DETERMINATION OF TUNNEL SUPPORT SYSTEMS OF BELKAHVE (İZMİR) TUNNEL WITH EMPIRICAL AND NUMERICAL METHODS

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DETERMINATION OF TUNNEL SUPPORT SYSTEMS OF BELKAHVE (İZMİR) TUNNEL WITH EMPIRICAL AND NUMERICAL METHODS

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ABSTRACT

DETERMINATION OF TUNNEL SUPPORT SYSTEMS OF BELKAHVE (İZMİR) TUNNEL WITH EMPIRICAL AND NUMERICAL METHODS

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In this study, determining the geological and geotechnical characteristics of the Belkhave tunnel with a length of 1650 m and width of 16 m along Manisa-İzmir Highway, selecting the appropriate support system and verifying with numerical modeling are aimed.

Limestone and schist are the main lithologies along the Belkahve tunnel. RMR, Q and NATM classification systems are used to classify the rock mass. Appropriate support systems are determined by using these classification methods. In order to verify the determined support systems, 2D finite element analyses are performed to check the stabilities of seven sections through the tunnel route. The primary support systems determined according to RMR, Q and NATM and 4-6 m long bolt with intervals of 1-1.5 m, 10-30 cm shotcrete, steel sets wherever required are recommended. Moreover, numerical analyses are used to check the deformation at different sections of the tunnel and stabilities of the tunnel portals. Based on the analyses performed, tunnel deformations are found to be acceptable with the applied supports, and no slope failure is expected for the portals.

Keywords: Limestone, NATM, Numerical modeling, RMR system, Schist, Q system, tunnel support, Belkahve, Manisa, İzmir.

ÖZ

BELKAHVE (İZMİR) TÜNELİNİN DESTEK SİSTEMLERİNİN AMPİRİK VE SAYISAL YÖNTEMLERLE BELİRLENMESİ

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Bu çalışmada, Manisa-İzmir Otoyolu üzerinde bulunan, uzunluğu 1650 m. ve genişliği 16m. olan Belkahve tünelinin, jeolojik ve jeoteknik özelliklerini belirleyip, bu bağlamda, uygun destek sistemleri seçip, sayısal analizler ile sağlamasının yapılması amaçlanmıştır.

Kireçtaşı ve şist, tünel güzergâhı boyunca görülen hâkim birimlerdir. Kaya kütlesinin sınıflandırılması için RMR, Q ve NATM kaya sınıflamaları kullanılmıştır. Uygun destek sistemlerinin belirlenmesi, bu kaya sınıflamaları aracılığı ile yapılmıştır. Belirlenen destek sistemlerinin stabilitesi, tünel güzergâhı boyunca 7 ayrı kesitte 2-boyutlu sonlu elemanlar analizi kullanılarak kontrol edilmiştir. RMR, Q ve NATM kaya sınıflamaları ışığında belirlenen ana destek sistemleri için, 4-6 m. boyunda 1-1,5 m. aralıklı bulon,10-30 cm. kalınlığında püskürtme beton ve gerektiğinde kullanılacak olan çelik iksa önerilmiştir. Ek olarak, sayısal analiz yapılarak, tünel güzergâhının değişik kesitlerinde ve tünel giriş çıkış portal bölgelerinde deformasyonlar kontrol edilmiştir. Analiz sonuçlarına göre, destek sistemleri uygulandıktan sonra oluşan deformasyonlar kabul edilebilir mertebelerde olup, portal bölgelerinde herhangi bir şev duraylılık problemi beklenmemektedir.

Anahtar Kelimeler: Kireçtaşı, NATM, Sayısal modelleme, RMR kaya sınıflama sistemi, Şist, Q sistemi, tünel destek, Belkahve, Manisa, İzmir.

(To myself…)

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LIST OF ABBREVIATIONS

c	Cohesion (kPa)
ø	Internal friction angle (˚)
γ	Density of the rock (N/m^3)
D	Disturbance factor
E_i	Deformation modulus of intact rock (GPa)
E_{rm}	Deformation modulus of rock mass (GPa)
J_a	Joint Alteration Number
J_n	Joint Set Number
J_r	Joint Roughness Number
J_w	Joint Water Reduction Factor
SRF	Stress Reduction Factor
k	Horizontal to vertical stress ratio
σ_c	Uniaxial Compressive Strength (MPa)
RQD	Rock Quality Designation
RMR	Rock Mass Rating
Q	Rock mass quality
NATM	New Austrian Tunneling Method
GDH	General Directorate of Highways
GWD	Groundwater Depth

CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope

Belkahve tunnel is planned to be constructed as part of Manisa – İzmir highway of İstanbul-Bursa-Balıkesir-İzmir Highway project. The length of the Manisa-İzmir highway is 57,698 kilometers with three lanes round-trip (2x3). There is only one tunnel along the highway route. The Belkahve tunnel is located approximately 30 km south east of İzmir, and between kilometers of 399+180 and 400+930. The length of the right tube and left tube of the tunnel is 1650 m 1750m, respectively. The maximum diameter of the tunnel section is 16 m. Belkahve Tunnel has 2.70% longitudinal slope. Through the tunnel route, the distance between the tubes is defined as 24 m which corresponds to 1.5 times of the tunnel width. Figure 1.1. shows the typical cross section of the Belkahve Tunnel. According to GDH, a tunnel with length greater than 1000m, have to contain emergency vehicle passage and emergency pedestrian passages. So, Belkahve Tunnel contains an emergency vehicle passage at the middle part of the tunnel route and two emergency pedestrian passages at two different sections.

The primary objective of this study is the classification of rock masses along the tunnel alignment, determination of engineering parameters and support systems of the tunnel, and verification of the determined support systems

In order to accomplish this task, available data were collected, field and laboratory studies were performed, samples were tested in the laboratory, rock masses were classified, support systems were determined and checked by numerical analyses.

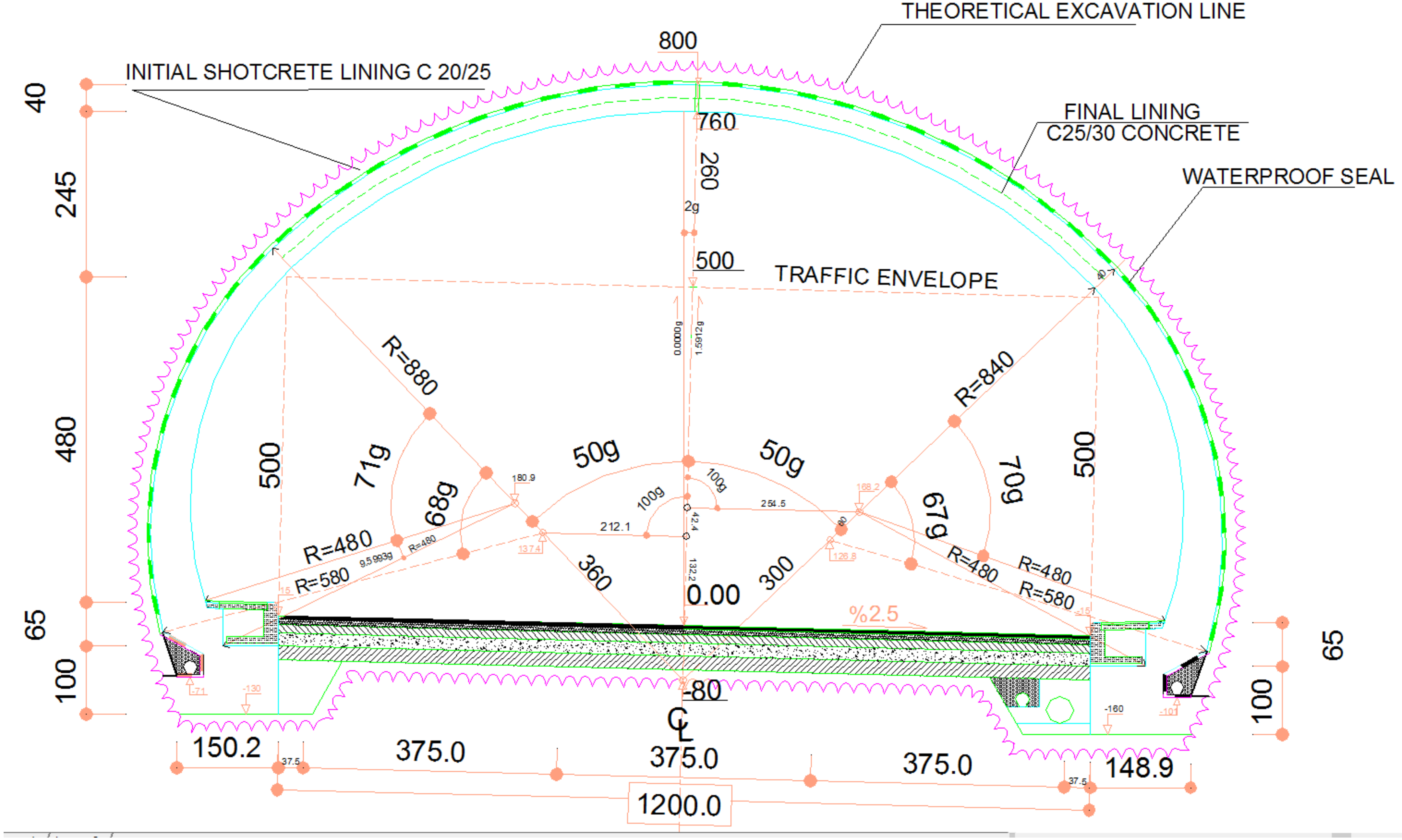

Figure 1. 1 Typical cross section of the tunnel (Scale:1/50)

1.2 Location and Accessibility of the Study Area

The location of the study area is in Belkahve pass near Kavaklıdere village and approximately 30 km southeast of İzmir. The tunnel is located between the longitudes N38˚28’04” and N38˚27’30”and the latitudes E27˚19’30” and E27˚18’37” (Google Earth Software, 2014). Figure 1.2. shows the location of the study area.

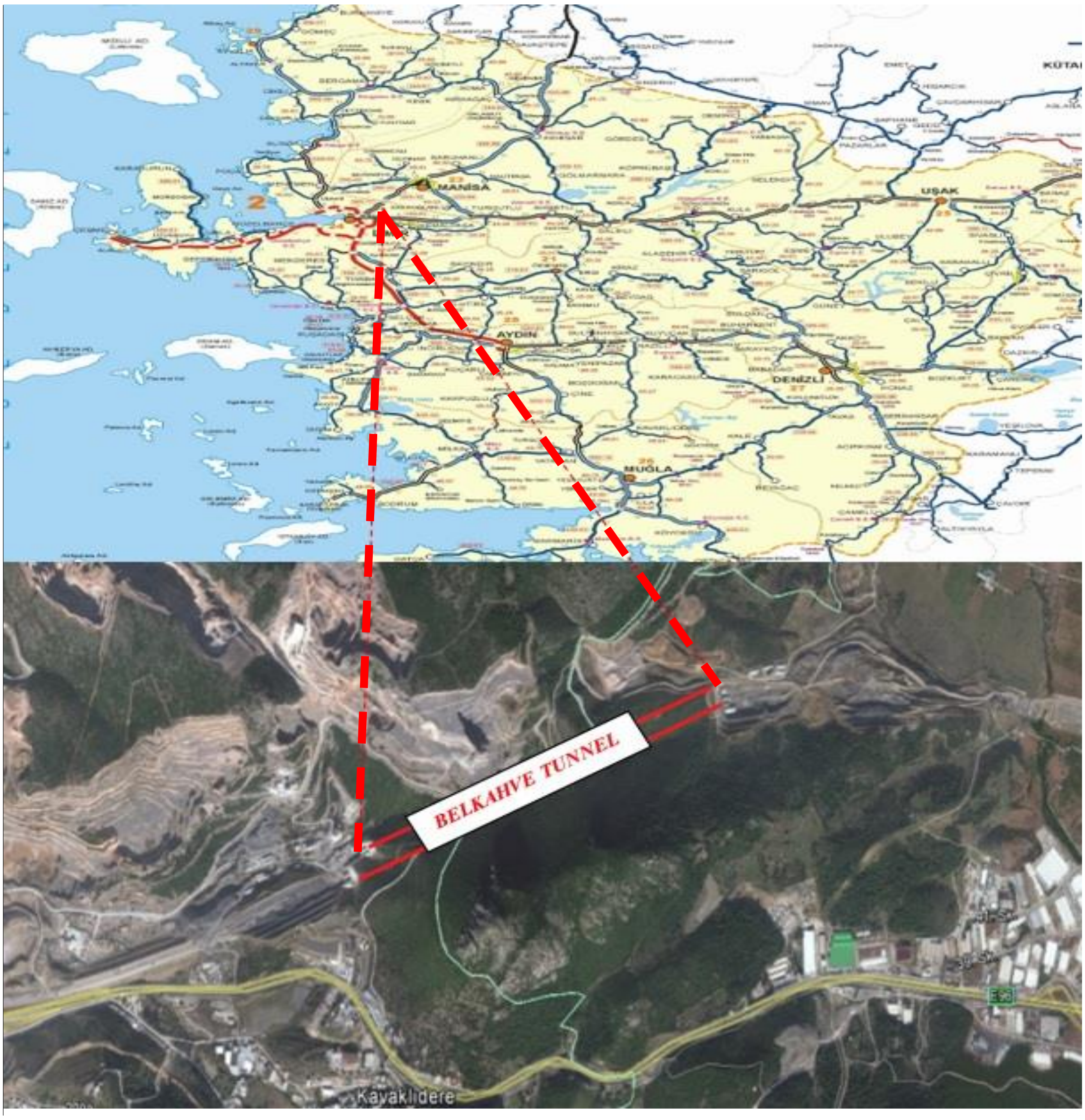

Figure 1. 2 Location map of the study area.

1.3 Climate and Vegetation

In the study area, Mediterranean climate characterized by long, hot and dry summers; and mild to cool, rainy winters, exists. The highest temperature is recorded in August (43˚C), the coldest temperature is recorded in January (-6.4˚C), with an average temperature of 17.93˚C. The mean rainfall in İzmir is about 690.1 mm. 53 % of the annual rainfall occurs in winter. 22% of the annual rainfall occurs in spring, 1% of the annual rainfall occurs in summer and 24% of the annual rainfall occurs in Autumn. Oak is covering the most part of the region. The mean relative humidity is around 57.8 % (MGM, 2015).

1.4 Methodology

Several steps were followed for the purpose of succeeding the task of this thesis. At very first step; literature survey about geology of the study area (Manisa-İzmir), determination of engineering parameters of rock masses, several different rock mass classification systems and rock support applications were reviewed. Second stage of the study involves performing site investigation with the aim of obtaining geological and geotechnical information through the tunnel route. Site investigation program comprises field study which contains drilling of five boreholes by Fugro Sial Company (2012). The main goal of drilling is to identify the subsurface geology, to collect discontinuity conditions data and also to collect the hand specimens from the outcrops. In the third step of the study, laboratory tests were performed by Limit Lab. (2012). These bunch of tests aim to determine the unit weight, uniaxial compressive strength, point load strength and modulus of elasticity of the rock mass along the tunnel route. Following the third step, rock mass classifications and determination of support systems were utilized. In addition, determination of basic input parameters of numerical analyses was completed by determination of rock mass parameters. In the fifth step, slope stability analyses for the tunnel portals were performed. Finally, models of the Belkahve tunnel using computer software (Phase2) were used to verify the determined support systems.

1.5 Previous Studies

Previous reports and maps related to the study area are very important to plan a well-done site investigation programme. The Manisa –İzmir highway had been projected by Yüksel Domanic and Eser engineering companies in 1997. According to the scope of the project, the Belkahve tunnel has not been fully projected. There were several boreholes open at that time to prepare pre-project of the tunnel including only both portals.

Analyzing some very basic concepts of rock mass quality, rock mass strength parameters, how a rock mass around a tunnel distorts and how the support systems works in order to check over this distortion are essential for a good understanding of the process for designing tunnel support.

For over 100 years, the rock mass classification systems have been progressing. Ritter (1879) tried to put forward an experimental remark on tunnel design. Terzaghi (1946) was the first person to mention about the usage of rock mass classification for design of tunnel support. The definitions quoted from his paper are; intact rock, stratified rock, moderately jointed rock, blocky and seamy rock, crushed rock, squeezing rock and swelling rock. Lauffer (1958) introduced a relationship between stand up time for an unsupported span and quality of rock mass. In order to assess the rock mass quality, Deere et al. (1967) built up rock mass quality designation index (RQD). RQD is defined as the ratio of length of rock pieces equal or greater than 10 cm to total length of core run. RMR (rock mass rating system) is a rock mass quality classification. South African Council for Scientific and Industrial Research (CSIR) developed RMR by closely associated with excavation for the mining industry (Bieniawski, 1973).

So, in order to determine rock mass classification, uniaxial compressive strength of intact rock, drilling core quality RQD, spacing of discontinuities, conditions of discontinuities, groundwater condition, are used (see Table 1.1-1.4). RMR system charts which are used to determine the basic RMR value the rock mass and guidelines for excavation and support are presented in Tables 1.1 and 1.2.

Table 1. 1 Rock mass rating system (after Bieniawski, 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

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

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

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

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

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

D. MEANING OF ROCK CLASSES

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

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence)	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Ratings	6	5	3	1	0

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

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	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).

Table 1. 2 Rock tunnels Guideline for excavation and support of 10 m span rock tunnels in accordance to RMR value. (after 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 crown 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 excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Barton et al. (1974, 1976) developed the Q system at the Norwegian Geotechnical Institute (NGI). The Q system includes six parameters which are:

RQD, Jn, Jr, Ja, Jw, SRF

Table 1.3 is used to determine each parameter given above.

Table 1. 3 Q rock classification system with individual parameters shown (After Barton et al. 1974)

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

Table1.3 (continued)

4, JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)	
b. Rock wall contact before 10 cm shear			
F. Sandy particles, clay-free, disintegrating rock etc.	4.0	25 - 30	
G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick)	6.0	16 - 24	
H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 - 16	
J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water.	8.0 - 12.0	6 - 12	
c. No rock wall contact when sheared			
K. Zones or bands of disintegrated or crushed	6.0		
L. rock and clay (see G, H and J for clay	8.0		
M. conditions)	8.0 - 12.0	6 - 24	
N. Zones or bands of silty- or sandy-clay, small clay fraction, non-softening	5.0		
O. Thick continuous zones or bands of clay	10.0 - 13.0		
P. & R. (see G.H and J for clay conditions)	6.0 - 24.0		
5. JOINT WATER REDUCTION	J_w	approx. water pressure (kgf/cm^2)	
A. Dry excavation or minor inflow i.e. < 5 l/m locally	1.0	< 1.0	
B. Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C. Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates; increase J_w if drainage installed.
D. Large inflow or high pressure	0.33	2.5 - 10.0	
E. Exceptionally high inflow or pressure at blasting, decaying with time	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F. Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6. STRESS REDUCTION FACTOR		***SRF***	
a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth)		10.0	1. Reduce these values of *SRF* by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B. Single weakness zones containing clay, or chemically dis-tegrated rock (excavation depth < 50 m)		5.0	
C. Single weakness zones containing clay, or chemically dis-tegrated rock (excavation depth > 50 m)		2.5	
D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E. Single shear zone in competent rock (clay free). (depth of excavation < 50 m)		5.0	
F. Single shear zone in competent rock (clay free). (depth of excavation > 50 m)		2.5	
G. Loose open joints, heavily jointed or 'sugar cube', (any depth)		5.0	

Table 1. 3 (continued)

DESCRIPTION	VALUE			NOTES
6. STRESS REDUCTION FACTOR			***SRF***	
b. Competent rock, rock stress problems				
	σ_c/σ_1	$\sigma_t\sigma_1$		2. For strongly anisotropic virgin stress field
H. Low stress, near surface	> 200	> 13	2.5	(if measured): when $5 \le \sigma_1/\sigma_3 \le 10$, reduce σ_c
J. Medium stress	200 - 10	13 - 0.66	1.0	to $0.8\sigma_c$ and σ_t to $0.8\sigma_t$. When σ_1/σ_3 > 10,
K. High stress, very tight structure	10 - 5	0.66 - 0.33	0.5 - 2	reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$, where
(usually favourable to stability, may				σ_c = unconfined compressive strength, and
be unfavourable to wall stability)				σ_t = tensile strength (point load) and σ_1 and
L. Mild rockburst (massive rock)	5 - 2.5	0.33 - 0.16	5 - 10	σ_3 are the major and minor principal stresses.
M. Heavy rockburst (massive rock)	< 2.5	< 0.16	10 - 20	3. Few case records available where depth of
c. Squeezing rock, plastic flow of incompetent rock				crown below surface is less than span width.
under influence of high rock pressure				Suggest *SRF* increase from 2.5 to 5 for such
N. Mild squeezing rock pressure			5 - 10	cases (see H).
O. Heavy squeezing rock pressure			10 - 20	
d. Swelling rock, chemical swelling activity depending on presence of water				
P. Mild swelling rock pressure			5 - 10	
R. Heavy swelling rock pressure			10 - 15	

ADDITIONAL NOTES ON THE USE OF THESE TABLES

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

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

Figure 1.3 shows the support categories with respect to Q system.

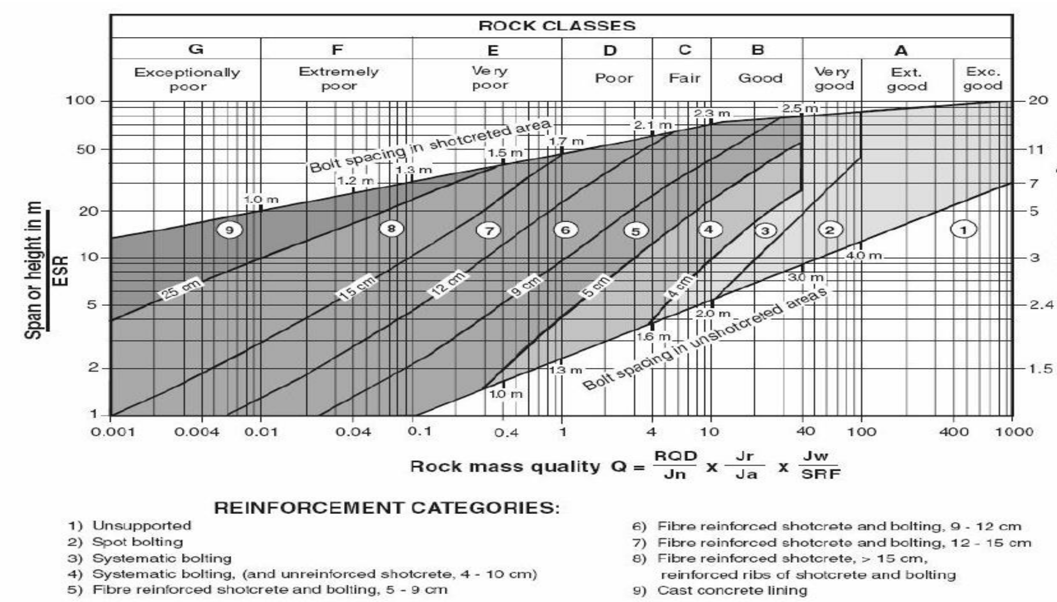

Figure 1. 3 Estimated support categories based on the Q system (Barton, 2002a)

There are some empirical equations in the literature for correlation between Q and RMR values. Most common of these equations is presented by Bieniawski (1989);

$$RMR = 9 * \ln Q + 44$$

Another one based on statistics equation is given by Preston (1989);

$$RMR = 5.9 * \ln Q + 43$$

Today one of the most popular method used in tunnel construction is The New Austrian Tunneling Method (NATM). Between 1957 and 1965 NATM was developed in Austria. Today the name known as NATM was given in London in 1962 to differentiate it from the old Austrian tunneling approach. The main idea behind the NATM which made it this much popular is to use the geological stress of the surrounding rock mass to stabilize the tunnel.

The NATM combines the principles of the behavior of rock masses under load and monitoring the performance of underground construction during construction. The NATM has often been referred to as a "design as you go" approach, by providing an optimized support based on observed ground conditions. Better definition, it can be described as a "design as you monitor" approach, based on observed convergence and divergence in the lining and mapping of prevailing rock conditions.

NATM is based on several features (Bieniawski, 1989) which are;

- Rock mass strength

The method relies on using the surrounding rock mass to support itself as a primary support system, thus rock mass strength is the most important parameter for NATM support system.

- Support system protection

Deformation of the rock must be minimized. For this purpose, a thin layer of shotcrete should be applied right after every span.

- Monitoring

Monitoring the displacements during excavation must be done correctly. This is achieved by installing measurement instruments.

- Flexible support

Since the primary lining is thin and aims to reflect recent strata conditions, additional flexible combination of support elements such as rock bolts, wire mesh are accounted for the support of the tunnel.

- Contractual arrangements

Because the monitoring measurements forms an important part of NATM philosophy, simultaneous changes in supporting and excavation method are possible during construction.

According to NATM, ground is classified qualitatively. The rock mass behavior and its classes are evaluated according to the criteria of Austrian Standard ONORM B 2203. Table 1.4 shows the different several rock mass classes with respect to NATM The correlation between the classification systems RMR, Q and NATM is presented in Figure 1.4.

Table 1. 4 NATM rock mass classification according to ÖNORM B 2203 (Geoconsult, 1993 and ONORM B 2203, 1994)

Rock Mass Class	Behaviour 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 Sligthly Overbreaking	A2 Sligthly 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 discontin- uities 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 nonelastic 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		
C	C1 Rock Bursting	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.

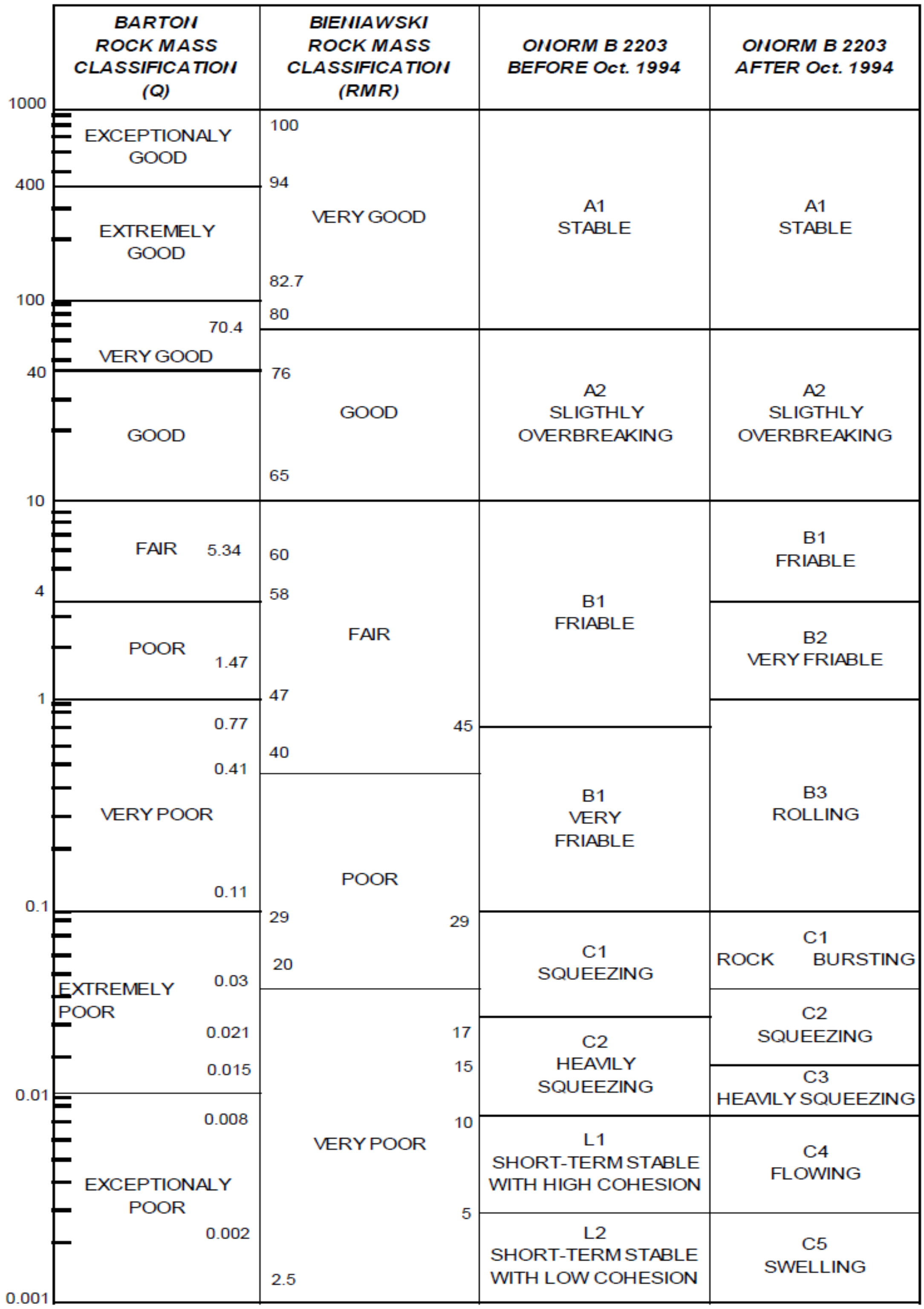

Figure 1. 4 The correlation between the classification systems RMR, Q and NATM (ONORM B 2203, 1994)

CHAPTER 2

GEOLOGY

2.1 General Geology

Belkahve tunnel takes place in south-western part of “İzmir-Ankara-Erzincan Zone” which can be characterized by Cretaceous ophiolitic mélange and highly deformed flysch units within Western Anatolian Horst and Graben province (Brinkmann, 1966). The zone lies between Sakarya continent to the north and Menderes massif to the east and southeast. The zone has been defined as 3 main rock packages; eastern part (a) ultramafics and low degree metaclastic basement, (b) above this "ophiolitic unit (mixtures of submarine volcanics, layered chert, limestone)" and (c) uppermost part by flysch (Kaya, 1972). This chaotic belt is unconformably overlain by Miocene clastics and volcanics (Öngür, 1972).

Dora (1964) was the first person to name the “Bornova flysh” within İzmir-Ankara-Erzincan Zone and also map the formation as phyllite, clay bearing schists and low grade metamorphosed quartzite, greywacke and very low grade metamorphosed arkose alternating with schists and phyllites. Crystalline schists are Paleozoic age. Later on, Oğuz (1966) described the formation as "flysch association" of Upper Cretaceous age with respect to regional correlations done. This unit is made up of chlorite schists, phyllite, metasandstone, albite-epidote schists, actinolite schists, spillite, cherty limestone, meta-conglomerate, bituminous schists which were metamorphosed under greenschist facies. However, the part with exotic blocks which contains of Permian, Triassic, Jurassic and Lower Cretaceous age limestones and serpantinites are named as "Bornova complex" of Maastrichtian- Danian age (Dönmez et al., 1998).

The belt is unconformably sealed by the Miocene units (Figure 2.1). The Miocene volcanic rocks containing mineralizations in the study area are divided into three types as dacites, andesites and andesitic dykes by Dora (1964). Akdeniz et al. (1986) named these volcanics as "Yamanlar volcanites", meantime the ore bearing volcanics was named as "Altıntepe volcanics" by Dönmez et al. (1998).

2.2 Site Geology and Stratigraphy

The study area where the tunnel will be constructed is characterized by Upper Cretaceous Anadağ limestone, Damlacık formation, Upper Cretaceous - Lower Paleocene Belkahve formation (Akdeniz et al., 1986) of "Bornova Flysch", colluvium, alluvium, and slope debris. According to the field studies and field observations, the Belkahve formation (Kb) is seen along the tunnel route. Geological maps and longitudinal geological section of the tunnel route are shown in Figures 2.2-2.4.

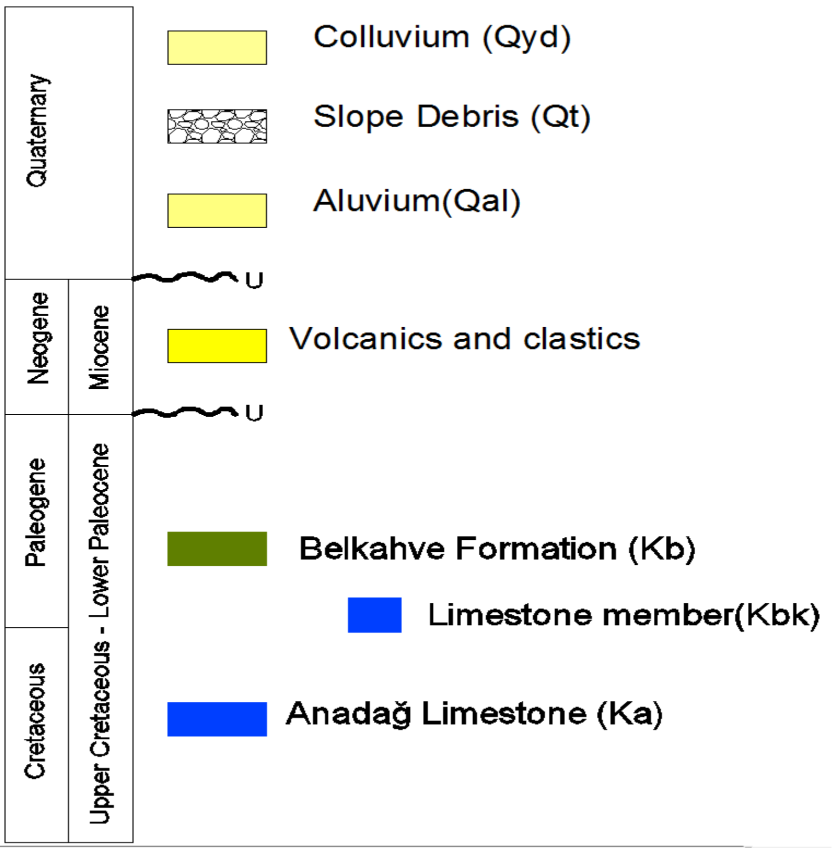

Figure 2. 1 Generalized stratigraphic columnar section of study area

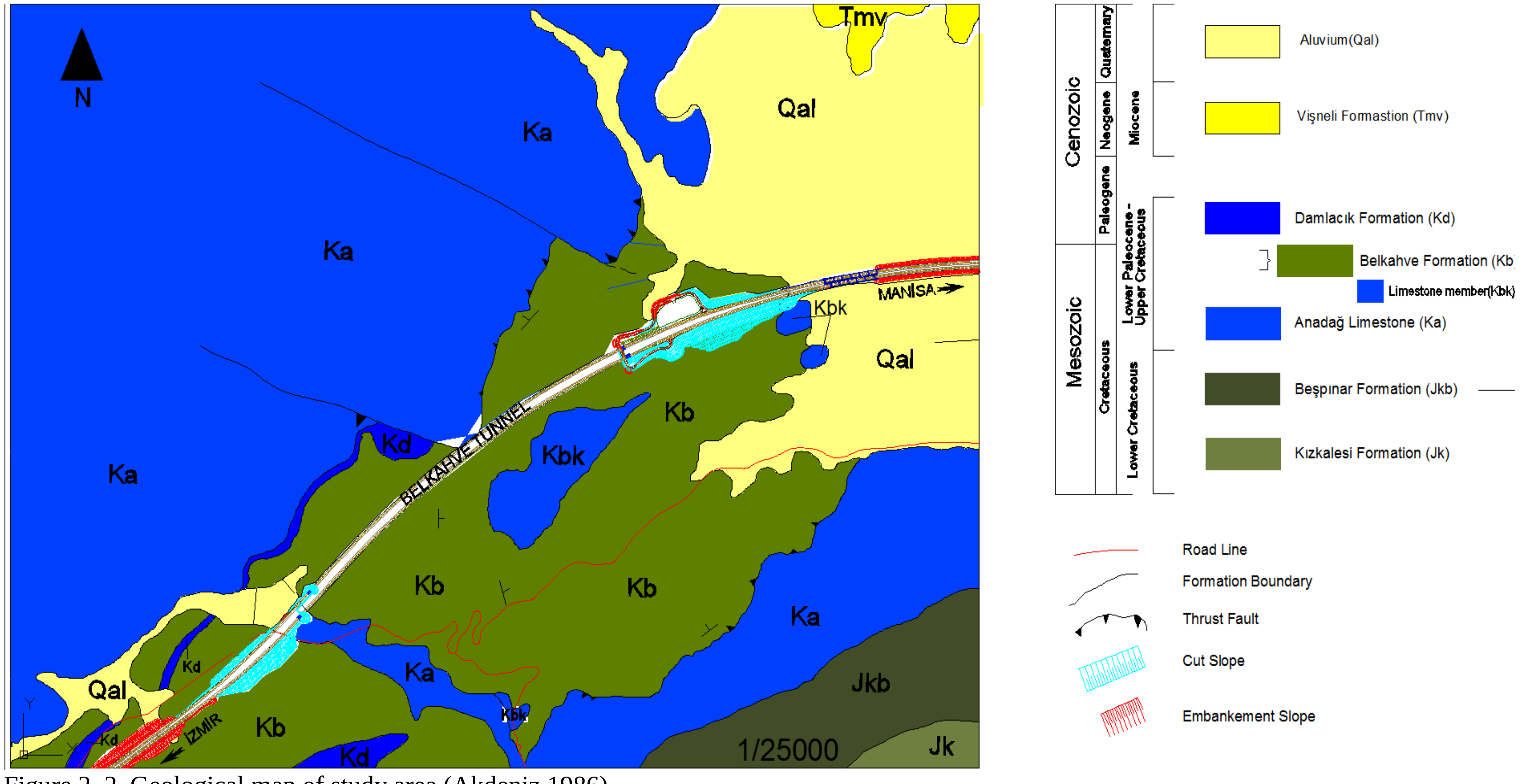

Figure 2. 2 Geological map of study area (Akdeniz,1986)

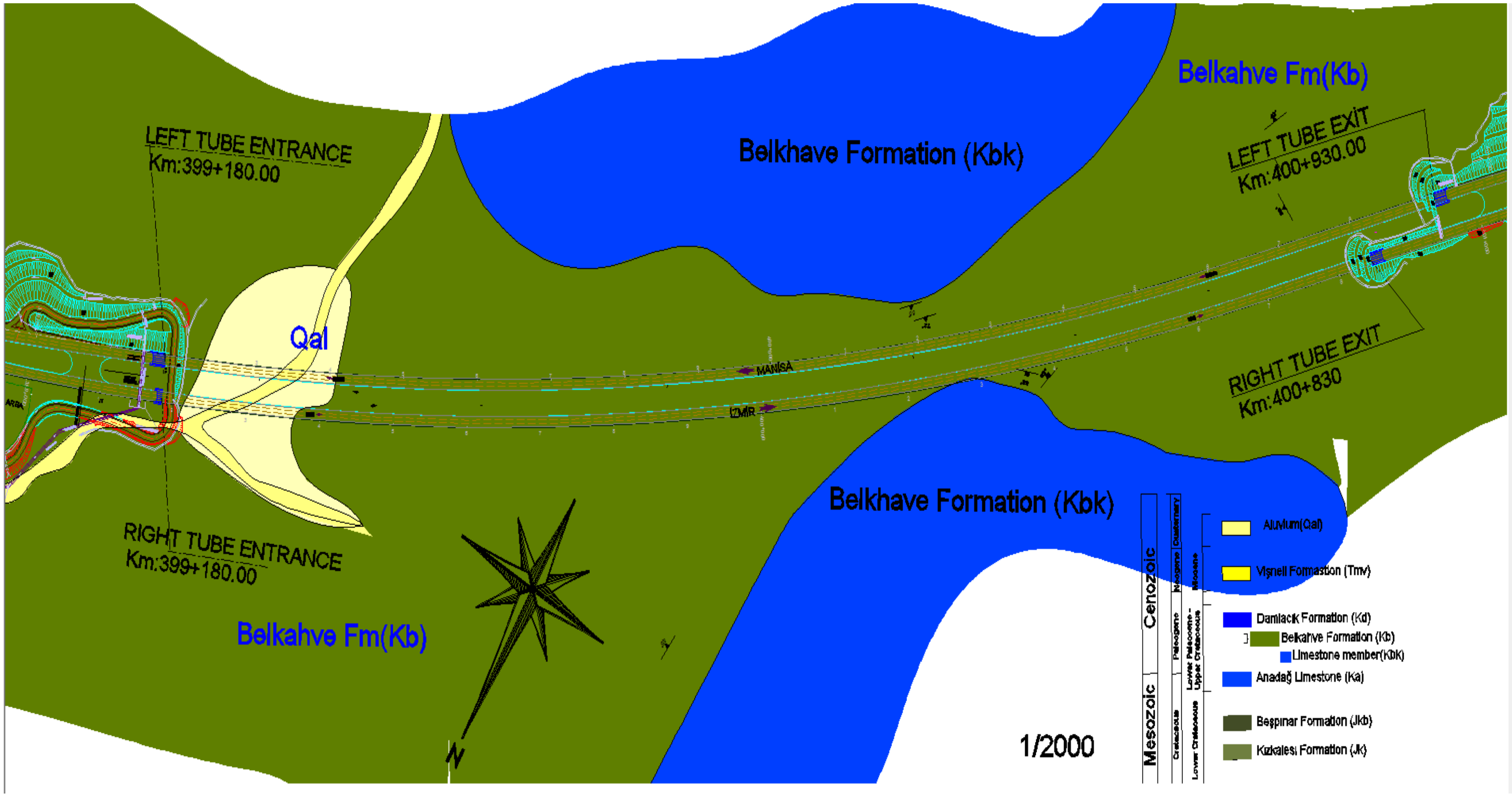

Figure 2. 3 Geological plan view of the tunnel route.

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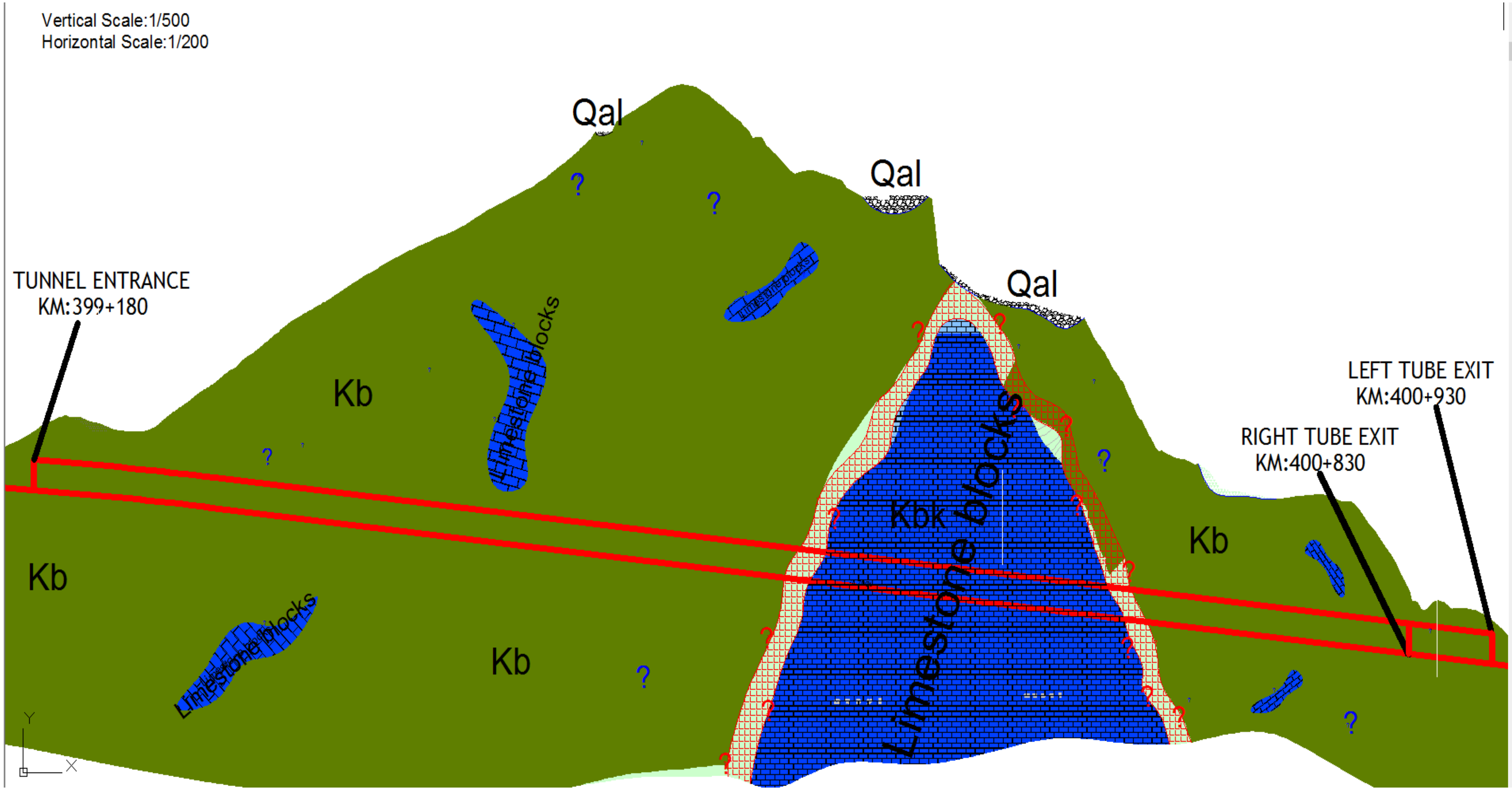

Figure 2. 4 Longitudinal geological section of the tunnel route (Vertical scale:1/500 and Horizontal scale:1/2000)

The detailed description and classification of rocks are essential parts of the geotechnical information obtained to design tunnel support. The description and classification have been done at very early stage of this study by tunnel route observation in the field. Two different geological units dominate the tunnel route which are Belkahve formation (Kb) and Belkahve formation-limestone member (Kbk).

Belkahve Formation (Kb)

This unit which covers large area around İzmir in the frame of "İzmir - Ankara Zone" (Brinkmann, 1966) has been named as "Bornova flysch formation" where it is observed widespread (Öngür, 1972). In general, it is made up of a matrix of clastics, radiolarite and basic volcanic rocks and blocks of various size, age and lithology. In most of the previous works, it was defined with various names, however, in regionwide concept "Bornova flysch" is widely excepted (Konak et al., 1980). In this thesis, "Belkahve" formation name (Akdeniz et al., 1986) is preferred. The Belkahve formation (Kb) consists of clastic rocks in flysch character with limestone blocks. The clastic rocks contain conglomerate-sandstone, shale-marl, clay bearing limestone alternations and and blocks of limestone, radiolarite, greywacke, tuff, spilite and serpentines. The age of the unit unit is Upper Cretaceous (Akdeniz et al., 1986). In the study area, the dominant lithology of the Belkahve formation is green, brownish green, brownish yellow, pinkish beige colored schists. The schist layers are intensely folded (Figure 2.5). The limestone blocks are also observed in thee unit.

Belkahve Limestone Member (Kbk)

Limestone defined in the Belkahve formation is correlated with Anadağ formation. According to Akdeniz et al. (1986), the Belkahve formation includes serpantinite, radiolarite, diabase and various limestone blocks. These limestone blocks are defined as allochtonous (Akdeniz et al., 1986). This allochtonous limestone is mostly observed at the northern and southern side of the tunnel route. In the study area, the Belkahve formation limestone is observed as beige, pinkish beige, gray, dark gray colored biomicritic limestone. The unit is highly fractured (Figure 2.6).

