	9	2	3	3	2	8	3	8	3	5	2	5	2	3	2	3	5	2	5	2	5
2	RQD	19	3	13	3	10	3	6	3	8	3	13	3	4	4	3	5	3	5	3	7	3	3	3	3	3	3	3	3	8	3	6
3	SPACING	7	5	6	5	5	5	5	5	6	5	6	5	5	5	5	5	5	6	5	6	5	5	5	5	5	5	5	5	6	5	5
4	DISCONTINUITY																															
	persistence	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4
	separation	6	4	6	4	4	4	4	6	4	4	4	4	4	4	4	4	4	6	4	4	4	6	4	6	4	6	6	6	6	4	4
	rougness	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	5
	infilling	4	6	4	6	6	6	6	4	6	6	6	6	6	6	6	6	6	2	6	4	6	4	6	4	6	4	4	4	4	6	4
	weathering	5	3	3	1	3	1	3	1	5	1	1	1	1	3	3	3	3	3	3	3	1	3	1	3	1	3	3	3	3	3	3
5	GROUNDWATER	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	67	43	56	40	54	40	52	40	57	40	58	40	42	44	42	50	43	49	43	48	40	45	40	43	40	43	45	42	49	42	51
	RMRo	62	38	51	35	49	35	47	35	52	35	53	35	37	39	37	45	38	44	38	43	35	40	35	38	35	38	40	37	44	37	46

Table E.lI.2. Rock Mass Rating (RMR) calculations for SK-6+570, SK-6+880, SK-7+130 and SK-7+250 boreholes

	Borehole No	SK-6+570																							
	Structural Domain Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Parameters	Rating																							
1	PL/UCS	4	5	4	5	4	5	4	6	2	7	2	6	3	6	2	7	2	7	2	7	2	7	8	7
2	RQD	3	19	3	7	4	7	3	11	3	5	3	15	3	3	3	8	3	7	3	5	3	3	7	2
3	SPACING	5	8	5	6	5	6	5	6	5	6	5	7	5	6	5	5	5	6	5	6	5	5	6	3
4	DISCONTINUITY																								
	persistence	1	1	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1
	separation	6	4	4	4	4	4	4	6	4	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	rougness	3	3	3	5	3	3	3	3	3	5	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	infilling	4	6	6	4	6	4	6	4	6	4	6	6	6	6	6	6	6	6	6	4	6	6	6	6
	weathering	3	5	3	5	3	5	3	3	1	3	1	5	3	5	5	3	1	3	3	3	1	3	5	3
5	GROUNDWATER	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	36	58	36	47	37	42	36	47	32	44	32	54	35	41	36	44	32	44	34	40	32	39	48	36
	RMRo	31	53	31	42	32	37	31	42	27	39	27	49	30	36	31	39	27	39	29	35	27	34	43	31

	Borehole No	SK-6+880					
	Structural Domain Number	1	2	3	4	5	6
	Parameters	Rating					
1	PL/UCS	2	2	3	2	9	9
2	RQD	3	3	3	3	8	5
3	SPACING	5	5	5	5	8	6
4	DISCONTINUITY						
	persistence	1	1	1	1	4	4
	separation	4	4	4	4	1	1
	rougness	3	3	3	3	5	3
	infilling	6	6	6	6	6	6
	weathering	1	1	1	1	3	1
5	GROUNDWATER	15	15	15	15	15	15
6	ORIENTATION	-5	-5	-5	-5	-5	-5
	RMR-Basic	40	40	41	40	59	50
	RMRo	35	35	36	35	54	45

	Borehole No	SK-7+130										
	Structural Domain Number	1	2	3	4	5	6	7	8	9	10	11
	Parameters	Rating										
1	PL/UCS	2	1	2	1	2	2	2	2	2	2	2
2	RQD	19	3	19	9	17	3	6	12	15	15	8
3	SPACING	9	5	9	6	9	5	5	6	8	8	6
4	DISCONTINUITY											
	persistence	4	4	4	1	1	1	1	1	2	2	2
	separation	1	4	1	4	4	4	4	4	4	4	4
	rougness	6	3	3	3	3	3	3	3	3	3	3
	infilling	6	6	6	6	6	6	6	6	6	6	6
	weathering	1	1	3	3	3	1	5	3	3	3	3
5	GROUNDWATER	15	15	15	15	15	15	15	15	15	15	15
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	63	42	62	48	60	40	47	52	58	58	49
	RMRo	58	37	57	43	55	35	42	47	53	53	44

	Borehole No	SK-7+250																							
	Structural Domain Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Parameters	Rating																							
1	PL/UCS	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2	RQD	3	3	6	3	16	3	10	3	8	3	6	3	4	3	4	14	3	3	5	3	8	3	6	4
3	SPACING	5	5	5	5	6	5	6	5	6	6	6	5	6	5	7	6	5	5	6	5	6	5	6	5
4	DISCONTINUITY																								
	persistence	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	separation	4	4	4	4	4	4	4	6	6	6	6	4	4	6	4	4	4	4	6	4	6	6	6	6
	rougness	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	5	3	3	3
	infilling	6	6	4	6	4	6	6	4	4	4	4	6	6	2	6	6	6	6	6	6	4	4	2	4
	weathering	0	0	3	1	3	1	5	1	5	1	5	3	3	3	3	3	3	3	3	1	3	3	3	3
5	GROUNDWATER	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
6	ORIENTATION	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
	RMR-Basic	42	42	46	43	57	43	55	43	53	44	51	45	47	43	48	57	45	45	50	43	53	45	47	46
	RMRo	37	37	41	38	52	38	50	38	48	39	46	40	42	38	43	52	40	40	45	38	48	40	42	41

APPENDIX E III
GEOLOGICAL STRENGTH INDEX (GSI)

Table-E.III.1 GSI calculations for SK-6+050 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	0.00 - 15.00	Schist	2	34,2	18	5	1	2	8	32

Note:
[a] RQD = 115 - 3.3 Jv [b] SR = -17.5 ln (J_v) + 79.8 [c] SCR= R_r+R_w+R_f

Table-E.III.2 GSI calculations for SK-6+180 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	50.00 - 51.00	Schist	42	22,1	26	3	5	4	12	42
2	51.00 - 54.70	Schist	0	34,8	18	3	3	4	10	36
3	54.70 - 55.95	Schist	66	14,8	33	3	6	6	15	51
4	55.95 - 56.70	Schist	0	34,8	18	3	1	4	8	32
5	56.70 - 57.35	Schist	32	25,2	23	3	5	6	14	45
6	57.35 - 58.35	Schist	0	34,8	18	3	1	4	8	32
7	58.35 - 59.10	Schist	44	21,5	26	3	3	6	12	42
8	59.10 - 64.15	Schist	16	30,0	20	3	1	4	8	33
9	64.15 - 65.10	Schist	48	20,3	27	3	5	4	12	43
10	65.10 - 65.70	Schist	0	34,8	18	3	3	4	10	36
11	65.70 - 66.30	Schist	18	29,4	21	5	5	6	16	46
12	66.30 - 67.15	Schist	0	34,8	18	3	1	4	8	32
13	67.15 - 68.25	Schist	28	26,4	23	3	5	6	14	45
14	68.25 - 70.70	Schist	0	34,8	18	3	3	6	12	40

Table E.III.2 (Continued)

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
15	70.70 - 73.55	Schist	47	20,6	27	1	3	6	10	39
16	73.55 - 74.00	Schist	0	34,8	18	3	3	6	12	40
17	74.00 - 74.65	Schist	31	25,5	23	1	3	6	10	38
18	74.65 - 75.10	Schist	0	34,8	18	3	3	6	12	40
19	75.10 - 79.80	Schist	8	32,4	19	3	3	6	12	40
20	79.80 - 82.60	Schist	6	33,0	19	3	1	4	8	32
21	82.60 - 85.0	Schist	58	17,3	30	5	3	6	14	48

Note:
[a] RQD = 115 - 3.3 Jv [b] SR = -17.5 ln (J_v) + 79.8 [c] SCR= R_r+R_w+R_f

Table E.III.3 GSI Calculations for SK-6+280 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	26.70 - 31.45	Schist	5	33,3	18	4	3	3	10	36
2	31.45 - 31.95	Schist	52	19,1	28	6	5	5	16	51
3	31.95 - 32.50	Schist	0	34,8	18	4	3	3	10	36
4	32.50 - 34.25	Schist	17	29,7	20	6	3	5	14	44
5	34.25 - 36.80	Schist	7	32,7	19	6	3	3	12	40
6	36.80 - 37.80	Schist	21	28,5	21	4	3	5	12	41
7	37.80 - 42.50	Schist	3	33,9	18	6	3	3	12	40
8	42.50 - 63.00	Schist	2	34,2	18	6	3	3	12	40

Note:
[a] RQD = 115 - 3.3 Jv [b] SR = -17.5 ln (J_v) + 79.8 [c] SCR= R_r+R_w+R_f

Table 4 E.III.4 GSI Calculations for SK-6+400 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	41.50 - 42.05	Schist	95	6,1	48	3	5	4	12	51
2	42.05 - 43.10	Schist	0	34,8	18	3	3	6	12	40
3	43.10 - 43.50	Schist	63	15,8	32	1	3	4	8	36
4	43.50 - 44.00	Schist	0	34,8	18	3	1	6	10	36
5	44.00 - 44.30	Schist	50	19,7	28	3	3	6	12	43
6	44.30 - 44.90	Schist	0	34,8	18	3	1	6	10	36
7	44.90 - 46.80	Schist	26	27,0	22	3	3	6	12	41
8	46.80 - 47.40	Schist	0	34,8	18	3	1	4	8	32
9	47.40 - 47.90	Schist	38	23,3	25	3	5	6	14	46
10	47.90 - 48.95	Schist	0	34,8	18	3	1	6	10	36
11	48.95 - 49.80	Schist	64	15,5	32	3	1	6	10	41
12	49.80 - 50.50	Schist	0	34,8	18	3	1	6	10	36
13	50.50 - 52.40	Schist	7	32,7	19	3	1	6	10	37
14	52.40 - 54.20	Schist	14	30,6	20	3	3	6	12	41
15	54.20 - 55.90	Schist	0	34,8	18	3	3	6	12	40
16	55.90 - 57.40	Schist	20	28,8	21	3	3	6	12	41
17	57.40 - 61.40	Schist	3	33,9	18	3	3	6	12	40
18	61.40 - 62.40	Schist	20	28,8	21	3	3	2	8	33
19	62.40 - 63.90	Schist	0	34,8	18	3	3	6	12	40
20	63.90 - 64.50	Schist	33	24,8	24	3	3	4	10	38
21	64.50 - 64.80	Schist	0	34,8	18	3	1	6	10	36
22	64.80 - 65.40	Schist	0	34,8	18	3	3	4	10	36
23	65.40 - 65.90	Schist	0	34,8	18	3	1	6	10	36
24	65.90 - 67.65	Schist	0	34,8	18	3	3	4	10	36