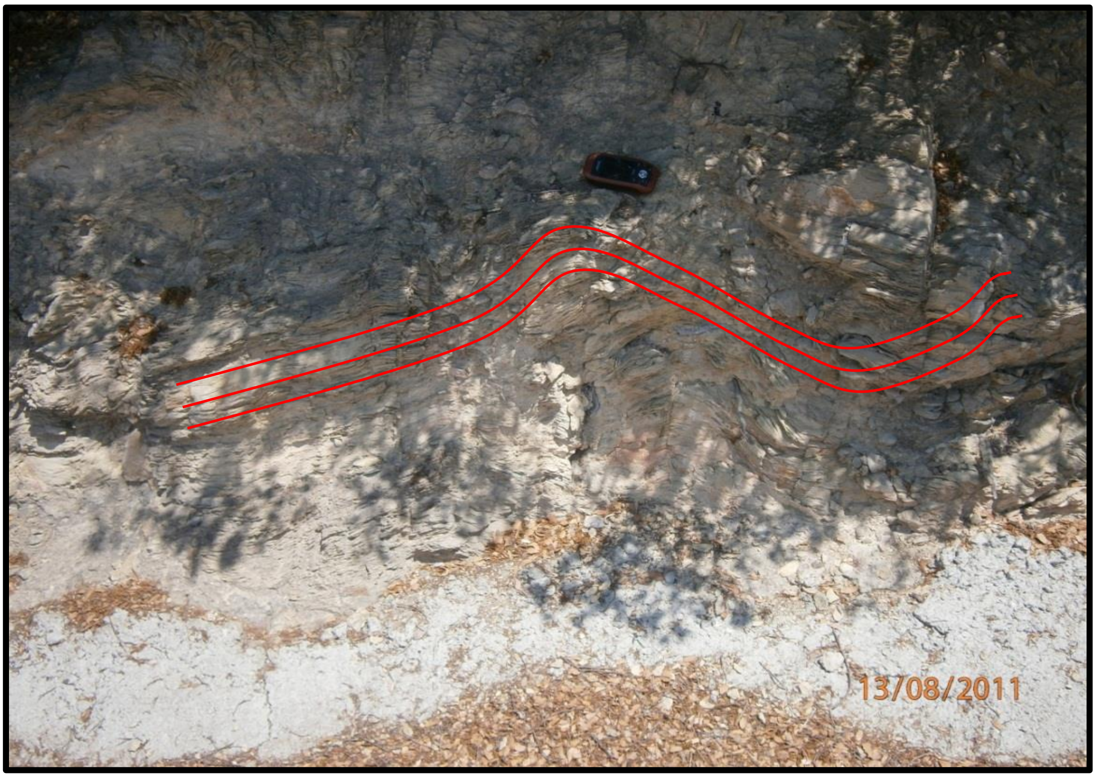

Figure 2. 5 Folded schist layers in the study area.

Figure 2. 6 A view of limestone block (Kbk) in the Belkahve formation along the tunnel route.

2.3 Structural Geology

In the study area, folded and jointed structures within the Belkahve formation are observed. The faults are the regional structures that affect tunnel area, too. However, there are no faults cross cutting the tunnel route.

Folds

Folds located within the İzmir-Ankara Zone being formed by thrust and fold structures are parallel to each other. Folds are generally oriented in the NE-SW direction. The shearing zones are observed along the fold axis. The Belkahve formation is in a NE-SW oriented syncline (Akdeniz et al., 1986). At the northern side of the tunnel route, dip of the schist belonging to the Belkahve formation is mainly towards east. Moreover, at the southern side of the tunnel route, dip of the schist is mainly towards west. This observation shows that the tunnel route passes through the axis of a syncline.

Joints

According to the field studies, at the entrance portal of the tunnel which is between Km: 399+180 – Km: 399+400, three joint sets and random joints exist. The dip amounts and dip directions of the main joint sets are (j1) 83/113, (j2) 80/338, (j3) 54/213. At the exit portal of the tunnel which is between Km: 400+750 – Km: 400+930, two joint sets and random joints exist. The dip amount and dip directions of the main joint sets are (j1) 89/115, (j2) 42/207. Kinematics analyses and the pole concentrations of these joint sets will be discussed and presented in Chapter 3.

Faults

İzmir and its surroundings take place in West Anatolian region which is dominated by tectonic regime developed during neotectonic period. The İzmir bay is settled in the western part of the graben of Gediz in east-west tectonic channel. Most of the tectonic structures, normal faults, are in E-W directions. NW-SE and NE-SW oriented faults are also seen around İzmir region. It can be stated that all neotectonic structures are normal faults. Active fault mapping was performed by MTA (2005) for a circle of 50 km radius centered by the city of İzmir. These active faults are listed below and shown in the Figure 2.7.

1- Güzelhisar Fault
2- Menemen Fault Zone
3- Yenifoça Fault
4- İzmir Fault
5- Bornova Fault
6- Tuzla Fault
7- Seferihisar Fault
8- Gülbahçe Fault
9- Gümüldür Fault
10- Gediz Graben Fault
11- Dağkızılca Fault
12- Kemalpaşa Fault
13- Manisa Fault

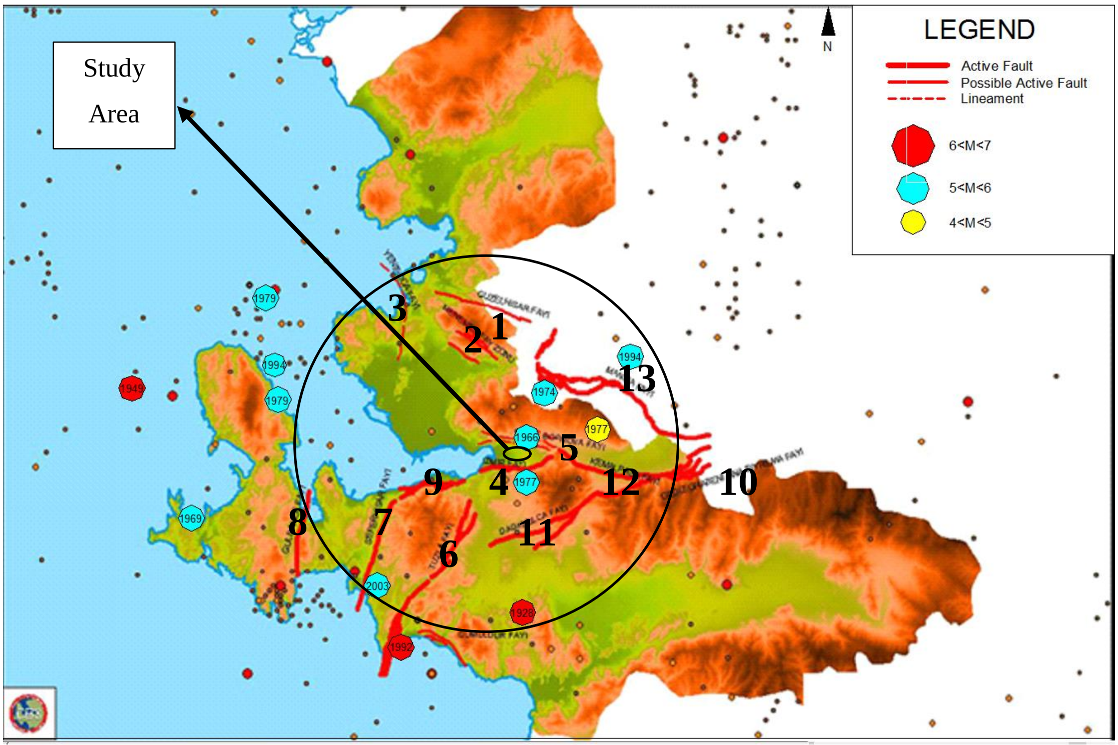

Figure 2. 7 The active fault map of tunnel route and the study area (MTA,2005)

2.4 Seismicity of the Tunnel Area

The geology of its surroundings and its historical earthquakes show that İzmir is one of the regions with high earthquake risk. There are active faults around İzmir region and most of them are close to the Belkahve tunnel route. Moreover, İzmir and the study area have been in the area of high seismic activity. Earthquake epicenter around the study area mostly seen at Aegean Sea, Karaburun, Sakız island, İzmir bay, Midilli island and Sisam Island (Figure 2.7).

According to the distribution of earthquake epicenters, some of the earthquakes occurred around Akhisar, Soma, and Manisa. In the last century, three devastating earthquakes affecting İzmir and its surroundings occurred. These are 1928 Torbalı earthquake possibly along the Tuzla fault (M: 6.5) (Salomon-Calvi et. al., 1940), 1949 Karaburun earthquake possibly along the Seferihisar fault (Jackson and McKenzie, 1984) and 1992 Seferihisar earthquake possibly along the Seferihisar fault (M: 6.0) (Türkelli et al., 1992, 1994).

According to AFAD, tunnel area located in the 1st degree of earthquake zone of Turkey (Figure 2.8) and ground acceleration value should be taken as A0=0.4g according to Technical Specification of GDH (2006). It is expected that, the Belkahve tunnel entrance and exit will be opened in weak and highly fractured schist. Damage of the tunnel due to earthquakes mostly expected where weak structures exist. Therefore, entrance and exit parts of the tunnel are considered to be critical.

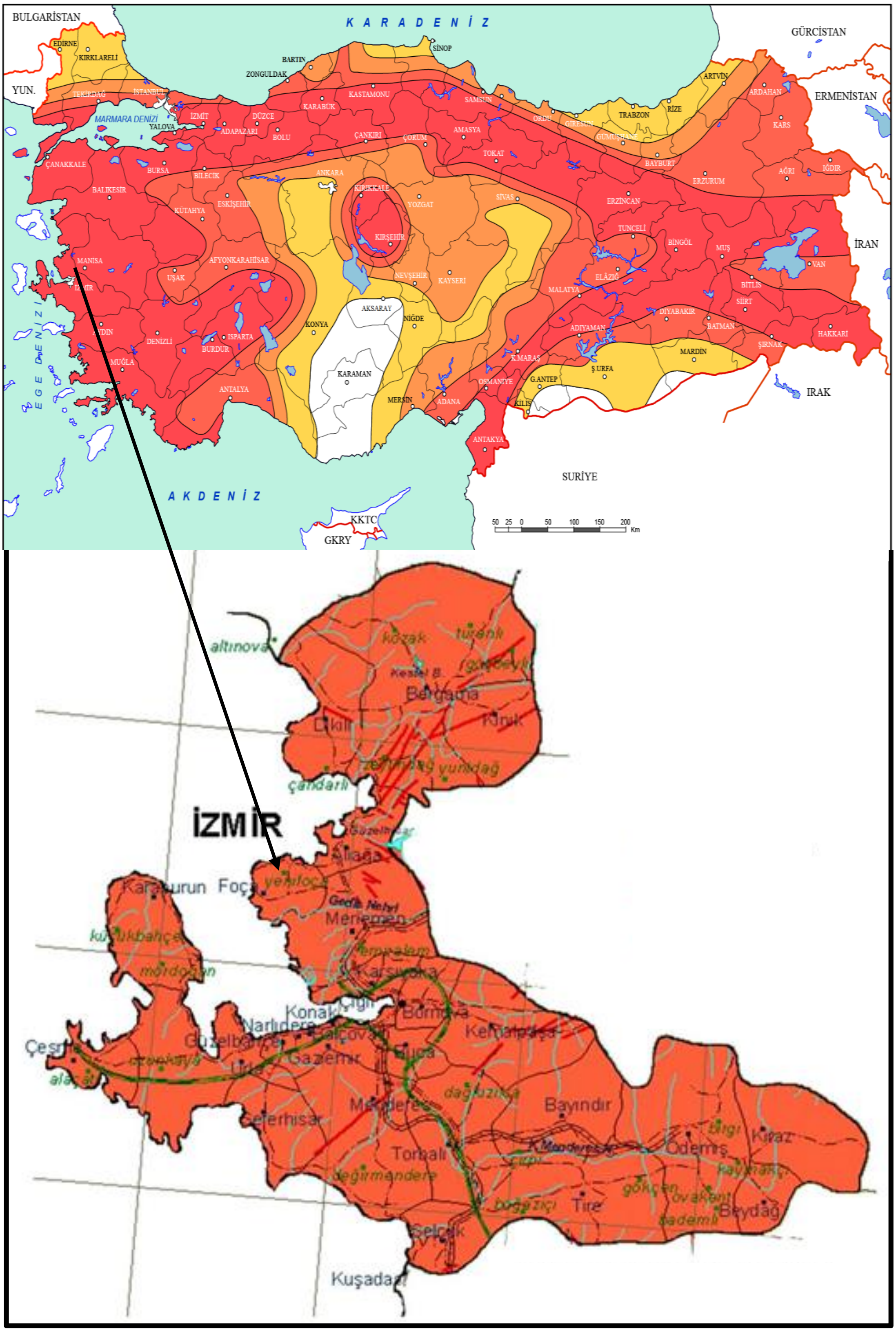

Figure 2. 8 Seismic zonation map of Turkey and the study area (AFAD, 1996)

CHAPTER 3

ENGINEERING GEOLOGY OF THE STUDY AREA

This chapter includes the assessment of engineering geological parameters of the rocks to be cut along the tunnel route. For this purpose, field and laboratory studies were performed. Then, rock mass classifications and strength parameters of the intact rock were determined.

3.1 Field Studies

Field studies were performed on outcrops of the geological units which can be seen through the tunnel route. With the purpose of defining the rock mass, type of discontinuity, spacing, aperture, persistence, roughness, infilling properties, strength and alteration degree of the discontinuity surface, joint water condition, number of sets were determined in accordance with ISRM (1981).

Tunnel portal is the most important part of the tunnel designing. In this context, discontinuity surveys were performed by scanline method (ISRM, 1981; Priest, 1993), especially at the entrance and exit part of the tunnel. The survey line is approximately 10 m. During the survey, at least 150-350 readings should be taken (Priest, 1993). However, in some cases, it was not possible to find outcrops wide enough to collect data in the field. In this thesis, 35-40 readings could be taken at each field exposure during the scanline survey. Classification of discontinuity orientations with respect to tunnel direction recommended by Barton (1989) is presented in Table 3.1.

Table 3. 1 Classification of discontinuity orientation with respect to tunnel direction (Bieniawski, 1989)

EFFECT OF DISCONTINUTY STRIKE AND DIP ORIENTATION AT TUNNELING			
Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with DIP-DIP 45-90°	Drive with DIP-DIP 20-45°	DIP 45-90°	DIP 20-45°
Very Favorable	Favorable	Very Unfavorable	Fair
Drive against DIP-DIP 45-90°	Drive against DIP-DIP 20-45°	DIP 20-45° irrespective of strike	
Fair	Unfavorable	Fair	

According to the field studies, at the entrance portal of the tunnel which is between Km: 399+180 – Km: 399+400, three joint sets and random joints exist. The dip amount and dip directions of the main joint sets are (j1) 83/113, (j2) 80/338, (j3) 54/213. DIPS software is used to obtain pole concentrations and the results are shown in Figure 3.1.

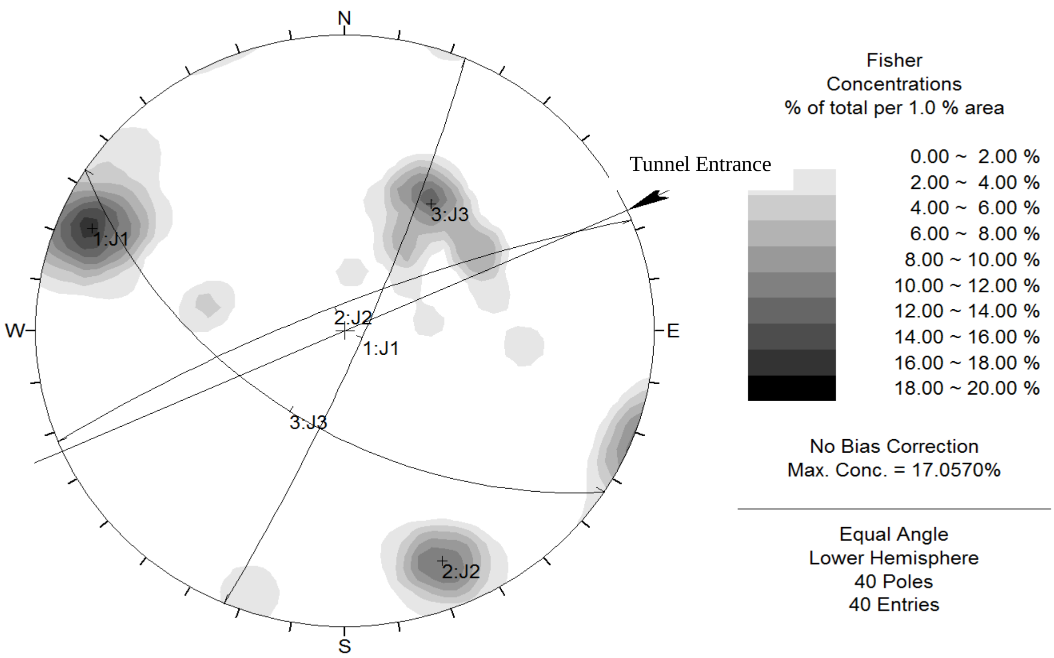

Figure 3. 1 The pole concentration contours and dominant discontinuity sets seen at the entrance portal of the tunnel.

As it seen in Figure 3.1, J1 is cutting the tunnel axis with high angle and driving with dip at an angle of 83°. According to the rock mass rating system (Bieniawski, 1989), J1 is considered to be very favorable. J2 is parallel to tunnel axis and dip amount is 80°. According to the rock mass rating system, J2 is very unfavorable. J3 is almost perpendicular to the tunnel axis and driving against dip with an angle of 54°. According to the rock mass rating system, J3 is fair (Table 3.2).

Table 3. 2 Strike and DIP of the discontinuities at the tunnel entrance portal

Discontinuity	Strike	DIP	Definition
J1 (83/113)	Perpendicular to tunnel axis	Drive with DIP 83°	Very Favorable
J2 (80/338)	Parallel to tunnel axis	DIP 80°	Very Unfavorable
J3 (54/213)	Perpendicular to tunnel axis	Drive against DIP 54°	Fair

According to the results given in Table 3.2, for the tunnel entrance portal, the effect of discontinuity strike and dip amount for tunneling is stated to be “Fair” as an average of three joints’ descriptions.

At the exit portal of the tunnel which is between Km: 400+750 – Km: 400+930, two joint sets and random joints exists. The dip amount and dip directions of the main joint sets are (j1) 89/115, (j2) 42/207. DIPS software is used to obtain pole concentrations and the results are shown in Figure 3.2.

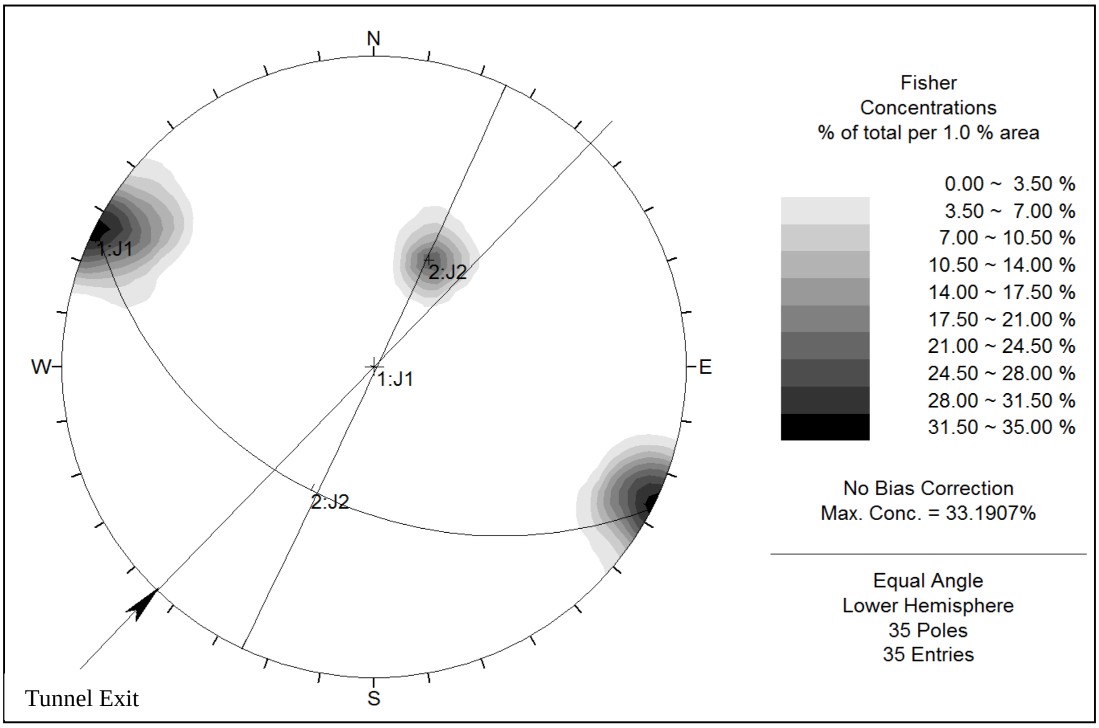

Figure 3. 2 The pole concentration contours and dominant discontinuity sets seen at the entrance portal of the tunnel.

As it seen in Figure 3.2, J1 is perpendicular to tunnel axis and driving with dip with an angle of 83°. According to the rock mass rating system (Bieniawski, 1989), J1 is very favorable. J2 is parallel to tunnel axis and dip angle is 80°. According to the rock mass rating system, J2 is very unfavorable (Table 3.3).

Table 3.3 Strike and DIP of the discontinuities at the tunnel exit portal.

Discontinuity	Strike	DIP	Definition
J1 (89/115)	Parellel to tunnel axis	DIP 89°	Very Unfavorable
J2 (42/207)	Perpendicular to tunnel axis	Drive with DIP 42°	Favorable

According to the results given in Table 3.3, for the tunnel exit portal, the effect of discontinuity strike and dip amount for tunneling is concluded as “Unfavorable” as an average of two joints’ descriptions.

3.2 Drillings

Eight boreholes were drilled (Table 3.4) with a total length of 641.5 m to finalize the cross-section and determine the geotechnical parameters of the rock mass through the tunnel route. ÖZTAY Group (2012) drilled the boreholes. During drilling, the rotary core drilling method with water swivel type double tube core barrel was used for obtaining core samples. During drillings, double mud pump wire line HQ and NQ equipped trucks, D-900 and D-750 were used (Figure 3.3). During drillings, lithological aspect of rocks, strength, alteration, discontinuity condition, roughness, TCR, RQD descriptions were done and logged as soon as possible.

Cores obtained from the drillings covered with paraffin in order not to loose its natural water content. Rock samples labeled with the name of the project, name of the borehole, rock sample type and depth right before sending them to the laboratory. During the drillings, groundwater depth (GWD) was measured very carefully 48 hours after the drillings were completed. To make the measurements properly, 50 mm diameter PVC pipe was placed into the borehole.

Photographs of the core box and the borehole logs are presented in Appendix A and Appendix B. Also the location of the boreholes is given in Figures 3.4 and 3.5.

Table 3.4 Location, coordinates and depth of the boreholes drilled along the tunnel.

Borehole No	Location	Coordinates		Depth (m)	Km
		x	y		
SK-802	Entrance	4259592	528418	42	KM: 399+310
SK-804	Middle	4259115	527699	130	KM: 400+200
SK-805	Middle	4259457	528157	90	KM: 399+600
SK-807	Middle	4259315	527944	128	KM: 399+860
SK-808	Middle	4258979	527505	100	KM: 400+415
SK-809	Middle	4258845	527374	59	KM: 400+600
SK-806	Exit	4258675	527212	45	KM: 400+836
SK-810	Exit	4258582	527189	47,5	KM: 400+915

Figure 3. 3 Drilling machine at the middle section of the tunnel route.

3.3 Hydrogeology of the Tunnel Route

The Belkahve formation will be cut through the tunnel route. The Belkahve limestone is highly fractured and contains groundwater. On the other hand, the schist involved in the Belkahve formation can be defined as impermeable. However, the sandstone layers included within the schist may contain some water. Along tunnel route, measured groundwater depths of the boreholes from the surface are presented in Table 3.5.

Table 3.5 Groundwater levels measured at the boreholes

BOREHOLE NAME	GWD (m)
SK-802	5.91
SK-804	9.98
SK-805	29.50
SK-807	59.00
SK-808	47.00
SK-809	7.50
SK-806	5.46
SK-810	6.40

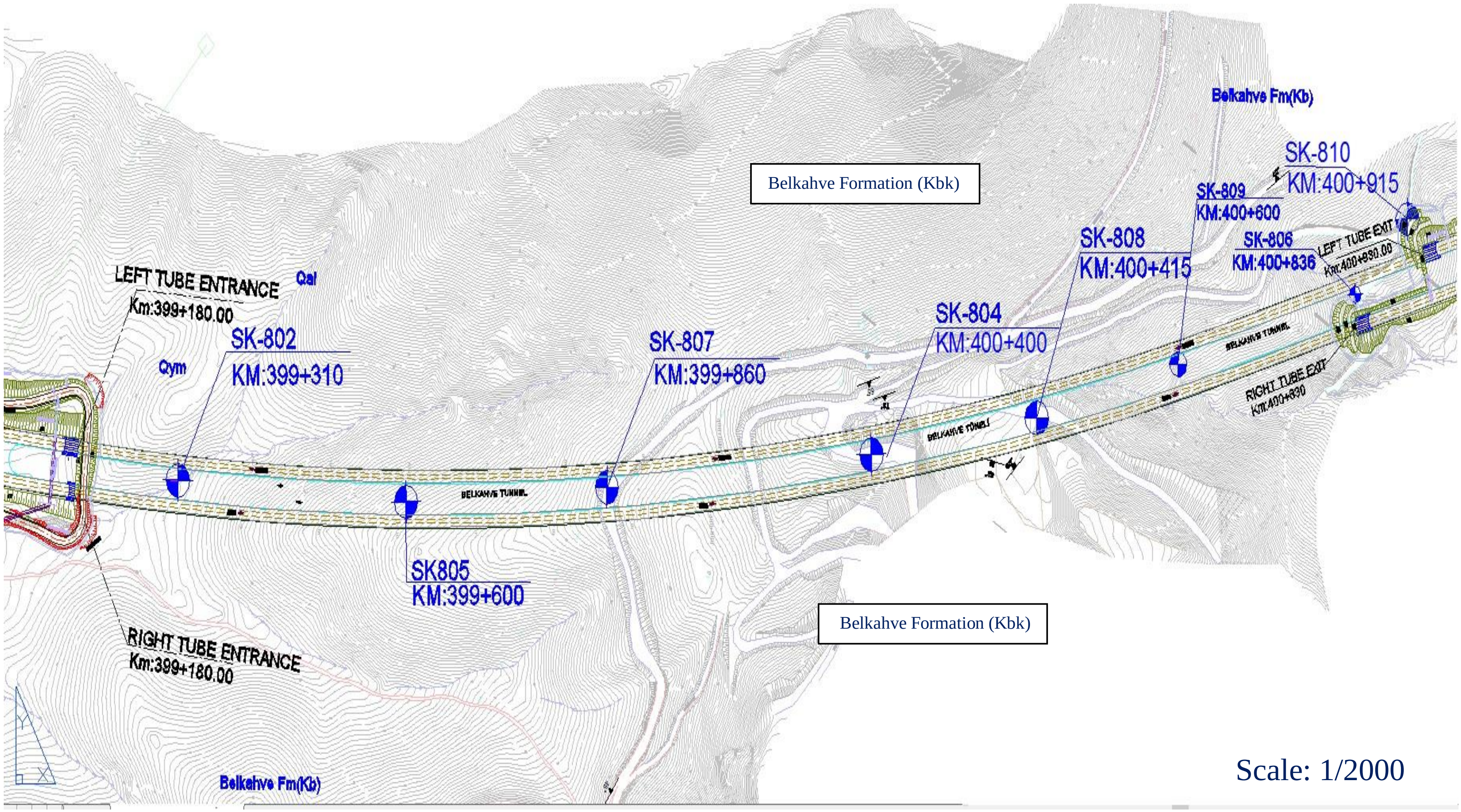

Figure 3. 4. Map showing borehole locations along the tunnel route.

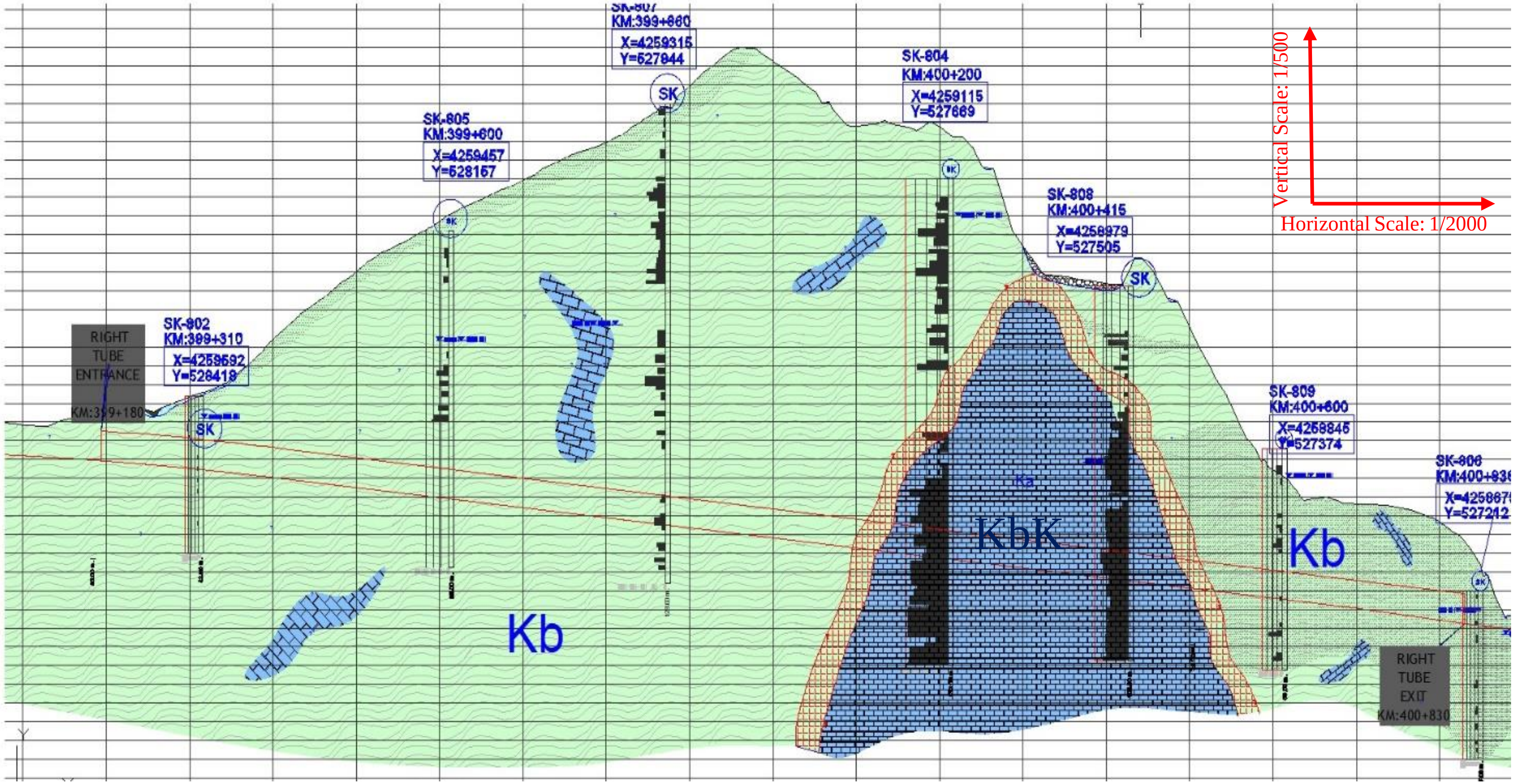

Figure 3. 5 The longitudinal geological section of the tunnel with borehole locations show.

According to the GWD measurements, groundwater table is close to the surface (5m-10m) at portal areas. However, at the middle section of the tunnel route, depth of the groundwater from the surface varies approximately between 30 m and 60 m.

According to GWL measurements, it can be easily stated that groundwater will be a problem for both open cuts at the entrance and exit of the tunnel. It's a known fact that groundwater has negative effects on the stability of the slopes. The main reason that creates this negative effect is the effective stress reduction due to pore pressure of the groundwater. Consequently, shear strength of the rock mass is reduced.

Packer (lugeon) tests were performed in boreholes SK -807 and SK-808. Packer Test consists of the measurement of the volume of escaping water from an unsealed section of a borehole under a specific pressure. Applied pressures to the borehole were selected as 2-4-6-8-10-8-6-4-2 atm. By measuring the volume of escaped water, lugeon values of the rock mass were determined. The manual prepared by Altuğ (1971) is used to calculate the Lugeon values. The classification of the Lugeon values is presented in Table 3.6 and the test results are shown in Table 3.7.

Table 3.6 Classification of lugeon values (Altuğ, 1971)

Lugeon value	Description
Less than 1	Impervious
1-5	Slightly pervious
5-25	Pervious
Greater than 25	Highly pervious

Table 3. 7 Results of packer tests performed in boreholes.

Borehole Name	Depth of Intervals		LU
SK-807	84,00 m.	87,00 m.	1,4
SK-807	90,00 m.	93,00 m.	2,76
SK-807	103,50 m.	106,50 m.	0,8
SK-807	106,50 m.	109,50 m.	0,27
SK-808	53,00 m.	56,00 m.	0,35
SK-808	59,00 m.	62,00 m.	0,32
SK-808	65,00 m.	68,00 m.	0,28
SK-808	71,00 m.	74,00 m.	2,66
SK-808	77,00 m.	80,00 m.	0,59
SK-808	83,00 m.	86,00 m.	1,16

In SK 807, at depth intervals of 84.0 m - 87.0 m, 90.0 m - 93.0 m, 103.5 m - 106.5 m, 106.5 m - 109.5 m, lugeon values were found to be 1.40, 2.76, 0.8, and 0.27, respectively. According to the lugeon values obtained, schist-sandstone interbedded unit can be defined as impervious to slightly pervious.

In SK-808, at depth intervals of 53.0 m - 56.0 m, 59.0 m - 62.0 m, 65.0 m - 68.0 m, 71.0 m - 74.0 m, 77.0 m - 80.0 m, 83.0 m - 86.0 m, lugeon values were found to be 0.35, 0.32, 0.28, 2,66, 0,59, and 1.16, respectively. According to the lugeon values obtained from the test, the limestone unit can be defined as impervious to slightly pervious. However, despite the high fractured nature of the limestone, low lugeon values can be interpreted as the filling of the fractures with chemicals used during drillings. Therefore, the limestone should be at least considered to be slightly pervious.

Moreover, two sections along the tunnel route have been described as “shear zone”. They may cause possible groundwater inflow problems during tunnel excavation due to the highly fractured nature of the rock. Unfortunately, there is no lugeon test for the corresponding kilometers of the shear zones at the tunnel route. However, considering that the zones are expected to be highly pervious due to its highly fractured structure, some precautions should be taken during the excavations. These will be discussed at later part of this thesis.

3.4 Geotechnical Assessment of Formations

According to the field observations, schist belonging to the Belkhave formation can be defined as weak-very weak in strength. Laboratory test results performed on the samples obtained from Belkhave formation also proves that. In this respect, parts which will be excavated in the Belkahve formation, entrance and exit portals should be properly supported in order to eliminate stability problems due to the highly fractured nature (low RQD values) of the Belkahve formation. It's reasonable to worry about the stability problems which would be caused by groundwater. Therefore, additional geotechnical solutions, such as weep-hole drains could be installed in order to discharge the groundwater safely from the slopes.

The limestone (Kbk) which also belongs to the Belkahve formation, can be considered as strong rock however fractured nature of the limestone may be a problem for the tunnel. The limestone observed in the study area was not present directly along the tunnel route. So it is predicted that, only during tunnel excavation the limestone may be observed. In this unit, groundwater inflow is expected to be a problem during tunnel excavation due to the fractured limestone.

Shear Zone

According to the geological survey, Upper Cretaceous-Paleocene Belkahve formation and Upper Cretaceous limestone are incompatible with each other. Younger limestone is located within the schists of the Belkhave formation. Based on the drilling data, there exists a weak, highly fractured zone discovered at the contacts of the two formations. Due to the incompatibility of the two formations, it is decided to define the shearing zone in order to explain the relationship of these two formations. Moreover, according to the correlations done using the borehole data, it is predicted that this weak shear zone will be cut along the tunnel route at two different sections. However, it is very difficult to define the exact location of this kind of zone which couldn't be observed at the surface and only be predicted by limited number of boreholes.

3.5 Laboratory Tests

With the aim of determining the material properties of the rock mass, laboratory tests were performed by Limit Geotechnical Services Limited Company (2012) on the rock core samples. In Appendix C the results of laboratory tests are given. Also Table 3.8 shows the laboratory test results.

Table 3.8 Laboratory test results of the rocks along the tunnel

Borehole Nanme	Depth		Natural Unit Weight	Elastic Modulus	Poisson's Ratio	Uniaxial Comp. Strength Test	Point Load Strength Test
	m. from	m. to	γ_n	E	υ	q_c	$I_{s\,(50)\text{-}AV}$
			kN/m^3	GPa		Kgf/cm^2	MPa
SK-802	4,5	8	25,7				0,49
SK-802	8	15	26,19				2,02
SK-802	16	23	26,68				2,89
SK-802	24	30	26,59				8,95
SK-802	31	36,5	26,68				3,62
SK-804	66,5	67	19,62	1,29	0,366	83	
SK-804	68,3	68,8	22,96	2,48	0,337	122	
SK-804	100	100,5	24,62	7,95	0,313	438	

Table 3.8 continued

Borehole Nanme	Depth		Natural Unit Weight	Elastic Modulus	Poisson's Ratio	Uniaxial Comp. Strength Test	Point Load Strength Test
	m. from	m. to	γn	E	υ	q_c	Is $_{(50)\text{-AV}}$
			kN/m^3	GPa		Kgf/cm^2	MPa
SK-804	104,5	105	26,88	11,05	0,277	707	
SK-804	108	108,5	26,39	9,95	0,309	650	
SK-804	109,5	110	28,25	10,15	0,327	632	
SK-804	115	115,5	28,06	8,95	0,346	560	
SK-804	118	118,5	26,59	10,19	0,252	717	
SK-805	17,3	18,8	16,09				0,08
SK-805	32,5	34	26				0,3
SK-805	36	37,5	26,49	22,04	0,23	349,63	
SK-805	41,5	44,2	18,64				0,12
SK-805	46,9	48,2	16,09				0,66
SK-805	49,4	50,55	26,29	61,77	0,32	785,25	
SK-805	52,7	57	26,68				2,65
SK-805	73,4	75	26,68				4,05
SK-806	1,5	7	26,09				5,3
SK-806	8,6	9	25,41	8,83	0,281	435	
SK-806	13	15	25,9				4,12
SK-806	20	20,15	25,9				
SK-806	21	21,7	26,39				
SK-806	25,5	26	26				
SK-806	32,6	33	25,9				
SK-806	36,5	36,8	26,09				3,32
SK-807	22,5	23,5	26,09	57,11	0,18	546,83	
SK-807	31,5	33	26,29				1,72
SK-807	39	41	26	36,5	0,24	459,6	
SK-807	47,2	47,8	26,29	58,96	0,21	781,55	
SK-807	53	56,8	26,49				1,64
SK-807	70,4	72	26,49				0,37

Table 3.8 continued

Borehole Nanme	Depth		Natural Unit Weight	Elastic Modulus	Poisson's Ratio	Uniaxial Comp. Strength Test	Point Load Strength Test
	m. from	m. to	γn	E	υ	q_c	$Is_{(50)-AV}$
			kN/m^3	GPa		Kgf/cm^2	MPa
SK-807	72,7	75,2	27,66	5,18	0,21	132,93	
SK-807	75,2	77	26,09				1,21
SK-807	82	83,2	26,09				3,28
SK-807	87,4	88,3	26,59	52,1	0,21	1575,09	
SK-807	90	92	26				3,75
SK-807	97	99,2	26,88				3,45
SK-807	102,1	103,5	26,29				5,3
SK-807	105,6	106,5	22,86				
SK-807	108,2	110,5	25,9				4,47
SK-807	110,5	112,5	26,49	50,92	0,19	1086,72	
SK-807	112,5	115,6	26,59				1,18
SK-807	117,3	119,3	26,29				6,32
SK-807	121,3	123,3	25,02				3,67
SK-808	18,35	22,35	25,51			131,3	0,16
SK-808	30,55	31,7	23,25				
SK-808	36,3	38,5	24,92	7,22	0,4	87,02	
SK-808	45,5	48,5	26,29	69,73	0,32	813,82	
SK-808	55,4	56	26,29	76,42	0,25	514,94	3,22
SK-808	59,6	62	26,39	52,05	0,33	320,17	
SK-808	65	71	26,29	54,95	0,27	551,09	2,34
SK-808	74	80	26,19	44,77	0,26	462,53	3,35
SK-808	83	86	26,49	54,15	0,32	192,85	
SK-808	90	96	24,92	38,17	0,4	270,28	3,05
SK-809	4,6	6,8	26,49				5,7
SK-809	9,5	12,5	26,68				5,46
SK-809	14	16,7	27,57				5,47
SK-809	20,4	22,3	26	31,39	0,2	454,34	7,57
SK-809	24	24,5	24,79	43,07	0,28	645,43	

Table 3.8 continued

Borehole Nanme	Depth		Natural Unit Weight	Elastic Modulus	Poisson's Ratio	Uniaxial Comp. Strength Test	Point Load Strength Test
	m. from	m. to	γ_n	E	υ	q_c	$I_{s\ (50)\text{-}AV}$
			kN/m^3	GPa		Kgf/cm^2	MPa
SK-809	27	28	26,19				3,59
SK-809	28,4	31	26,59				1,11
SK-809	33,3	35,8	20,99				0,07
SK-809	38,5	39,5	22,37	1,93	0,27	55,11	
SK-809	40,5	41,5	20,8				
SK-809	43,1	44,5	26,68				4,54
SK-809	45,2	45,7	26				
SK-809	46,5	48,5	26,29				3,41
SK-809	49	50	26,59	20,21	0,19	91,76	
SK-809	52,5	54,5	26				1,22
SK-809	55,5	56,5	26,39	44,85	0,16	688,9	
SK-810	Mar.50	Nis.50	25,6				0.40
SK-810	May.50	Haz.50	25,51				
SK-810	Ara.20	14.20	26,09				0.81
SK-810	23.90	24.50	26,19				2,660
SK-810	30.00	31.00	26				
SK-810	31.00	33.50	26,39				4,25
SK-810	44.00	47.50	26,49				2,67

According to the laboratory results given above in Table 3.8, for borehole SK- 802 drilled in the Belkahve formation, natural unit weight values range between 25,70 kN/m^3 and 26,68 kN/m^3, and point load strength values range between 0,49 MPa and 8,95 MPa.

For borehole SK- 804 drilled in the Belkahve formation, natural unit weight values vary from 19,62 kN/m^3 to 28,25 kN/m^3, Elastic modulus values vary from 1,290 GPa to 11,050 GPa, poisson's ratio values vary from 0,252 to 0,366 and uniaxial compressive strength values vary from 83 Kgf/cm^2 to 717 Kgf/cm^2.

For borehole SK- 805 drilled in the Belkahve formation, natural unit weight values change between 16,09 kN/m^3 and 26,68 kN/m^3, elastic modulus values change between 22,04 GPa and 61,77 GPa, poisson's ratio values change between 0,23 and 0,32, uniaxial compressive strength values change between 349,63 Kgf/cm^2 and 785,25 Kgf/cm^2, and point load strength values change between 0,12 MPa and 4,05 MPa.

For borehole SK- 806 drilled in the Belkahve formation, natural unit weight values vary from 25,41 kN/m^3 to 26,39 kN/m^3, elastic modulus value is 8,83 GPa, poisson's ratio value is 0,28, uniaxial compressive strength value is 435 Kgf/cm^2 and point load strength values vary from 3,32 MPa to 5,30 MPa.

For borehole SK- 807 drilled in the Belkahve formation, natural unit weight values range between 25,90 kN/m^3 and 27,66 kN/m^3, elastic modulus values range between 5,18 GPa and 58,96 GPa, poisson's ratio values range between 0,18 and 0,24, uniaxial compressive strength values range between 132,93 Kgf/cm^2 and 1575,09 Kgf/cm^2, and point load strength values range between 0,37 MPa and 6,32 MPa.

For borehole SK- 808 drilled in the Belkahve formation, natural unit weight values vary from 22,86 kN/m^3 to 26,49 kN/m^3, elastic modulus values vary from 7,22 GPa to 76,42 GPa, poisson's ratio values vary from 0,25 to 0,4, uniaxial compressive strength values vary from 87,02 Kgf/cm^2 to 813,82 Kgf/cm^2, and point load strength values vary from 0,16 MPa to 3,35 MPa.

For borehole SK- 809 drilled in the Belkahve formation, natural unit weight values range between 22,86 kN/m^3 and 26,49 kN/m^3, elastic modulus values range between 1,93 GPa and 44,85 GPa, poisson's ratio values range between 0,16 and 0,28, uniaxial compressive strength values range between 55,11 Kgf/cm^2 and 688,90 Kgf/cm^2, and point load strength values range between 0,07 MPa and 7,57 MPa.

CHAPTER 4

ROCK MASS CLASSIFICATIONS OF THE ROCKS ALONG THE BELKAHVE TUNNEL

Rock mass rating classification (RMR), rock mass quality classification (Q), New Austrian Tunneling Method classification (NATM) and geological strength index (GSI) classifications have been used in this thesis based on the data collected from site,

4.1 Rock Mass Rating Classifications

The rock mass rating (RMR) system is a rock mass quality classification developed by South African Council for Scientific and Industrial Research (CSIR), closely associated with excavation for the mining industry (Bieniawski, 1973). Bieniawski (1976) published the details of a rock mass rating (RMR) system. Over the years, this system has been successively refined as more case records have been examined. In the application of the latest version of RMR classification system (Bieniawski 1989), the rock mass is divided into zones with uniform geotechnical characteristics in accordance with the geological units and major structural features. Five parameters, given below are determined for each of the geotechnical unit:

1- Strength of intact rock material
2- Drill Core Quality, RQD
3- Spacing of Discontinuities
4- Condition of Discontinuities
5- Groundwater Conditions of Groundwater

Table 4.1 shows The Rock Mass Rating (RMR) system is used to determine the ratings for each of the five parameters listed above. As final step, these ratings are summed to determine a value of basic RMR.

Table 4. 1 Rock Mass Rating System (After Bieniawski 1989).

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

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

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

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

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

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

D. MEANING OF ROCK CLASSES

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

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence)	< 1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Ratings	6	5	3	1	0

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

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

Entrance Section (KM: 399+180 – KM: 399+400)

SK-802 is evaluated for rock mass classification of entrance section. According to drilling data and laboratory test results RMR rating determined and presented below in Figure 4.1.

Figure 4. 1. Basic and total RMR rating calculation with respect to SK-802

	Rating
Uniaxial Compressive Strength, σ_c (1-5 MPa) :	1
Rock Quality Designation (RQD <%25) :	3
Spacing of Discontinuities (<60 mm) :	5
Persistence of Discontinuities (1-3 meter) :	4
Aperture of Discontinuities (1-5.0 mm):	1
Roughness of Discontinuities (Slightly rough):	0
Infilling (Calcite<5mm):	2
Weathering (Highly weathered):	1
Groundwater condition (Damp):	7
Basic RMR:	24
Discontinuity Orientation (Fair):	-5
Total RMR Point:	19
Class	Very Poor Rock

Middle Section (KM: 399+400 – KM: 400+750)

SK-804, SK-805, SK-807, SK-808, SK-809 are evaluated for the rock mass classification of the middle section. This section is divided into seven geotechnical zones. According to the drilling data and laboratory test results, RMR rating of the rocks determined and presented below for different kilometer ranges.