Table E.III.4 (Continued)

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
25	67.65 - 69.00	Schist	0	34,8	18	3	1	6	10	36
26	69.00 - 72.80	Schist	0	34,8	18	3	3	4	10	36
27	72.80 - 73.10	Schist	0	34,8	18	3	3	4	10	36
28	73.10 - 73.50	Schist	0	34,8	18	3	3	4	10	36
29	73.50 - 75.00	Schist	39	23,0	25	1	3	4	8	34
30	75.00 - 75.25	Schist	0	34,8	18	3	3	6	12	40
31	75.25 - 76.00	Schist	27	26,7	22	5	3	4	12	41

Note:

[a] $RQD = 115 - 3.3 Jv$ [b] $SR = -17.5 \ln(J_v) + 79.8$ [c] $SCR = R_r + R_w + R_f$

Table E.III.5 GSI Calculations for SK-6+570 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	46.80 - 47.50	Schist	0	34,8	18	3	3	4	10	36
2	47.50 - 48.00	Schist	94	6,4	47	3	5	6	14	56
3	48.00 - 48.80	Schist	0	34,8	18	3	3	6	12	40
4	48.80 - 49.15	Schist	34	24,5	24	5	5	4	14	45
5	49.15 - 50.00	Schist	12	31,2	20	3	3	6	12	19
6	50.00 - 50.70	Schist	31	25,5	23	3	5	4	12	42
7	50.70 - 52.90	Schist	5	33,3	18	3	3	6	12	40
8	52.90 - 54.35	Schist	57	17,6	30	3	3	4	10	40

Table E.III.5 (Continued)

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
9	54.35 - 55.10	Schist	0	34,8	18	3	1	6	10	36
10	55.10 - 58.10	Schist	19	29,1	21	5	3	4	12	41
11	58.10 - 60.20	Schist	0	34,8	18	3	1	6	10	36
12	60.20 - 61.50	Schist	77	11,5	37	3	5	6	14	51
13	61.50 - 64.50	Schist	7	32,7	19	3	3	6	12	41
14	64.50 - 65.20	Schist	0	34,8	18	3	5	6	14	44
15	65.20 - 66.70	Schist	0	34,8	18	3	5	6	14	44
16	66.70 - 67.00	Schist	37	23,6	24	3	3	6	12	42
17	67.00 - 68.10	Schist	0	34,8	18	3	1	6	10	36
18	68.10 - 68.70	Schist	28	26,4	23	3	3	6	12	42
19	68.70 - 69.10	Schist	0	34,8	18	3	3	6	12	40
20	69.10 - 74.10	Schist	19	29,1	21	3	3	4	10	39
21	74.10 - 75.60	Schist	0	34,8	18	3	1	6	10	36
22	75.60 - 76.20	Schist	0	34,8	18	3	3	6	12	40
23	76.20 - 76.70	Schist	32	25,2	23	3	5	6	14	45
24	76.70 - 80.00	Schist	9	32,1	19	3	3	6	12	41

Note:

[a] RQD = 115 - 3.3 Jv [b] $SR = -17.5 \ln (J_v) + 79.8$ [c] $SCR = R_r + R_w + R_f$

Table E.III.6 GSI Calculations for SK-6+880 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	0.00 - 7.50	Blocky Limestone	0	34,8	18	3	1	6	10	36
2	7.50 - 16.00	Blocky Limestone	9	32,1	19	3	1	6	10	37
3	16.00 - 33.50	Blocky Limestone	1	34,5	18	3	1	6	10	36
4	33.50 - 48.00	Blocky Limestone	8	32,4	19	3	1	6	10	37
5	48.00 - 49.00	Blocky Limestone	40	22,7	25	5	3	6	14	46
6	49.00 - 52.00	Blocky Limestone	15	30,3	20	3	1	6	10	37

Table E.III.7 GSI Calculations for SK-7+130 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	15.30 - 21.10	Conglomerate	94	6,4	47	6	1	6	13	53
2	21.10 - 21.30	Shale	0	34,8	18	3	1	6	10	36
3	21.30 - 23.38	Conglomerate	93	6,7	47	3	3	6	12	51
4	23.38 - 26.05	Shale-Sandstone	45	21,2	26	3	3	6	12	42
5	26.05 - 29.60	Shale-Sandstone	85	9,1	41	3	3	6	12	48
6	29.60 - 31.00	Shale-Sandstone	0	34,8	18	3	1	6	10	36
7	31.00 - 31.40	Shale-Sandstone	28	26,4	23	3	5	6	14	45
8	31.40 - 35.00	Sandstone	60	16,7	31	3	3	6	12	44
9	35.00 - 41.00	Sandstone	78	11,2	38	3	3	6	12	47
10	41.00 - 43.30	Sandstone	76	11,8	37	3	3	6	12	46
11	43.30 - 45.00	Shale-Sandstone	42	22,1	26	3	3	6	12	40