KM: 399+400 – KM: 399+700 (in accordance with SK-805)

Figure 4. 2 Basic and total RMR rating calculation with respect to SK-805

	Rating
Uniaxial Compressive Strength, σ_c (5 MPa) :	1
Rock Quality Designation (RQD <%25) :	3
Spacing of Discontinuities <60 mm):	5
Persistence of Discontinuities (1-3 m):	4
Aperture of Discontinuities (1.0-5.0 mm):	1
Roughness of Discontinuities (Slightly rough):	0
Infilling (Calcite<5mm) :	2
Weathering (Highly weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	27
Discontinuity Orientation (Fair):	-5
Total RMR Point:	22
Class	Poor Rock

KM: 399+700 – KM: 400+080 (in accordance with SK-807)

Figure 4. 3 Basic and total RMR rating calculation with respect to SK-807

	Rating
Uniaxial Compressive Strength, σ_c (10 MPa):	2
Rock Quality Designation (RQD <%25):	3
Spacing of Discontinuities (<60 mm):	5
Persistence of Discontinuities (1-3 m):	4
Aperture of Discontinuities (1.0-5.0 mm):	1
Roughness of Discontinuities (Slightly rough):	0
Infilling (Calcite-Quartz<5mm) :	2
Weathering (Highly weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	28
Discontinuity Orientation (Fair):	-5
Total RMR Point:	23
Class	Poor Rock

KM: 400+080 – KM: 400+150

As it can be seen on the geological cross-section, this part of the tunnel route is defined as shear zone. From the point of geotechnical view, in order to be on the safe side, very poor rock class is assigned for shearing zone. However, the real specification and location of shear zone should only be determined during the excavation. Horizontal boreholes should be drilled from the face of the tunnel excavation. Geologically, this part can be defined as meta-sandstone-schist with clay matrix. According to the drilling logs RMR rating calculated for this weak zone and to be on the safe side, engineering parameters c= 20 kPa, Ø= 25°, Erm= 100 MPa and weak strength rock are assumed for this section.

Figure 4. 4 Basic and total RMR rating calculation for shear zone.

	Rating
Uniaxial Compressive Strength, σ_c (5 MPa) :	2
Rock Quality Designation (RQD %21):	3
Spacing of Discontinuities (60-200 mm) :	5
Persistence of Discontinuities (3-10 meter):	2
Aperture of Discontinuities (0.1-1.0 mm):	1
Roughness of Discontinuities (rough):	0
Infilling (hard filling<5mm) :	2
Weathering (slightly weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	26
Discontinuity Orientation (Unfavorable):	-10
Total RMR Point:	16
Class	Very Poor Rock

KM: 400+200 – KM: 400+450 (in accordance with SK-804)

Figure 4. 5 Basic and total RMR rating calculation with respect to SK-804

	Rating
Uniaxial Compressive Strength, σ_c (44 MPa) :	4
Rock Quality Designation (RQD %50-%75) :	13
Spacing of Discontinuities (60-200 mm) :	8
Persistence of Discontinuities (10-20 meter):	1
Aperture of Discontinuities (1-5.0 mm):	1
Roughness of Discontinuities (Slightly rough):	3
Infilling (Calcite<5mm) :	4
Weathering (Slightly weathered):	5
Groundwater condition (Damp):	10
Basic RMR:	49
Discontinuity Orientation (Fair):	-5
Total RMR Point:	44
Class	Fair Rock

KM: 400+200 – KM: 400+450 (in accordance with SK-808)

Figure 4. 6 Basic and total RMR rating calculation with respect to SK-808

	Rating
Uniaxial Compressive Strength, σ_c (50 MPa) :	4
Rock Quality Designation (RQD %21):	13
Spacing of Discontinuities (60-200 mm) :	8
Persistence of Discontinuities (3-10 meter):	1
Aperture of Discontinuities (0.1-1.0 mm):	1
Roughness of Discontinuities (rough):	3
Infilling (hard filling<5mm) :	4
Weathering (slightly weathered):	5
Groundwater condition (Damp):	10
Basic RMR:	49
Discontinuity Orientation (Fair):	-5
Total RMR Point:	44
Class	Fair Rock

KM: 400+450 – KM: 400+520

As it can be seen on the geological cross-section, this part of the tunnel route is defined as shear zone. From the point of geotechnical view, in order to be on the safe side, very poor rock class is assigned for shearing zone. However, the real specification and location of shear zone should only be determined during the excavation. Horizontal boreholes should be drilled from the face of the tunnel excavation. Geologically, this part can be defined as meta-sandstone-schist with clay matrix. According to the drilling logs RMR rating calculated for this weak zone and to be on the safe side, engineering parameters c= 20 kPa, Ø= 25°, Erm= 100 MPa and weak strength rock are assumed for this section.

Figure 4. 7 Basic and total RMR rating calculation for shear zone.

	Rating
Uniaxial Compressive Strength, σ_c (5 MPa) :	2
Rock Quality Designation (RQD %21):	3
Spacing of Discontinuities (60-200 mm) :	5
Persistence of Discontinuities (3-10 meter):	2
Aperture of Discontinuities (0.1-1.0 mm):	1
Roughness of Discontinuities (rough):	0
Infilling (hard filling<5mm) :	2
Weathering (slightly weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	26
Discontinuity Orientation (Unfavorable):	-10
Total RMR Point:	16
Class	Very Poor Rock

KM: 400+520 – KM: 400+750 (in accordance with SK-809)

Figure 4. 8 Basic and total RMR rating calculation with respect to SK-809

	Rating
Uniaxial Compressive Strength, σ_c (25 MPa) :	2
Rock Quality Designation (RQD %21):	3
Spacing of Discontinuities (60-200 mm) :	5
Persistence of Discontinuities (3-10 meter):	2
Aperture of Discontinuities (0.1-1.0 mm):	1
Roughness of Discontinuities (rough):	0
Infilling (hard filling<5mm) :	2
Weathering (slightly weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	26
Discontinuity Orientation (Unfavorable):	-10
Total RMR Point:	16
Class	Very Poor Rock

Exit Section (KM: 400+750 – KM: 400+930) (in accordance with SK-806)

Figure 4. 9 Basic and total RMR rating calculation with respect to SK-806

Rating

Uniaxial Compressive Strength, σ_c (5 MPa): ……………………………………..…..2

Rock Quality Designation (RQD %12): 3

Spacing of Discontinuities (<60 mm) : 5

Persistence of Discontinuities (3-10 m): 4

Aperture of Discontinuities (1-5.0 mm): 1

Roughness of Discontinuities (Slightly rough): 0

Infilling (Clay filling<5mm) : 2

Weathering (Moderately weathered): 1

Groundwater condition (Damp): …………………………………………………...…10

Basic RMR: ……………………………………………………………………..……28

Discontinuity Orientation (Unfavourable): ……………………………………..…….-10

Total RMR Point: ………………………………………………………...………18

Class….…………………………………………………….……………Very Poor Rock

Exit Section (KM: 400+750 – KM: 400+930) (in accordance with SK-810)

Figure 4. 10 Basic and total RMR rating calculation with respect to SK-810

	Rating
Uniaxial Compressive Strength, σ_c (5 MPa):	2
Rock Quality Designation (RQD %12):	3
Spacing of Discontinuities (<60 mm) :	5
Persistence of Discontinuities (3-10 m):	4
Aperture of Discontinuities (1-5.0 mm):	1
Roughness of Discontinuities (Slightly rough):	0
Infilling (Clay filling<5mm) :	2
Weathering (Moderately weathered):	1
Groundwater condition (Damp):	10
Basic RMR:	28
Discontinuity Orientation (Unfavourable):	-10
Total RMR Point:	18
Class	Very Poor Rock

4.2 GSI Classification of the Rocks Along the Tunnel

According to Hoek and Brown rock-mass failure criterion would have no practical usage unless it could be related to geological observations that could be made quickly and easily by an engineering geologist or geologist in the field. They considered developing a new classification system during the evolution of the criterion in the late

1970s but they soon gave up the idea and settled for the already published RMR system.

In the early days the use of the RMR classification (modified as described above) worked well because most of the problems were in reasonable quality rock masses (30<RMR<70) under moderate stress conditions. However, it soon became obvious that the RMR system was difficult to apply to rock masses that are of very poor quality. The relationship between RMR and the constants m and s of the Hoek–Brown failure criterion begins to break down for severely fractured and weak rock masses.

Both the RMR and the Q classifications include are heavily dependent upon the RQD classification introduced by Deere (1964). Since RQD in most of the weak rock masses is essentially zero or less than 10, it became necessary to consider an alternative classification system. The required system would not include RQD, would place greater emphasis on basic geological observations of rock-mass characteristics, reflect the material, its structure and its geological history, and would be developed specifically for the estimation of rock mass properties rather than for tunnel reinforcement and support.

Hoek and Brown (1997) proposed a new classification called Geological Strength Index (GSI), instead of RMR due to the limitations in the RMR system for very poor quality rock masses. The GSI system based upon the visual impression on the rock mass structure has twenty codes to identify each rock mass category and estimates the GSI value ranging between 10 and 85. On the basis of the studies on the Athens schist by Hoek et al. (1998), a new rock mass category was introduced into the GSI system called ‘foliated/laminated rock mass structure’. Hoek (1999a) also inserted an upper row to the GSI system to deal with ‘intact or massive’ rock. The index and its use for the Hoek and Brown failure criterion was further developed by Hoek (1994), Hoek et al. (1995) and Hoek and Brown (1997). However, due to lack of measurable and more representative parameters, and related interval limits of the discontinuities, the GSI for each rock mass category in the chart represents a range of values. In other words, it is possible to estimate different GSI values from the chart for the same rock mass by different persons, depending on their personal experience. Therefore, an attempt has been made by Sönmez and Ulusay (1999) to provide more quantitative assessment for evaluating the GSI and to suggest quantities that make more sense than that of the RMR system when used for the estimation of the rock mass strength as an additional tool.

The papers by Marinos and Hoek (2000, 2001) put more geology into the Hoek-Brown failure criterion, and introduced a new GSI chart for heterogeneous weak rock masses. Marinos and Hoek (2000) also slightly changed the upper most part of the current GSI chart. The 1997 and latest versions of the GSI chart are quite sufficient for field observations, since it is only necessary to note the code that identifies the rock mass category. It is also noted that the intention of Hoek and his co-workers was to present an approximate method for rock mass characterization using the GSI. Evert Hoek and Paul Marinos, incredibly dealing with difficult materials encountered in tunneling in Greece, developed the GSI system to the present form to include poor quality rock masses (Table 4.3) (Hoek et al. 1998; Marinos and Hoek 2000, 2001).

The main goal of GSI is to provide information to estimate the strength parameters of rock mass for different geological conditions. GSI value calculation system is shown in Table 4.2. GSI values are calculated by the equation $GSI= RMR_{89}-5$ $c= <100$ *kPa*, $Ø= <15°$ (recommended by Bieniawski, 1989) for each borehole (Table 4.3).

During the process of obtaining GSI values by using RMR ratings, the basic RMR rating with dry condition was taken in to account. Table 4.3 presents the results. In order to estimate the intervals for GSI values, Table 4.2 is used. Table 4.4 shows the comparison of the GSI values calculated from RMR with GSI values determined based on the field observations. Values obtained from the field and the values obtained from RMR are found to be compatible to each other.

Table 4. 2 The modified quantitative GSI system suggested by Sönmez and Ulusay (2002).

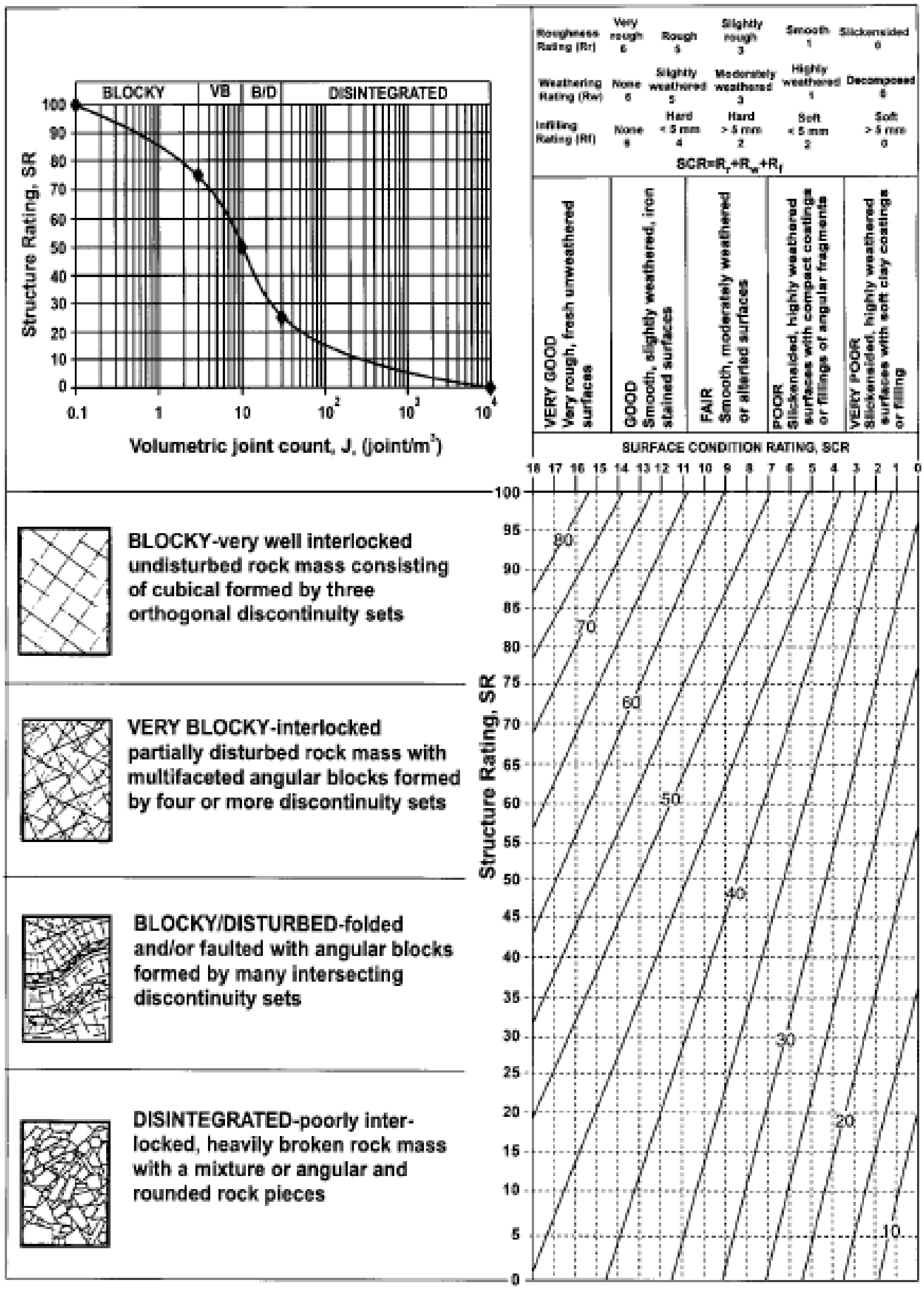

Table 4.3 GSI guideline for jointed rocks (Hoek and Marinos, 2001)

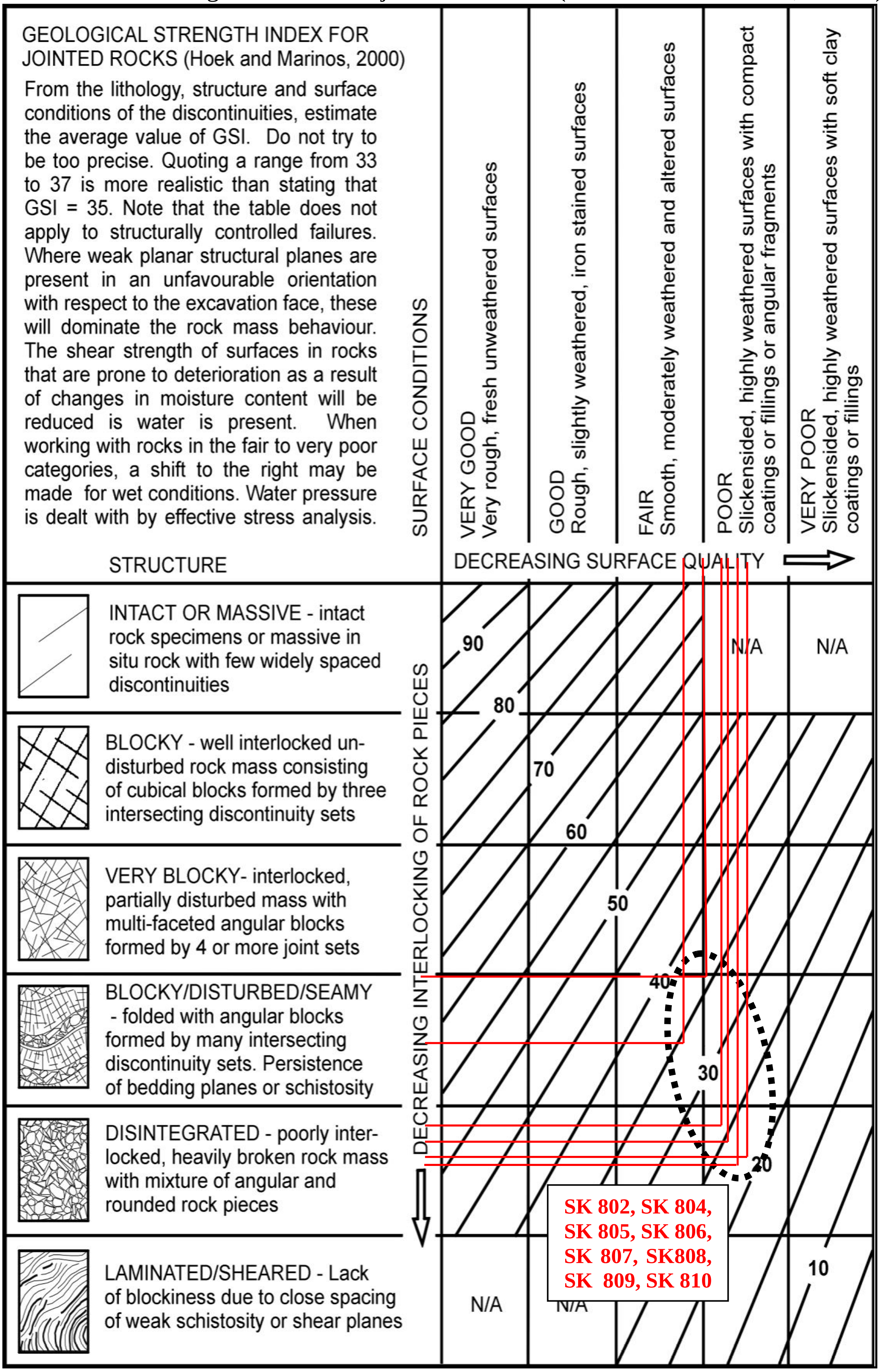

Table 4. 4 Calculated GSI and RMR values along the tunnel route.

Tunnel Section	Total RMR	Basic RMR	Rock Mass Class	GSI
Entrance Section (KM: 399+180 – KM: 399+400)	19	24	very poor rock	19
KM: 399+400 – KM: 399+700	22	27	poor rock	22
KM: 399+700 – KM: 400+080	23	28	poor rock	23
KM: 400+080 – KM: 400+150	-	-	very poor rock	-
KM: 400+200 – KM: 400+450	44	49	Fair rock	44
KM: 400+450 – KM: 400+520	-	-	very poor rock	-
KM: 400+520 – KM: 400+750	16	26	very poor rock	16
Exit Section (KM: 400+750 – KM: 400+930)	18	28	very poor rock	23

Table 4. 5 Comparison of GSI values for different section of the tunnel.

Tunnel Section	GSI calcualted from Basic RMR	GSI determined from the field observations	Bore Hole
Entrance Section (KM: 399+180 – KM: 399+400)	19	16	SK 802
KM: 399+400 – KM: 399+700	22	23	SK 805
KM: 399+700 – KM: 400+080	23	21	SK 807
KM: 400+080 – KM: 400+150	Shearing zone	Shearing zone	SK 804
KM: 400+200 – KM: 400+450	44	36	SK 804, SK 808
KM: 400+450 – KM: 400+520	Shearing zone	Shearing zone	SK 808
KM: 400+520 – KM: 400+750	16	17	SK 809
Exit Section (KM: 400+750 – KM: 400+930)	23	21	SK 806, SK 810

4.3 Q- Classification of the Rocks Along the Tunnel

The Q system was developed at the Norwegian Geotechnical Institute (NGI) by Barton et al. (1974, 1975, 1976, 1988). Q System rating tables (Barton et al., 1974) are used for rock mass classifications based on borehole and field data. The equation used to define the Q-value is shown in Figure 4.11.

Figure 4. 11 Defination of the Q system

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) where;

RQD: rock quality designation

J_n : joint set number

J_r : joint roughness number

J_a : joint alteration number

J_w : joint water reduction factor

SRF: stress reduction factor

Calculated Q values through the tunnel route are shown in Tables 4.6-4.10.

Table 4. 6 Q classifications of the rock masses for KM: 399+400 – KM: 399+700 (SK-805)

BH NO	Q System Parameters	Description	Value
SK-805	RQD (%)	Very poor rock	5
	Joint Set Number (Jn)	Four joint sets plus random joints (x2 for portals)	15
	Joint Roughness Number (Jr)	Rough	0,5
	Joint Alteration Number (Ja)	Hard filling (Calcite)	4,0
	Joint Water Reduction (Jw)	Dry excavation	1
	Stress Reduction Factor (SRF)	Loose, heavily jointed	2,5
	Rating		0.02
	Description		Very Poor Rock

$$Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) = (5/15)*(0.5/4.0)*(1/2.5) = 0.02$$

Table 4. 7 Q classifications of the rock masses for KM: 399+700 – KM: 400+080 (SK-807)

BH NO	Q System Parameters	Description	Value
SK-807	RQD (%)	Poor rock	6
	Joint Set Number (Jn)	Three joint sets plus random joints	15
	Joint Roughness Number (Jr)	Rough	0,5
	Joint Alteration Number (Ja)	Hard filling (Calcite)	4
	Joint Water Reduction (Jw)	Dry excavation	1
	Stress Reduction Factor (SRF)	Single shear zones, depth of excavation>50 m	2,5
	Rating		0.02
	Description		Very Poor Rock

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) = (6/15)*(0.5/4)*(1/2.5) = 0.02

Table 4. 8 Q classifications of the rock masses for KM: 400+080 – KM: 400+150 (SK-804)

BH NO	Q System Parameters	Description	Value
SK-804	RQD (%)	Fair rock	53
	Joint Set Number (Jn)	Three joint sets plus random joints	12
	Joint Roughness Number (Jr)	Rough	2
	Joint Alteration Number (Ja)	Hard filling (Calcite)	0,75
	Joint Water Reduction (Jw)	Dry excavation	1
	Stress Reduction Factor (SRF)	Single shear zones, depth of excavation>50 m	2,5
	Rating		4,7
	Description		Fair Rock

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) = (53/12)*(2/0.75)*(1/2.5) = 4.7

Table 4. 9 Q classifications of the rock masses for KM: 400+080 – KM: 400+150 (SK-808)

BH NO	Q System Parameters	Description	Value
SK-808	RQD (%)	Very Poor Rock	56
	Joint Set Number (Jn)	Three joint sets plus random joints	12
	Joint Roughness Number (Jr)	Rough	2
	Joint Alteration Number (Ja)	Hard filling (Calcite)	0,75
	Joint Water Reduction (Jw)	Dry excavation	1
	Stress Reduction Factor (SRF)	Single shear zones, depth of excavation>50 m	2,5
	Rating		4,98
	Description		Fair Rock

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) = (56/12)*(2/0.75)*(1/2.5) = 4.98

Table 4. 10 Q classifications of the rock masses for KM: 400+520 – KM: 400+750 (SK-809)

BH NO	Q System Parameters	Description	Value
SK-809	RQD (%)	Very poor rock	6
	Joint Set Number (Jn)	Three joint sets plus random joints	15
	Joint Roughness Number (Jr)	Rough	0,5
	Joint Alteration Number (Ja)	Soft filling (Clay)	4
	Joint Water Reduction (Jw)	Dry excavation	1
	Stress Reduction Factor (SRF)	Single shear zones, depth of excavation<50 m	2,5
	Rating		0,016
	Description		Very Poor Rock

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF) = (6/15)*(0.5/4.0)*(1/2.5) = 0.016

Rock description obtained from Q classification for SK 805, SK 807, SK 804, SK 808, SK 809 are very poor rock, very poor rock, fair rock, fair rock, very poor rock, respectively. After comparing these rock mass classes with RMR, they are found to be compatible to each other.

4.4 NATM Classifications

NATM is a concept, or more precise, a mixture of design, contracting, excavation and active use of rock support experience. Müller (1978) indicates that "the NATM is rather a tunneling concept than a method, with a set of principles, which the tunneller tries to follow". These features have been systematized into the NATM concept where the different parties involved have worked out a splendid cooperation.

NATM has been developed to improve construction methods for tunneling in weak rocks. Definition of "weak rock" here represents material which requires the use of structural supports during excavation. The rock material itself may be soft or hard. According to Rabcewicz (1975), the goal of NATM is; "To provide safe and economic support in tunnels excavated in materials incapable of supporting themselves - e.g. crushed rock, debris, even soil. Support is achieved by mobilizing whatever humble strength the rock or earth possesses".

NATM, is a common application including many construction practices. As part of this, NATM is also available in its own rock mass classification. However, this classification system of NATM based on verbal approaches which make almost impossible to determine geotechnical parameters needed for numerical analysis. Because of this, it is reasonable to determine the support system with respect to empirical classifications systems such as RMR and Q. Figure 4.1 shows a cart which helps to determine the NATM support system with respect to RMR and Q.

NATM classes are determined after correlations of RMR and Q Ratings as given in Table 4.11. According to the Table 4.11, middle part of the tunnel has better NATM classes than the portals. For sections defined as shear zone, presence of meta-sandstone-schist with clay matrix is assumed. Shear zone sections are also considered to have weak strength with very poor rock. NATM class C3 is assigned for these sections.

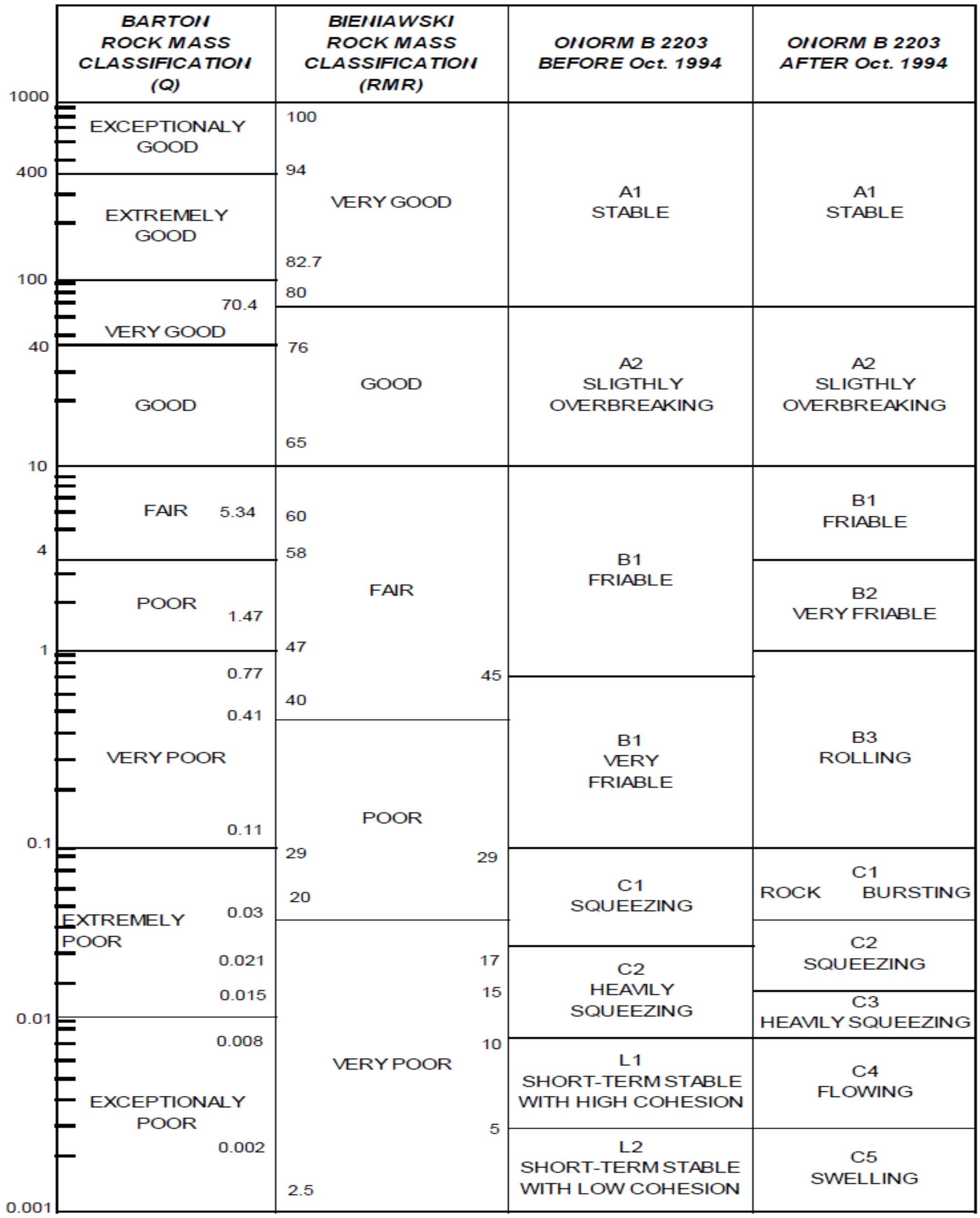

Figure 4. 12 Correlations among RMR, Q and NATM (ONORM B 2203, 1994)

Table 4. 11 NATM Classification though the tunnel route

Intervals of KM	BH No	RMR Rating	Q Rating	NATM Classification
KM: 399+180-KM: 399+400	SK-802	19	---	C2
KM: 399+400-KM: 399+700	SK-805	22	0,02	C2
KM: 399+700-KM: 400+080	SK-807	23	0,02	C2
KM: 400+080-KM: 400+150	---	---	---	C3
KM: 400+150-KM: 400+200	SK-804	---	---	B3
KM: 400+200-KM: 400+400	SK-804	44	4,7	B2
KM: 400+200-KM: 400+400	SK-808	44	4,98	B2
KM: 400+400-KM: 400+450	SK-808	---	---	B3
KM: 400+450-KM: 400+520	---	---	---	C3
KM: 400+520-KM: 400+750	SK-809	16	0,016	C2
KM: 400+750-KM: 400+930	Sk-806	18	---	C2
KM: 400+750-KM: 400+930	SK-810	17	---	C2

4.5 Classifications involving stand up time

Hoek and Brown (1980) defined the unsupported span as the span of the tunnel or in other words the distance between the face and the nearest support. Also according to Lauffer (1958), the stand-up time for an unsupported span is related to the quality of rock mass. In other words, unsupported span distance would be higher with respect to the quality of the rock mass. Barton et al. (1976) create an equation which related the maximum unsupported length of tunnel to ESR and Q values:

$S_u=2(ESR)Q^{0.4}$ (m)

Moreover, Barton et al. (1974) suggest the following guideline which explains the relationship between ESR values and the excavation category. (Table 4.12).

Table 4. 12 Guideline for ESR value and excavation category. (After Barton et al., 1974)

Excavation category		*ESR*
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 large excavations.	1.6
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers, access tunnels.	1.3
D	Power stations, major road and railway tunnels, civil defence chambers, portal intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, factories.	0.8

Also, Bieniawski (1976) proposed a relationship between the standup time of an unsupported underground excavation span and geomechanics classification. This relationship is presented in Figure 4.2. Bieniawski (1989) also recommends stand up time according to the rock mass classifications. According to the rock mass classifications through the tunnel studied in this thesis, the stand up time and unsupported span time is presented in Table 4.13.

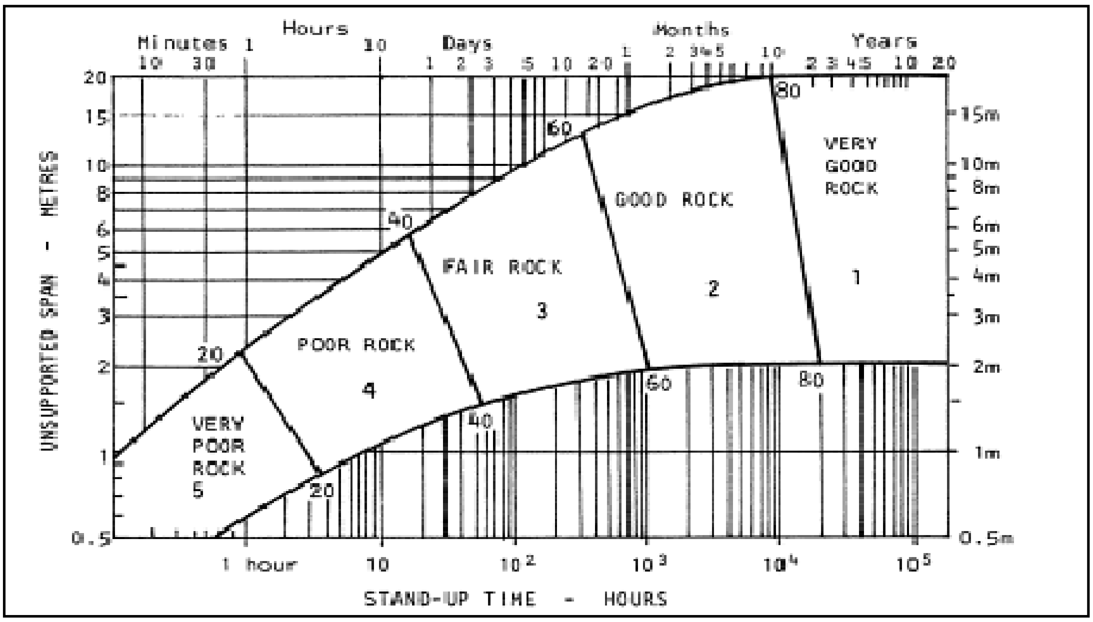

Figure 4. 13 The relationship between the stand up time of an unsupported underground excavation span and the CSIR Geomechanics Classification proposed by Bieniawski (1976)

Table 4. 13 Average stand up time according to rock mass classifications

Intervals of KM	Rock Mass Classification	Average Stand up Time for different Spans
KM: 399+180-KM: 399+400	Very Poor Rock	30 min. For 0.5 m span
KM: 399+400-KM: 399+700	Very Poor Rock	30 min. For 0.5 m span
KM: 399+700-KM: 400+080	Very Poor Rock	30 min. For 0.5 m span
KM: 400+080-KM: 400+150	Very Poor Rock	30 min. For 0.5 m span
KM: 400+150-KM: 400+200	Poor Rock	10 hrs. For 2.5 m span
KM: 400+200-KM: 400+400	Fair Rock	1 week for 5 m span
KM: 400+200-KM: 400+400	Fair Rock	1 week for 5 m span
KM: 400+400-KM: 400+450	Poor Rock	10 hrs. For 2.5 m span
KM: 400+450-KM: 400+520	Very Poor Rock	30 min. For 0.5 m span
KM: 400+520-KM: 400+750	Very Poor Rock	30 min. For 0.5 m span
KM: 400+750-KM: 400+930	Very Poor Rock	30 min. For 0.5 m span
KM: 400+750-KM: 400+930	Very Poor Rock	30 min. For 0.5 m span

CHAPTER 5

DETERMINATION OF SUPPORT SYSTEMS FOR THE BELKAHVE TUNNEL USING EMPIRICAL METHODS

The rock mass classification systems, which are RMR, Q and NATM, performed to determine the support systems for the Belkhave tunnel empirically.

5.1 Support Systems Based on RMR Classification

Bieniawski (1989) proposed a guideline in order to select the proper support in tunnel excavation. This guideline aims to explaining excavation methods and determining support systems of 10 m span rock tunnels with respect to RMR system (Table 5.1).

Table 5. 1 Guidelines for excavation method and support system 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 crown 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 excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Table 5. 2 Suggested excavation and support systems of for the Belkahve tunnel based on RMR classification.

Intervals of KM	RMR	Excavation	Rock Bolts (20 mm diameter, fully grouted)	Shotcrete	Steel Sets
399+180-399+400	19	Multiple Dirfts 0,5-1,5 m. Advance in top heading. Install support concyrrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1,5 m in crown and walls with wire mesh. Bolt invert	150-200 mm in crown 150 mm in sides 50 mm on face	Medium to heavy ribs spaced 0,75 m. With steel lagging and forepoling if required. close invert.
399+400-399+700	22	Top heading and bench 1,0-1,5 m advance in top heading. İnstall 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. Bolt invert	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1,5 m. Where required
399+700-400+080	23	Top heading and bench 1,0-1,5 m advance in top heading. İnstall 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. Bolt invert	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1,5 m. Where required
400+080-400+150	--	Multiple Dirfts 0,5-1,5 m. Advance in top heading. Install support concyrrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1,5 m in crown and walls with wire mesh	150-200 mm in crown 150 mm in sides 50 mm on face	Medium to heavy ribs spaced 0,75 m. With steel lagging and forepoling if required. close invert.
400+150-400+200	--	Top heading and bench 1,0-1,5 m advance in top heading. İnstall 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. Bolt invert	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1,5 m. Where required

Table 5. 2 Continued

Intervals of KM	RMR	Excavation	Rock Bolts (20 mm diameter, fully grouted)	Shotcrete	Steel Sets
400+200-400+400	44	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 1.5-2.0 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None
400+400-400+450	--	Top heading and bench 1,0-1,5 m advance in top heading. İnstall 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. Bolt invert	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1,5 m. Where required
400+450-400+520	--	Multiple Dirfts 0,5-1,5 m. Advance in top heading. Install support concyrrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1,5 m in crown and walls with wire mesh	150-200 mm in crown 150 mm in sides 50 mm on face	Medium to heavy ribs spaced 0,75 m. With steel lagging and forepoling if required. close invert.
400+520-400+750	16	Multiple Dirfts 0,5-1,5 m. Advance in top heading. Install support concyrrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1,5 m in crown and walls with wire mesh	150-200 mm in crown 150 mm in sides 50 mm on face	Medium to heavy ribs spaced 0,75 m. With steel lagging and forepoling if required. close invert.
400+750-400+930	18	Multiple Dirfts 0,5-1,5 m. Advance in top heading. Install support concyrrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1,5 m in crown and walls with wire mesh	150-200 mm in crown 150 mm in sides 50 mm on face	Medium to heavy ribs spaced 0,75 m. With steel lagging and forepoling if required. close invert.

Suggested excavation and support systems of for different sections of the Belkahve tunnel based on the RMR classification are given above in Table 5. 2.

5.2 Support Systems Based on Q system

The estimated support categories based on Q-system (Barton, 2002) are determined by using Figure 5.1. Q-values calculated in Chapter 4 are used here.

For Q value of 0.69; 1.5 m spaced rock bolt with a length of 4.8 m are recommended. Shotcrete with thickness of 12 cm. is suggested. For Q value of 4.3; 2.2m spaced rock bolt with a length of 4.2 m are recommended. Shotcrete with thickness of 5 cm. is suggested.

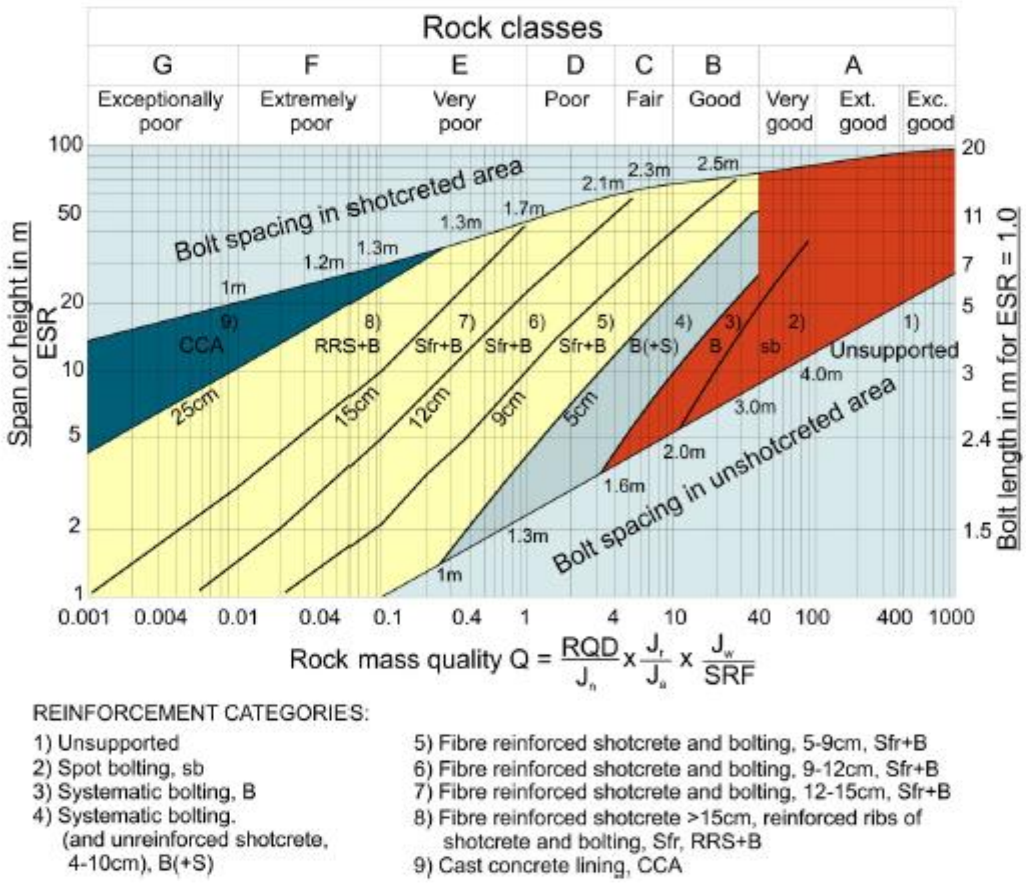

Figure 5. 1 Support categories based on Q-system (Barton, 2002)

For Q value of 12.1; 2.6 m spaced rock bolt with a length of 4.8 m are recommended. Shotcrete with thickness of 3-4 cm. is suggested. For Q value of 2.9; 1.8 m spaced rock bolt with a length of 4.0 m are recommended. Shotcrete with thickness of 7 cm. is suggested.

For Q value of 0.1; 1.5 m spaced rock bolt with a length of 3.0 m are recommended. Shotcrete with thickness of 15 cm. is suggested. For Q value of 0.4; 1.5 m spaced rock bolt with a length of 3.8 m are recommended. Shotcrete with thickness of 9 cm. is suggested.

5.3 Support systems depending on NATM

The support systems according to the NATM classifications (Geoconsult, 1993 and ONORM B 2203, 1994) based on the classes obtained in Chapter 4 are presented in Table 5.3.

For NATM B3 class, the tunnel could be excavated by top heading (1,25m-1,50m.) and bench (3,0 m.). Excavation should be done with smooth blasting or mechanical excavation techniques. Shotcrete and systematic bolting are recommended. Wire mesh and Invert slab is suggested in case of necessary.

For NATM C2 class, the tunnel could be excavated by top heading (0,75m-1,25m.) and bench (2,0 m.) and invert slab. Excavation should be done with smooth blasting or mechanical excavation techniques. Shotcrete and systematic bolting are recommended at the tunnel face. Forepole application is also recommended along the upper part of the excavation. Wire mesh and Invert slab is suggested in case of necessary.

For NATM C3 class, the tunnel could be excavated by top heading (0,75m-1,00m.) and bench (1,5 m.) and invert slab. Excavation should be done with smooth blasting or mechanical excavation techniques. Shotcrete and systematic bolting should be applied to the tunnel face. Forepole application is also recommended along the upper part of the excavation. Systematic wire mesh and Invert slab is also recommended.

Table 5. 3 NATM support systems (Specifications of GDH, 2006)

Intervals of KM	NATM Class	Excavation	Support Systems
KM: 399+180-KM: 399+400	C2	Top heading (0.75-1.25 m) and bench (2.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 399+400-KM: 399+700	C2	Top heading (0.75-1.25 m) and bench (2.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 399+700-KM: 400+080	C2	Top heading (0.75-1.25 m) and bench (2.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 400+080-KM: 400+150	C3	Top heading (0.75-1.00 m) and bench (1.5 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 400+150-KM: 400+200	B3	Top heading (1.25-1.5 m) and bench (3.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set. Wire mesh may be necessary. Invert slab may be necessary.
KM: 400+200-KM: 400+400	30% B3, 70% B2	Top heading (1.5-2.0 m) and bench (3.0-3.5 m). Smooth blasting.	Shotcrete and systematic bolting, forepoling. Invert slab may be necessary.
KM: 400+400-KM: 400+450	B3	Top heading (1.25-1.5 m) and bench (3.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set. Wire mesh may be necessary. Invert slab may be necessary.
KM: 400+450-KM: 400+520	C3	Top heading (0.75-1.00 m) and bench (1.5 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 400+520-KM: 400+750	C2	Top heading (0.75-1.25 m) and bench (2.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.
KM: 400+750-KM: 400+930	C2	Top heading (0.75-1.25 m) and bench (2.0 m). Smooth blasting or mechanical excavation.	Shotcrete and systematic bolting, forepoling, systematic Steel set, Wire mesh, Invert slab.

CHAPTER 6

ESTIMATION OF THE ROCK MASS STRENGTH PARAMETERS

The most important preparation step for numerical modeling is the estimation of rock mass strength parameters. In-situ test is a method to determine these parameters ultimately. However, in the early stage of the design, rock mass strength parameters and support systems should be determined by using rock mass classification systems such as RMR, Q, GSI.

6.1 Estimation of Rock Mass Parameters

In order to determine the strength parameters (m, s, c, ø, $E_{rm,}$ etc.) of the rock mass of the tunnel, the computer program Roclab 1.0 (2007) was used. The uniaxial compressive strength (σ_c), modulus of elasticity of intact rock (E_i) and unit weight (γ) are obtained from the laboratory tests and entered to the program as input parameters. The parameter of m_i value is selected from the Roclab software with respect to the rock type. Both, excellent quality blasting and poor quality blasting conditions were chosen by selecting the value of D= 0 or D= 0.7. Also, while determining the depth of tunnel, depth from ground level to the tunnel route level is taken into account. At Figure 6.1. all needed input parameters can be seen.

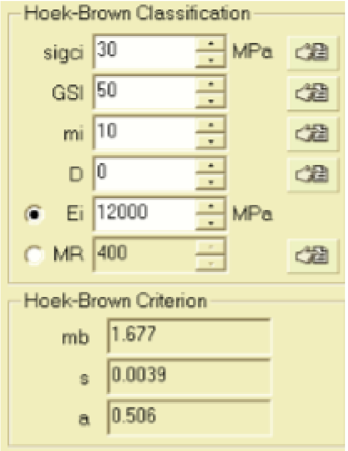

Figure 6. 1 needed input parameters for roclab.

Required parameters of the generalized Hoek-Brown failure criterion which are mb, s and a, has been determined by the software Roclab as a result of calculation performed by using given set of input parameters (sigci, GSI, mi, Ei and D). RocLab also calculates the deformation modulus of the rock mass Erm using the Generalized Hoek-Diederichs equation with respect to input value of intact modulus Ei (Hoek and Diederichs, 2006). In this thesis, all of these parameters are calculated using the latest version of the HoekBrown failure criterion. Furthermore, RocLab always calculates equivalent Mohr-Coulomb parameters (cohesion and friction angle) for the rock mass. Since most rock engineering software (both Mohr-Coulomb and Hoek-Brown is available for Phase 2) is still written in terms of the Mohr-Coulomb failure criterion, it is necessary to determine equivalent angles of friction and cohesive strengths for each rock mass and stress range.

This is done by fitting an average linear relationship to the curve generated by solving equation for a range of minor principal stress values defined by $\sigma_t < \sigma_3 < \sigma'_{3max}$ as illustrated in Figure 6.2. The fitting process involves balancing the areas above and below the Mohr-Coulomb plot. This results in the following equations for the angle of friction ϕ' and cohesive strength c':

Note that the value of σ'_{3max}, the upper limit of confining stress over which the relationship between the Hoek-Brown and the Mohr-Coulomb criteria is considered, has to be determined for each individual case. Guidelines for selecting these values for slopes as well as shallow and deep tunnels are presented later. The Mohr-Coulomb shear strength τ , for a given normal stress σ , is found by substitution of these values of c' and ϕ' in to the equation:

$$\tau = c' + \sigma \tan\phi$$

The equivalent plot (Figure 6.2), in terms of the major and minor principal stresses, is defined by:

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

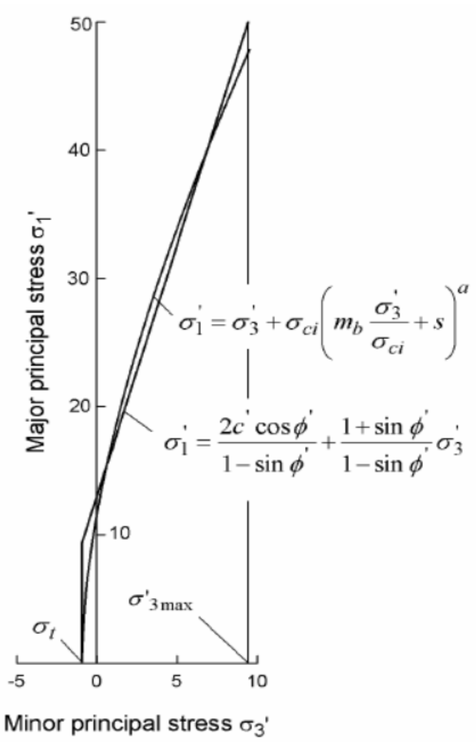

Figure 6. 2 Relationships between major and minor principal stresses for Hoek-Brown and equivalent Mohr-Coulomb criteria.

The engineering parameters of the rock masses for different sections of the tunnel are presented in Figures 6.3-6.15.

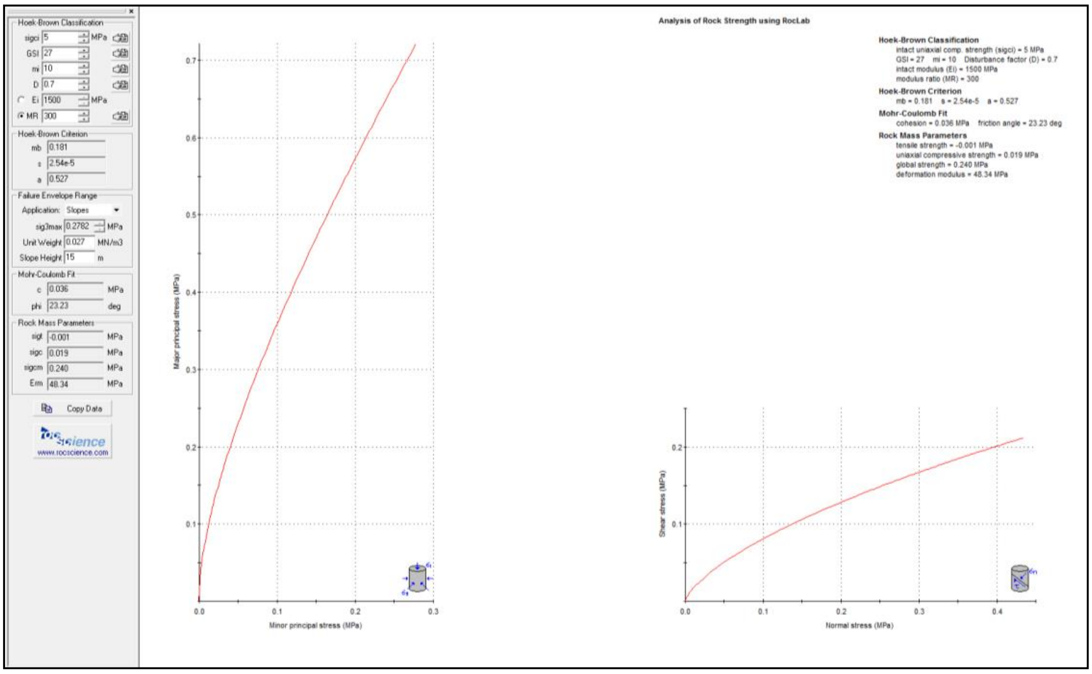

Figure 6. 3 Engineering parameters of the rock mass for D=0.7 (Entrance Section KM: 399+180 – KM: 399+400)

c= 36 kPa, Ø= 23° ve E_{rm}= 48 MPa

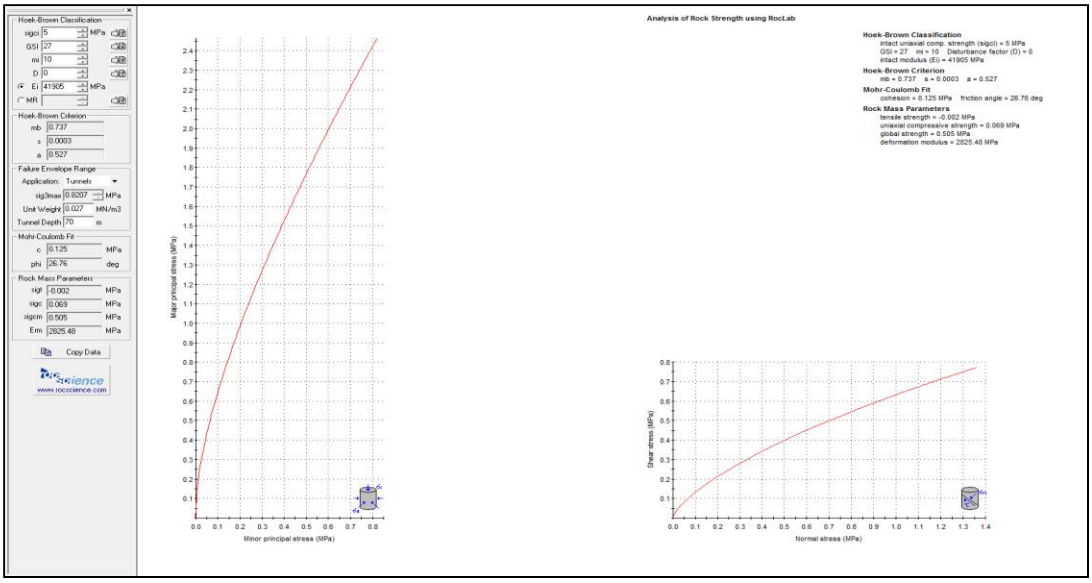

Figure 6. 4 Engineering parameters of the rock mass for D=0 (KM: 399+400 – KM: 399+700 in accordance with SK-805)

c= 125 kPa, Ø= 27° ve E_{rm}= 2825 MPa

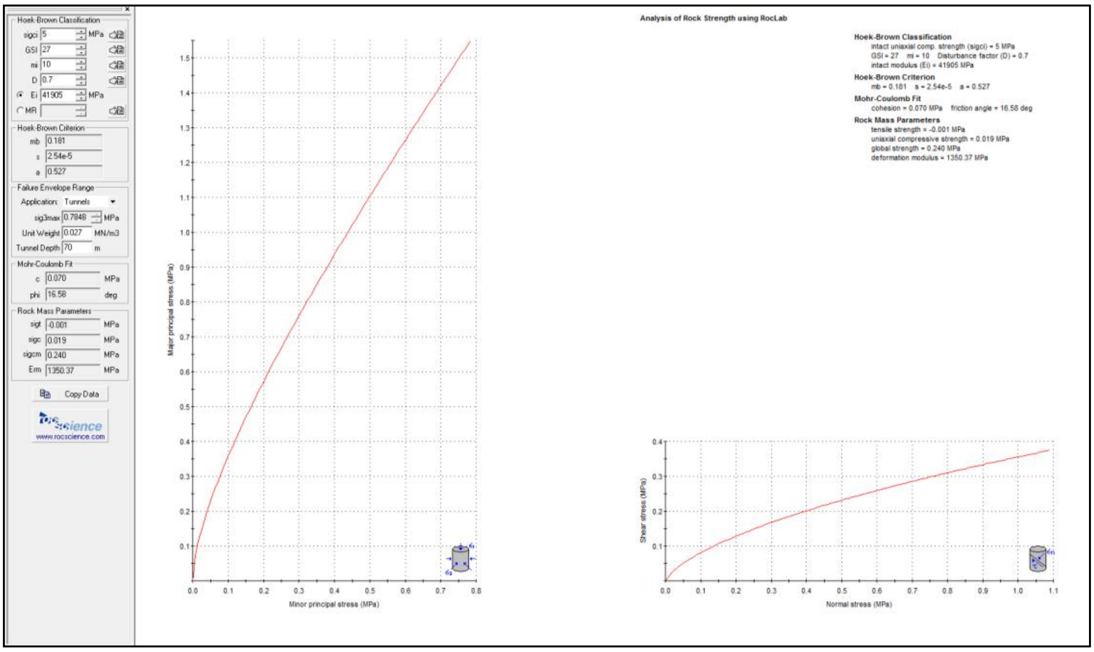

Figure 6. 5 Engineering parameters of the rock mass for D=0,7 (KM: 399+400 – KM: 399+700 in accordance with SK-805)

c= 70 kPa, Ø= 17° ve E_{rm}= 1350 MPa

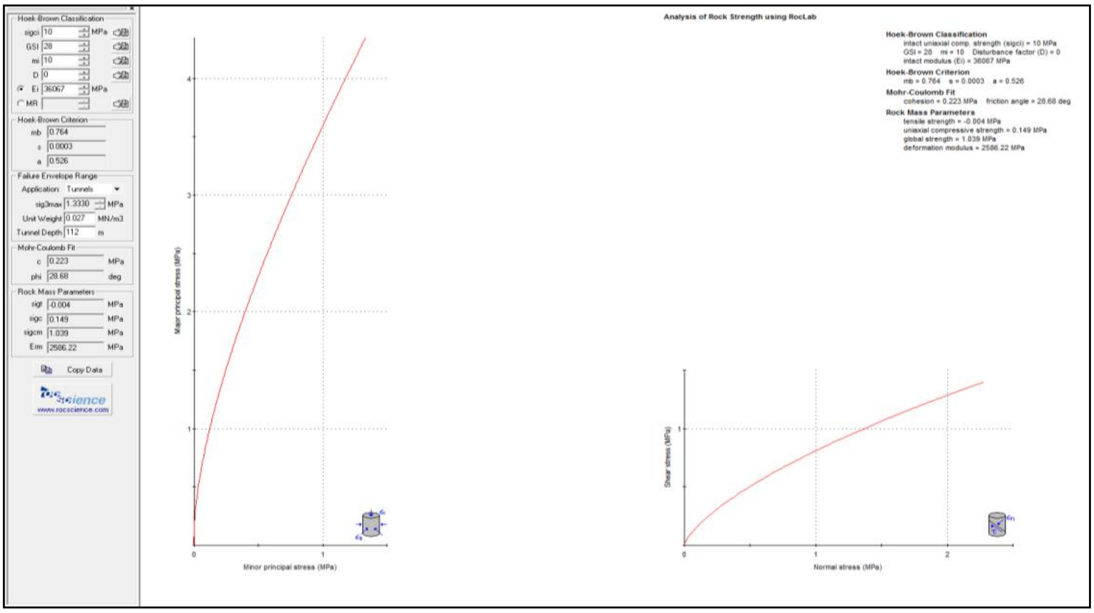

Figure 6. 6 Engineering parameters of the rock mass for D=0 (KM: 399+700 – KM: 400+080 in accordance with SK-807)

c= 223 kPa, Ø= 29° ve E_{rm}= 2586 MPa

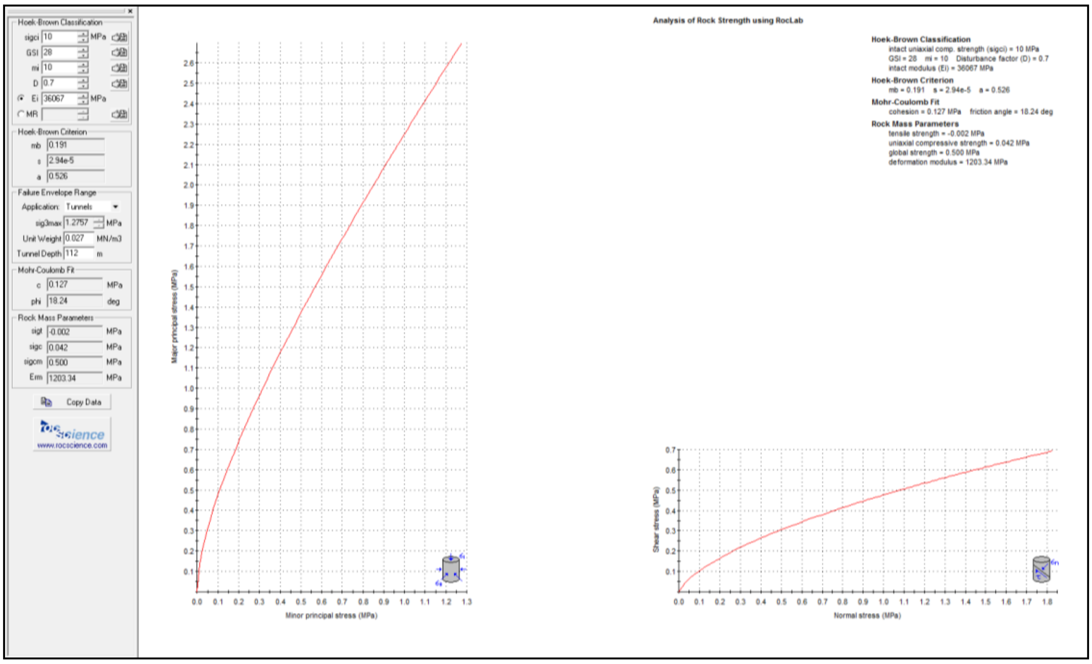

Figure 6. 7 Engineering parameters of the rock mass for D=0,7 (KM: 399+700 – KM: 400+080 in accordance with SK-807)

c= 127 kPa, Ø= 18° ve E_{rm}= 1203 MPa

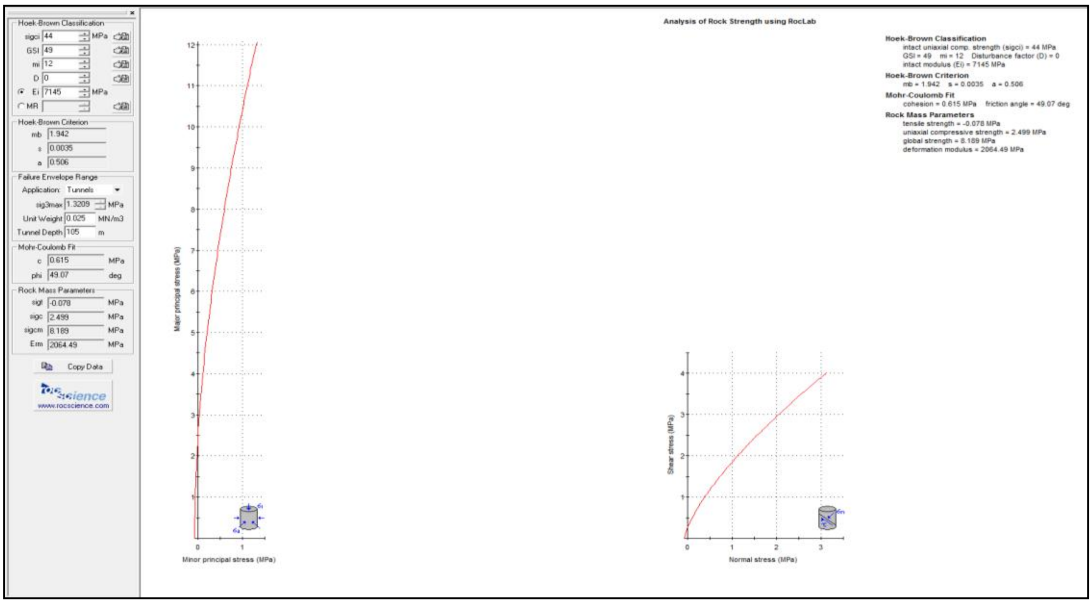

Figure 6. 8 Engineering parameters of the rock mass for D=0 (KM: 400+150 – KM: 400+200 in accordance with SK-804)

c= 615 kPa, Ø= 49° ve E_{rm}= 2064 MPa

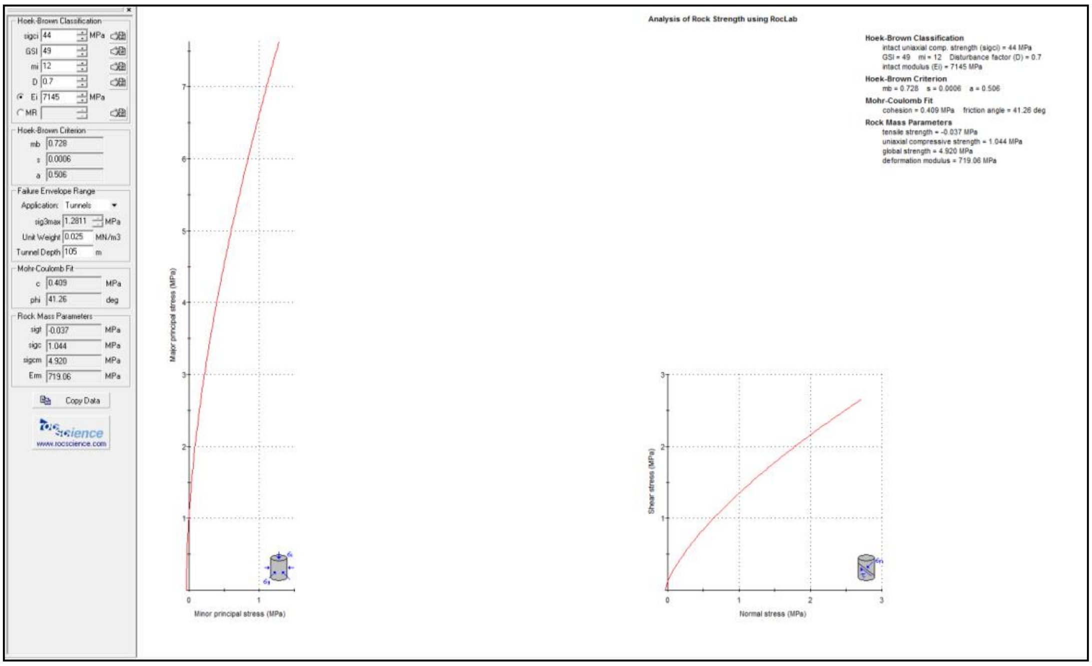

Figure 6. 9 Engineering parameters of the rock mass for D=0,7 (KM: 400+150 – KM: 400+200 in accordance with SK-804)

c= 409 kPa, Ø= 41° ve E_{rm}= 719 MPa

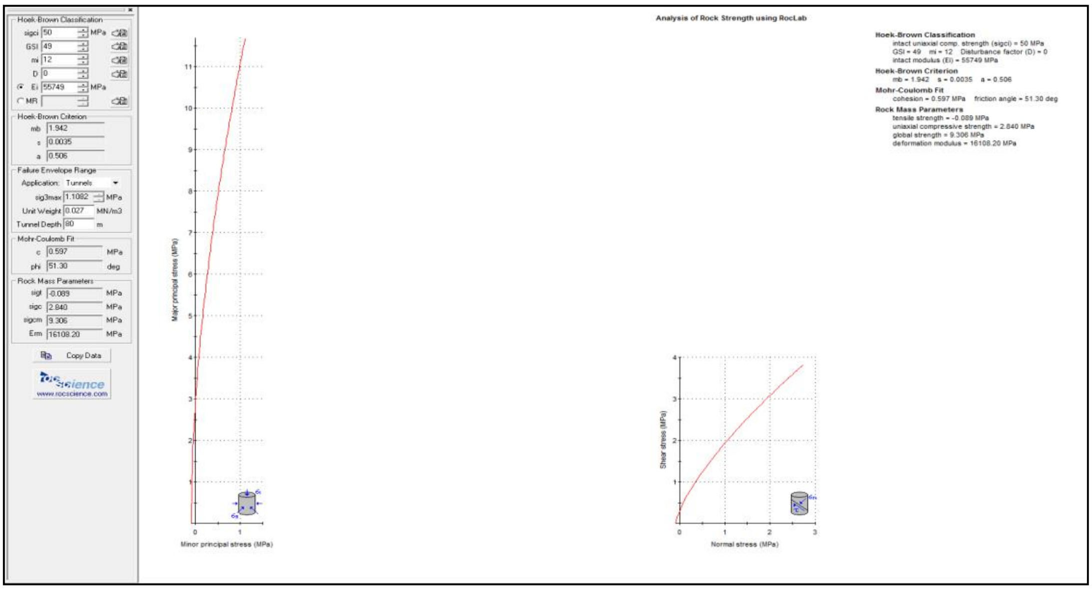

Figure 6. 10 Engineering parameters of the rock mass for D=0 (KM: 400+200 – KM: 400+520 in accordance with SK-808)

c= 597 kPa, Ø= 51° ve E_{rm}= 16108 MPa

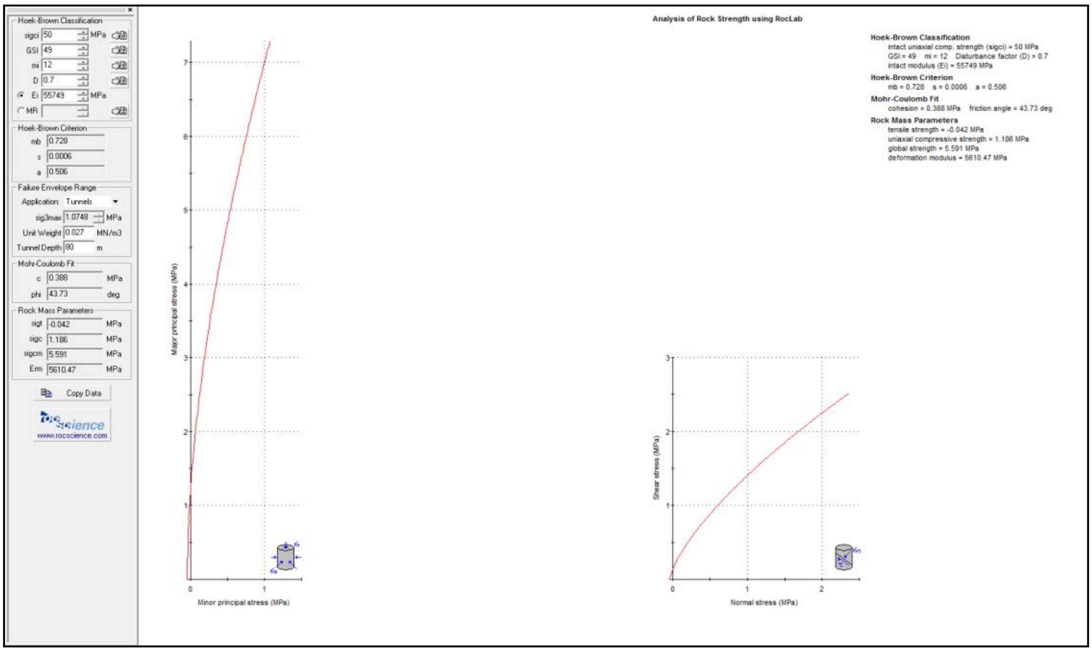

Figure 6. 11 Engineering parameters of the rock mass for D=0,7 (KM: 400+200 – KM: 400+520 in accordance with SK-808)

c= 388 kPa, Ø= 44° ve E_{rm}= 5610 MPa

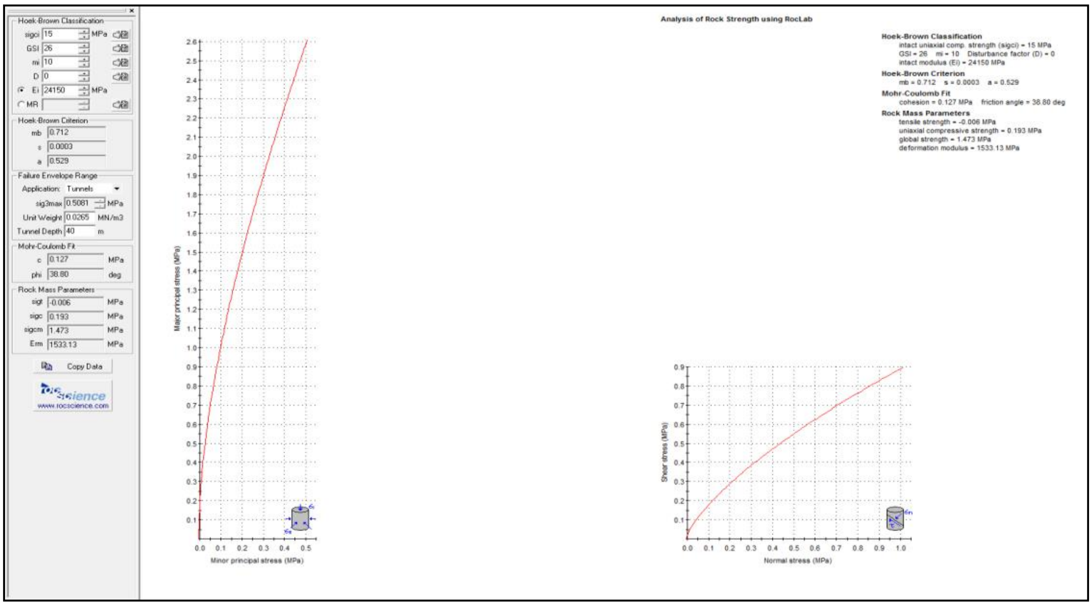

Figure 6. 12 Engineering parameters of the rock mass for D=0 (KM: 400+520 – KM: 400+750 in accordance with SK-809)

c= 127 kPa, Ø= 39° ve E_{rm}= 1533 MPa

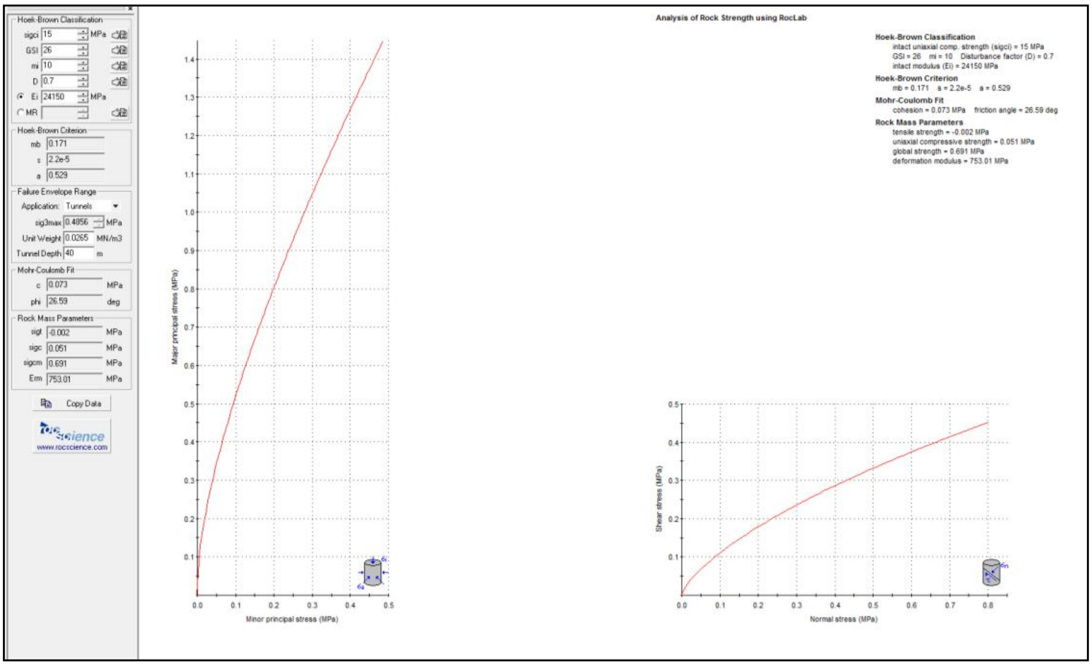

Figure 6. 13 Engineering parameters of the rock mass for D=0,7 (KM: 400+520 – KM: 400+750 in accordance with SK-809)

c= 73 kPa, Ø= 27° ve E_{rm}= 753 MPa

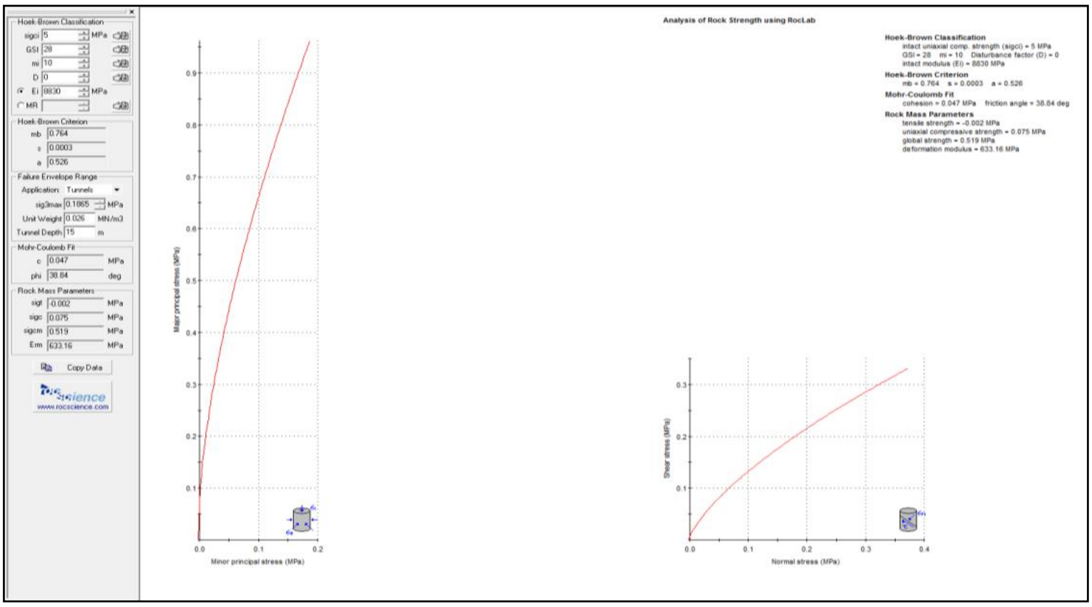

Figure 6. 14 Engineering parameters of the rock mass for D=0,7 (Exit Section KM: 400+750 – KM: 400+930 in accordance with SK-806)

c= 47 kPa, Ø= 39° ve E_{rm}= 633 MPa

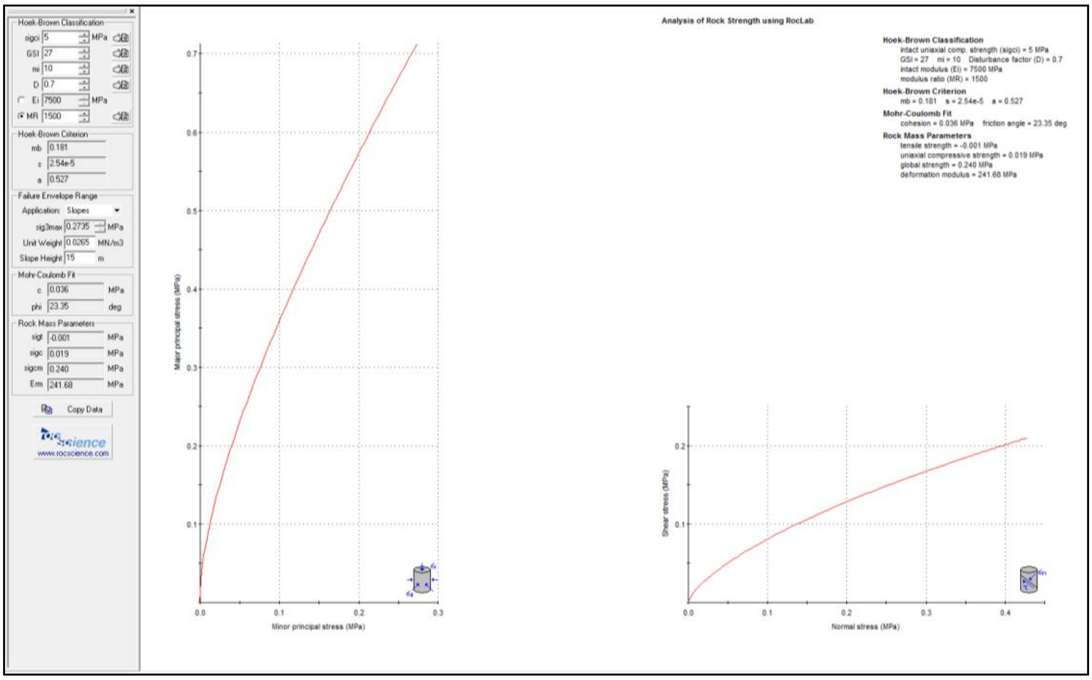

Figure 6. 15 Engineering parameters of the rock mass for D=0,7 (Exit Section KM: 400+750 – KM: 400+930 in accordance with SK-810)

c= 36 kPa, Ø= 23° ve E_{rm}= 242 MPa

Determination of necessary paramaters cohesion (c), angle of friction (ø) and modulus of elasticity of the rock mass (Erm) for numerical modeling are completed by using roclab. Table 6.1 summarizes the rock mass parameters obtained in this study.

Table 6. 1 Engineering parameters of the rock mass obtained from Roclab

	Disturbance Factor (D)	Unit weight (kN/m2)	Cohesion (c) (kPa)	ø(˚)	Depth (m)	Erm (MPa)
Entrance Portal	0.7	27	36	23	20	48
KM: 399+400-KM: 399+700	0	27	125	27	70	2825
	0.7	27	70	17		1350
KM: 399+700-KM: 400+080	0	27	223	29	112	2586
	0.7	27	127	18		1203
KM: 400+080-KM: 400+150	shearing zone		20	25	100	100
KM: 400+150-KM: 400+200	0	25	615	49	105	2064
	0.7	25	409	41		719
KM: 400+200-KM: 400+450	0	27	597	51	80	16108
	0.7	27	388	44		5610
KM: 400+450-KM: 400+520	shearing zone		20	25	100	100
KM: 400+520-KM: 400+750	0	26	127	39	40	1533
	0.7	26	73	27		753
Exit Portal	0.7	26	36	23	15	242

6.2 Estimation of Deformation Modulus

Determinating the parameter of modulus of elasticity of rock mass (E_{rm}) is very important for numerical analyses. Roclab is an accepted method for determination of the deformation modulus of rock mass. However, in this study different empirical equations have been also used to determine the deformation modulus of rock mass.

All of the accepted equations are presented in Table 6.2. However, the mostly preferred equations (Bieniawski, 1978; Serafim and Pereira, 1983, Barton, 2002; Hoek and Diederichs, 2006) are used in this thesis. These equations are preferred because they need parameters of RMR, Q or GSI in order to calculate deformation value of the rock mass which makes the determination of rock strength parameters process related to field observation data. Calculated deformation modulus values are presented in Table 6.3.

Table 6. 2 List of empirical equations for estimating the deformation modulus

Originator of Empirical Equation	**Required Parameters**	**Limitations**	**Equations**
Bienawski (1978)	RMR	RMR > 50	$E_{rm}=2RMR-100$ (GPa)
Serafim and Pereira (1983)	RMR	RMR < 50	$E_{rm}=10^{[(RMR-10)/40]}$ (GPa)
Barton (2002)	Q, σ_c	σ_c <100MPa	$E_{rm}=10Qc^{(1/3)}$ (GPa)
Hoek et al. (2002)	GSI, σ_c, D	σ_c <100MPa	$E_{rm=}(1-D/2)*\ ((q_c/100)^{0.5})*(10^{(GSI-10)/40})$ (GPa)
		σ_c >100MPa	*Erm=(1-D/2)* ((qc/100)0.5)* (10(GSI-10)/40) (GPa)*
Kayabaşı et al. (2003)	E_i, RQD, WD	-	*Erm=0.135[(Ei(1+RQD/100))/WD] (Gpa)*
Gökçeoğlu et al. (2003)	E_i, RQD, WD, σ_c	-	$Erm=0.001\ [((Ei/qc)(1+RQD/100))/WD]^{1.1811}$ GPa
Sönmez et al. (2004a)	E_i, s, a	-	$Erm=Ei\ (s^a)^{0.4}$ (Gpa)
Hoek and Diederichs (2006)	GSI, D	-	*Erm= 100 000*(1-(D/2)/1+e((75+25D-GSI)/11) (MPa)*
Hoek and Diederichs (2006)	E_i, GSI, D	-	*Erm=Ei ((1-D/2)/(1+e((60+15D-GSI)/11))) (MPa)*
Sönmez et al. (2004b)	E_i, RMR	-	Erm=Ei10((RMR-100)*(100-RMR))/(4000*exp (-RMR/100)) (MPa)

Table 6. 3 Estimation of deformation modulus of the rock masses along tunnel route

Sections	$E_{rm}=10Qc^{(1/3)}$ **(GPa)** (Barton,2002)	$E_{rm}=Ei\ ((1-D/2)/(1+e^{((60+15D-GSI)/11)}))$ **(MPa)** (Hoek& Diederichs, 2006)	$E_{rm}=(1-D/2)*((q_c/100)^{0.5})*(10^{(GSI-10)/40})$ **(GPa)** (Hoek,2002)	$E_{rm}=Ei10^{((RMR-100)*(100-RMR))/(4000*exp(-RMR/100))}$ **(MPa)** (Sönmez ve diğ.,2006)	$E_{rm}=100\,000*(1-(D/2)/1+e^{((75+25D-GSI)/11)}$ **(MPa)** (Hoek& Diederichs, 2006)	***GSI***	***Basic RMR***	***RMR***	q_c ***(MPa)***	E_i ***(lab& MR) (MPa)***
Entrance Portal	*1,71 GPa*	*35,16 MPa*	*0,38 GPa*	*130,94 MPa*	*609,53 MPa*	*19*	*24*	*19*	*5*	*1500*
KM: 399+400-KM: 399+700	*1,71 GPa*	*1280,99 MPa*	*0,45 GPa*	*5078,94 MPa*	*799,25 MPa*	*22*	*27*	*22*	*5*	*41905*
KM: 399+700-KM: 400+080	*2,15 GPa*	*1204,02 MPa*	*0,67 GPa*	*4833,89 MPa*	*874,70 MPa*	*23*	*28*	*23*	*10*	*36067*
KM: 400+150-KM: 400+200	*3,53 GPa*	*1351,56 MPa*	*4,70 GPa*	*3709,79 MPa*	*5625,49 MPa*	*44*	*49*	*44*	*44*	*7145*
KM: 400+200-KM: 400+450	*3,68 GPa*	*10545,59 MPa*	*5,01 GPa*	*28945,69 MPa*	*5625,49 MPa*	*44*	*49*	*44*	*50*	*55749*
KM: 400+520-KM: 400+750	*2,47 GPa*	*675,84 MPa*	*0,73 GPa*	*1453,88 MPa*	*730,26 MPa*	*21*	*26*	*16*	*15*	*24150*
Exit Portal	*1,71 GPa*	*294,77 MPa*	*0,47 GPa*	*684,44 MPa*	*874,70 MPa*	*23*	*28*	*18*	*5*	*8830*

For the exit section of the tunnel, 40 kPa, 25˚ are determined for the cohesion (c) and angle of friction (ø) values, respectively. It can be said that the values determined for entrance section is worse than the values determined for entrance section (55 kPa and 25˚). In the middle section of the tunnel, the highest parameters (c= 615 kPa and ø= 49˚) are obtained. According to Wood (2004), the dilation angle is calculated as 0.33 times of the friction angle. So, the dilation angle value 9˚ is taken into account for both entrance and exit sections of the tunnel. For the middle section of the tunnel, the dilation angle is taken between 7˚and16˚. In Table 6.4 shows the summary of the rock mass parameters to be used for the numerical analyses.

Table 6. 4 Summary of the rock mass parameters to be used for numerical analyses.

Section	Disturbance Factor (D)	Unit weight (kN/m2)	Cohesion (c) (kPa)	ø(˚)	Depth (m)	Erm (MPa)
Entrance Portal	0.7	27	40	25	20	350
KM: 399+400-KM: 399+700	0	27	125	27	70	2825
	0.7	27	70	17		1350
KM: 399+700-KM: 400+080	0	27	223	29	112	2586
	0.7	27	127	18		1203
KM: 400+080-KM: 400+150	shearing zone		20	25	100	100
KM: 400+150-KM: 400+200	0	25	615	49	105	2064
	0.7	25	409	41		719
KM: 400+200-KM: 400+450	0	27	597	51	80	16108
	0.7	27	388	44		5610
KM: 400+450-KM: 400+520	shearing zone		20	25	100	100
KM: 400+520-KM: 400+750	0	26	127	39	40	1533
	0.7	26	73	27		753
Exit Portal	0.7	26	55	25	15	500

CHAPTER 7

THE VERIFICATION OF TUNNEL SUPPORT SYSTEMS WITH NUMERICAL ANALYSIS

Mostly applied methods for rock mass classification and rock support systems are the methodologies of Bieniawski (RMR) and Barton (Q). Nevertheless, thanks to the developments in Finite Element Methods, huge amounts of possibilities are also accomplished. The Finite Element Method (FEM) possesses a great capacity of analyzing the complex underground conditions through non homogeneities. The subsurface is modeled as continuum. Meshes consisting of limited number of elements form this model. The concepts of solving unknowns at each element cause highly complex matrix equations. However, in solving the formed complex matrix equations, the capability belongs to the FEM.

Several numerical analyses programs to be used for the purpose discussed above, is based on " finite elements" or "finite difference" methods. Phase 2 and Flac are the most common 2D finite elements programs. For 3D analysis Adina, 3DEC, Flac and Plaxis can be used.

In this thesis, Phase2 software was used to model the tunnel sections. It uses two dimensional finite element method. Phase 2 software was created by Toronto University and still being developed by Rocscience group. The program also provides applications of rock bolts and shotcrete which are the currently used temporary support systems for NATM tunneling. Safety factor in Phase 2 program is measured through c-ø reduction option of the finite element method. By using this option, strength properties of all material in the model have been decreased with an amount of reduction factor and FEM analysis are reiterated again. In the event that the program cannot measure the model with reduced strength parameters, as a safety factor the ratio of reduction is taken.

To simulate the negative effect of groundwater, the coefficient of permeability was included in the analyses. Value of coefficient of permeability obtained from the laboratory test results which is given at appendix section in this thesis. After each analyses performed for different section of the tunnel, the strain values around the tubes and yielded bolt-liners are checked in the context of the tunnel stability. According to Hoek (2001), strain values around the tubes should be smaller than %1 in order to stay in the safe side.

7.1 Determining Support Properties for Numerical Analyses

According to General Directorate of Highways, the properties of the supports for the assigned NATM classes to be used in the numerical analyses are given below at Tables 7.1-7.4. In this study, properties of bolts, shotcrete, steel mesh, steel set and forepole have been determined based on the experience (accepted by General Directorate of Highways) of YUKSEL DOMANİÇ company.

Table 7. 1 Properties of C2 support system

Support Systems	***C2***
Bolt Diameter	*28 mm*
Bolt Spacing	*1,0x1,0*
Bolt length	*4-6 m*
Shotcrete class and thickness	*C20/25(25cm)*
steel mesh type	*Q221/221*
	Double layer
Steel set type and spacing	*HEA140,1,00m*
Forepole spacing and length	*t=0,5m, L=4-6 m*
Span time	***C2***
Top heading	*1,00 m*
bench	*2,0 m*

Table 7. 2 Properties of C3 support system

Support Systems	***C3***
Bolt Diameter	*28 mm*
Bolt Spacing	*1,0x1,0*
Bolt length	*6 m*
Shotcrete class and thickness	*C20/25(40cm)*
steel mesh type	*Q221/221*
	Double layer
Steel set type and spacing	*HEA140,1,00m*
Forepole spacing and length	*t=0,5m, L=4-6 m*
Span time	***C2***
Top heading	*0,75 m*
Bench	*1,5 m*

Table 7. 3 Properties of B3 support system

Support Systems	***B3***
Bolt Diameter	*28 mm*
Bolt Spacing	*1,5x1,5*
Bolt length	*4m*
Shotcrete class and thickness	*C20/25(20cm)*
steel mesh type	*Q221/221*
	Double layer
Steel set type and spacing	*HEA120,1,50m*
Forepole spacing and length	*t=0,5m, L=4-6 m (if required)*
Span time	***B3***
Top heading	*1,50 m*
bench	*3,00 m*

Table 7. 4 Properties of B2 support system

Support Systems	***B2***
Bolt Diameter	*28 mm*
Bolt Spacing	*2,0x-2,0*
Bolt length	*4m*
Shotcrete class and thickness	*C20/25(15cm)*
steel mesh type	*Q221/221*
	TEK KAT
Steel set type and spacing	*HEA100,2.0 m (if required)*
Forepole spacing and length	*-*
Span time	***B2***
Top heading	*2,00 m*
bench	*3,00 m*

7.2 Steps of Modeling with Finite Element Method

The Belkave tunnel section is designed with finite element method. In order to design the tunnel, firstly, geotechnical sectors of the tunnel should be defined. Secondly, the section is separated into limited number of elements that are connected at nodal points. In this study, triangular element type is used. In the third step of the modeling, external boundary definition has been done. The upper part is designed as free boundary which can be define as σyy=0. The parts of the section are restrain x (lubricated mixed boundary) which means u_x=0, σ_{xy} and σ_{xz}=0. The lower boundary of the section is called as restrain y (lubricated mixed boundary) so as to define uy=0, σxz=σyz=0 and σyy=γL. Mesh and boundary conditions can be seen below Figure 7.1.