Note:
[a] RQD = 115 - 3.3 Jv   [b] $SR = -17.5 \ln (J_v) + 79.8$ [c] $SCR = R_r + R_w + R_f$

Table E.III.8 GSI Calculations for SK-7+250 borehole

Str. Dmn. #	Depth Interval (m)	Rock Type	RQD	Volumetric Joint Count, J_v [a]	Structural Rating, SR [b]	Rougness Rating, R_r	Weathering Rating, R_w	Infilling Rating, R_f	Surface Condition Rating, SCR [c]	GSI
1	0.00 - 6.00	Schist	0	34,8	18	3	0	6	9	34
2	6.00 - 20.95	Schist	2	34,2	18	3	0	6	9	34
3	20.95 - 21.40	Schist	27	26,7	22	3	3	4	10	43
4	21.40 - 25.32	Schist	3	33,9	18	3	1	6	10	36
5	25.32 - 26.20	Schist	82	10,0	40	3	3	4	10	43
6	26.20 - 26.70	Schist	0	34,8	18	3	1	6	10	36
7	26.70 - 26.95	Schist	52	19,1	28	3	5	6	14	47
8	26.95 - 27.25	Schist	0	34,8	18	3	1	4	8	34
9	27.25 - 27.55	Schist	40	22,7	25	3	5	4	12	42
10	27.55 - 27.90	Schist	0	34,8	18	3	1	4	8	34
11	27.90 - 28.40	Schist	30	25,8	23	3	5	4	12	42
12	28.40 - 30.50	Schist	0	34,8	18	3	3	6	12	40
13	30.50 - 33.00	Schist	16	30,0	20	3	3	6	12	41
14	33.00 - 33.60	Schist	0	34,8	18	3	3	2	8	34
15	33.60 - 34.25	Schist	22	28,2	21	3	3	6	12	41
16	34.25 - 36.00	Schist	68	14,2	33	3	3	6	12	45
17	36.00 - 36.40	Schist	0	34,8	18	3	3	6	12	40
18	36.40 - 37.50	Schist	0	34,8	18	3	3	6	12	40
19	37.50 - 40.80	Schist	21	28,5	21	3	3	6	12	41
20	40.80 - 41.30	Schist	0	34,8	18	3	1	6	10	36
21	41.30 - 41.80	Schist	38	23,3	25	5	3	4	12	42
22	41.80 - 43.20	Schist	0	34,8	18	3	3	4	10	36
23	43.20 - 44.55	Schist	25	27,3	22	3	3	2	8	33
24	44.55 - 46.00	Schist	12	31,2	20	3	3	4	10	37