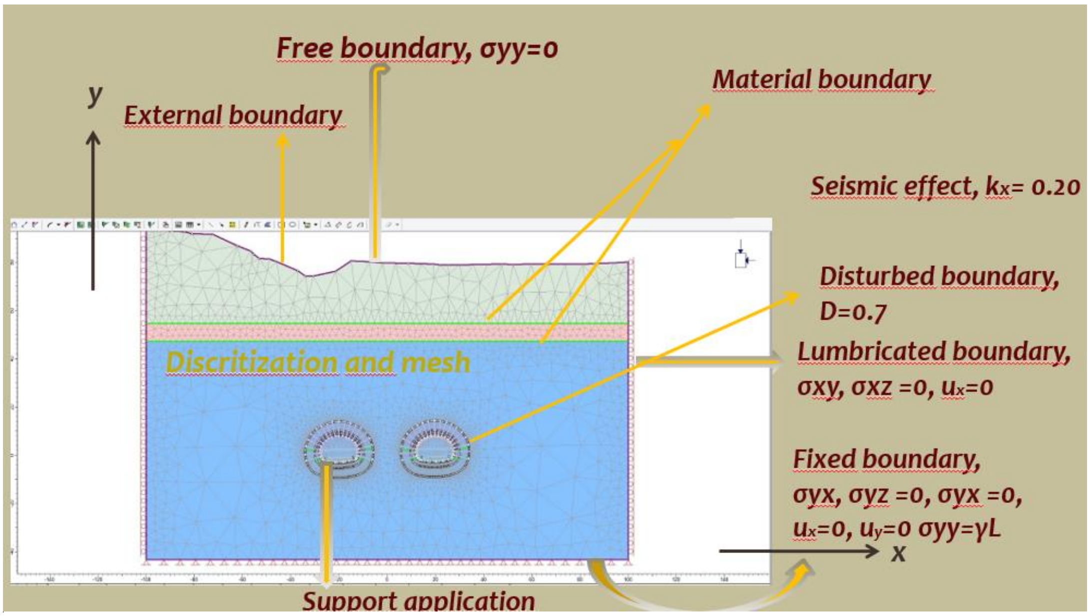

Figure 7. 1 The mesh and boundary condition of the section

Poor blasting disturbance factor is taken into account for plastic boundary around the tunnel to be on the safe side. The thickness of the plastic boundary is taken as 0.5D, half of the of tunnel diameter in operation. There are several ways to determine the plastic boundary around the tunnel. However, in practice, 0.5D is accepted for the plastic radius. Phase 2 (2008) software and RocSupport 3.0 (2007) software also verify this assumption. So, 6m. is taken as the radius of plastic zone in this study. In the next step of the modeling, assignment of the material properties is completed. Gravity type of field stress is chosen by using actual ground surface and predicting the horizontal to vertical stress ratio, k which is expanded as k= 0.25+7Eh(0.001+(1/z)) according to Sheorey (1994).

After defining the number of steps in designing, support application which determined empirically is done in several steps. The timing of support application and support interaction with rock masses is not suitable for 2D models. To understand d and solve this issue, its needed to be underline two important stages before the application of the support systems. First one is that the rock mass should be allowed to be relaxed, and the second one is that rock mass should be allowed to carry some of the load itself. In Phase 2, there are two methods used to fulfill load split within rock mass and support systems. These two methods are called “load split” option and “material softening”. In the designing of the tunnel sections to simulate 3D to 2D, material softening method is used in this study. The material stiffness is multiplied by a reduction factor β. β is the coefficient from 0 to 1 that is multiplied by the material stiffness to yield the material inside the tunnel. Seismic load is applied in the last step of the modeling. The coefficient of the seismic load is taken as 0.2 according to suggestion of GDH (2006). The strain around the tunnel and yielded support elements are checked right after computing the model.

7.3 Slope Stability Analyses for Entrance Portal

At this part, highest cut before entrance of the tunnel was modeled and stability analyses were performed. In practice excavation is performed from natural topography to the first float as the very first step. As soon as the first cut completed, the support elements installation (shotcrete, rock bolts) are to be completed. The excavation of the cut will be completed right after reaching to the road grade. According to the Technical Specifications of General Directorate of Highways (2006), the sufficient safety factors under static and dynamic conditions are 1.5 and 1.15, respectively.

To analyze the stability of highest cut, the model was prepared in five steps. The slope of side was 3H:2V and forehead was 1H:3V (H: horizontal, V: vertical). In the first step, the natural condition of the surface was modeled. In the following steps, the cut and support applications were done. Seismic load was applied to the system as the final step.

For forehead slope which is the slope of tunnel entrance at KM: 399+400, the model was prepared in three stages. In the first step, the natural condition of the surface was modeled. In the following steps, the cut and support applications were done. Seismic load was applied to the system as the final step. Table 7.5 shows the specifications of supports used in analyses.

Table 7. 5 Supports used in modeling of the entrance portal.

Bolt spacing	1.5m*1.5m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	25 cm
Young's modulus of shotcrete	15 000 MPa

For both static and seismic conditions, numerical analyses performed for the side slopes at the entrance portal in order to check the stability of the tunnel section. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side (Figures 7.2 and 7.3).

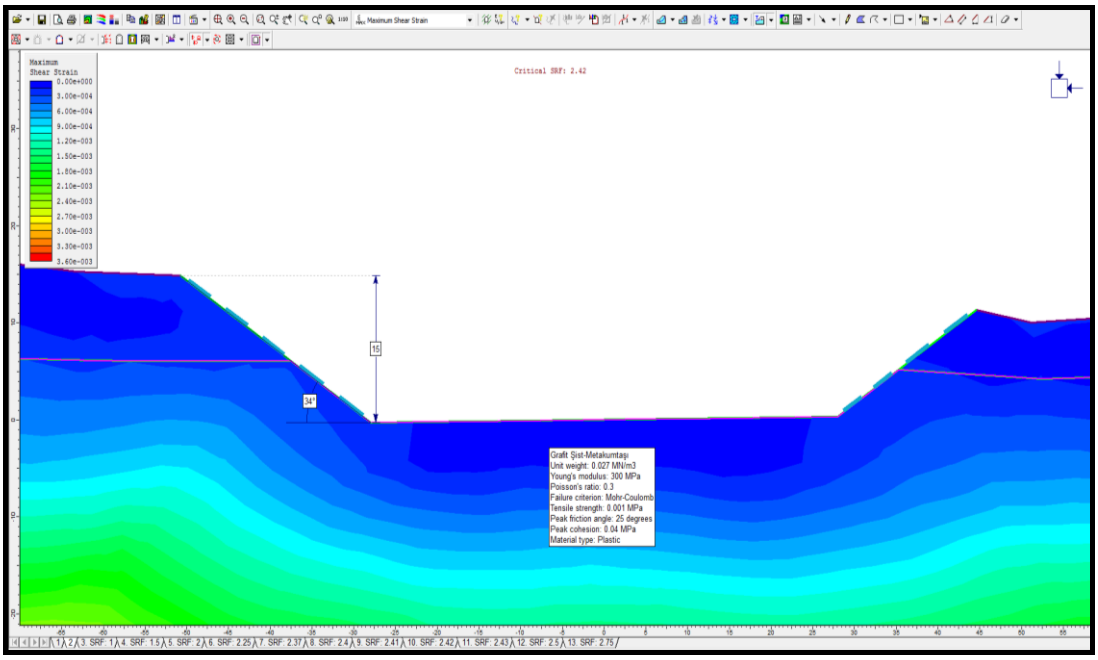

Figure 7. 2 Slope stability analysis for the side slopes at the entrance portal showing maximum shear strain under static condition (3H/2V) (SF: 2. 42)

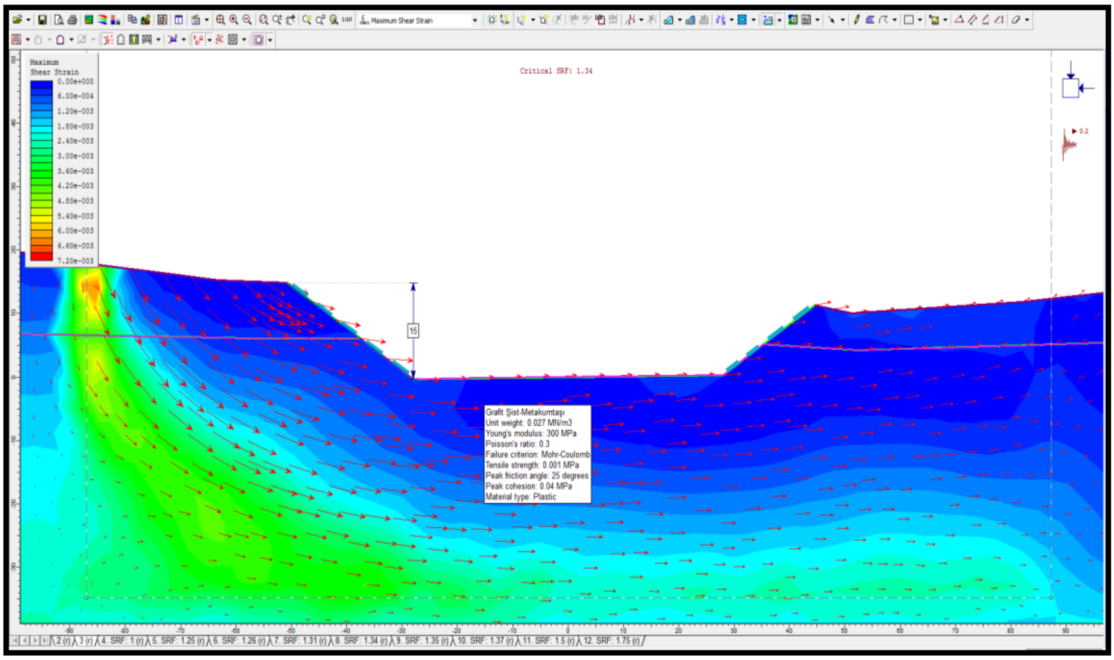

Figure 7. 3 Slope stability analysis for the side slopes at the entrance portal showing maximum shear strain under the effect of seismic load of kx=0.20 (3H/2V) (SF: 1.34)

When the cut is completed Total displacement is 3 cm under static condition. Value of 2.42 obtained at this stage for the safety factor. However, total displacement is increased to 4 cm after seismic load applied to the model (kx=0.20). At this stage, there are no yielded liners. Value of 1.34 obtained at this stage for the safety factor. According to the Technical Specifications of GDH (2006), the values are sufficient for the slope stability.

Figures 7.4 and 7.5 show the side slopes at entrance of the tunnel during excavation. The results obtained from numerical analyses for side slopes at entrance portal and real slopes (field performance) are compatible with each other. No slope instability problems have appeared during slope excavation as it was predicted by numerical analyses.

Figure 7. 4 shotcrete and water pipes installed for side slope

Figure 7. 5 wire mesh and shotcrete installation for side slope

For both static and dynamic (under seismic load) conditions, slope stability analyses were performed. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side. The results of analyses performed are shown in Figures 7.6 and 7.7.

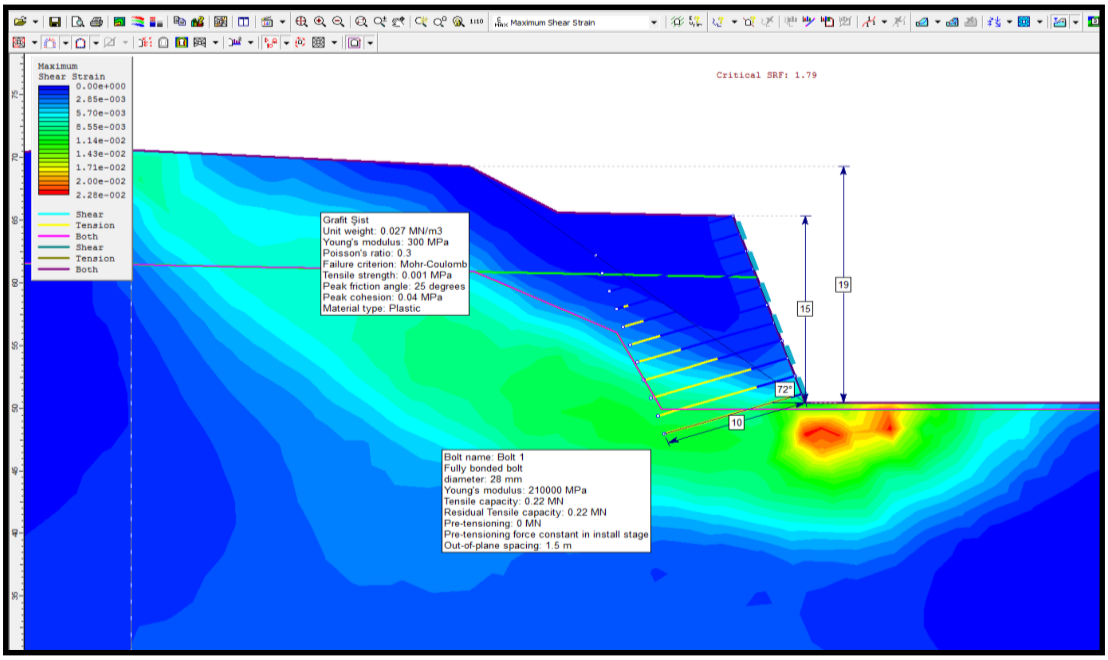

Figure 7. 6 Slope stability analysis for the forehead slopes at the entrance portal showing maximum shear strain under static condition (1H/3V) (SF: 1.75)

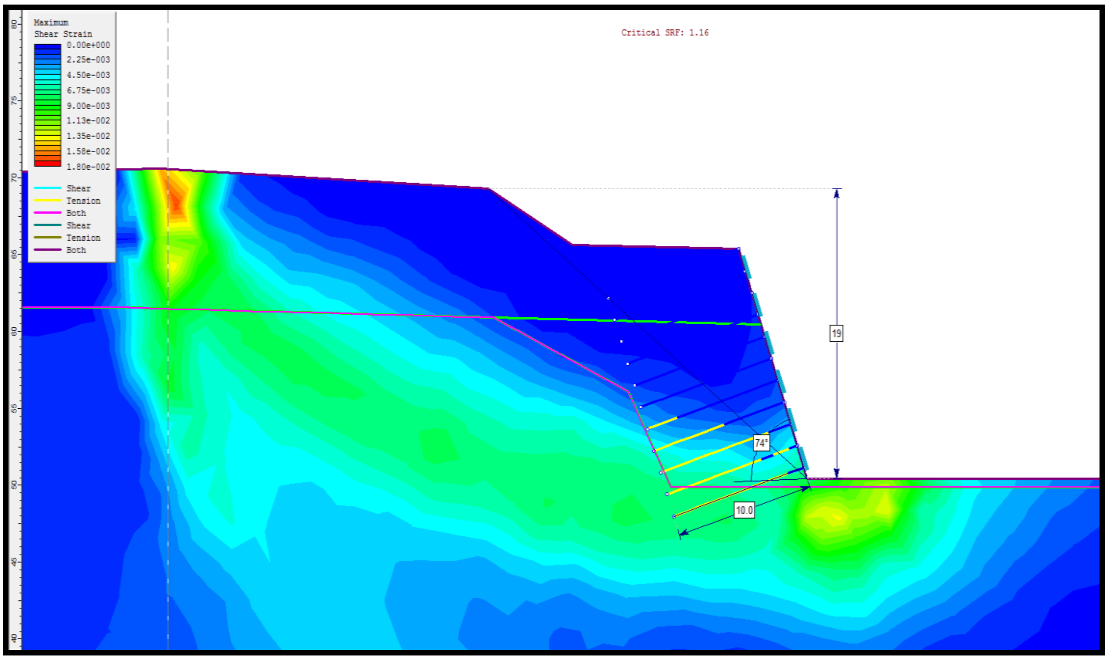

Figure 7. 7 Slope stability analysis for the forehead slopes at the entrance portal showing maximum shear strain under effect of seismic load of kx=0.20 (1H/3V) (SF: 1.25)

When the cut is completed Total displacement is 2 cm under static condition. Value of 1.75 obtained at this stage for the safety factor. However, total displacement is increased to 3 cm after seismic load applied to the model (kx=0.20). At this stage, there are no yielded liners but some of the bolt elements are yielded. Value of 1.25 obtained at this stage for the safety factor. According to the Technical Specifications of GDH (2006), the values are sufficient for the slope stability.

To sum up, results obtained from the slope stability analyses performed show that the slopes are on the safe side according to Technical Specifications of GDH (2006). Figures 7.8, 7.9 and 7.10 show the forehead slopes at the entrance portal of the tunnel during excavation. The results obtained from the numerical analyses for the forehead slopes at the entrance portal and real slopes (field performance) are compatible with each other. No slope instability problems have occurred during slope excavation as it was predicted by numerical analyses.

Figure 7. 8 A view of the supported forehead slope at the tunnel entrance.

Figure 7. 9 Another view of the supported forehead slope at the tunnel entrance.

Figure 7. 10 A general view of the supported slopes at the tunnel entrance.

7.4 Stability analyses of the tunnel

Km: 399+190 and Km: 400+820 are defined as critical sections for the entrance and exit s of the tunnel due to the lowest overburden. Because of lowest overburden and low engineering parameters, arching effect would not be occurred. At kilometers of 399+700, 399+960, 400+200, 400+240, 400+500, 400+550, the tunnel section analyses were performed because these are considered as critical sections.

At KM: 399+190, the entrance section of the tunnel was modeled in 14 stages. These steps are given below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

Simulation of the stages explained above and support specification used for modeling are given in Figure 7.11 and Table7.6, respectively.

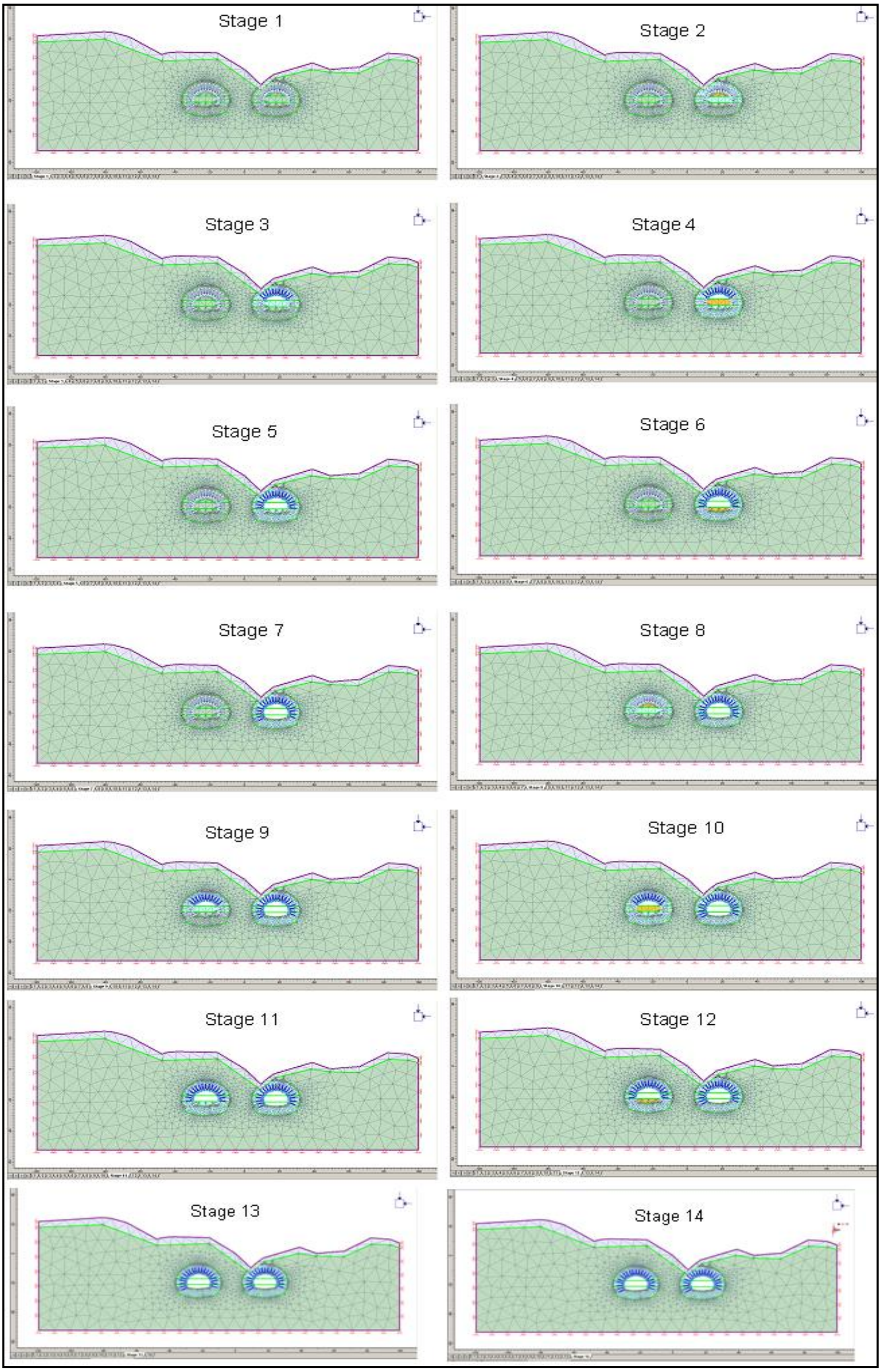

Figure 7. 11 Steps of modeling of the tunnel.

Table 7. 6 Supports used in the modeling of the tunnel at KM: 399+190

Bolt spacing	1 m*1 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	15 000 MPa

As the tunnel excavation moves on in three dimensions, displacement may be increased. Decreasing the stiffness of the filled material in the tunnel is used to simulate this effect in 2D model. With the aim of determining the proper softness ratio, stiffness versus displacement curve is generated. X-axis on the graph represents the displacements. On the y-axis, 1-β is plotted where β is coefficient varying from 0 to 1 (Figure 7.12). This coefficient can be defined as softening ratio of the material inside the tunnel (Phase2, 2008).

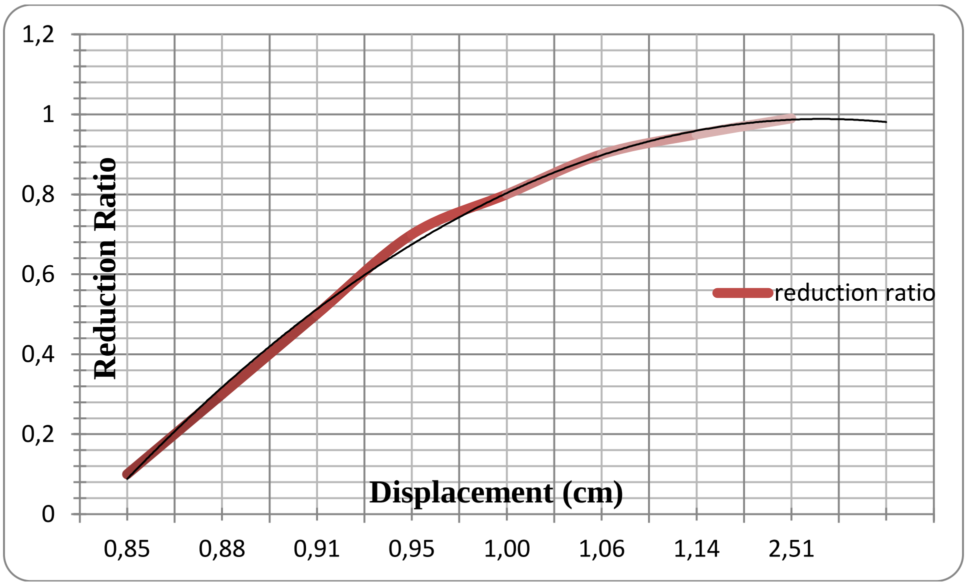

Figure 7. 12 Reduction ratio vs. displacement graph for KM: 399+190

As seen in Figure 7.12, at the point of 0,6 the linearity is disturbed. So, 0.6 reduction ratio is chosen to decrease the stiffness. 20 cm shotcrete and I160 steel sets spaced in 1.5 m intervals and Q221 wire mesh were applied. Figure 7.13. shows the diagram of the axial force - bending moment which was plotted for the shotcrete. According to Figure 7.13, 20 cm shotcrete is considered to be sufficient.

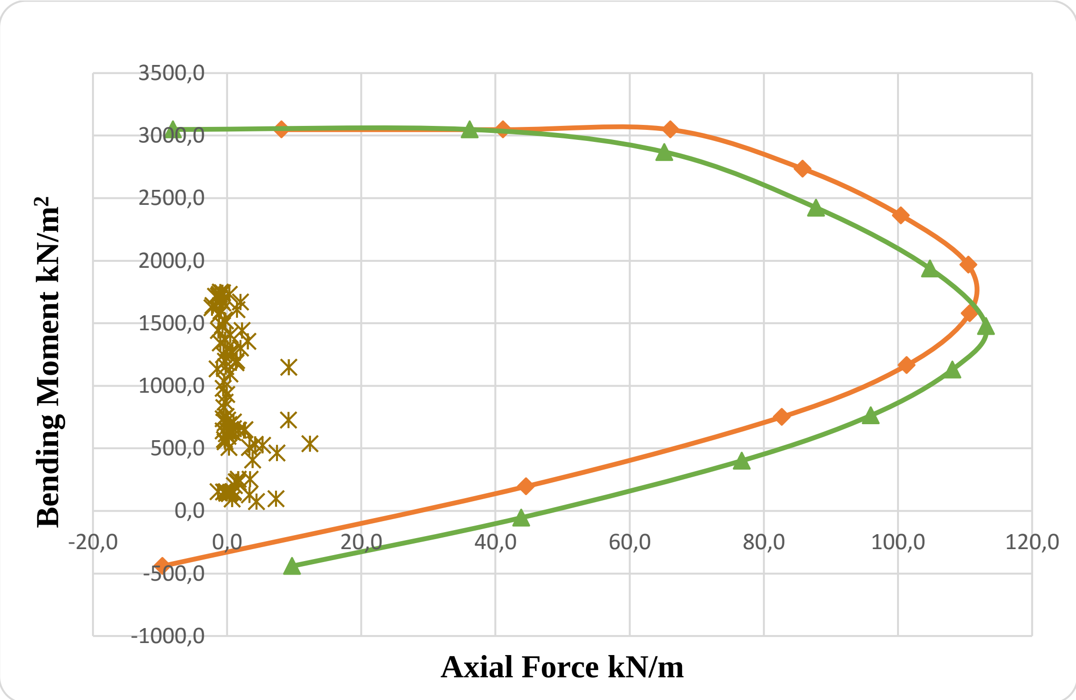

Figure 7. 13 Bending moment vs. axial force graph of 20 cm shotcrete, I160 steel sets spaced in 1.5 m intervals and wire mesh for the tunnel entrance

For both static and dynamic (under seismic load) conditions, slope stability analyses were performed. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side. Bolts and liners was not yielded. The results of analyses performed are shown in Figures 7.14 and 7.16.

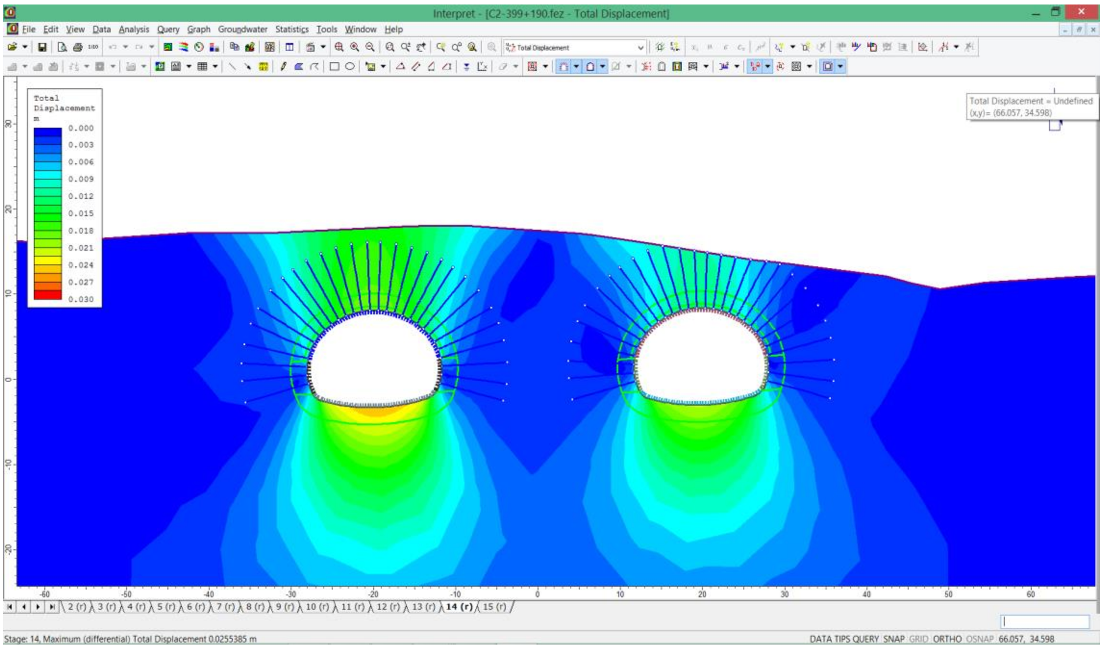

Figure 7. 14 Total displacements around tunnel section at KM: 399+190

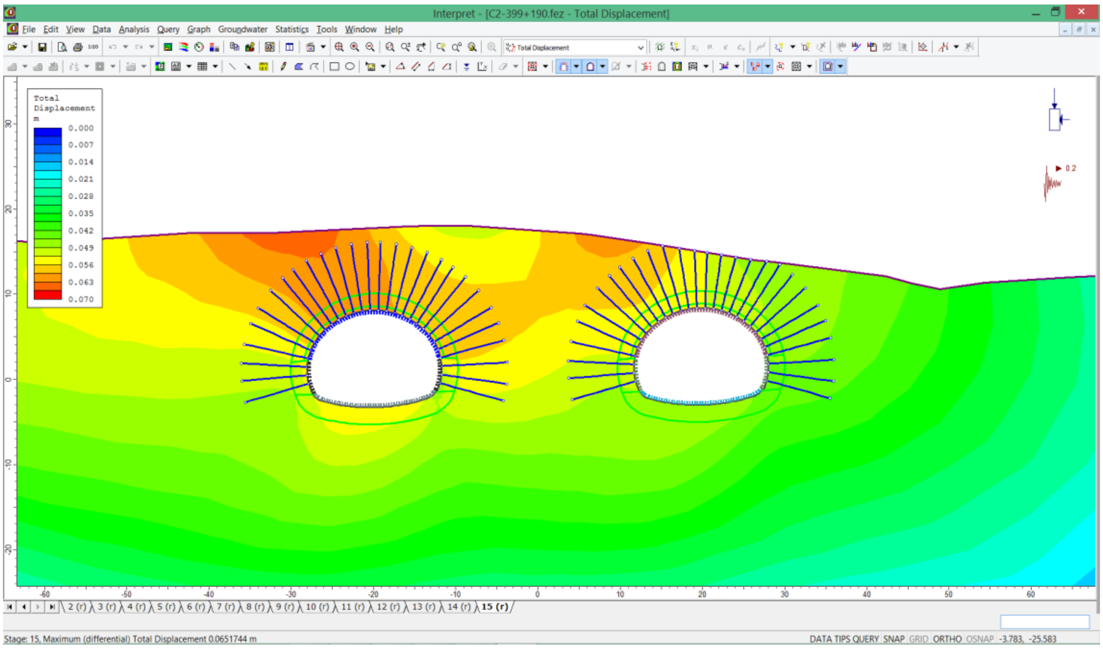

Figure 7. 15 Total displacement around tunnel section under seismic effect (kx=0.20) at KM: 399+190

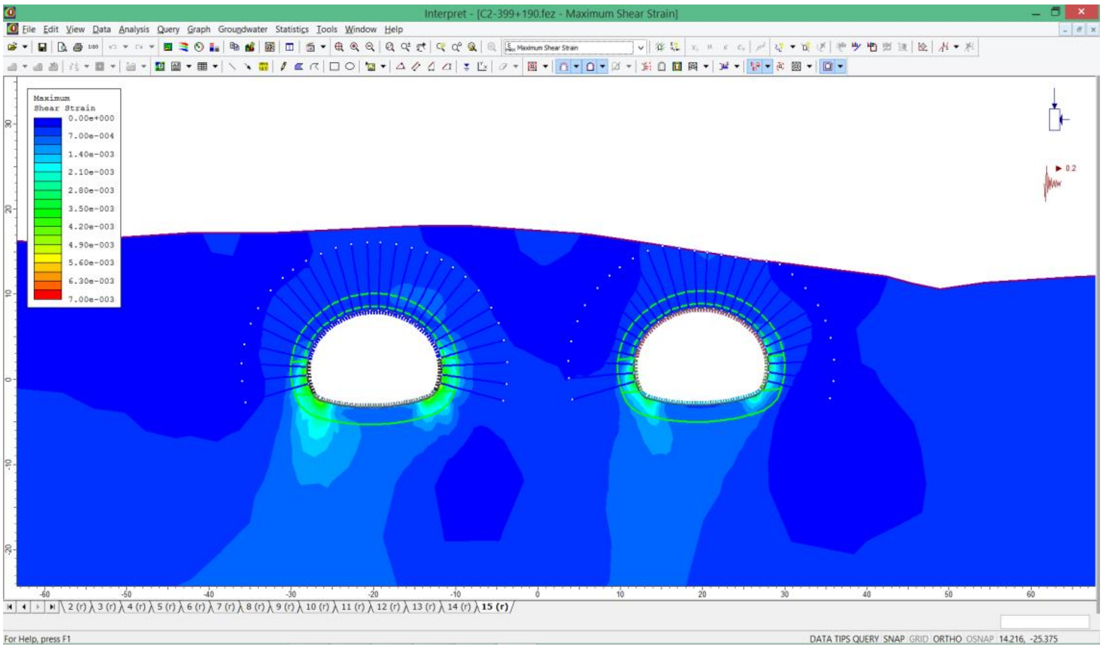

Figure 7. 16 Maximum shear strain around tunnel under seismic condition (kx=0.20) at KM: 399+190

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 1.9 cm and 1.2 cm, respectively. For the left tube under seismic effect of kx= 0.20, the total displacement is raised to 2.1 cm, and for the right tube total displacement is raised to 1.3 cm. These results are acceptable and it can be stated that C2 support systems for the section of the tunnel is verified by numerical analyses.

According to strain values obtained from Phase 2 software, they never reach %1, specified by Hoek (2001). At figure 7.17 and 7.18, Belkahve tunnel entrance excavation is shown. No stability problems have occurred during the excavation.

Figure 7. 17 A close-up view of the excavation at the Belkahve tunnel entrance

Figure 7. 18 A general view of the excavation at the Belkhave tunnel entrance

The entrance section of the tunnel at KM: 399+700 was modeled by Phase 2 software. Modeling of the tunnel tubes was performed in 14 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

Table 7.7 presents the supports used in the numerical analyses. As seen in Figure 7.19, the linearity is disturbed at reduction ratio of 0.6. So, 0.6 reduction ratio is chosen to decrease the stiffness. 20 cm shotcrete were applied. Figure 7.20. shows the diagram of the axial force - bending moment which was plotted for the shotcrete. According to Figure 7.20, 20 cm shotcrete is considered to be sufficient.

Table 7. 7 Support used in the modeling of the tunnel at KM: 399+700

Bolt spacing	1 m*1 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	15 000 MPa

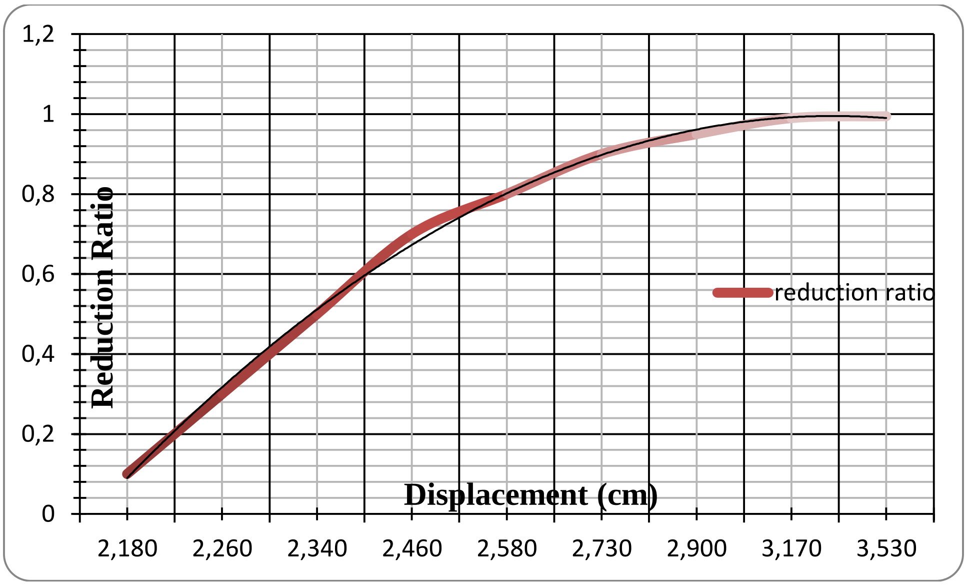

Figure 7. 19 Reduction ratio vs. displacement graph for KM: 399+700

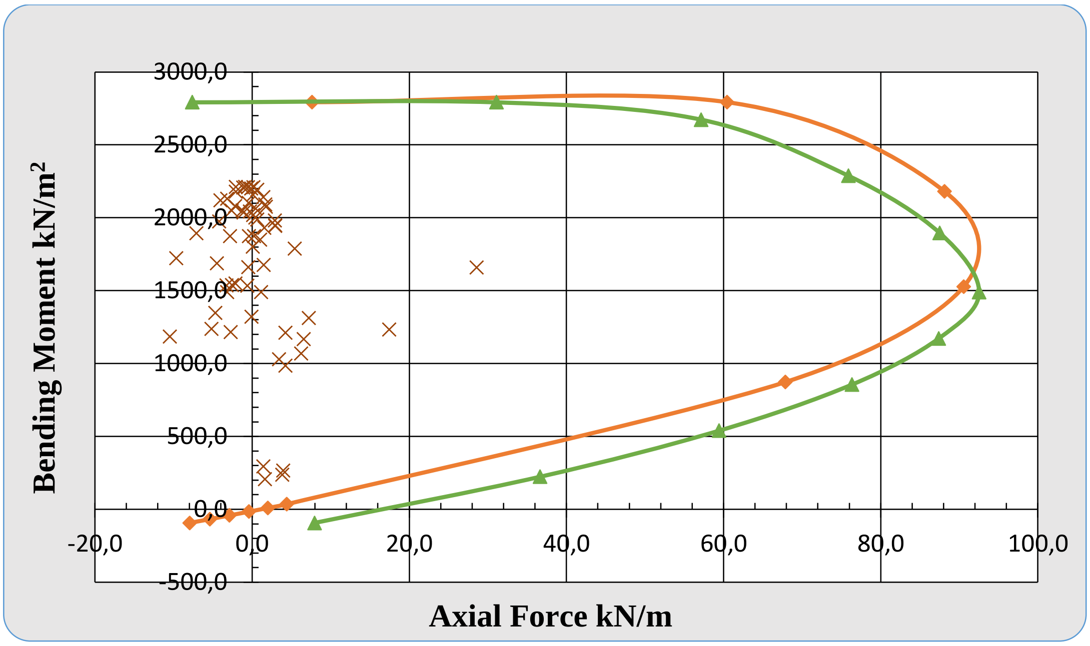

Figure 7. 20 Bending moment vs. axial force graph of 20 cm shotcrete, Q221/221 wire mesh for Km: 399+700

For both static and dynamic (under seismic load) conditions, total displacements were checked. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side. Liner elements were not yielded. However, some of the bolt elements were yielded. The results of analyses performed are shown in Figures 7.21 and 7.23.

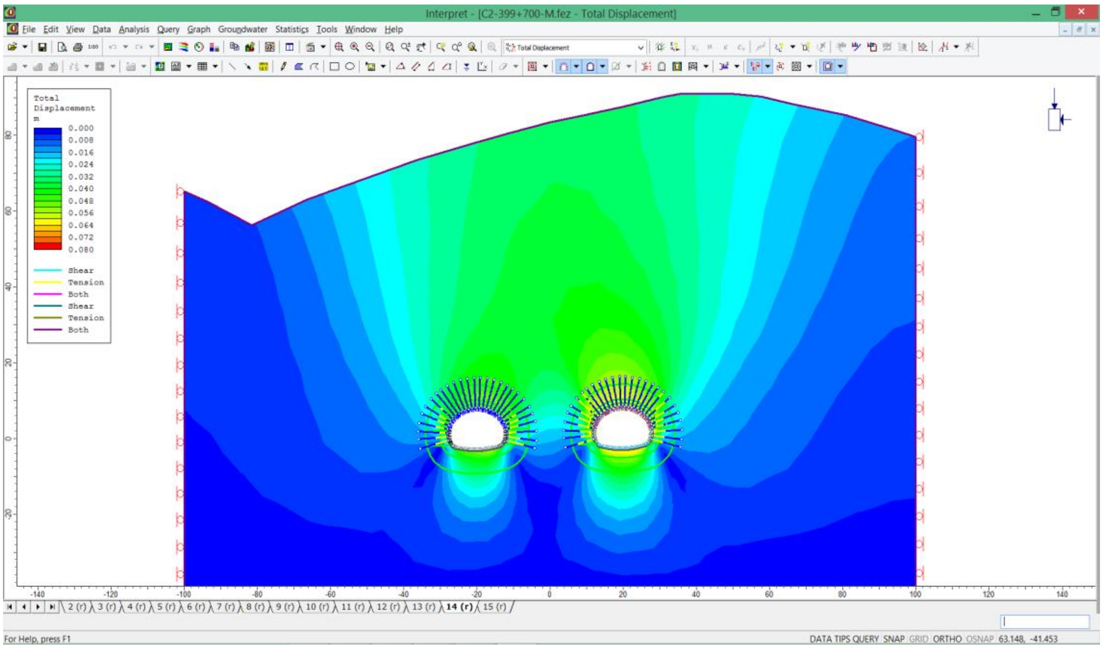

Figure 7. 21 Total displacements around tunnel section KM: 399+700

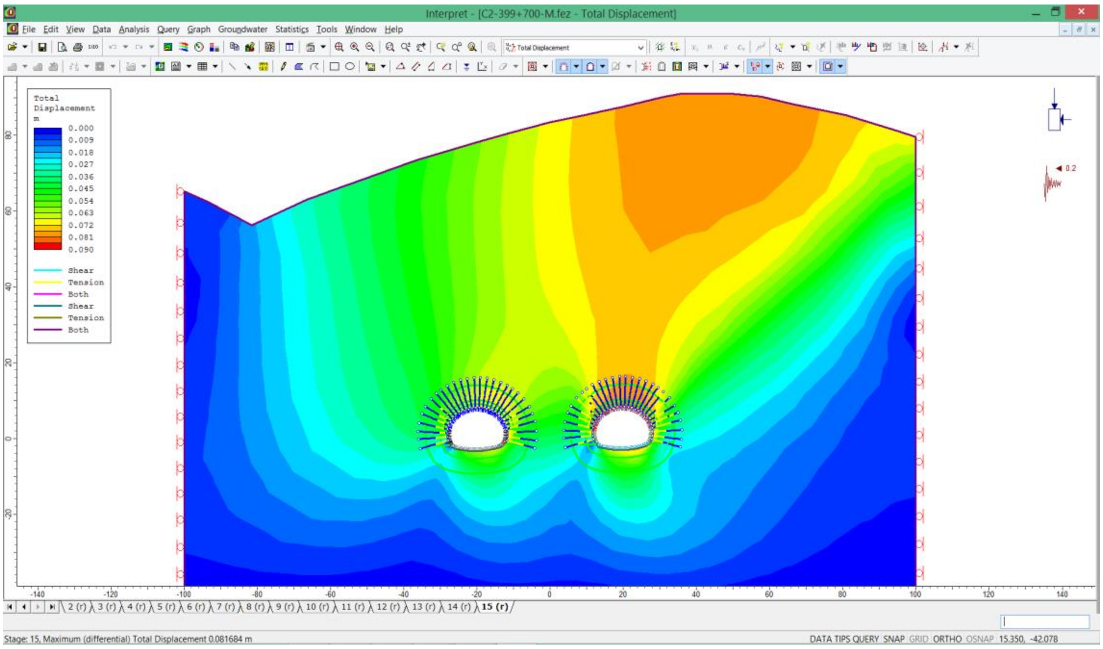

Figure 7. 22 Total displacement around tunnel section under seismic effect (kx=0.20) KM: 399+700

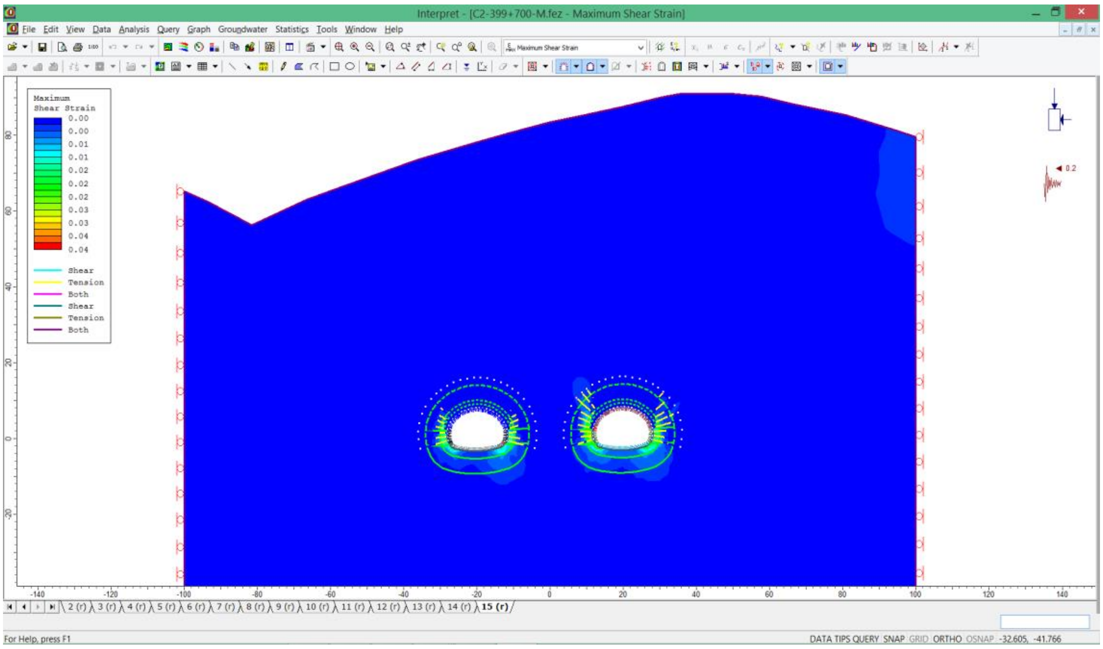

Figure 7. 23 Maximum shear strain around tunnel under seismic condition (kx=0.20) KM: 399+700

Without effect of the seismicity, total displacements at the peak point of left and right tubes are 5.6 cm and 6.3 cm, respectively. Under the seismic effect of kx= 0.20, total displacement for left and right tubes are raised to 5.9 cm and 7.1 cm, respectively. These results are definitely acceptable and it can be stated that C2 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from the analysis, they never exceed %1 limiting value (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel.

The entrance section of the tunnel at KM: 399+960 was also modeled in 14 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

The supports used in modeling are presented in Table 7.8.

Table 7. 8 Support used in the modeling of the tunnel at KM: 399+960

Bolt spacing	1 m*1 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	10 000 MPa

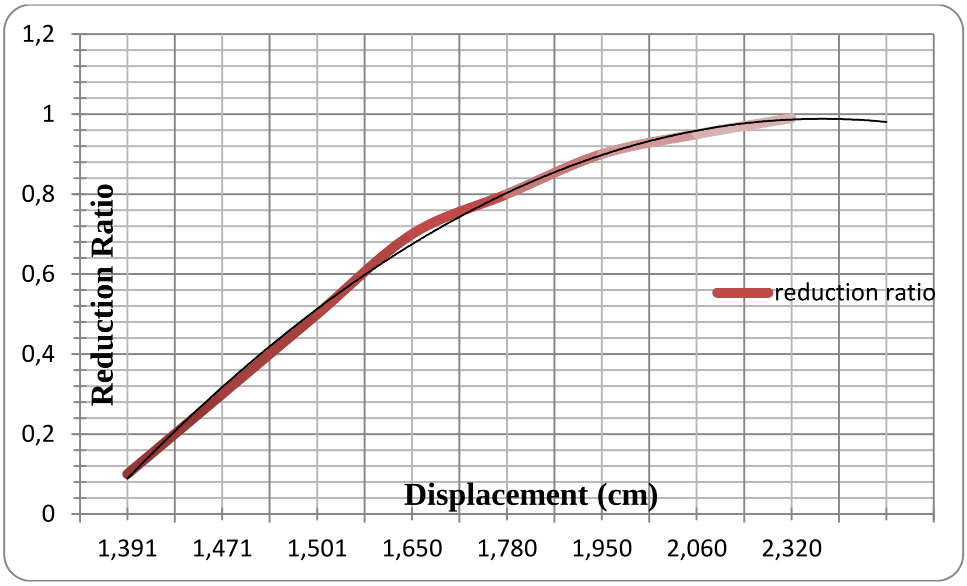

Figure 7. 24 Reduction ratio vs. displacement graph at KM: 399+960

As seen in Figure 7.24, at the point of 0,6 the linearity is disturbed. So, 0.6 reduction ratio is chosen to decrease the stiffness. 20 cm shotcrete were applied. Figure 7.25. shows the diagram of the axial force - bending moment which was plotted for the shotcrete. According to Figure 7.25, 20 cm shotcrete is considered to be sufficient.

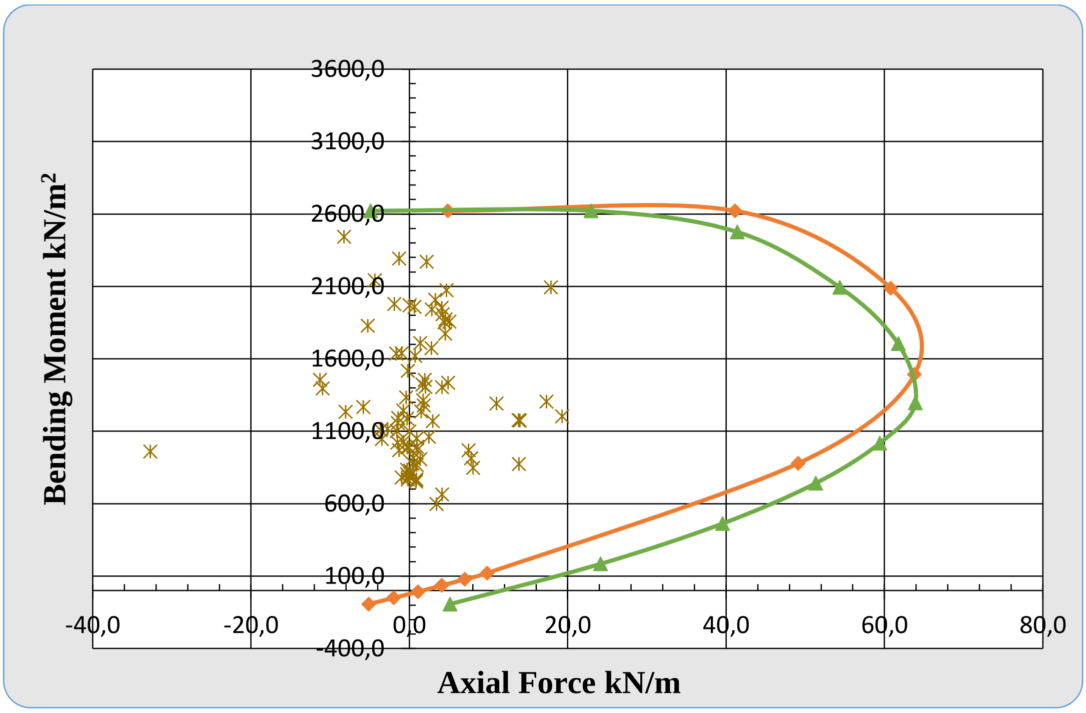

Figure 7. 25 Moment vs. axial force diagram of 15 cm shotcrete and Q221/221 wire mesh for Km: 399+960

For both static and dynamic (under seismic load) conditions, total displacements were checked. Liner elements were not yielded. However, some of the bolt elements were yielded. The results of analyses performed are shown in Figures 7.26 and 7.28.

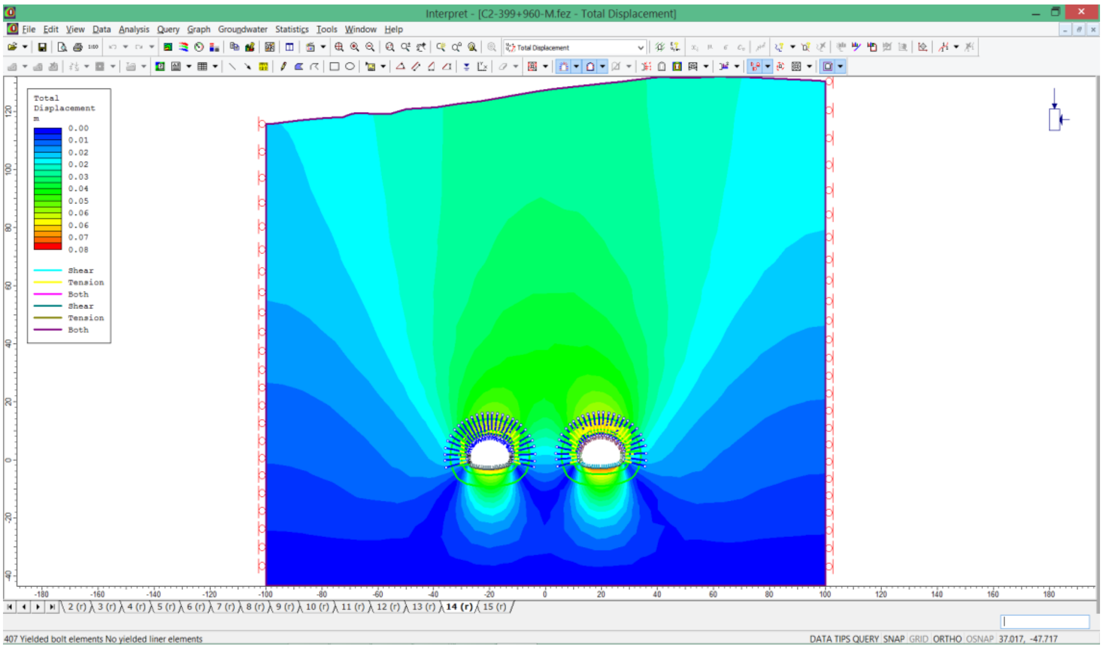

Figure 7. 26 Total displacements around the tunnel section at KM: 399+960

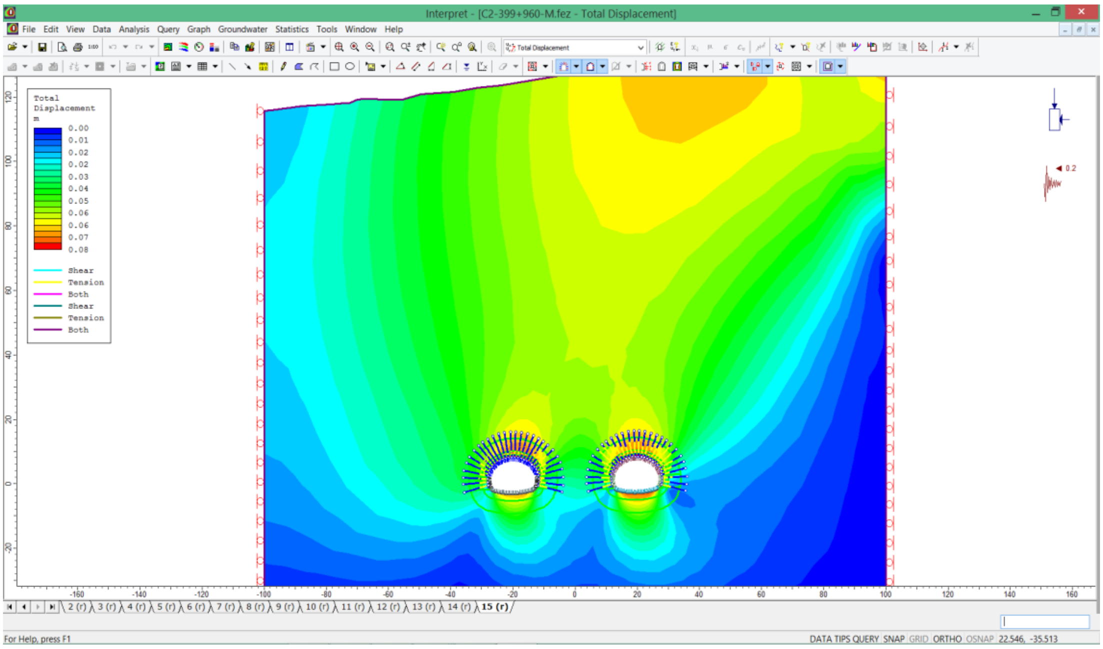

Figure 7. 27 Total displacement around tunnel section under seismic effect (kx=0.20) at KM: 399+960

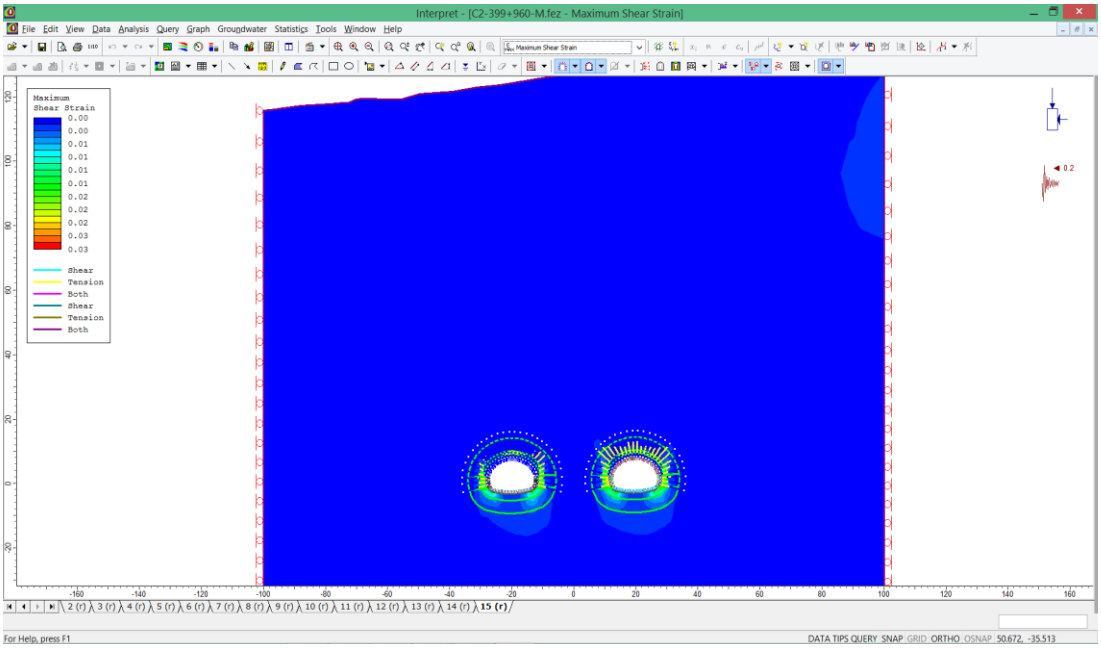

Figure 7. 28 Maximum shear strain around tunnel under seismic condition (kx=0.20) at KM: 399+960

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 6.8 cm and 6.6 cm, respectively. Total displacements under seismic effect of kx= 0.20, are raised to 7.0 cm for left tube and 7.1 cm for the right tube. These results are acceptable and it can be stated that C2 category support systems for the section of the tunnel is verified by numerical analyses.

According to the strain values obtained from the analysis, they never exceed %1 limiting values (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel. Steel rib application is shown in Figure 7.29.

Figure 7. 29 Steel sets installation at Belkahve Tunnel

The entrance section of the tunnel at KM: 400+200 was modeled by Phase 2 software. Modeling of the tunnel tubes was performed in 14 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions

Stage 2: upper part of right tube has been softened

Stage 3: upper part of right tube excavation and supporting has been completed

Stage 4: lower part of right tube has been softened

Stage 5: lower part of right tube excavation and supporting has been completed

Stage 6: invert excavation of right tube has been softened

Stage 7: invert part of right tube excavation and supporting has been completed

Stage 8: upper part of left tube has been softened

Stage 9: upper part of left tube excavation and supporting has been completed

Stage 10: lower part of left tube has been softened

Stage 11: lower part of left tube excavation and supporting has been completed

Stage 12: invert excavation of left tube has been softened

Stage 13: invert part of left tube excavation and supporting has been completed

Stage 14: seismic load has been applied to the model

The supports used in modeling are presented in Table 7.9.

Table 7. 9 Support used in the modeling

Bolt spacing	1.5 m*1.5 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	15 cm
Young's modulus of shotcrete	15 000 MPa

For both static and seismic conditions, total displacements were checked around the both right and left tubes. According to results obtained, there were no yielded liners. Nevertheless, some of the bolt elements were yielded. The results of the analyses are presented in Figures 7.30-7.32.

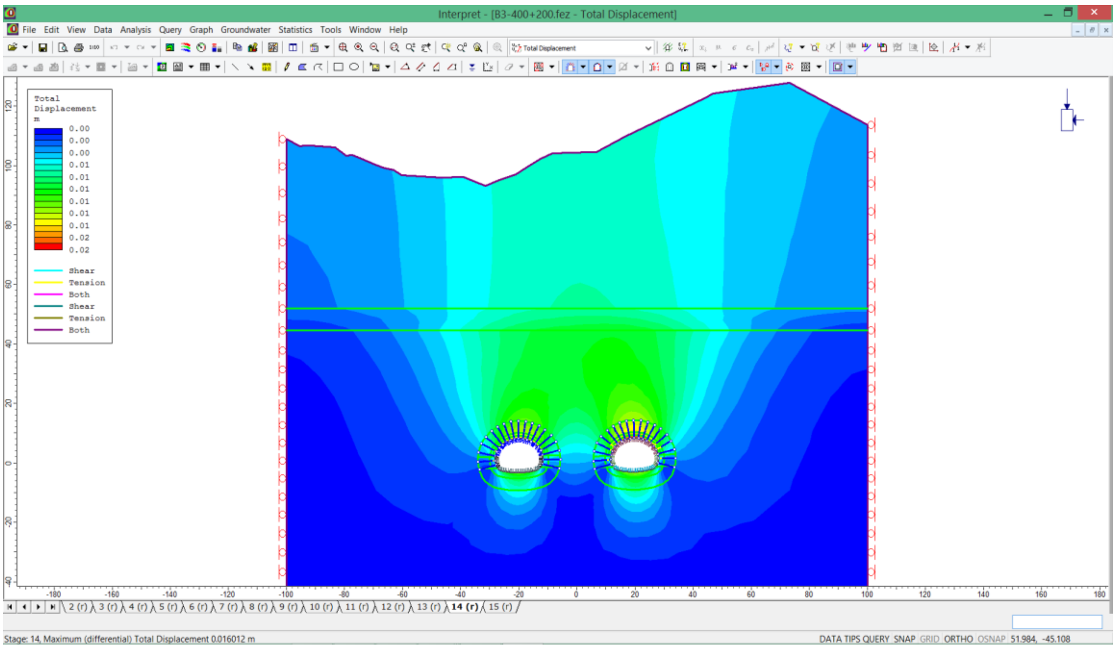

Figure 7. 30 Total displacements around tunnel section at KM:400+200

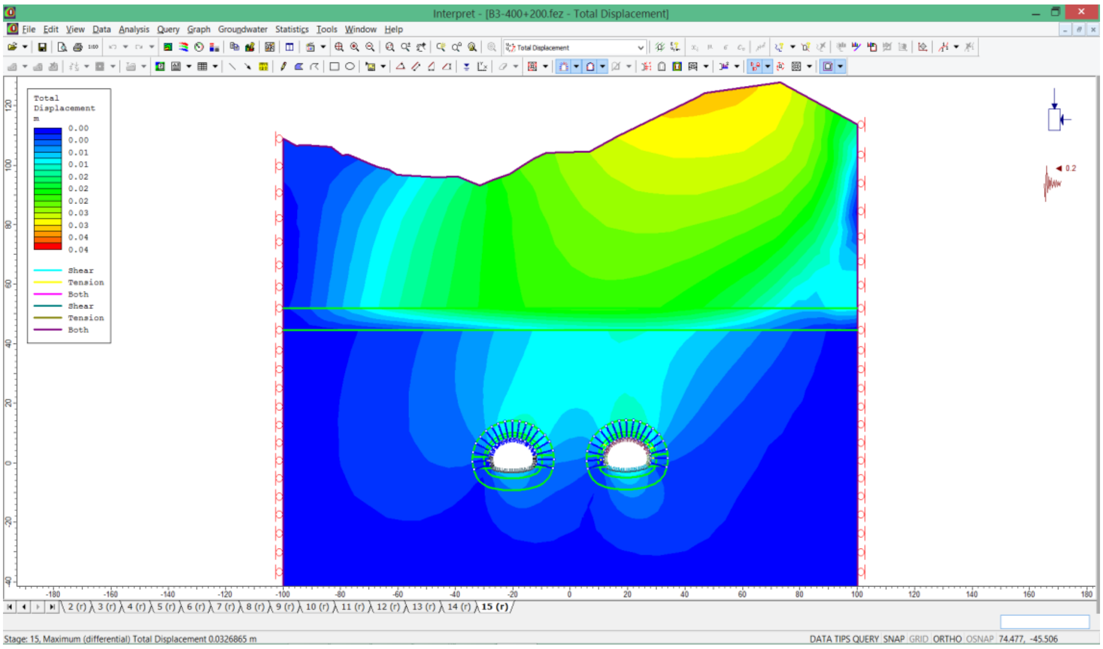

Figure 7. 31 Total displacement around tunnel section under seismic effect (kx=0.20) at KM:400+200

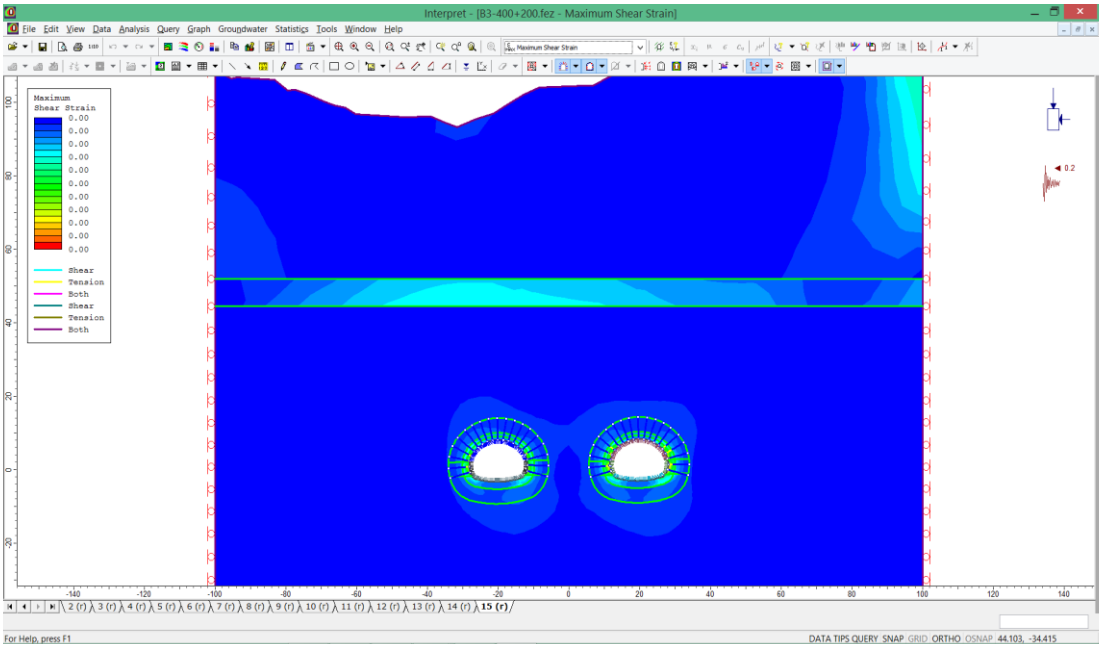

Figure 7. 32 Maximum shear strain around tunnel under seismic condition (kx=0.20) at KM:400+200

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 1.1 cm and 2.1 cm, respectively. Under seismic effect of kx= 0.20, for left tube total displacement is raised to 2.0 cm and for the right tube it is raised to 2.1 cm. These results are acceptable and it can be said that B3 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from Phase 2 software, they never exceed %1 limiting values (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel.

The entrance section of the tunnel at KM: 400+240 is modeled by Phase 2 software. Modeling of tunnel tubes is performed in 10 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: upper part of left tube has been softened
Stage 7: upper part of left tube excavation and supporting has been completed
Stage 8: lower part of left tube has been softened
Stage 9: lower part of left tube excavation and supporting has been completed
Stage 10: seismic load has been applied to the model

The supports used in modeling are presented in Table 7.10.

Table 7. 10 Support used in the modeling

Bolt spacing	2 m*2 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	10 cm
Young's modulus of shotcrete	15 000 MPa

For both static and seismic conditions, total displacements were checked around the both right and left tubes. According to results obtained, there were no yielded liners. However, some of the bolt elements were yielded. The results of the analyses are presented in Figures 7.33 – 7.35.

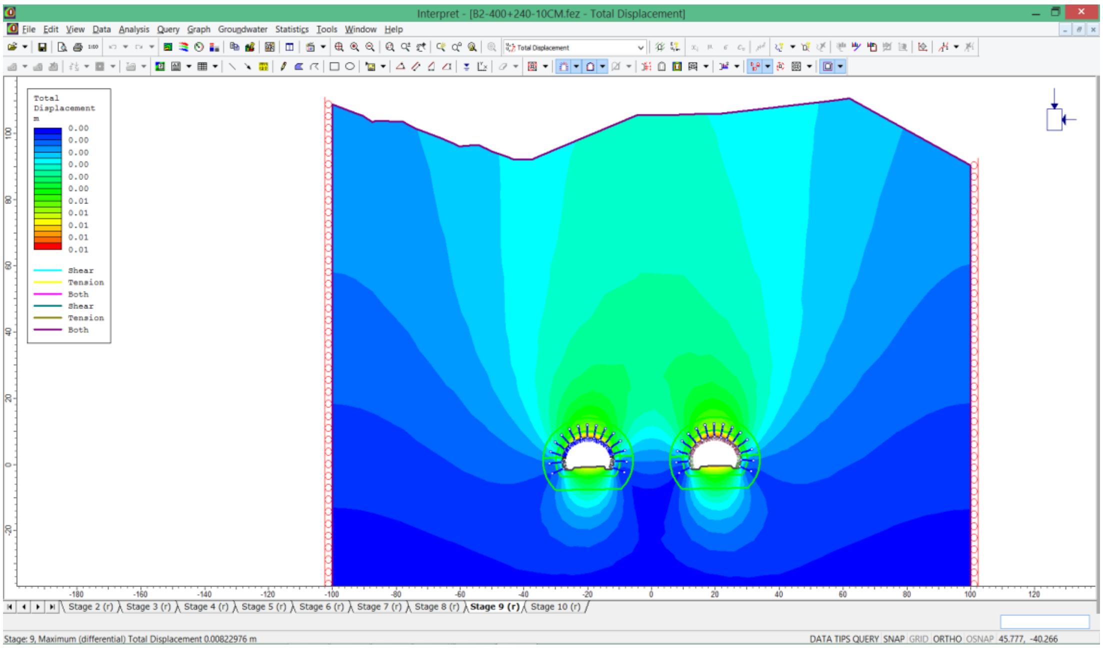

Figure 7. 33 Total displacements around the tunnel section at KM:400+240

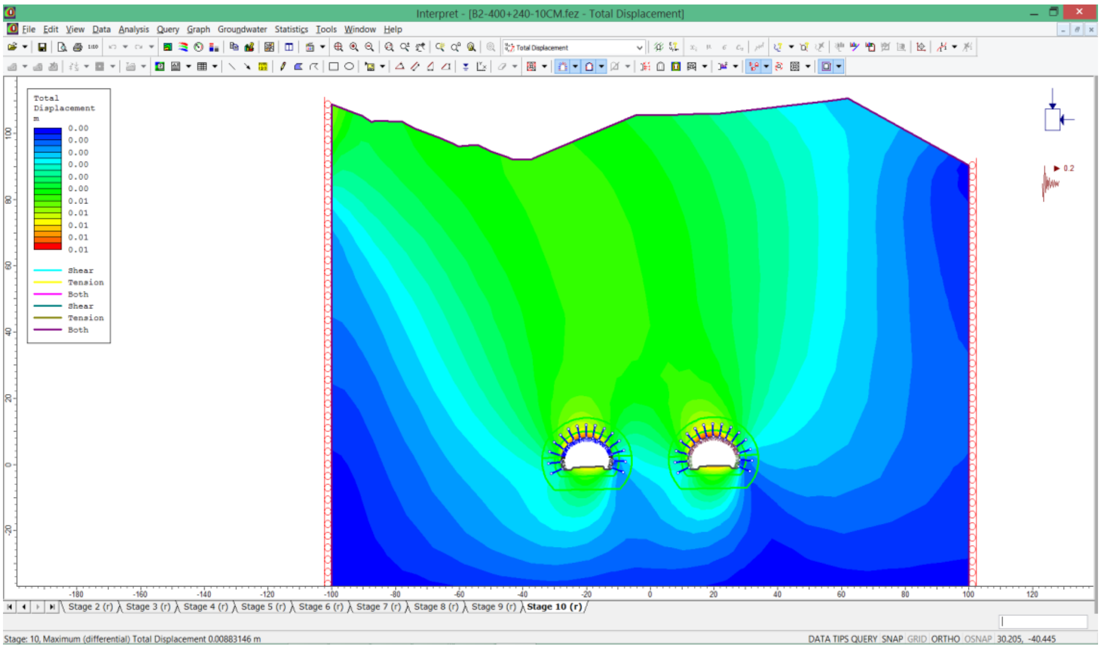

Figure 7. 34 Total displacement around the tunnel section under seismic effect (kx=0.20) at KM:400+240

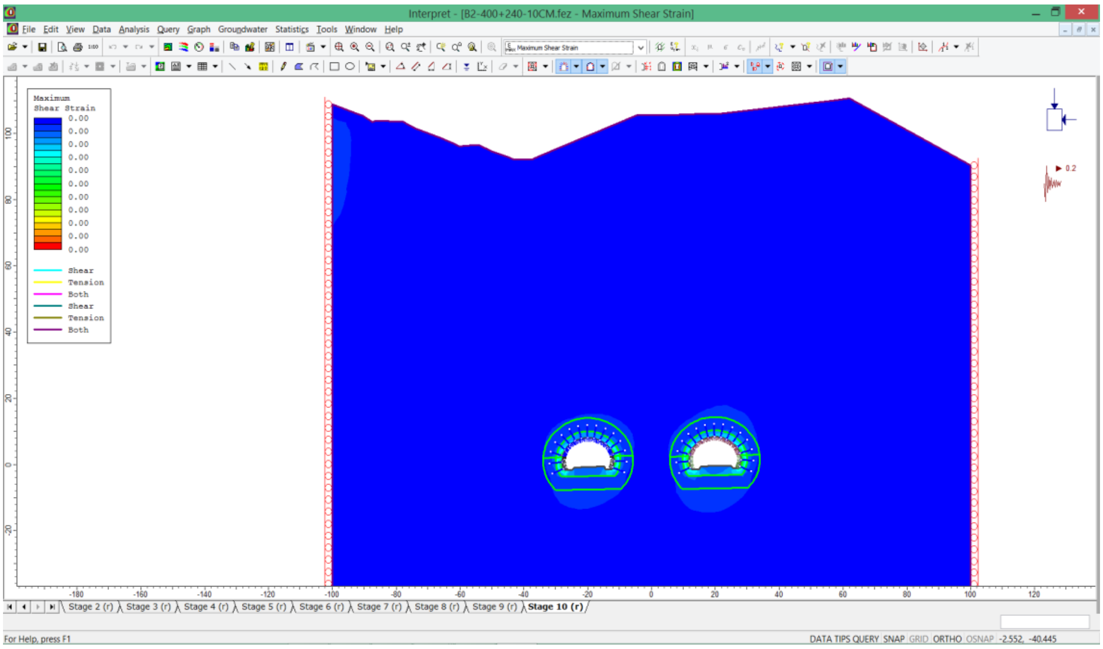

Figure 7. 35 Maximum shear strain around the tunnel under seismic condition (kx=0.20) at KM:400+240

Without effect of seismicity, total displacements at the peak point of the left and right tube are 1.1 cm and 1.1 cm, respectively. Under seismic effect of kx= 0.20, for left tube total displacement is raised to 1.2 cm and for the right tube the total displacement is raised to 1.3 cm. These results are acceptable and it can be said that B2 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from Phase 2 software, they never exceed %1 limiting value so (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel.

The entrance section of the tunnel at KM: 400+500 was modeled by Phase 2 software. Modeling of the tunnel tubes was performed in 14 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

The supports used in modelling are presented in Table 7.11.

Table 7. 11 Support used in the modeling

Bolt spacing	0.75m*0.75m
Bolt length	6 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	40 cm
Young's modulus of shotcrete	15 000 MPa

For both static and seismic conditions, total displacements were checked around the both right and left tubes. According to results obtained, there were no yielded liners. Nevertheless, some of the bolt elements were yielded. The results of the analyses are presented in Figures 7.36-7.38.

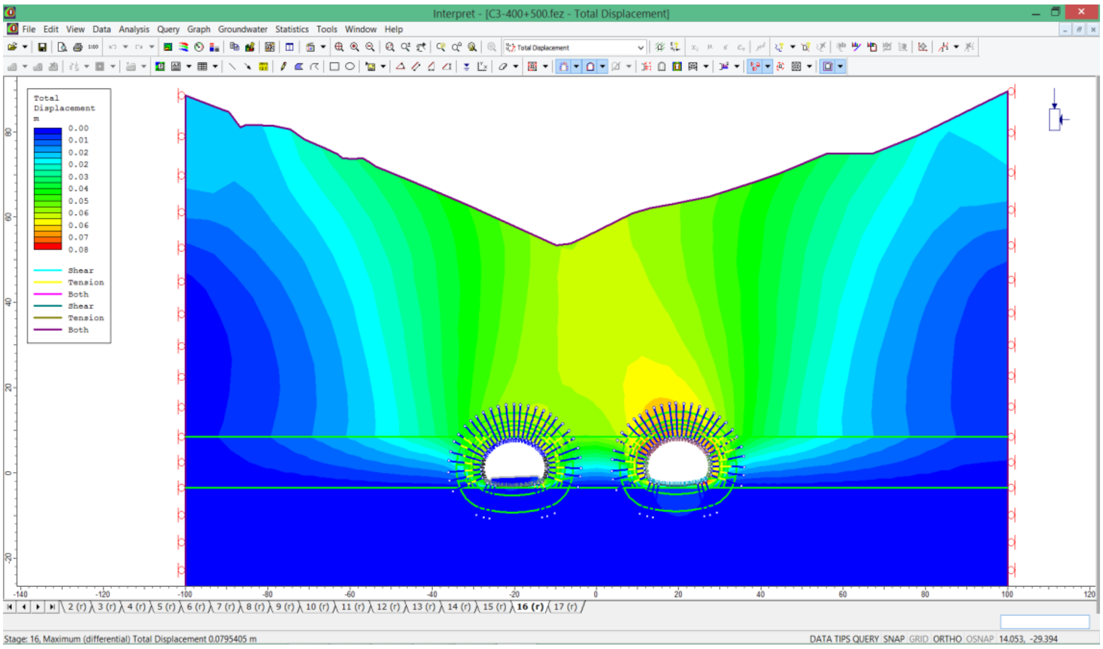

Figure 7. 36 Total displacements around the tunnel section at KM:400+500.

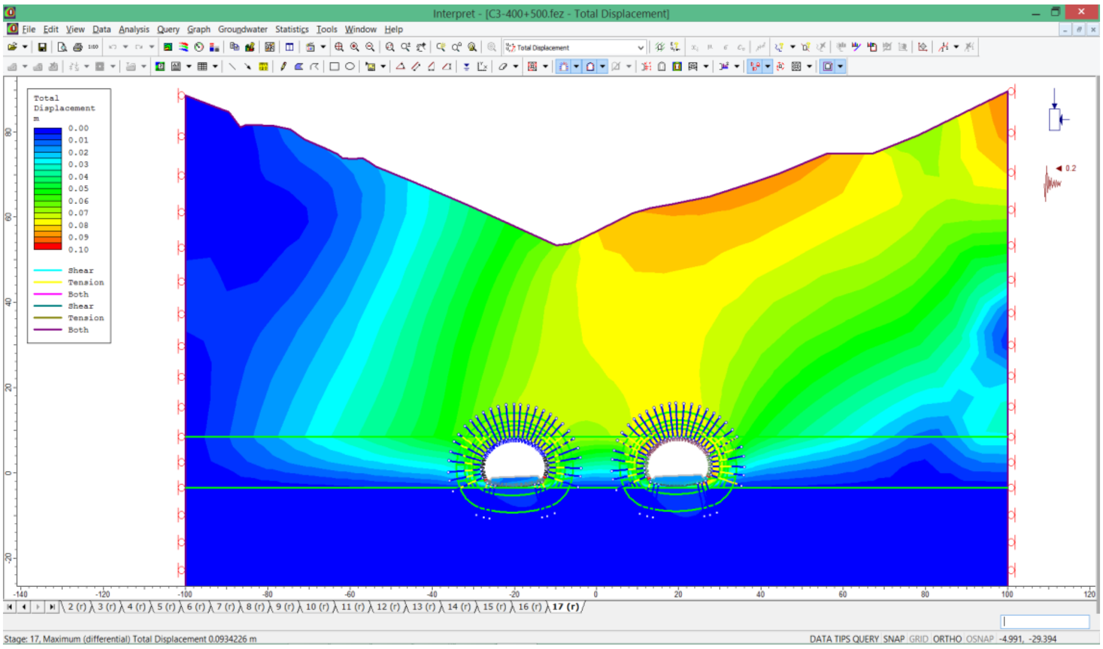

Figure 7. 37 Total displacement around tunnel section under seismic effect (kx=0.20) at KM:400+500

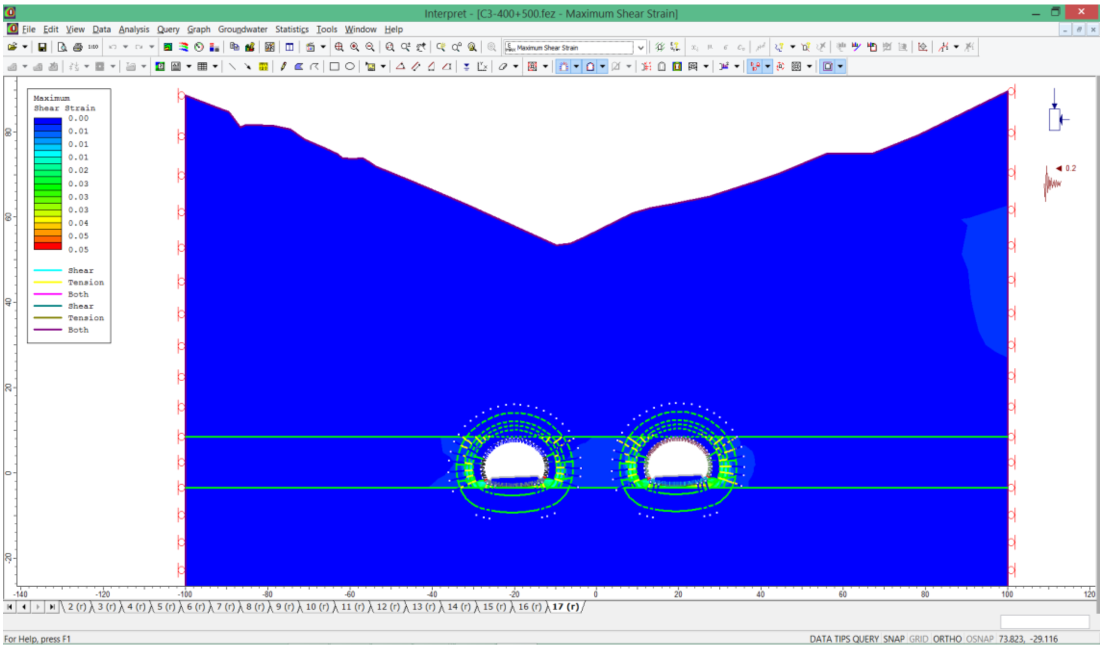

Figure 7. 38 Maximum shear strain around tunnel under seismic condition (kx=0.20) at KM:400+500

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 5.6 cm and 6.7 cm. Under seismic effect of kx= 0.20, for left tube total displacement is raised to 7.2 cm and for the right tube total displacement is raised to 7.8 cm. These results are acceptable and it can be said that C3 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from Phase 2 software, they never exceed %1 limiting value so (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel

The entrance section of the tunnel at KM: 400+550 was modeled by Phase 2 software. Modeling of the tunnel tubes was performed in 14 stages. These steps explained below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

The supports used in modelling are presented in Table 7.12.

Table 7. 12 Support used in the modeling of the tunnel at KM: 400+550

Bolt spacing	1 m*1 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	10 000 MPa

For both static and seismic conditions, total displacements were checked around the both right and left tubes. According to results obtained, there were no yielded liners. However, some of the bolt elements were yielded. The results of the analyses are presented in Figures 7.39-7.41.

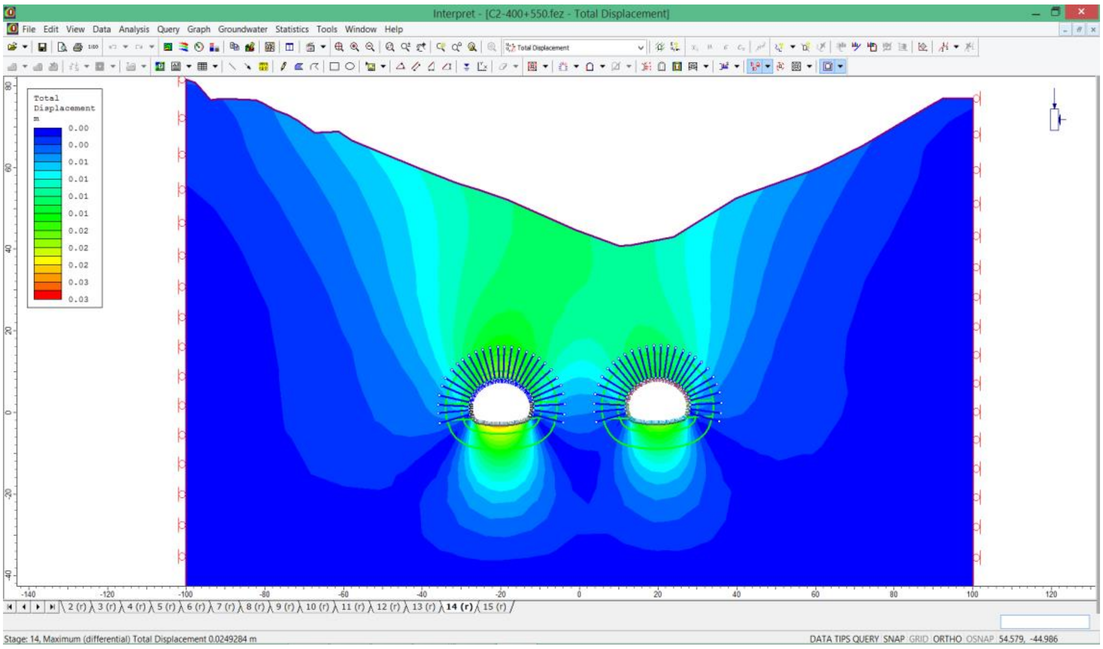

Figure 7. 39 Total displacements around the tunnel section at KM: 400+550

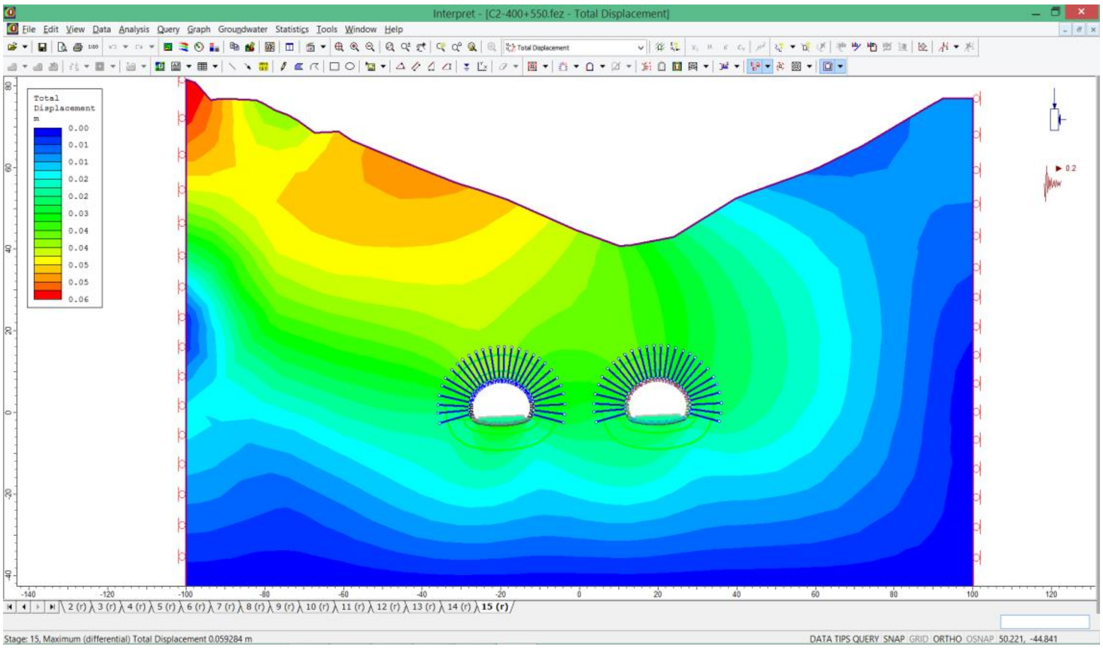

Figure 7. 40 Total displacement around the tunnel section under seismic effect (kx=0.20) at KM: 400+550

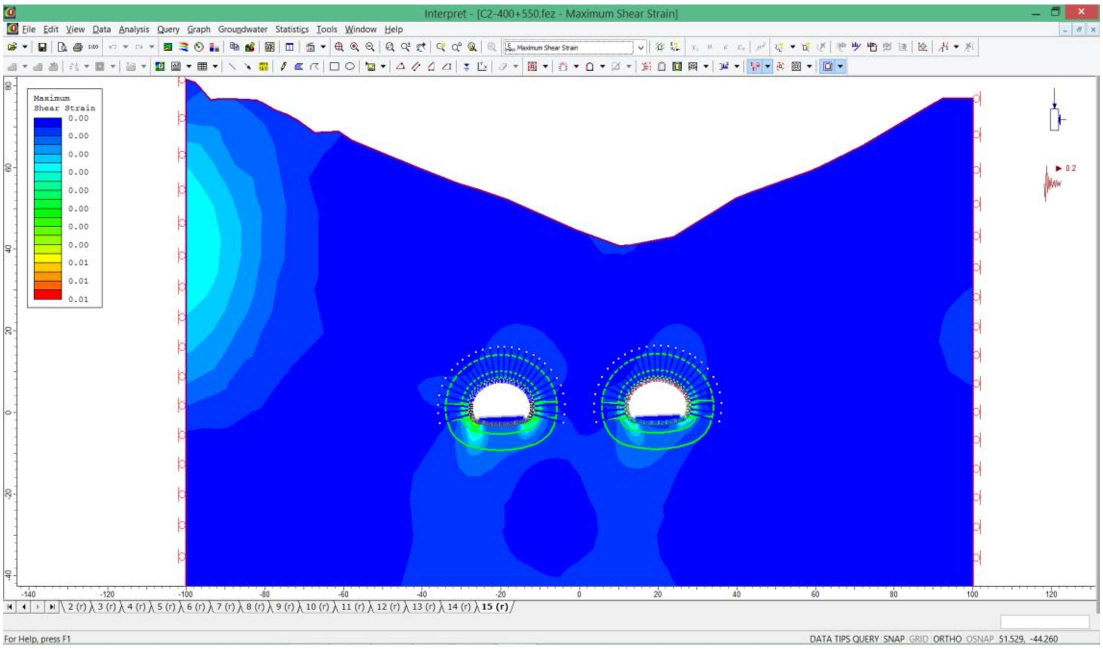

Figure 7. 41 Maximum shear strain around the tunnel under seismic condition (kx=0.20) at KM: 400+550

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 2.8 cm and 1.6 cm, respectively. Under seismic effect of kx= 0.20, for left tube total displacement is raised to 4.1 cm and for the right tube total displacement is raised to 3.5 cm. These results are acceptable and it can be stated that C2 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from Phase 2 software, they never exceed %1 limiting value so (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel.

The entrance section of the tunnel at KM: 400+820 was modeled by Phase 2 software. Modeling of the tunnel tubes was performed in 14 stages. These steps given below:

Stage 1: inspection of in situ stress distributions
Stage 2: upper part of right tube has been softened
Stage 3: upper part of right tube excavation and supporting has been completed
Stage 4: lower part of right tube has been softened
Stage 5: lower part of right tube excavation and supporting has been completed
Stage 6: invert excavation of right tube has been softened
Stage 7: invert part of right tube excavation and supporting has been completed
Stage 8: upper part of left tube has been softened
Stage 9: upper part of left tube excavation and supporting has been completed
Stage 10: lower part of left tube has been softened
Stage 11: lower part of left tube excavation and supporting has been completed
Stage 12: invert excavation of left tube has been softened
Stage 13: invert part of left tube excavation and supporting has been completed
Stage 14: seismic load has been applied to the model

The supports used in modelling are presented in Table 7.13. below.

Table 7. 13 Support used in the modeling of the tunnel at KM:400+820

Bolt spacing	1 m*1 m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	10 000 MPa

For both static and seismic conditions, total displacements were checked around the both right and left tubes. According to results obtained, there were no yielded liners, but some of the bolt elements were yielded. The results of the analyses are presented in Figures 7.42 -7.44.