Note:
[a] RQD = 115 - 3.3 Jv [b] SR = -17.5 ln (J_v) + 79.8 [c] SCR= R_r+R_w+R_f

APPENDIX F

CORRELATIONS CHARTS FOR M-RMR, RMR, GSI AND Q SYSTEM

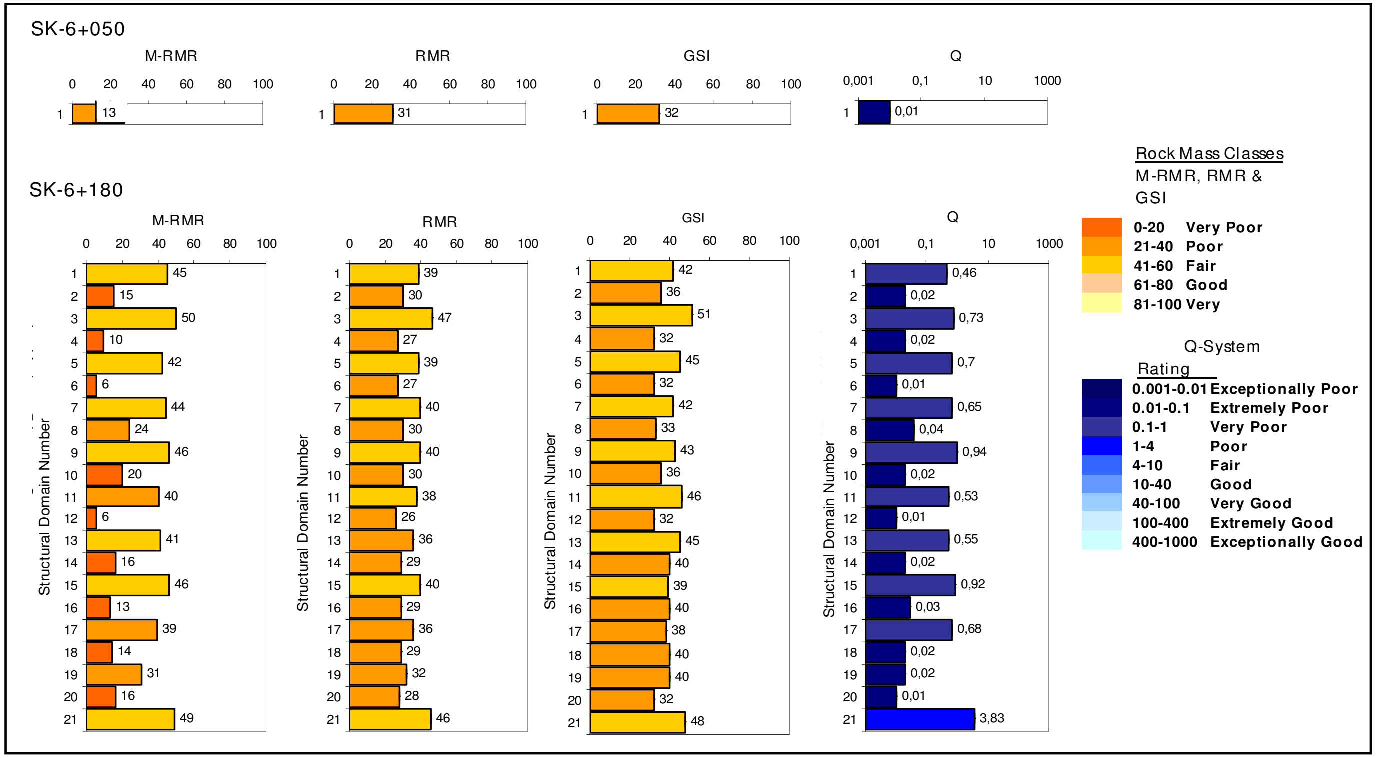


Figure F.1 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-6+050 and SK-6+180 boreholes.

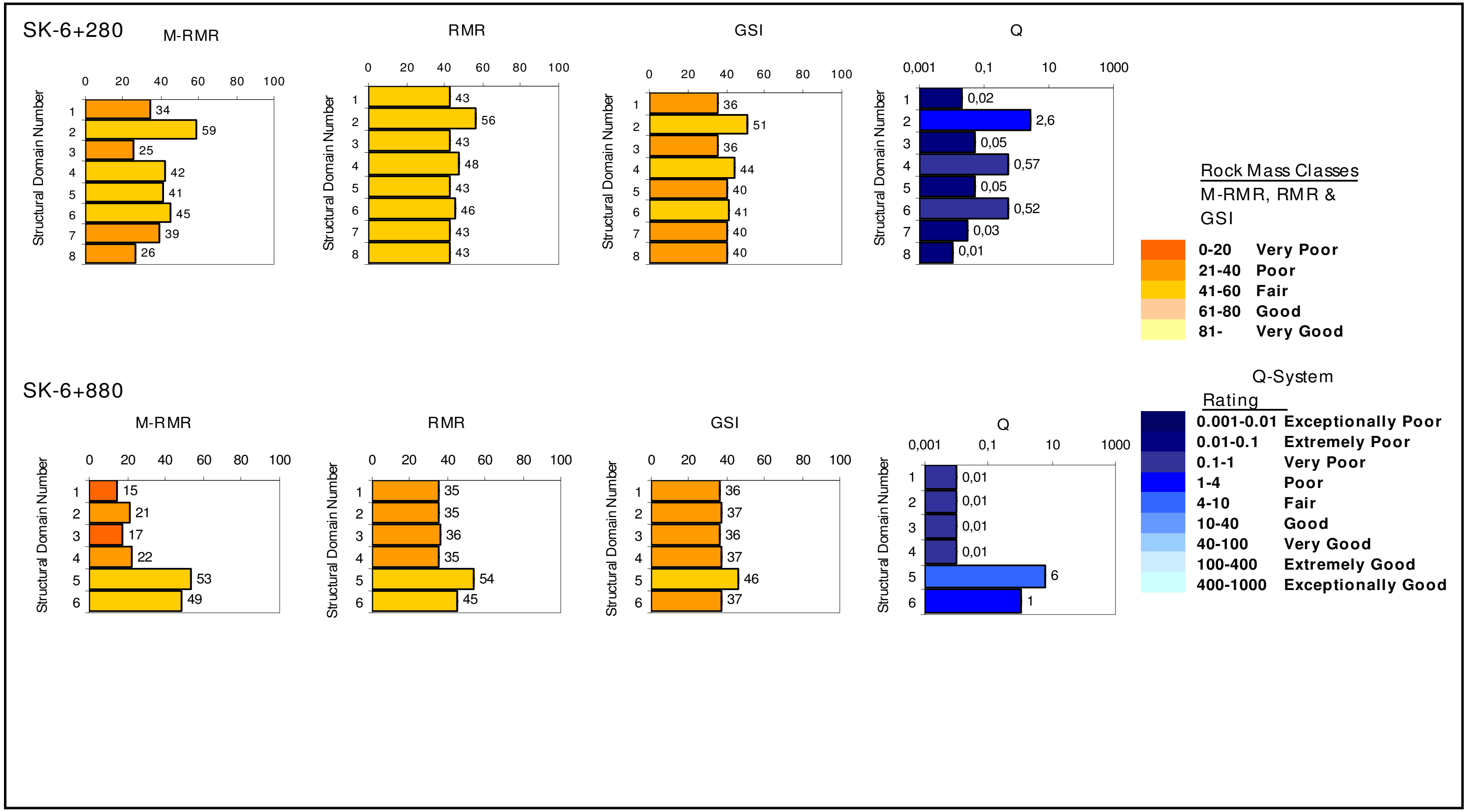


Figure F.2 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-6+280 and SK-6+880 boreholes.

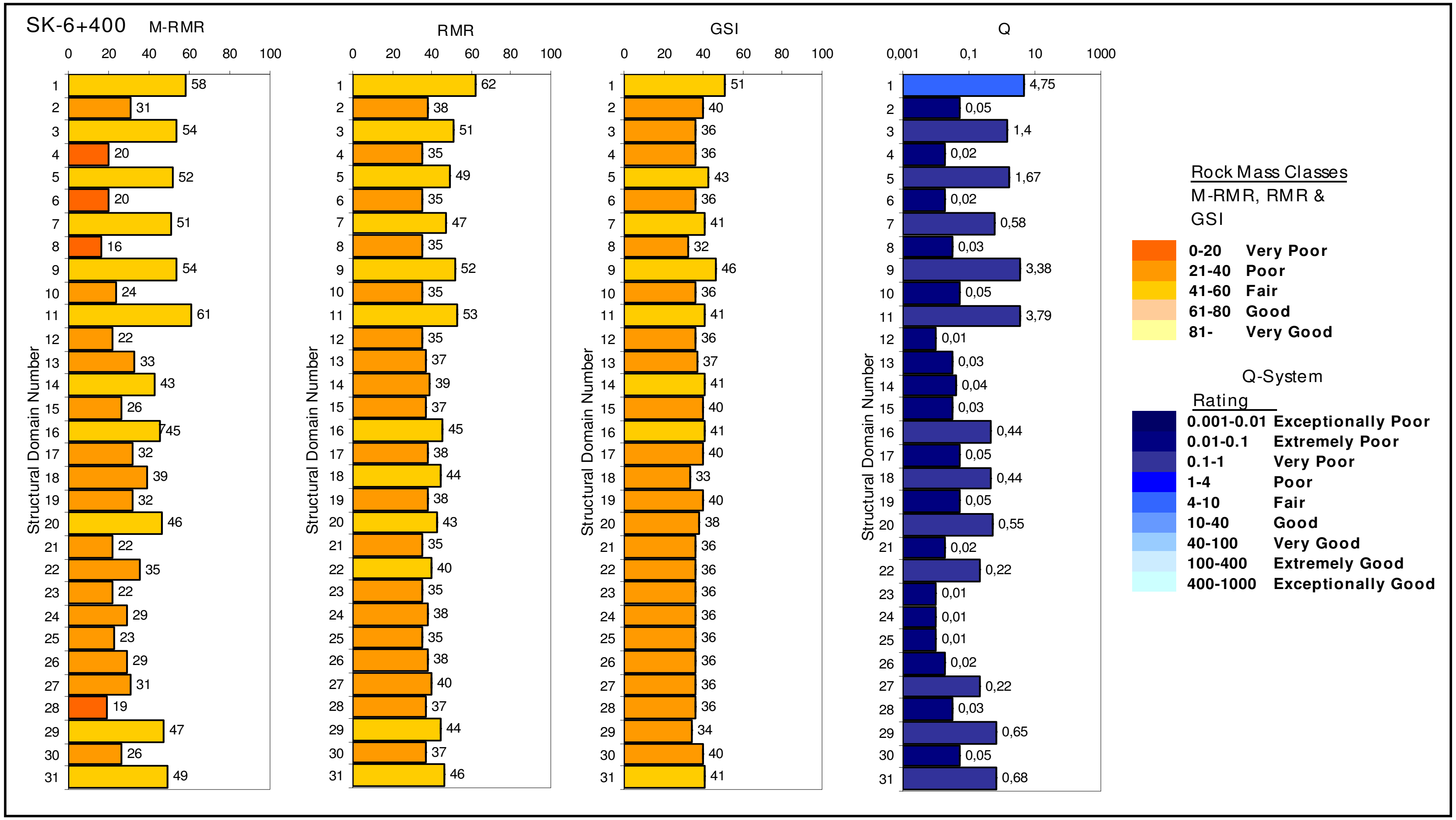


Figure F.3 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-6+400 borehole.