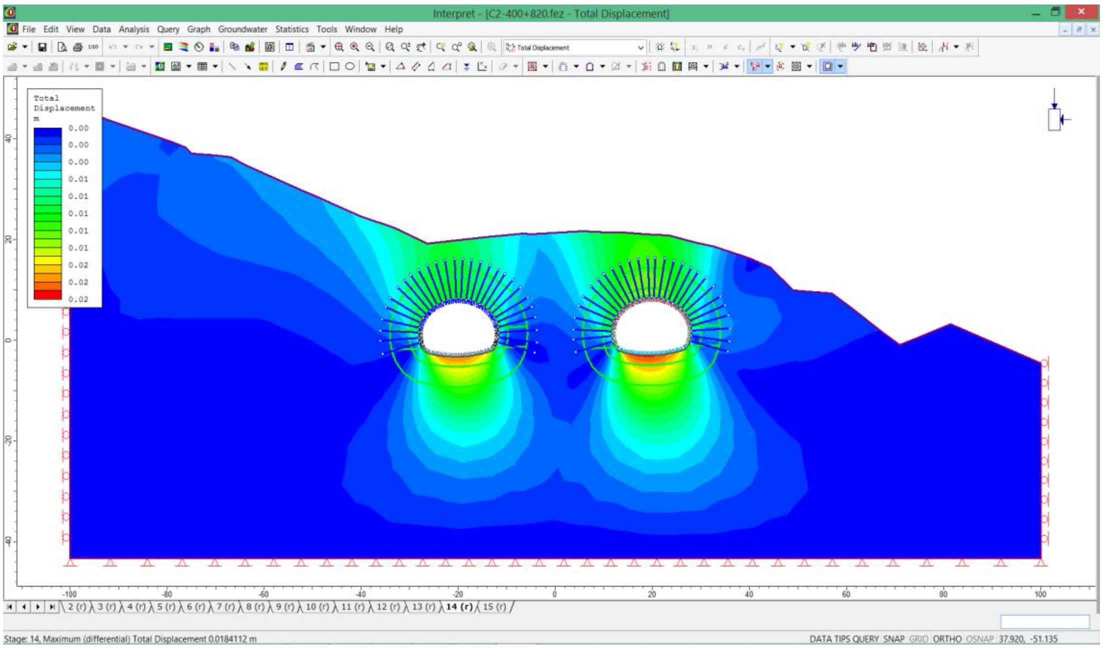

Figure 7. 42 Total displacements around the tunnel section at KM: 400+820

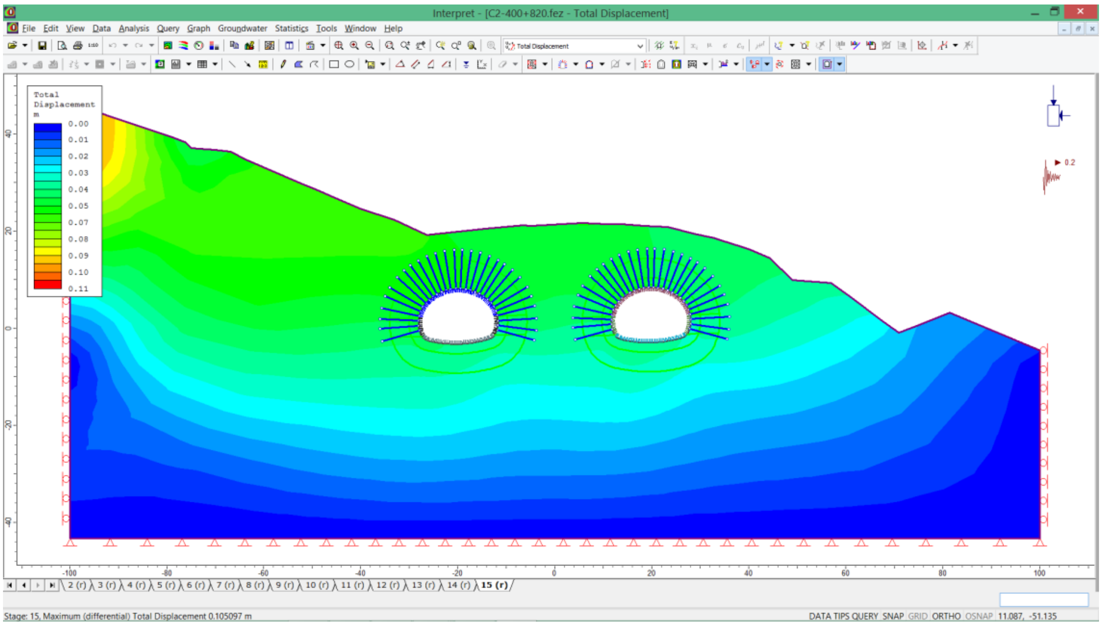

Figure 7. 43 Total displacement around the tunnel section under seismic effect (kx=0.20) at KM: 400+820

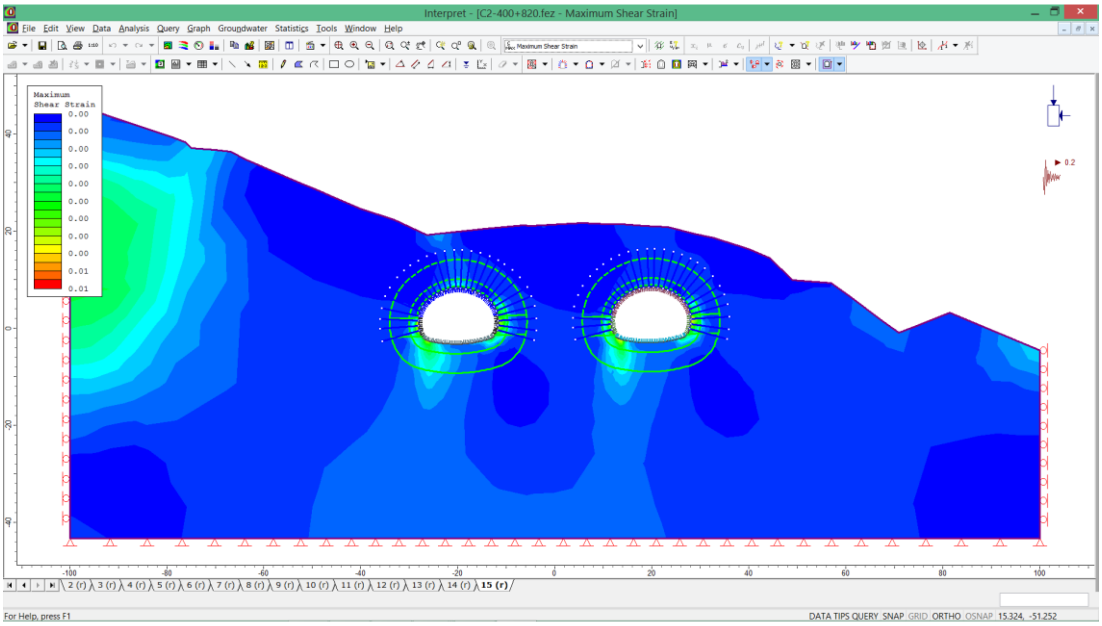

Figure 7. 44 Maximum shear strain around the tunnel under seismic condition (kx=0.20) at KM: 400+820

Without effect of seismicity, total displacements at the peak point of the left and right tubes are 1.1 cm and 1.3 cm, respectively. Under seismic effect of kx= 0.20, for left tube total displacement is raised to 5.5 cm and for the right tube total displacement is raised to 4.9 cm. These results are acceptable and it can be stated that C2 category support systems for the section of the tunnel is verified by numerical analyses. According to the strain values obtained from Phase 2 software, they don't exceed %1 limiting values (Hoek, 2001). Therefore, no problem related to tunnel deformation is expected for this section of the tunnel.

7.5 Slope Stability Analysis for Exit Portal

At this part, highest cut before entrance of the tunnel was modeled and stability analyses were performed. In practice excavation is performed from natural topography to first float as very first step. As soon as first cut completed, the support elements installation (shotcrete, rock bolts) should be completed. The excavation of the cut will be completed right after reaching to the road grade. According to the Technical Specifications of General Directorate of Highways (2006), the sufficient safety factors under static and dynamic conditions are 1.5 and 1.15, respectively.

To analyze the stability of highest cut, the model was prepared in five steps. The slope of side was 3H:2V and forehead was 1H:3V (H: horizontal, V: vertical). In the first step, the natural condition of the surface was modeled. In the following steps, the cut and support applications were done. Seismic load was applied to the system as final step.

For forehead slope which is the slope of tunnel entrance at KM: 400+930, the model was prepared in three steps. As first step, the natural condition of the surface was modeled. In the following steps, the cut and support applications were done. Seismic load was applied to the system as final step. Table 7.14 shows the specifications of supports used in analyses.

Table 7. 14 Supports used in the modeling of the exit portal slope of the tunnel

Bolt spacing	2m*2m
Bolt length	4 m
Bolt diameter	32 mm
Bolt modulus	200 000
Tensile capacity	250 kN
Shotcrete thickness	20 cm
Young's modulus of shotcrete	15 000 MPa

For both static and dynamic (under seismic load) conditions, slope stability analyses were performed. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side. The results of analyses performed are shown in Figures 7.45 and 7.46.

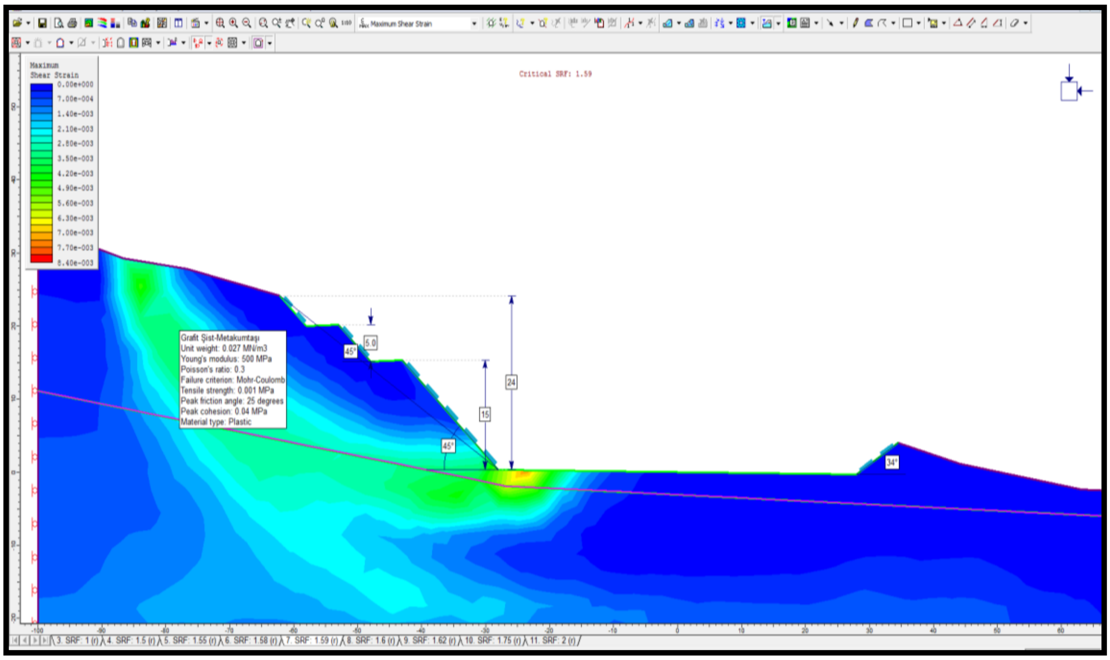

Figure 7. 45 Slope stability analysis of the exit portal side slope showing maximum shear strain under the static condition (3H/2V) (SF: 1. 59)

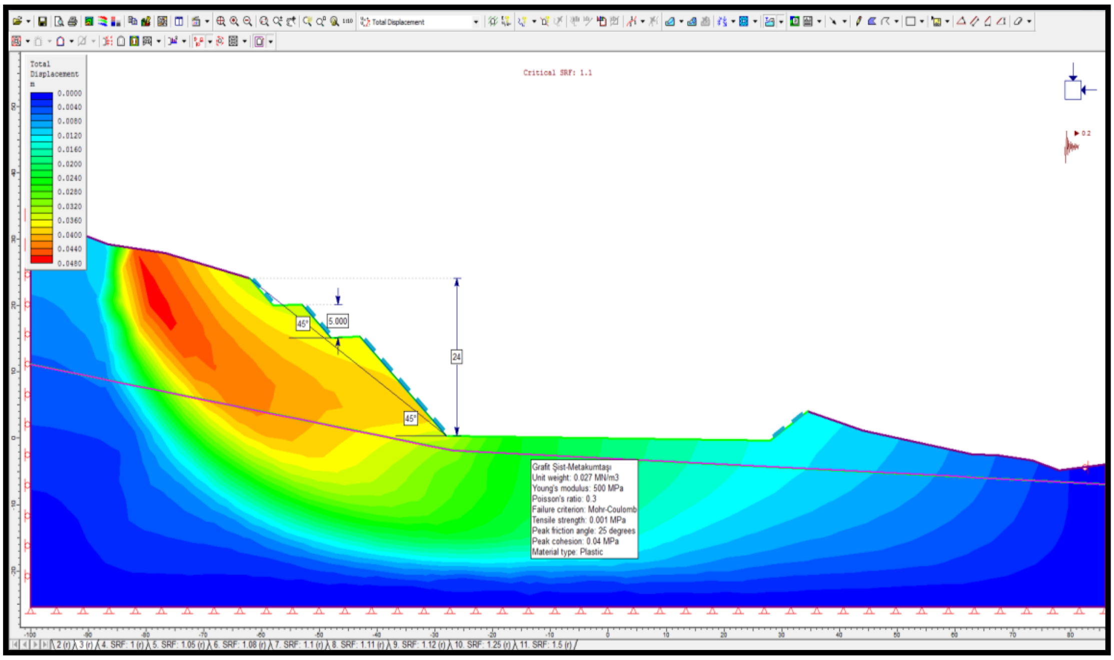

Figure 7. 46 Slope stability analysis of the exit portal side slope showing maximum shear strain under the effect of seismic load of kx=0.20 (3H/2V) (SF: 1.34)

When the cut is completed Total displacement is 3 cm under static condition. Value of 1.59 obtained at this stage for the safety factor. However, total displacement is increased to 4,2 cm after seismic load applied to the model (kx=0.20). At this stage, there are no yielded liners. Value of 1.37 obtained at this stage for the safety factor. According to the Technical Specifications of GDH (2006), the values are sufficient for the slope stability.

Figure 7. 47 Wire mesh and shotcrete installation for the side slope of the exit portal

For both static and dynamic (under seismic load) conditions, slope stability analyses were performed. Because of the negative effect of groundwater on the strength of the rock mass, analyses were performed with effect of groundwater, thus it is aimed to stay in the safe side. The results of analyses performed are shown in Figures 7.48 and 7.49.

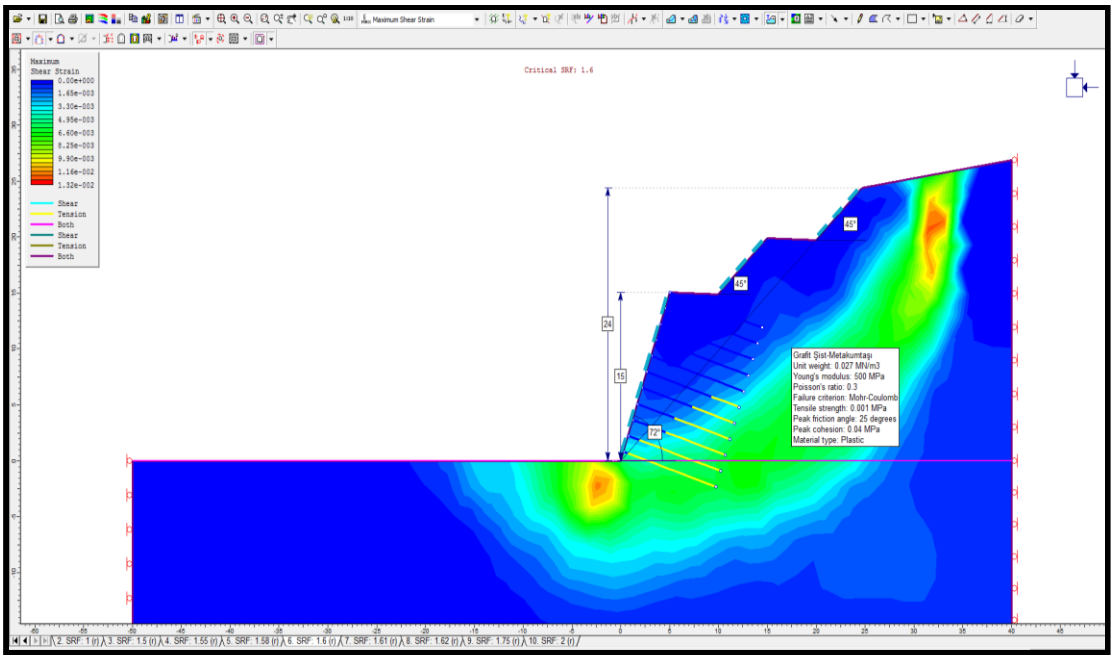

Figure 7. 48 Slope stability analysis for the forehead slopes of the exit portal showing maximum shear strain under static condition (1H/3V) (SF: 1.71)

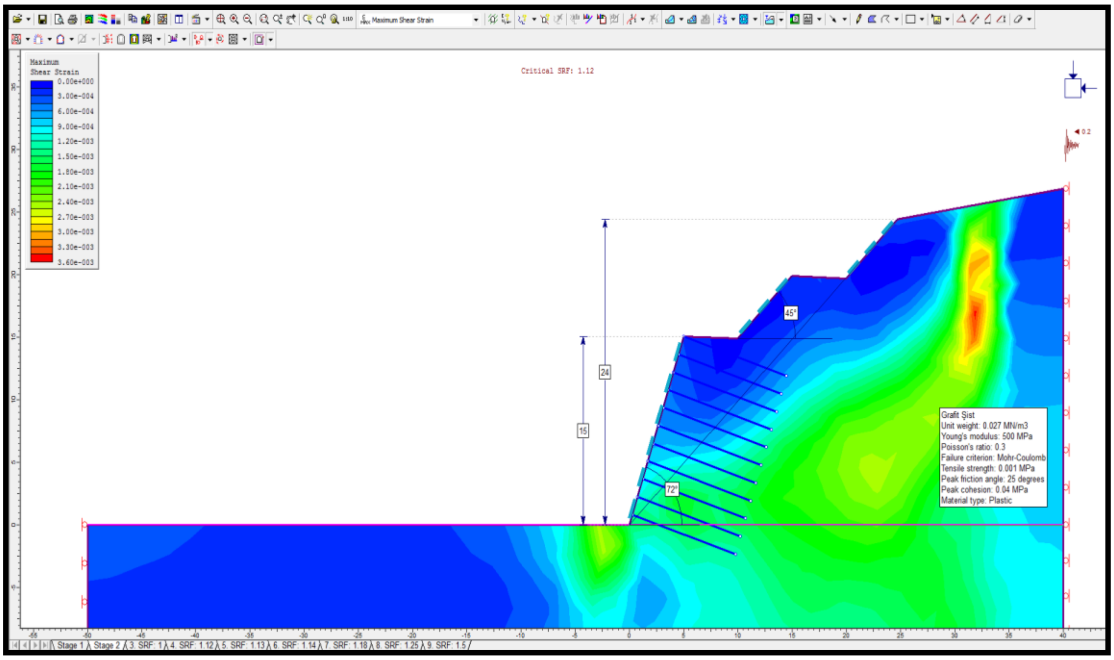

Figure 7. 49 Slope stability analysis of for the forehead slopes of the exit portal showing maximum shear strain under the effect of seismic load of kx=0.20 (1H/3V) (SF: 1.21)

When the cut is completed Total displacement is 3,4 cm under static condition. Value of 1.71 obtained at this stage for the safety factor. However, total displacement is increased to 4,5 cm after seismic load applied to the model (kx=0.20). At this stage, there are no yielded liners. Value of 1.21 obtained at this stage for the safety factor. According to the Technical Specifications of GDH (2006), the values are sufficient for the slope stability.

To sum up, the results obtained from the slope stability analyses performed with numerical analyses show that the slope is on the safe side according to Technical Specifications of GDH (2006). Figure 7.51 and 7.52 show safe slopes at the construction site.

Figure 7. 50 A general view of the forehead slopes after all suggested supports are installed

Figure 7. 51 Part of the forehead slope after the supports are installed

7.6 Sensitivity Analyses at Tunnel Section Km:399+700

Sensitivity analysis is a technique used to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions. This technique is used within specific boundaries that will depend on one or more input variables.

For this study, it is important to understand the relationship between numerical analyses input parameters (C, ø , E_{rm}, GSI, Seismic load coefficient) and deformations obtained from the numerical analyses (total displacements). Main goal for performing sensitivity analyses is testing the robustness of the results of a model or system in the presence of uncertainty.

For the five main input parameters mentioned above, the program was run by reducing the values systematically by 10%, and total vertical displacement value was attained at the peak point of tunnel section.

KM: 399+700 section was chosen for the sensitivity analyses in this thesis. The strength parameters of the rock mass for this section determined before (Chapter 6) is given below:

C = 223 kPa

Ø = 29°

E_{rm} = 2586 MPa

Firstly, the cohesion value of the rock mass was reduced by 10% each time starting from 223 kPa. In the meantime, other strength parameters were kept unchanged and total displacement in the tunnel was measured. Parameters used in the sensitivity analyses are given in Table 7.15, and cohesion-total displacement graph is presented in Figure 7. 52. Based on this figure, one can easily state that as the cohesion of the rock mass decreases, total displacement increases.

Table 7. 15 Parameters used in the sensitivity analyses with reduction in cohesion of the rock mass

Analyses no.	Cohesion (c) (kPa)	Reduction ratio	ø(˚)	Unit weight (kN/m^3)	E_{rm} (MPa)	GSI	Seismic load coefficient	Total Displacement (cm)
1	223,00	0%	29	27	2825	25	0,2	1,61
2	200,70	10%	29	27	2825	25	0,2	1,69
3	178,40	20%	29	27	2825	25	0,2	1,82
4	156,10	30%	29	27	2825	25	0,2	2,04
5	133,80	40%	29	27	2825	25	0,2	2,49
6	111,50	50%	29	27	2825	25	0,2	3,61
7	89,20	60%	29	27	2825	25	0,2	9,08

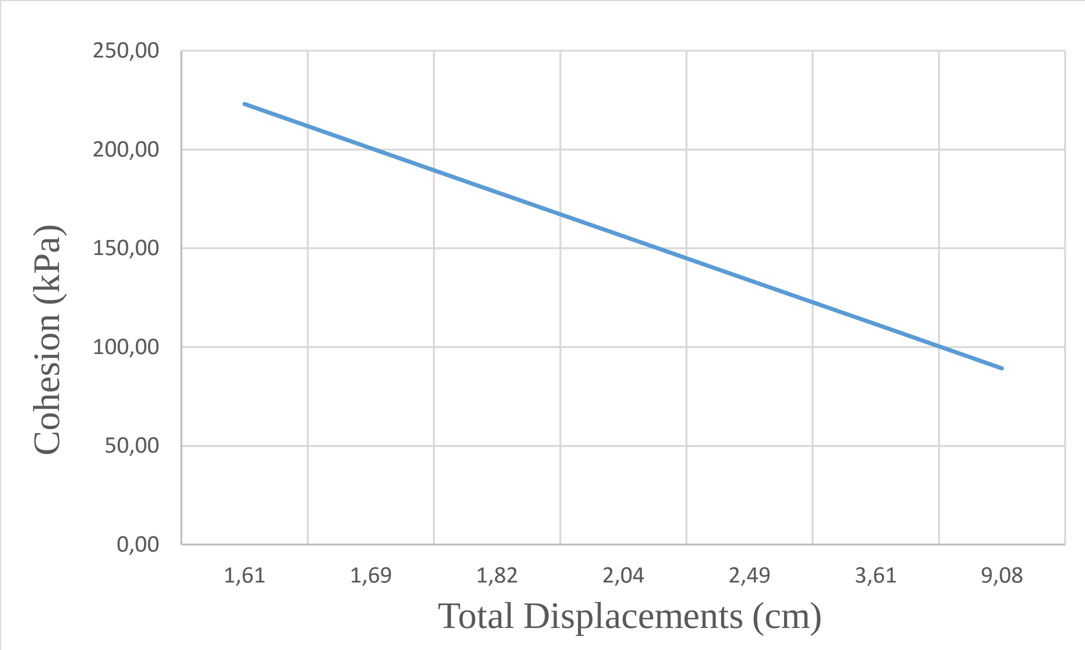

Figure 7. 52 Cohesion-total displacement graph for KM: 399+700

Secondly, the internal friction angle value of the rock mass was reduced by 10% each time starting from 29^{o}. In the meantime, other strength parameters were kept unchanged and total displacement was measured. Parameters used in the sensitivity analyses are given in Table 7.16, and internal friction angle-total displacement graph is presented in Figure 7. 53. Based on this figure, similar to cohesion case, as the internal friction angle of the rock mass decreases, total displacement increases.

Table 7. 16 Parameters used in the sensitivity analyses with reduction in internal friction angle of the rock mass

Analyses no.	ø(˚)	Reduction ratio	Cohesion (c) (kPa)	Unit weight (kN/m^3)	E_{rm} (MPa)	Total Displacement (cm)
1	29,00	0%	223	27	2825	1,61
2	26,10	10%	223	27	2825	1,71
3	23,20	20%	223	27	2825	2
4	20,30	30%	223	27	2825	2,4
5	17,40	40%	223	27	2825	3,45
6	14,50	50%	223	27	2825	5,7
7	11,60	60%	223	27	2825	35,94

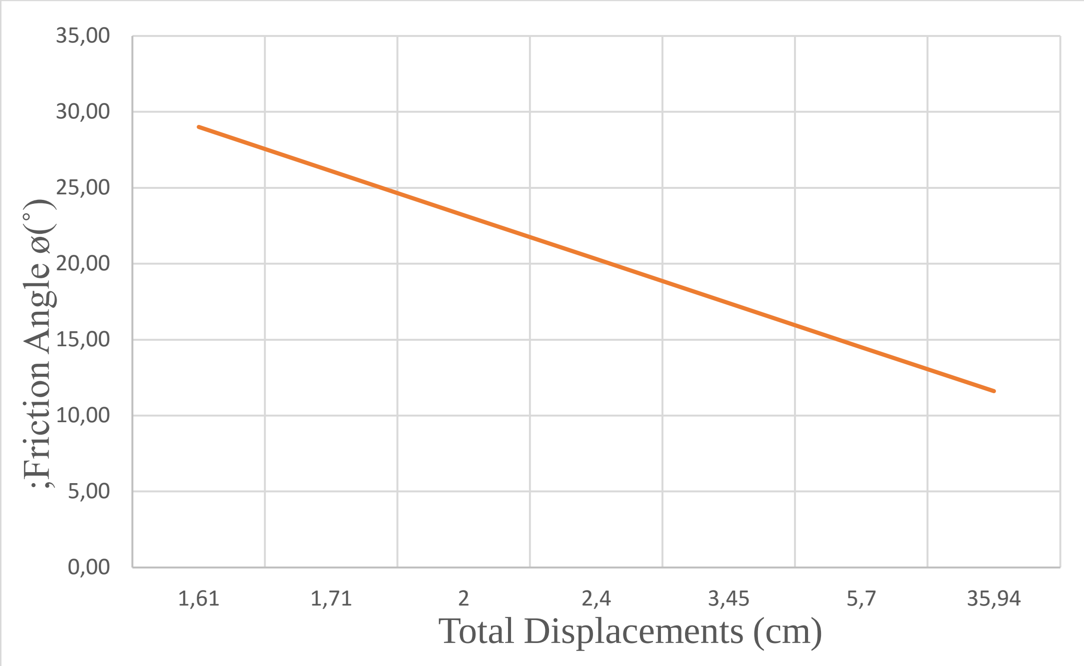

Figure 7. 53 Internal friction angle-total displacement graph for KM: 399+700

Thirdly, deformation modulus of rock mass value was reduced by 10% each time starting from 2586 MPa. In the meantime, other strength parameters were kept unchanged and total displacement was measured. Parameters used in the sensitivity analyses are given in Table 7.17, and deformation modulus-total displacement graph is presented in Figure 7. 54. Based on this figure, similar to cohesion and internal friction angle cases, as the deformation modulus of the rock mass decreases, total displacement increases.

Table 7. 17 Parameters used in the sensitivity analyses with reduction in deformation modulus of the rock mass

Analyses no.	E_{rm} (MPa)	Reduction ratio	ø(˚)	Unit weight (kN/m^3)	Cohesion (c) (kPa)	Total Displacement (cm)
1	2825,00	0%	29	27	223	1,61
2	2542,50	10%	29	27	223	1,63
3	2260,00	20%	29	27	223	1,83
4	1977,50	30%	29	27	223	2,1
5	1695,00	40%	29	27	223	2,4
6	1412,50	50%	29	27	223	2,93
7	1130,00	60%	29	27	223	3,66
8	847,50	70%	29	27	223	4,88
9	565,00	80%	29	27	223	7,32
10	282,50	90%	29	27	223	14,61

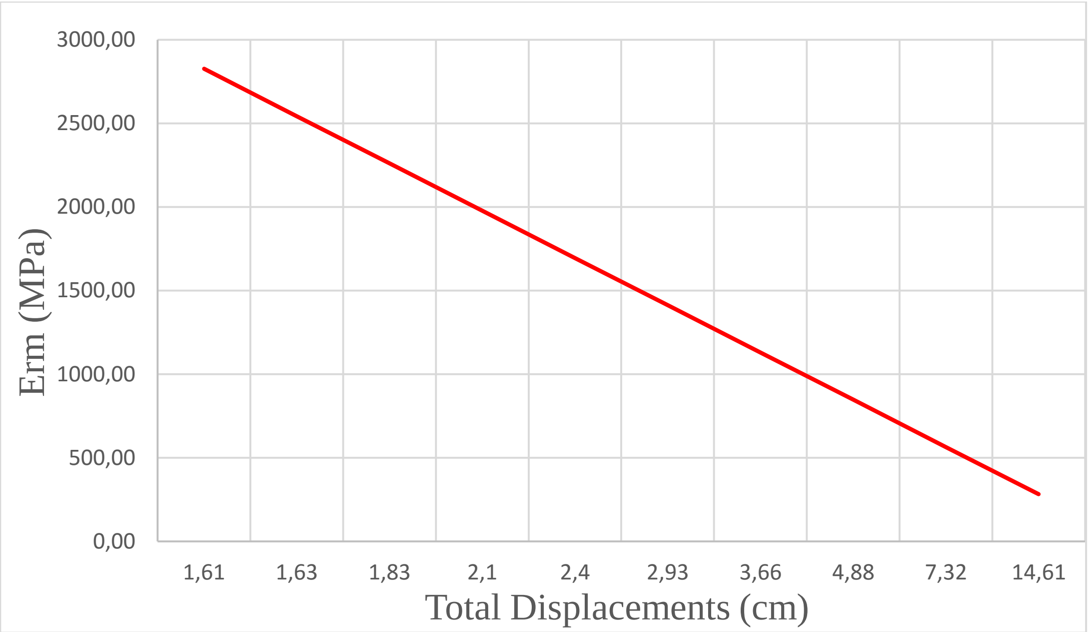

Figure 7. 54 Deformation modulus-total displacement graph for KM: 399+700

As the fourth step, GSI value of rock was reduced by 10% each time starting from 25 MPa. In the meantime, other strength parameters were kept unchanged and total displacement was measured. Parameters used in the sensitivity analyses are given in

Table 7.18, and GSI-total displacement graph is presented in Figure 7. 55. Similar to the other parameters, as the GSI of the rock mass decreases, total displacement increases.

Table 7. 18 Parameters used in the sensitivity analyses with reduction in GSI value of the rock mass

Analyses no:	**GSI**	**Reduction ratio**	**ø(˚)**	**Cohesion (c) (kPa)**	**E_{rm} (MPa)**	**Unit weight (kN/m^3)**	**Total Displacement (cm)**
1	28,00	0%	29,00	223	2825	27,00	1,61
2	25,20	10%	27,70	207	2825	27,00	1,66
3	22,40	20%	26,76	192	2825	27,00	1,72
4	19,60	30%	25,70	177	2825	27,00	2
5	16,80	40%	24,67	161	2825	27,00	2,53
6	14,00	50%	23,53	145	2825	27,00	3,79
7	11,20	60%	22,31	128	2825	27,00	8,8
8	8,40	70%	21,00	111	2825	27,00	93

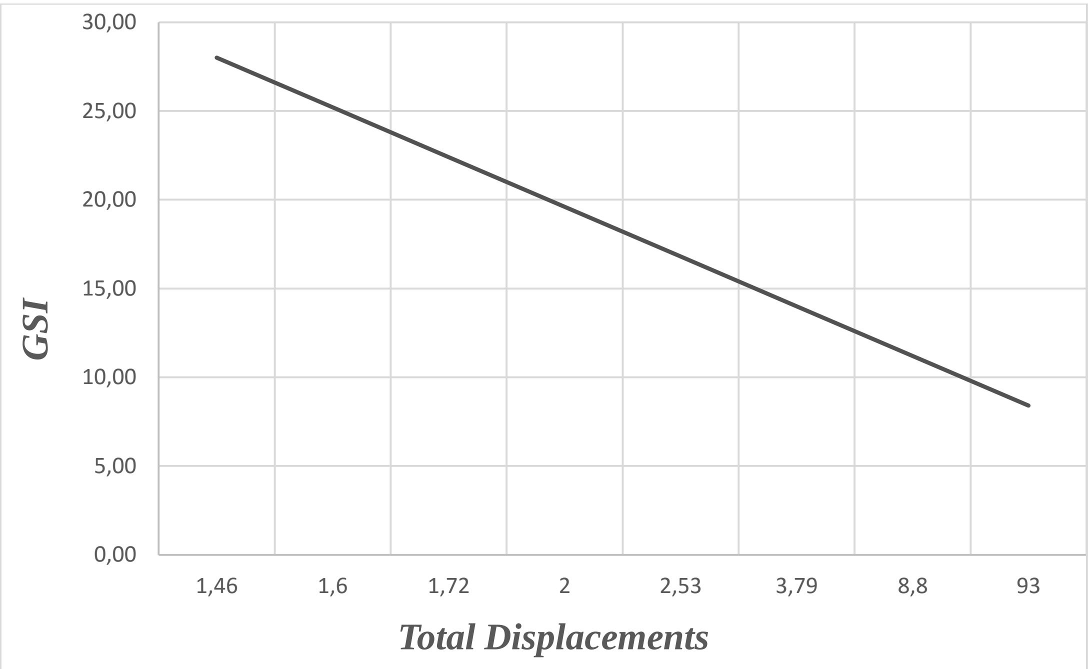

Figure 7. 55 GSI-total displacement graph for KM: 399+700

As the fourth step, seismic load coefficient value of system was increased by 10% each time starting from 0.2. In the meantime, other strength parameters were kept unchanged and total displacement in the tunnel was measured. Parameters used in the sensitivity analyses are given in Table 7.19, and seismic load coefficient-total displacement graph is presented in Figure 7. 56. It is observed that as the seismic coefficient increases, total displacement also increases.

Table 7. 19 Parameters used in the sensitivity analyses with reduction in seismic load coefficient of the rock mass

Analyses no:	Seismic Load Coefficient	Increase Ratio	ø(°)	Cohesion (c) (kPa)	E_{rm} (MPa)	GSI	Unit Weight (kN/m^3)	Total Displacement (cm)
1	0,20	0%	29	223	2825	25	27,00	1,61
2	0,22	10%	29	223	2825	25	27,00	1,73
3	0,24	20%	29	223	2825	25	27,00	2,01
4	0,26	30%	29	223	2825	25	27,00	2,1
5	0,28	40%	29	223	2825	25	27,00	2,25
6	0,30	50%	29	223	2825	25	27,00	2,36
7	0,32	60%	29	223	2825	25	27,00	2,54
8	0,34	70%	29	223	2825	25	27,00	2,65
9	0,36	80%	29	223	2825	25	27,00	2,77
10	0,38	90%	29	223	2825	25	27,00	2,84

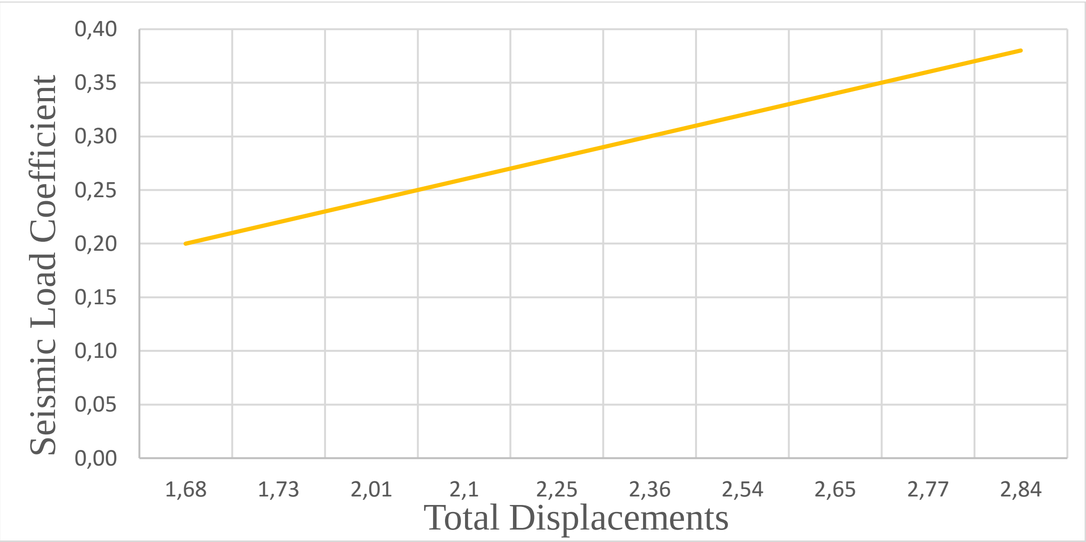

Figure 7. 56 Seismic load coefficient-total displacement graph for KM: 399+700

The sensitivity analyses at KM: 399+700 reveal that variation of the selected input parameters affects the deformation amount in the tunnel. Additionally, in case reduction ratio of the parameters is more than 60%, then the deformations in the tunnel exceed the acceptable strain limit (1%). At 60% reduction ratio, internal friction angle of the rock mass seems to be the most critical parameter affecting the total displacement. These are followed by cohesion and GSI. Nevertheless, increase in seismic load coefficient causes the least deformation change for the analysed section of the tunnel. All of these findings clearly indicate that correct assessment of rock mass parameters is of utmost importance for the support design of tunnel.

7.7 Comparison of the Results Obtained from Numerical Analyses with Field Observations

Since the Belkahve tunnel excavation is almost completed, it is a great opportunity to compare the results obtained from the numerical analyses with the measurements obtained from the field during the construction of the tunnel. However, most of the information couldn’t be reached due to the decision of General Directorate of Highways. So the information given below in Tables 7.20 and 7.21 is not totally enough to make a healthy interpretation but it gives a general idea about the performance of the analyses.

Table 7. 20 Measured Deformation values for right tube at the Belkahve tunnel

Right Tube				
intervals of Kilometers	***Vertical Displacement At Top Point***	***First Measurement Date***	***Last Measurement Date***	***Displacements Obtained via Numerical Analyses***
399,662	216 mm.	15.3.2015	3.11.2015	
399,674	195 mm.	22.3.2015	3.11.2015	
399,687	195 mm.	30.3.2015	3.11.2015	
399,700	110 mm.	6.4.2015	3.11.2015	63 mm.
399,713	116 mm.	14.4.2015	3.11.2015	
399,726	111 mm.	21.4.2105	3.11.2015	
399,738	103 mm.	28.4.2015	3.11.2015	
399,751	100 mm.	6.5.2015	3.11.2015	
399,852	39 mm.	6.7.2015	4.11.2015	
399,880	46 mm.	18.6.2015	4.11.2015	
399,960	39 mm.	31.3.2015	4.11.2015	70 mm.
400,006	59 mm.	21.3.2015	4.11.2015	

Table 7. 21 Measured Deformation values for left tube at the Belkahve tunnel

Left Tube				
intervals of Kilometers	***Vertical Displacement At Top Point***	***First Measurement Date***	***Last Measurement Date***	***Displacements Obtained via Numerical Analyses***
399,265	11 mm.	19.9.2015	8.11.2015	
399,365	54 mm.	11.10.2014	8.11.2015	
399,373	64 mm.	15.10.2014	8.11.2015	
399,382	89 mm.	21.10.2014	8.11.2015	
399,391	179 mm.	26.10.2014	8.11.2015	
399,401	156 mm.	2.11.2014	8.11.2015	
399,409	172 mm.	7.11.2014	8.11.2015	
399,419	161 mm.	12.11.2014	8.11.2015	
399,700	72 mm.	29.6.2015	3.11.2015	56 mm.
399,960	21 mm.	20.6.2015	3.11.2015	68 mm.
400,001	18 mm.	12.6.2015	3.11.2015	
400,015	27 mm.	29.5.2015	3.11.2015	
400,029	32 mm.	19.5.2015	3.11.2015	
400,071	32 mm.	23.4.2015	3.11.2015	
400,099	44 mm.	9.4.2015	3.11.2015	
400,127	20 mm.	27.3.2015	3.11.2015	

According to the measurement values obtained from the tunnel, which is vectorial and for only top point of the tunnel section, there are some differences in the deformation amount obtained from numerical analyses and field measurements, although the differences are quite small.

At KM: 399+700, the displacements obtained from numerical analyses for the left and right tubes are 5.6 cm and 6.3 cm, respectively. The displacement measured in the tunnel at KM: 399+700 for the right tube is 11 cm and for the left tube 7.2 cm.

At KM: 399+960, the displacements obtained from the numerical analyses for the left and right tubes are 6.8 cm and 7.0 cm, respectively. The displacements measured at this section of the tunnel for right tube is 3.9 cm and for the left tube 2.1 cm

When the results compared with the measurements done in the field during tunnel excavation, measurements obtained in the tunnel for KM:399+700 is higher than the results obtained from the numerical analyses. For KM:399+960 measurements obtained in the tunnel is less than the results obtained from the numerical analyses. It can be said that at some sections displacement values show some variations. These results can be interpreted in several different ways. At very firstly, the differences between the values obtained from numerical analyses and field measurements, can be attributed to the unpredicted weak or highly fractured zones. In general, such zones may generally be seen during tunneling. Since it is nearly impossible to explore all the geological and geotechnical specifications of tunnel route by drillings from surface, it is highly recommended to perform horizontal drilling (probing ahead) at the tunnel face, face mapping during the excavation, in-situ testing and further testing in order to update the geological and geotechnical model of the tunnel.

CHAPTER 8

DISCUSSIONS

Engineering judgment and field observations are very important for assignment of the strength parameters to rock masses. However, it has not been possible to explore all of the options available to design tunnel in weak rock. At this point, empirical approaches are the key for determining the geotechnical parameters of the rock mass. Moreover, numerical analyses are the most common way to verify assigned support systems. The parameters are valid only for the given intervals.

According to the deformations measured during the excavation of the tunnel, it seems that there exist differences between measured deformations and expected displacements obtained via numerical analyses. These could be attributed to the presence of weak zones observed during tunneling which cannot be predicted during site investigation. To avoid negative effect of the weak zones, horizontal borehole drilling (probing ahead), face mapping after each run during excavation, in-situ monitoring and further tests if needed should be performed.

It could be stated that the tunnel was overdesigned based on the numerical analyses. However, the field measurements show that determined support systems for the Belkahve tunnel work well even under higher stress than expected.

According to the field observations, schists of the Belkhave formation are defined as weak-very weak strength. Therefore, entrance and exit portals in the Belkahve should be properly supported in order to eliminate any tability problems. Moreover, due to high fractured structure of the Belkahve formation, low RQD values also prove that the stability problems due to groundwater may occur.

Although low lugeon values were obtained from the packer tests, chemicals used as drilling fluid might have sealed the boreholes. These may lead to extremely low values. For this reason, groundwater inflow into the tunnel especially in highly fractured and sheared zones is expected.

The sensitivity analyses at KM: 399+700 indicate that in case reduction ratio of the parameters is more than 60%, the deformations in the tunnel exceed the acceptable strain limit. Among the studied parameters, at 60% reduction ratio, internal friction angle of the rock mass is found to be the most critical parameter affecting the total displacement.

Braun (1930) stresses particularly in deep tunnels that timing of the rock support (bolts and shotcrete) installation is extremely important. It is, however, difficult to predict the time factor and its variations during tunneling even for the experienced tunnel engineer. In this respect, NATM recommends the use of tunnel support measures to avoid undesirable deformations of the surrounding rocks to occur. The optimal NATM involves also additional verification calculations carried out during the execution. Thus, geotechnical solutions should be taken into consideration such as checking and modifying the geology and rock mass classes during construction, preparing in-situ test and laboratory test program and mapping the face of the excavation systematically. This approach may eliminate problems related to the stability of the tunnel.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The Belkahve tunnel takes place in the Western Anatolian (Aegean) Horst and Graben Province which can be characterized by Cretaceous ophiolite and flysch rocks. According to the site investigation performed along the tunnel, the entrance section of the tunnel takes place in moderately weathered and moderately weak schist. The middle section of the tunnel is located in the strong limestone, and moderately weathered-moderately weak schist. In the tunnel exit section, moderately weathered and moderately weak schist crops out. According to the investigations carried out in the study area, there are some shear zones along the tunnel route.

Based on the statement of General Directorate of Disaster Affairs Earthquake, the tunnel area takes place in the 1st degree of earthquake zone of Turkey with a peak horizontal ground acceleration of 0.4g.

According to the field surveys, three joint sets and random joints (j1) 83/113, (j2) 80/338, (j3) 54/213 exist in the study area. However, at the exit part of the tunnel, only two joint sets and random joints are developed with the dip amount and dip directions of (j1) 89/115, (j2) 42/207.

In order to estimate the rock mass quality, NATM, RMR, and Q rock mass classification systems used. The entrance section of the tunnel between Km: 399+180 and Km: 399+400, according to RMR and Q classification systems, the rock mass is defined as “very poor rock” and according to NATM classified the rock mass is defined as C2. The middle section of the tunnel between Km: 399+400 and Km: 400+750 is divided into 6 parts. Between Km: 399+400 and Km: 399+700, the rock mass is defined as “poor rock” according to RMR and Q, and classified as B3 according to NATM. Between Km: 399+700 and Km: 400+080, according to RMR and Q classification systems, the rock mass is defined as “poor rock” and according to NATM classified the rock mass is defined as B3, between Km: 400+080 and Km: 400+150, defined as “very fractured and weak shearing zone” according to drillings and geological survey and classified as C3 according to NATM, Between Km: 400+150 and Km: 400+450, according to RMR and Q classification systems, the rock mass is defined as “fair rock” and according to NATM classified the rock mass is defined as B2., between Km: 400+450 and Km: 400+520, defined as “very fractured and weak shearing zone” according to drillings and geological survey and classified as C3 according to NATM, Between Km: 400+520 and Km: 400+750, according to RMR and Q classification systems, the rock mass is defined as “very poor rock” and according to NATM classified the rock mass is defined as B3, the exit section of the tunnel between Km: 400+750 and Km: 400+930, according to RMR and Q classification systems, the rock mass is defined as “poor rock” and according to NATM classified the rock mass is defined as C2.

Between Km: 399+180 and Km: 399+400, according to RMR and Q classification systems, the rock mass is defined as “very poor rock” and according to NATM classified the rock mass is defined as C2.

Since it is not possible to explore all the geological and geotechnical properties of the rock masses, along the tunnel route, its highly recommended to have systematic face mapping of the excavation. Moreover, horizontal drillings (probing ahead), monitoring, and in-situ or further laboratory tests should be performed in order to better understand the behavior of the geological units. Last but not least, great attention should be given to the stand-up time determined for different NATM rock classes during excavation in order to prevent stability problems, especially in weak zones.

The groundwater level is measured from boreholes. The rock masses are generally defined as impervious to slightly pervious according to the lugeon tests performed. However, it is expected that the use of chemicals as drilling fluid may alter the test results. Therefore, groundwater inflow problem is expected in shear and highly fractured zones. In order to prevent negative effect of groundwater, it is needed to create groundwater flow by making possible hydraulic head difference. In this thesis, all slopes are protected by shotcrete which may cause a problem for the groundwater inflow. Therefore, discharging the groundwater with perforated pvc surrounded by geotextiles can be considered to be a solution. However, groundwater shouldn’t have to travel long distance until reaching surface at lower elevations, otherwise the impervious layers (shotcrete) surrounding the groundwater, can be exposed to high pressure.