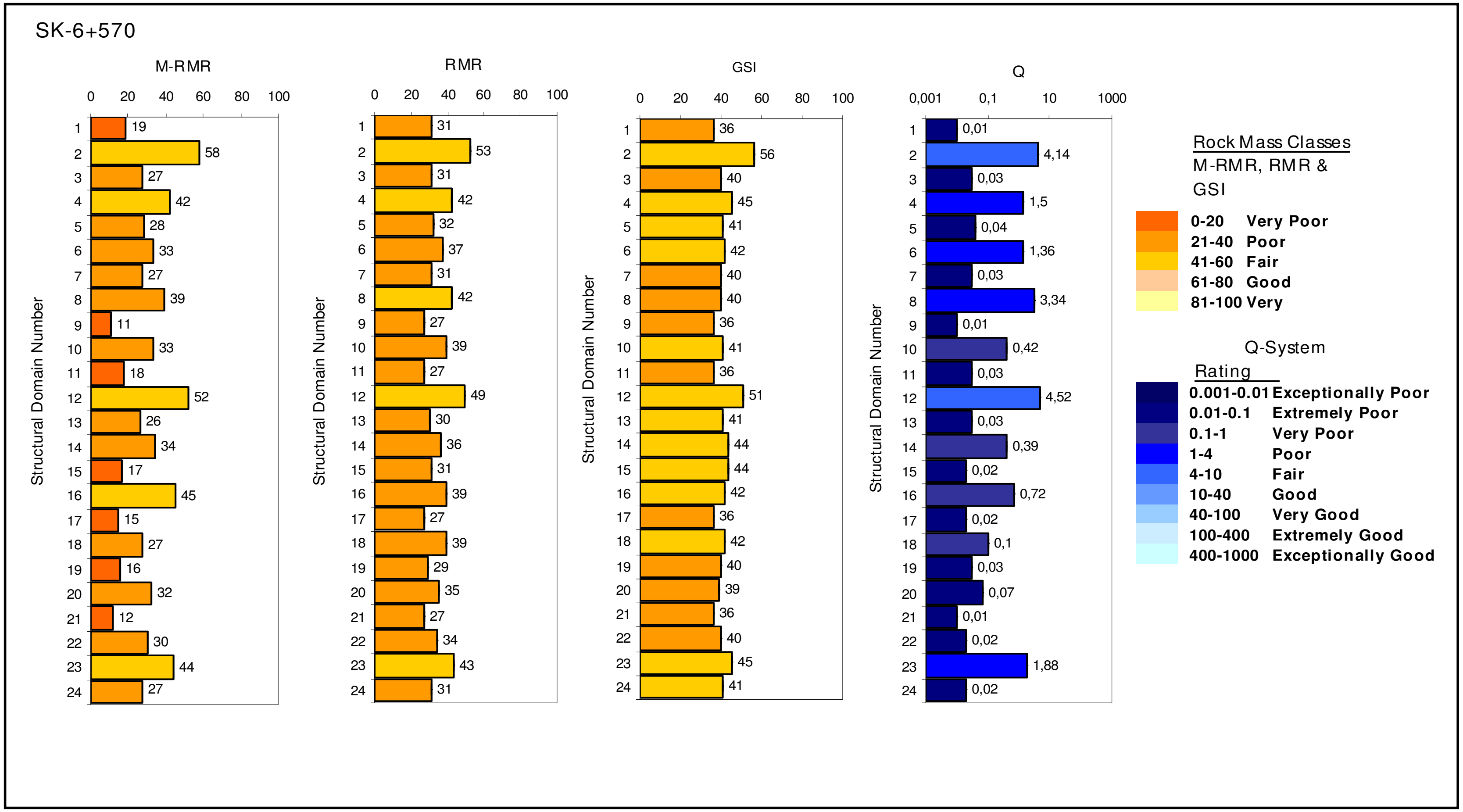


Figure F.4 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-6+570 borehole.

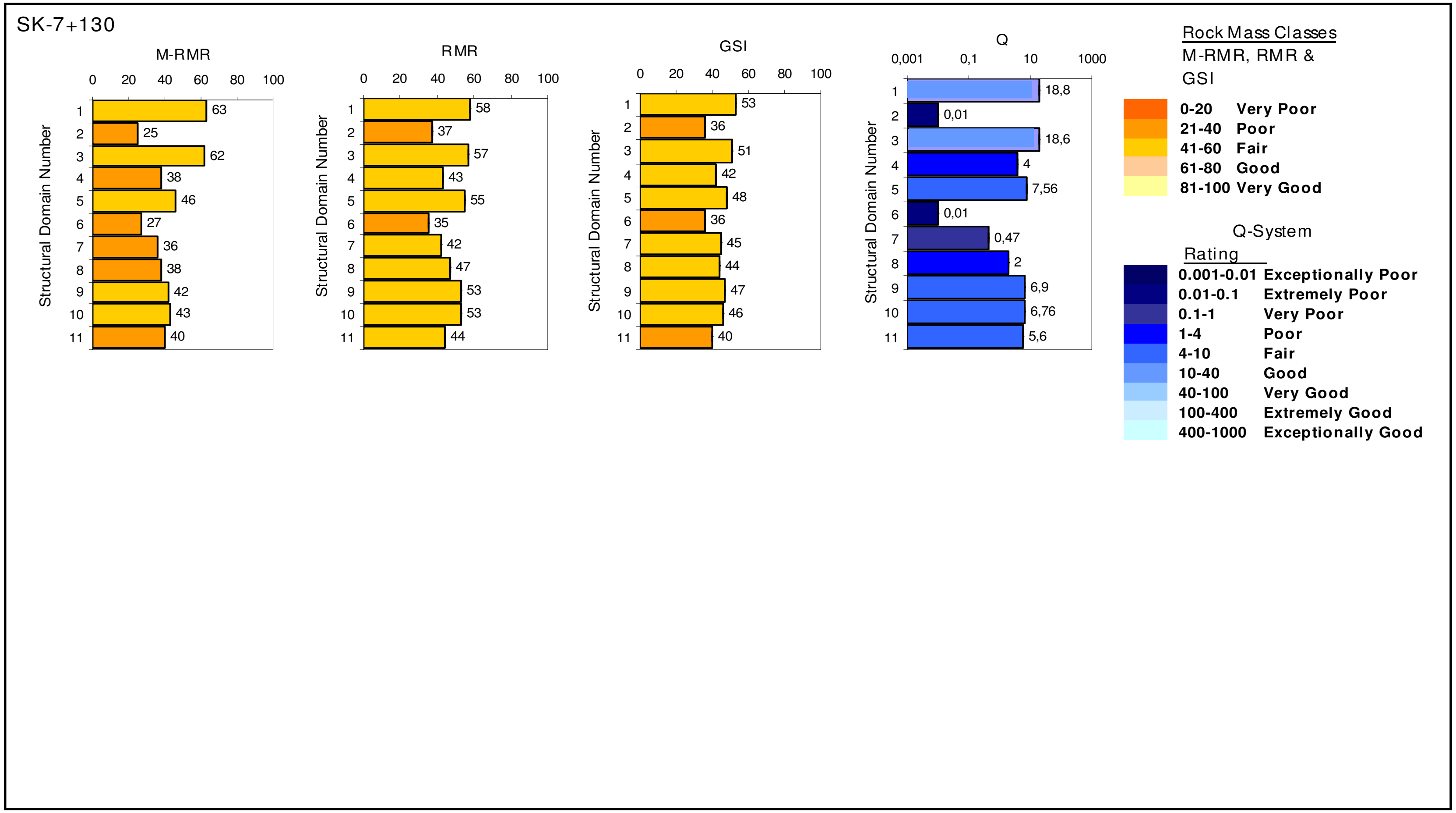


Figure F.5 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-7+130 borehole.

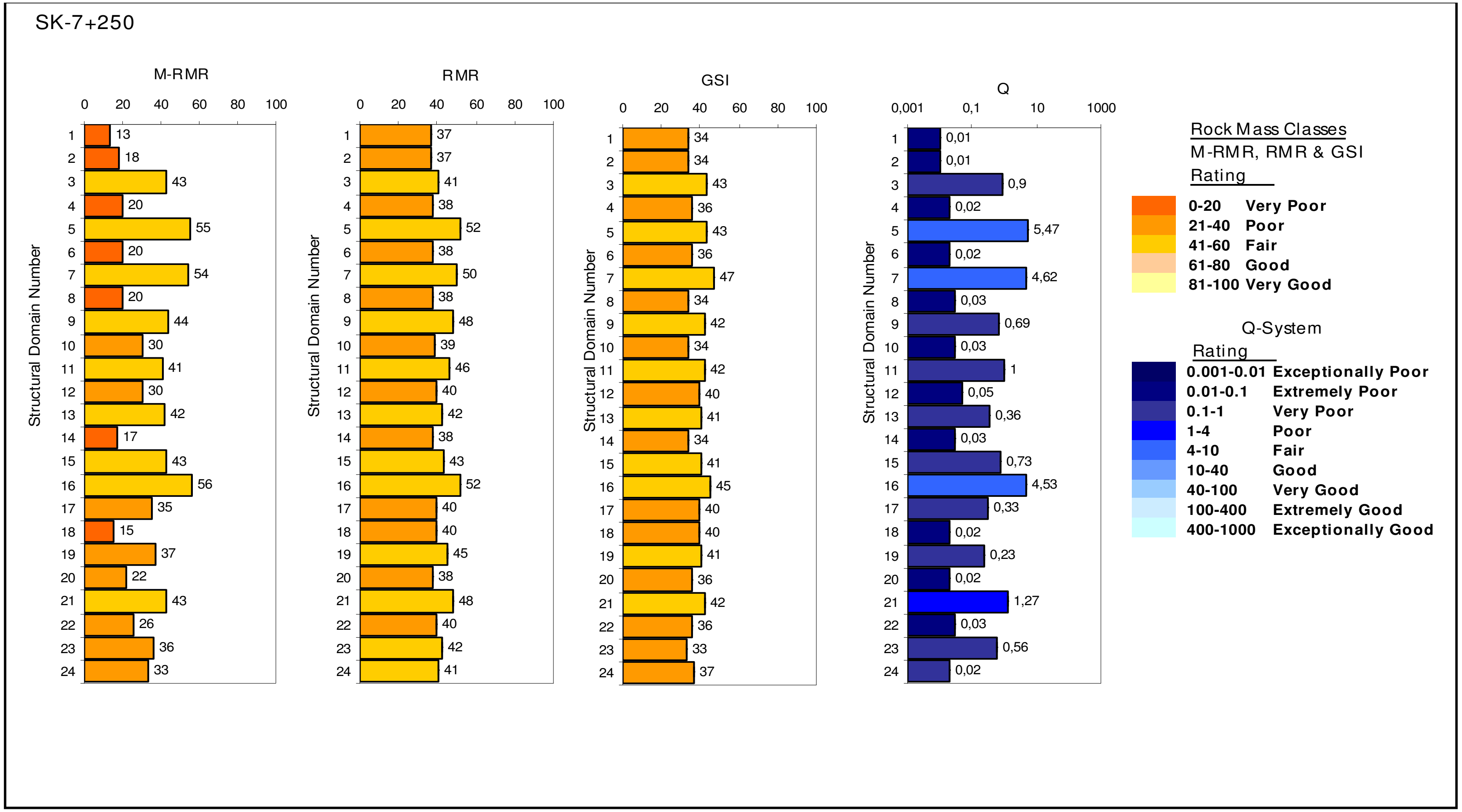


Figure F.6 Correlation of M-RMR, RMR, GSI and Q values for each structural domain of SK-7+250 borehole.