For both entrance and exit sections, slope stability analyses performed with Phase 2 with effect of groundwater. As a result, for both static and dynamic conditions indicated that the slopes are safe with factor of safety significantly higher than the accepted limiting values.

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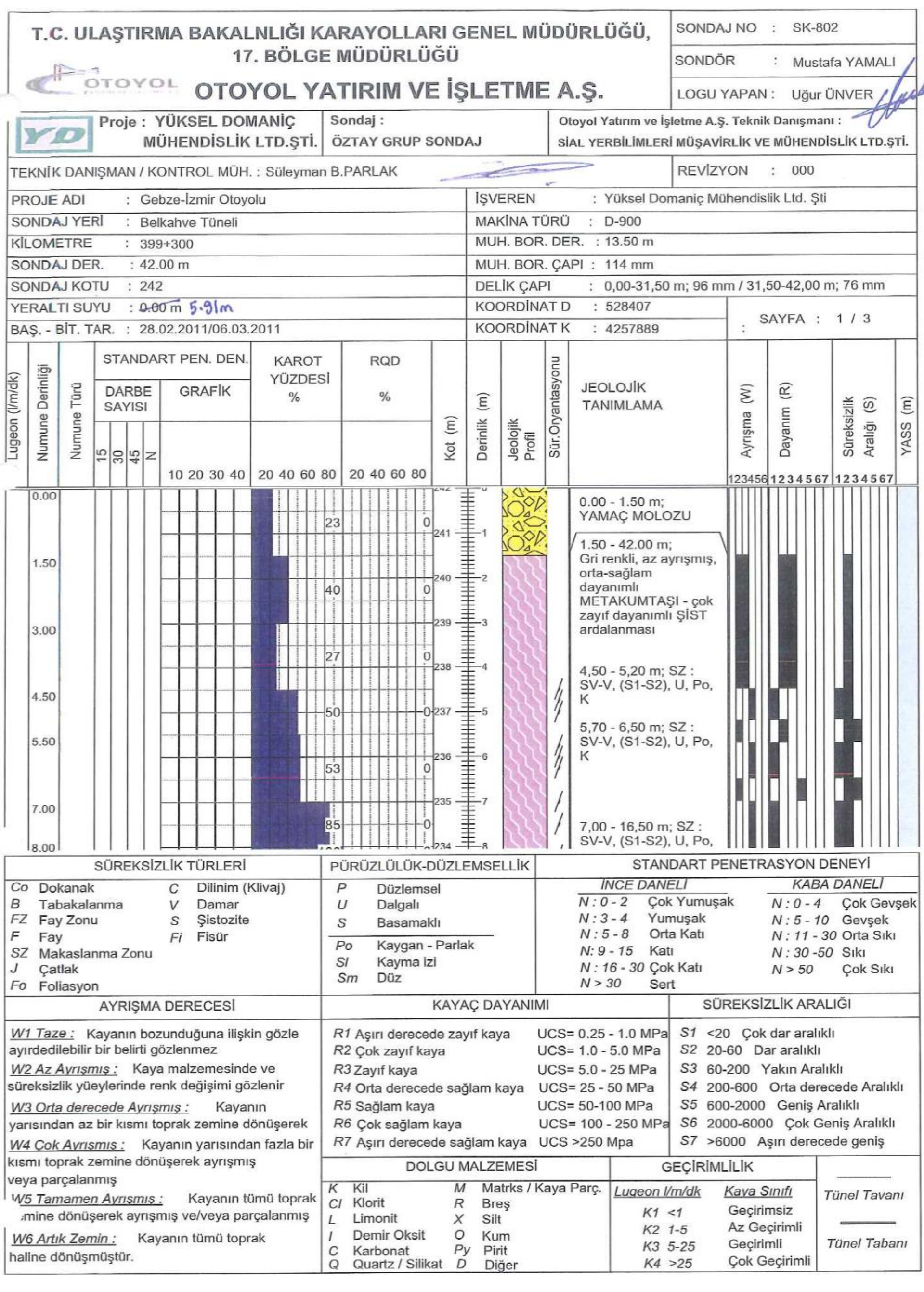
APPENDIX A:

BORING LOGS



T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO	: SK-802
SONDÖR	: Mustafa YAMALI
LOGU YAPAN	: Uğur ÜNVER

Proje : YÜKSEL DOMANİÇ MÜHENDİSLİK LTD.ŞTİ. | Sondaj : ÖZTAY GRUP SONDAJ | Otoyol Yatırım ve İşletme A.Ş. Teknik Danışmanı : SİAL YERBİLİMLERİ MÜŞAVİRLİK VE MÜHENDİSLİK LTD.ŞTİ.

TEKNİK DANIŞMAN / KONTROL MÜH. : Süleyman B.PARLAK — REVİZYON : 000

PROJE ADI	: Gebze-İzmir Otoyolu	İŞVEREN	: Yüksel Domaniç Mühendislik Ltd. Şti
SONDAJ YERİ	: Belkahve Tüneli	MAKİNA TÜRÜ	: D-900
KİLOMETRE	: 399+300	MUH. BOR. DER.	: 13.50 m
SONDAJ DER.	: 42.00 m	MUH. BOR. ÇAPI	: 114 mm
SONDAJ KOTU	: 242	DELİK ÇAPI	: 0,00-31,50 m; 96 mm / 31,50-42,00 m; 76 mm
YERALTI SUYU	: ~~0.00 m~~ 5.91m	KOORDİNAT D	: 528407
BAŞ. - BİT. TAR.	: 28.02.2011/06.03.2011	KOORDİNAT K	: 4257889

SAYFA : 1 / 3

SÜREKSİZLİK TÜRLERİ		PÜRÜZLÜLÜK-DÜZLEMSELLİK	STANDART PENETRASYON DENEYİ	
			İNCE DANELİ	KABA DANELİ
Co Dokanak	C Dilinim (Klivaj)	P Düzlemsel	N : 0 - 2 Çok Yumuşak	N : 0 - 4 Çok Gevşek
B Tabakalanma	V Damar	U Dalgalı	N : 3 - 4 Yumuşak	N : 5 - 10 Gevşek
FZ Fay Zonu	S Şistozite	S Basamaklı	N : 5 - 8 Orta Katı	N : 11 - 30 Orta Sıkı
F Fay	Fi Fisür	Po Kaygan - Parlak	N: 9 - 15 Katı	N : 30 -50 Sıkı
SZ Makaslanma Zonu		Sl Kayma izi	N : 16 - 30 Çok Katı	N > 50 Çok Sıkı
J Çatlak		Sm Düz	N > 30 Sert	
Fo Foliasyon				

AYRIŞMA DERECESİ

W1 Taze : Kayanın bozunduğuna ilişkin gözle ayırdedilebilir bir belirti gözlenmez

W2 Az Ayrışmış : Kaya malzemesinde ve süreksizlik yüeylerinde renk değişimi gözlenir

W3 Orta derecede Ayrışmış : Kayanın yarısından az bir kısmı toprak zemine dönüşerek

W4 Çok Ayrışmış : Kayanın yarısından fazla bir kısmı toprak zemine dönüşerek ayrışmış veya parçalanmış

W5 Tamamen Ayrışmış : Kayanın tümü toprak zemine dönüşerek ayrışmış ve/veya parçalanmış

W6 Artık Zemin : Kayanın tümü toprak haline dönüşmüştür.

KAYAÇ DAYANIMI		SÜREKSİZLİK ARALIĞI
R1 Aşırı derecede zayıf kaya	UCS= 0.25 - 1.0 MPa	S1 <20 Çok dar aralıklı
R2 Çok zayıf kaya	UCS= 1.0 - 5.0 MPa	S2 20-60 Dar aralıklı
R3 Zayıf kaya	UCS= 5.0 - 25 MPa	S3 60-200 Yakın Aralıklı
R4 Orta derecede sağlam kaya	UCS= 25 - 50 MPa	S4 200-600 Orta derecede Aralıklı
R5 Sağlam kaya	UCS= 50-100 MPa	S5 600-2000 Geniş Aralıklı
R6 Çok sağlam kaya	UCS= 100 - 250 MPa	S6 2000-6000 Çok Geniş Aralıklı
R7 Aşırı derecede sağlam kaya	UCS >250 Mpa	S7 >6000 Aşırı derecede geniş

DOLGU MALZEMESİ		GEÇİRİMLİLİK		
		Lugeon l/m/dk	Kaya Sınıfı	
K Kil	M Matrks / Kaya Parç.	K1 <1	Geçirimsiz	Tünel Tavanı
Cl Klorit	R Breş	K2 1-5	Az Geçirimli	Tünel Tabanı
L Limonit	X Silt	K3 5-25	Geçirimli	
I Demir Oksit	O Kum	K4 >25	Çok Geçirimli	
C Karbonat	Py Pirit			
Q Quartz / Silikat	D Diğer			

T.C. ULAŞTIRMA BAKANLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-802

LOGU YAPAN : Uğur ÜNVER

SAYFA : 2 / 3

Numune Derinliği	KAROT YÜZDESİ %	RQD %	JEOLOJİK TANIMLAMA
8.20	62	0	K
9.00	67	0	
10.50	30	0	
12.00	40	0	
13.00	40	0	
14.00	30	0	
15.00	35	0	
16.00	40	10	17,00 - 22,50 m; SZ : SV-V, (S1-S2), U, Po, K
17.00	35	0	
18.00	45	0	
19.00	35	10	
20.00	30	0	
21.00	20	0	
22.00	60	10	23,00 - 25,50 m; SZ : SV-V, (S1-S2), U, Po, K
23.00	35	0	
24.00	50	0	
25.00	35	10	26,00 - 31,50 m; SZ : SV-V, (S1-S2), U, Po, K
26.00	15	0	
27.00	20	0	
28.00	35	0	
29.00	40	0	
30.00			

Column headings: Lugeon (l/m/dk) | Numune Derinliği | Numune Türü | STANDART PEN. DEN. (DARBE SAYISI 15 30 45 N; GRAFİK 10 20 30 40) | KAROT YÜZDESİ % | RQD % | Kot (m) | Derinlik (m) | Jeolojik Profil | Sür.Oryantasyonu | JEOLOJİK TANIMLAMA | Ayrışma (W) 123456 | Dayanım (R) 1234567 | Süreksizlik Aralığı (S) 1234567 | YASS (m)

Not: *Zemin koşullarından dolayı BST yapılamadı. Kuyuda artezyen gözlemlendi.*

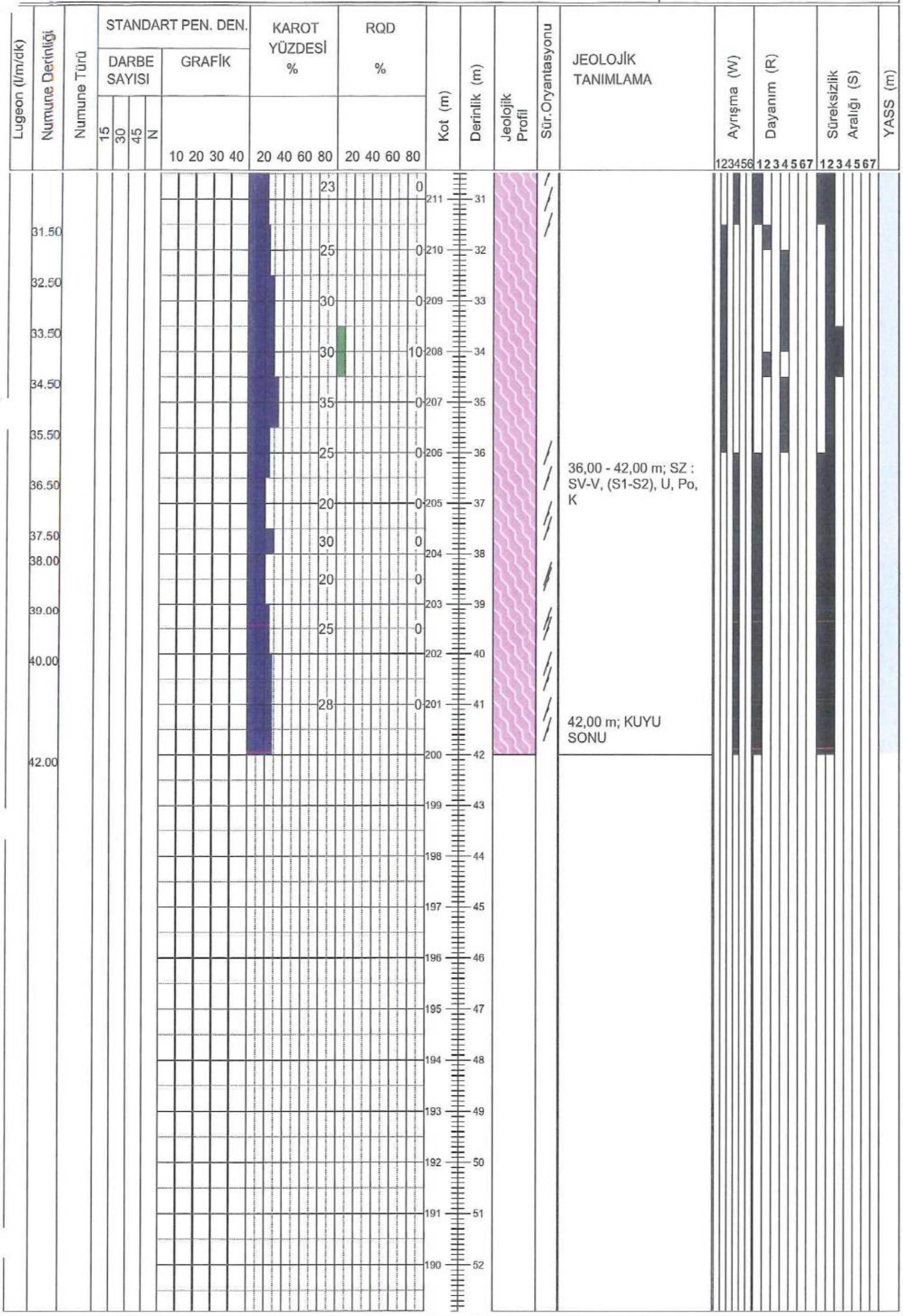
T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-802

LOGU YAPAN : Uğur ÜNVER

SAYFA : 3 / 3



Numune Derinliği (m)
31.50
32.50
33.50
34.50
35.50
36.50
37.50
38.00
39.00
40.00
42.00

Derinlik (m)	Karot Yüzdesi %	RQD %
30.50–31.50	23	0
31.50–32.50	25	0
32.50–33.50	30	0
33.50–34.50	30	10
34.50–35.50	35	0
35.50–36.50	25	0
36.50–37.50	20	0
37.50–38.00	30	0
38.00–39.00	20	0
39.00–40.00	25	0
40.00–42.00	28	0

Kot (m): 211 – 190; Derinlik (m): 31 – 52

JEOLOJİK TANIMLAMA:

36,00 - 42,00 m; SZ : SV-V, (S1-S2), U, Po, K

42,00 m; KUYU SONU

Not: Zemin koşullarından dolayı BST yapılamadı. Kuyuda artezyen gözlemlendi.

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO	: SK-804
SONDÖR	: Mustafa YAMALI
LOGU YAPAN	: Uğur ÜNVER

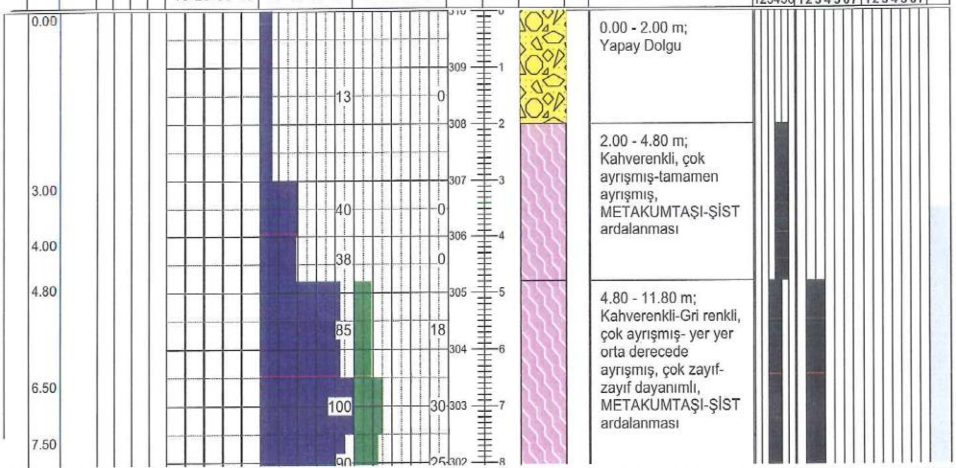
Proje : YÜKSEL DOMANİÇ MÜHENDİSLİK LTD.ŞTİ.	Sondaj : ÖZTAY GRUP SONDAJ	Otoyol Yatırım ve İşletme A.Ş. Teknik Danışmanı : SİAL YERBİLİMLERİ MÜŞAVİRLİK VE MÜHENDİSLİK LTD.ŞTİ.

TEKNİK DANIŞMAN / KONTROL MÜH. : Süleyman B. PARLAK — REVİZYON : 000

PROJE ADI	: Gebze-İzmir Otoyolu	İŞVEREN	: Yüksel Domaniç Mühendislik Ltd.Şti
SONDAJ YERİ	: Belkahve Tüneli	MAKİNA TÜRÜ	: D-900
KİLOMETRE	: 400+200	MUH. BOR. DER.	: 13,50 m
SONDAJ DER.	: 130,00 m	MUH. BOR. ÇAPI	: 114 mm
SONDAJ KOTU	: 310,00 m	DELİK ÇAPI	: 0,00-63,00m; 96mm / 63,00-130,00m; 76mm
YERALTI SUYU	: ~~3,50 m~~ 9.98m	KOORDİNAT D	: 527658
BAŞ. - BİT. TAR.	: 16.02.2011/27.02.2011	KOORDİNAT K	: 4257412

SAYFA : 1 / 7

Lugeon (l/m/dk)	Numune Derinliği	Numune Türü	STANDART PEN. DEN. DARBE SAYISI (15, 30, 45, N)	GRAFİK (10 20 30 40)	KAROT YÜZDESİ % (20 40 60 80)	RQD % (20 40 60 80)	Kot (m)	Derinlik (m)	Jeolojik Profil	Sür. Oryantasyonu	JEOLOJİK TANIMLAMA	Ayrışma (W) 123456	Dayanım (R) 1234567	Süreksizlik Aralığı (S) 1234567	YASS (m)
	0.00				13	0	310–308	0–2			0.00 - 2.00 m; Yapay Dolgu				
	3.00				40	0	308–305.2	2–4.8			2.00 - 4.80 m; Kahverenkli, çok ayrışmış-tamamen ayrışmış, METAKUMTAŞI-ŞİST ardalanması				
	4.00				38	0									
	4.80				85	18	305–302	4.8–8			4.80 - 11.80 m; Kahverenkli-Gri renkli, çok ayrışmış- yer yer orta derecede ayrışmış, çok zayıf-zayıf dayanımlı, METAKUMTAŞI-ŞİST ardalanması				
	6.50				100	30									
	7.50				90	25									



SÜREKSİZLİK TÜRLERİ

Co	Dokanak	C	Dilinim (Klivaj)
B	Tabakalanma	V	Damar
FZ	Fay Zonu	S	Şistozite
F	Fay	Fi	Fisür
SZ	Makaslanma Zonu		
J	Çatlak		
Fo	Foliasyon		

PÜRÜZLÜLÜK-DÜZLEMSELLİK

P	Düzlemsel
U	Dalgalı
S	Basamaklı
Po	Kaygan - Parlak
Sl	Kayma izi
Sm	Düz

STANDART PENETRASYON DENEYİ

İNCE DANELİ		KABA DANELİ	
N : 0 - 2	Çok Yumuşak	N : 0 - 4	Çok Gevşek
N : 3 - 4	Yumuşak	N : 5 - 10	Gevşek
N : 5 - 8	Orta Katı	N : 11 - 30	Orta Sıkı
N : 9 - 15	Katı	N : 30 -50	Sıkı
N : 16 - 30	Çok Katı	N > 50	Çok Sıkı
N > 30	Sert		

AYRIŞMA DERECESİ

W1 Taze : Kayanın bozunduğuna ilişkin gözle ayırdedilebilir bir belirti gözlenmez

W2 Az Ayrışmış : Kaya malzemesinde ve süreksizlik yüeylerinde renk değişimi gözlenir

W3 Orta derecede Ayrışmış : Kayanın yarısından az bir kısmı toprak zemine dönüşerek

W4 Çok Ayrışmış : Kayanın yarısından fazla bir kısmı toprak zemine dönüşerek ayrışmış veya parçalanmış

W5 Tamamen Ayrışmış : Kayanın tümü toprak emine dönüşerek ayrışmış ve/veya parçalanmış

W6 Artık Zemin : Kayanın tümü toprak haline dönüşmüştür.

KAYAÇ DAYANIMI

R1 Aşırı derecede zayıf kaya	UCS= 0.25 - 1.0 MPa
R2 Çok zayıf kaya	UCS= 1.0 - 5.0 MPa
R3 Zayıf kaya	UCS= 5.0 - 25 MPa
R4 Orta derecede sağlam kaya	UCS= 25 - 50 MPa
R5 Sağlam kaya	UCS= 50-100 MPa
R6 Çok sağlam kaya	UCS= 100 - 250 MPa
R7 Aşırı derecede sağlam kaya	UCS >250 Mpa

SÜREKSİZLİK ARALIĞI

S1	<20	Çok dar aralıklı
S2	20-60	Dar aralıklı
S3	60-200	Yakın Aralıklı
S4	200-600	Orta derecede Aralıklı
S5	600-2000	Geniş Aralıklı
S6	2000-6000	Çok Geniş Aralıklı
S7	>6000	Aşırı derecede geniş

DOLGU MALZEMESİ

K	Kil	M	Matrks / Kaya Parç.
Cl	Klorit	R	Breş
L	Limonit	X	Silt
I	Demir Oksit	O	Kum
C	Karbonat	Py	Pirit
Q	Quartz / Silikat	D	Diğer

GEÇİRİMLİLİK

Lugeon l/m/dk	Kaya Sınıfı
K1 <1	Geçirimsiz
K2 1-5	Az Geçirimli
K3 5-25	Geçirimli
K4 >25	Çok Geçirimli

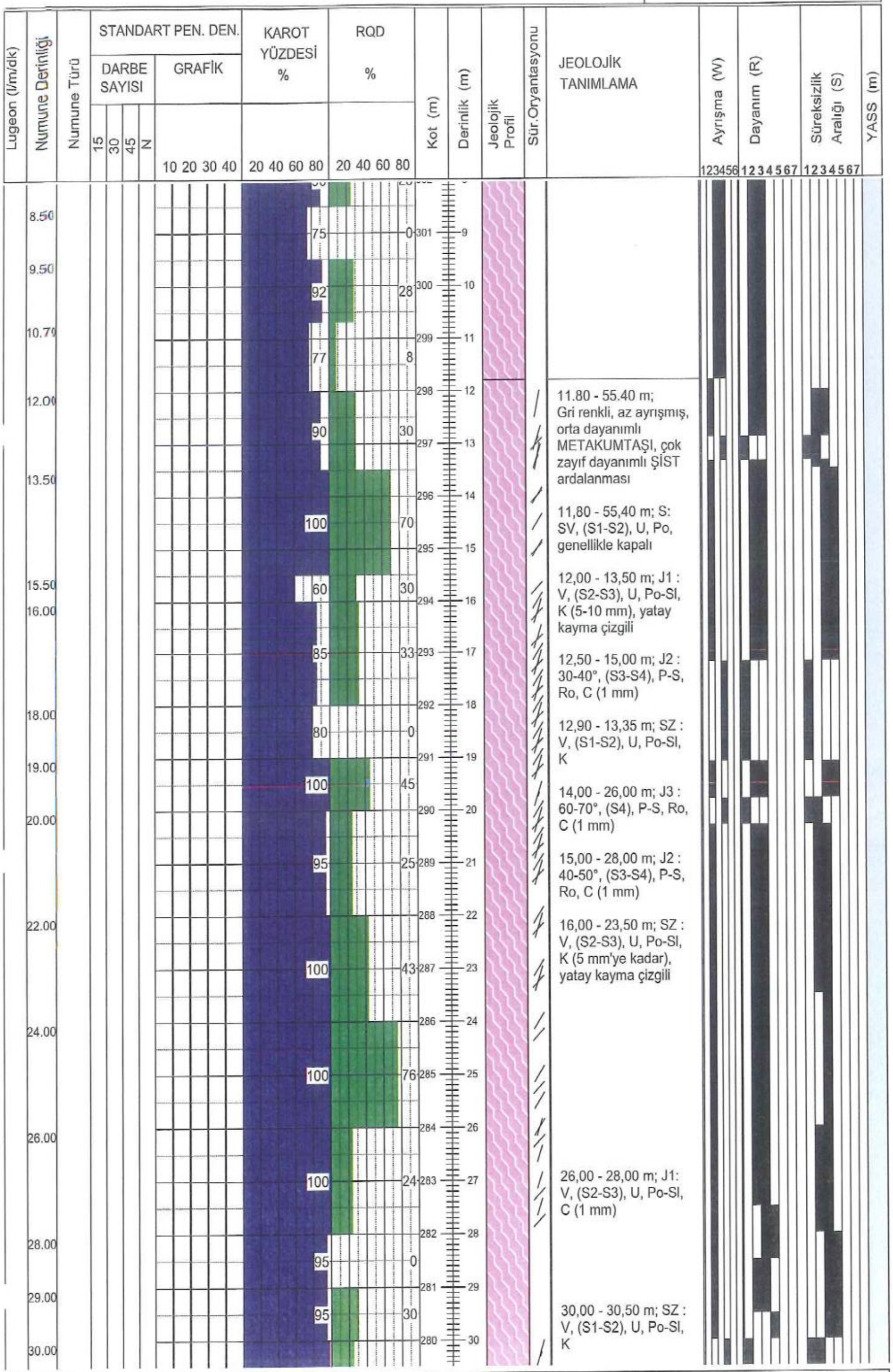
Tünel Tavanı

Tünel Tabanı

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

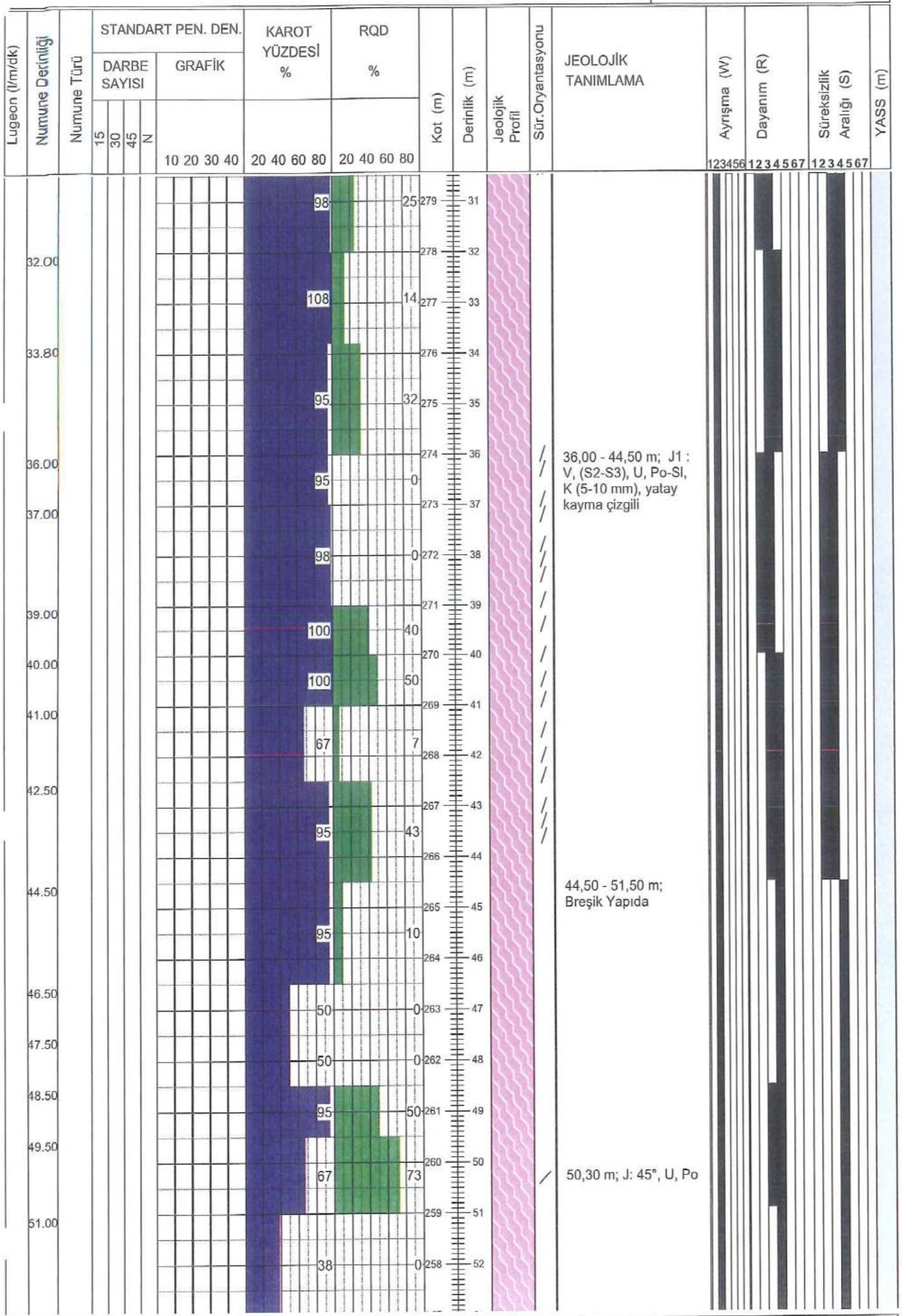
OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO	: SK-804
LOGU YAPAN	: Uğur ÜNVER
SAYFA	: 2 / 7



Not:

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ	SONDAJ NO : SK-804
	LOGU YAPAN : Uğur ÜNVER
OTOYOL OTOYOL YATIRIM VE İŞLETME A.Ş.	SAYFA : 3 / 7



Not:

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ	SONDAJ NO : SK-804
OTOYOL YATIRIM VE İŞLETME A.Ş.	LOGU YAPAN : Uğur ÜNVER
	SAYFA : 4 / 7

Columns: Lugeon (l/m/dk) | Numune Derinliği | Numune Türü | STANDART PEN. DEN. (DARBE SAYISI 15 30 45 N; GRAFİK 10 20 30 40) | KAROT YÜZDESİ % (20 40 60 80) | RQD % (20 40 60 80) | Kot (m) | Derinlik (m) | Jeolojik Profil | Sür. Oryantasyonu | JEOLOJİK TANIMLAMA | Ayrışma (W) 123456 | Dayanım (R) 1234567 | Süreksizlik Aralığı (S) 1234567 | YASS (m)

Numune Derinliği	Karot Yüzdesi %	RQD %
53.00	63	0
54.50	95	0
55.50	67	0
57.00	50	0
58.00	73	0
59.50	50	0
60.50	90	0
62.00	35	0
63.00	95	0
64.00	45	0
65.00	78	0
67.00	100	0
68.00	100	60
69.00	100	50
70.00	95	10
71.00	93	20
73.00	95	0
74.00	93	0

Kot (m): 257 – 235; Derinlik (m): 53 – 75

JEOLOJİK TANIMLAMA

54,50 - 55,40 m; Breşik Yapıda

55.40 - 68.80 m;

Fay Zonu :

55.40-63.00m; Siyahımsı gri-gri renkli, oldukça zayıf-çok zayıf dayanımlı, Metakumtaşı-Şist, kırıklı parçalı, genellikle killeşmiş

63.00-68.80m; Siyahımsı gri renkli, oldukça zayıf dayanımlı, ince kil matriks içerisinde Metakumtaşı - Şist - Kireçtaşı kaya parçalı, FAY KİLİ, breşik yapıda.

63.40-66.30m; S: 40-50, (S1-S2), P, Po

66,30-68,80m; S: SV, (S1-S2), P, Po

68.80 - 81.20 m; Gri-beyaz renkli, az ayrışmış, sağlam dayanımlı KİREÇTAŞI, yoğun erime boşluklu, boşluklar KİL dolgulu

69,90 - 70,00 m; / 70,10 - 70,90 m; / 71,15 - 71,50 m; / 72,50 - 72,60 m; / 72,80 - 74,00 m; / 74,20 - 76,20 m; / 77,00 - 77,15 m; Kızılımsı kahverenkli boşluk KİLİ, fisürlü, fisürler kayma izli

80,40 - 81,20 m; Sarımsı kahverenkli -

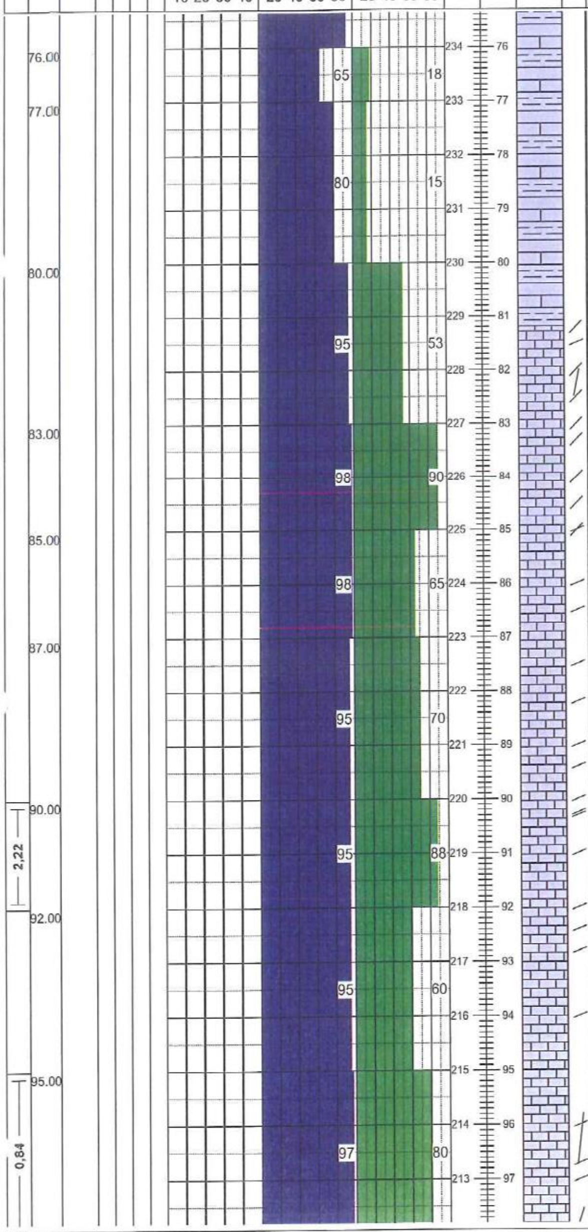
Not:

T.C. ULAŞTIRMA BAKANLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-804
LOGU YAPAN : Uğur ÜNVER
SAYFA : 5 / 7

Lugeon (l/m/dk)	Numune Derinliği	Numune Türü	STANDART PEN. DEN. DARBE SAYISI (15 / 30 / 45 / N)	GRAFİK (10 20 30 40)	KAROT YÜZDESİ % (20 40 60 80)	RQD % (20 40 60 80)	Kot (m)	Derinlik (m)	Jeolojik Profil	Sür. Oryantasyonu	JEOLOJİK TANIMLAMA	Ayrışma (W) 123456	Dayanım (R) 1234567	Süreksizlik Aralığı (S) 1234567	YASS (m)



gri - kızılımsı kahverenkli - alacalı KİL

68,80 - 73,00 m; J : V, U, Ro, K

69,00 m; J : 70°, P, K (10 mm), kapalı

69,05 - 69,90 m; J : V, U, Ro, C-I, genellikle kapalı

69,30 m; J : 45°, P, Ro, C-I

81.20 - 130.00 m; Gri-beyaz renkli, az ayrışmış, sağlam dayanımlı KİREÇTAŞI

81,20 - 85,00 m; J set : 45°, (S4), P, Ro, C-I, yer yer kapalı

81,50 m; J : 20°, P, Ro, C

82,00 - 82,50 m; J : V, U, Ro, K-C (1 mm)

85,00 - 90,25 m; J set : 20-30°, (S4-S5), U, Ro, C-I, kapalı ve açık

90,25 - 90,30 m; J set : 20-30°, (S2), U, Ro, C-I

90,30 - 118,50 m; J set : 20-30°, (S4-S5), U, Ro, C-I, kapalı ve açık

95,80 - 96,70 m; J : V, U, C-I, kapalı

97,70 - 99,00 m; J set : V, (S2), U, Ro, C-I

Not:

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-804

LOGU YAPAN : Uğur ÜNVER

SAYFA : 6 / 7

Lugeon (l/m/dk)	Numune Derinliği	Karot Yüzdesi %	RQD %	Jeolojik Tanımlama
	98.00	98	50	100,40 m; J : 50°, P, Ro, K (5 mm) 101,60 - 102,00 m; J set : V, (S2), U, Ro, C-I
0,76	100.00	98	60	
	102.00	97	87	103,00 - 103,60 m; J : V, U, C-I, kapalı
1,77	105.00	95	85	107,60 m; J : 45°, P, Ro, C-I
	108.00	83	73	
	109.50	95	80	109,50 - 110,50 m; J : V, U, Ro, C (5 mm), genellikle kapalı
2,40	11.50	100	90	
	13.50	75	45	
	14.50	95	93	117,50 - 118,50 m; J : V, U, Ro, C (5 mm), genellikle kapalı
	17.50	95	85	118,50 - 119,10 m; J set : 20-30°, (S3), U, Ro, C-I, kapalı ve açık 119,10 - 122,10 m; J set : 20-30°, (S4-S5), U, Ro, C-I, kapalı ve açık
	19.50			

Kolonlar: Lugeon (l/m/dk), Numune Derinliği, Numune Türü, STANDART PEN. DEN. (DARBE SAYISI: 15, 30, 45, N; GRAFİK: 10 20 30 40), KAROT YÜZDESİ % (20 40 60 80), RQD % (20 40 60 80), Kot (m), Derinlik (m), Jeolojik Profil, Sür. Oryantasyonu, JEOLOJİK TANIMLAMA, Ayrışma (W) 123456, Dayanım (R) 1234567, Süreksizlik Aralığı (S) 1234567, YASS (m)

Kot (m): 212 – 190; Derinlik (m): 98 – 120

Not:

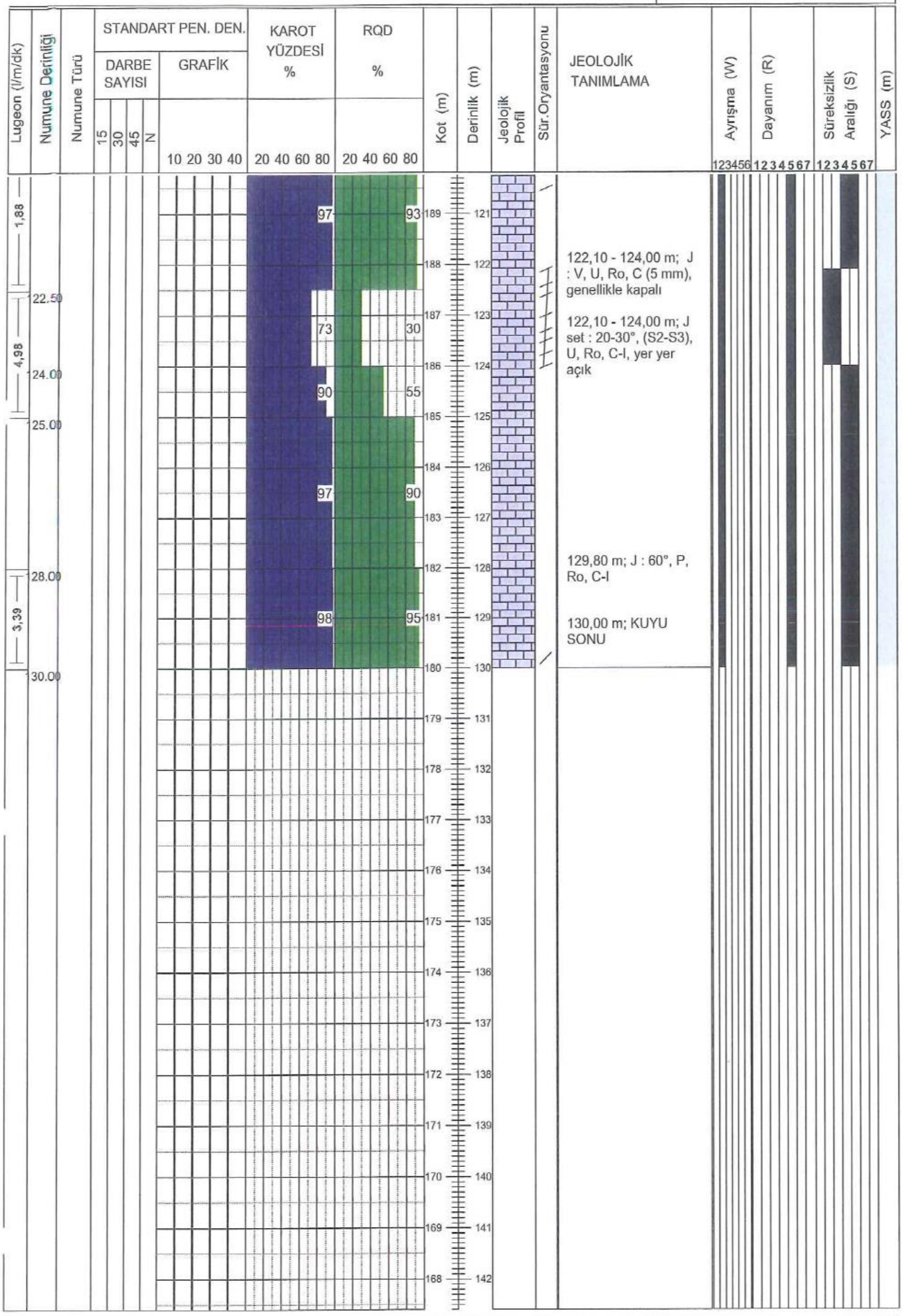
T.C. ULAŞTIRMA BAKANLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-804

LOGU YAPAN : Uğur ÜNVER

SAYFA : 7 / 7



122,10 - 124,00 m; J : V, U, Ro, C (5 mm), genellikle kapalı

122,10 - 124,00 m; J set : 20-30°, (S2-S3), U, Ro, C-I, yer yer açık

129,80 m; J : 60°, P, Ro, C-I

130,00 m; KUYU SONU

Not:

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	1 / 7
		İstasyon / *Station* KM.	399+600
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği, m / *BH Depth (m)*	90.00
Proje Firması / *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.	Başlangıç Tarihi / *Start Date*	27.07.2012
		Bitiş Tarihi / *Finish Date*	16.08.2012
Teknik Danışman / *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Kot, m / *Ground Elevation*	296.20
Yöntem / *Drill Method*	ROTARY SULU	Koordinatlar, m / *Coordinates* (ED-50/27-6°) N	4 259 458
Makine / *Drill Rig*	TSM-1000	E	528 158
		Sapma, m / *Offset*	

Tarih *Date*	Derinlik *Depth, m*	YAS Der. *GW depth, m*	Açıklama *Remarks*
2.09.12		30.50	-
18.09.12		29.50	-

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
0.00 - 2.50	1	2.50	RC	96	114		YOL DOLGUSU Yeşilimsi sarı - açık kahverenkli, çakıllı, kumlu KİL. Çakıllar; köşeli - yarı köşeli, metakumtaşı kökenlidir. 2.00 m. METAKUMTAŞI; Kahve - gri - koyu gri renkli, 2.00 - 6.50 m'ler arası; genelde çok - tamamen ayrışmış, yer yer orta derecede ayrışmış, çok zayıf - aşırı derecede zayıf dayanımlı, parçalanmış, 6.50 - 9.60 m'ler arası; genelde orta derecede - çok ayrışmış, yer yer az ayrışmış, genelde zayıf - çok zayıf dayanımlı, yer yer orta derecede sağlam dayanımlı, parçalanmış - kırıklı. *Çatlaklar;* 45° - 50° arasında, düz, pürüzlü, yer yer kapalı, kalsit damarlı, demiroksit sıvamalı. 9.60 m.	63.5	80	-	>50	W4 W5	R1 R0	
2.50 - 5.00	2	5.00	RC						80	-	>50	W4 W5	R1 R0	
5.00 - 7.50	3	7.50	RC						76	14	>50 4-10	W3 W4 W2	R1 R0 R3	
7.50 - 9.60	4		RC						72	4	>50	W3 W4	R2 R1	

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / *FINE GRAINED*			İRİ DANELİ / *COARSE GRAINED*			KAYA KALİTESİ / *RQD*			KIRIKLAR / *FRACTURES* (# m)		
N_{30}: 0 - 2	Çok yumuşak	/ *Very soft*	N_{30}: 0 - 4	Çok Gevşek	/ *Very Loose*	0 - 25 %	Çok Zayıf	/ *Very Poor*	< 1	Masif	/ *Massive*
N_{30}: 3 - 4	Yumuşak	/ *Soft*	N_{30}: 5 - 10	Gevşek	/ *Loose*	25 - 50 %	Zayıf	/ *Poor*	2 - 3	Az çatlaklı-kırıklı	/ *S.cracked-frac.*
N_{30}: 5 - 8	Orta Katı	/ *M. Stiff*	N_{30}: 11 - 30	Orta Sıkı	/ *M. Dense*	50 - 75 %	Orta	/ *Fair*	4 - 10	Kırıklı	/ *Fractured*
N_{30}: 9 - 15	Katı	/ *Stiff*	N_{30}: 31 - 50	Sıkı	/ *Dense*	75 - 90 %	İyi	/ *Good*	11 - 50	Çok çatlaklı-kırıklı	/ *H.cracked-frac.*
N_{30}: 16 - 30	Çok Katı	/ *Very Stiff*	N_{30}: >50	Çok Sıkı	/ *Very Dense*	90 - 100 %	Çok İyi	/ *Excellent*	> 50	Parçalanmış	/ *Crushed*
N_{30}: >30	Sert	/ *Hard*									

AYRIŞMA / *WEATHERING*			DAYANIM / *STRENGTH*				KISALTMALAR / *ABBREVIATIONS*		
W1	Taze	*Fresh*	R0	Aşırı Derecede Zayıf Kayaç	*Ext. Weak Rock*	q_u = 0.25 - 1.0 MPa	UD :	Şelbi Tüp	/ *Shelby Tube*
W2	Az Ayrışmış	*Slightly Weathered*	R1	Çok Zayıf Kayaç	*Very Weak Rock*	q_u = 1.0 - 5.0 MPa	RC :	Karot Numune	/ *Core Sample*
W3	Orta Derecede Ayrışmış	*Moderately Weat.*	R2	Zayıf Kayaç	*Week Rock*	q_u = 5.0 - 25 MPa	SPT :	St. Penetrasyon Den.	/ *St. Penetration Test*
W4	Çok Ayrışmış	*Highly Weathered*	R3	Orta Derecede Sağlam Kayaç	*Medium Strong Rock*	q_u = 25 - 50 MPa	PD :	Paker Deneyi	/ *Packer Test*
W5	Tamamen Ayrışmış	*Completely Weat.*	R4	Sağlam Kayaç	*Strong Rock*	q_u = 50 - 100 MPa	GD :	Geçirgenlik Deneyi	/ *Permeability Test*
W6	Rezidüel Zemin (Toprak)	*Residual Soil*	R5	Çok Sağlam Kayaç	*Very strong Rock*	q_u = 100 - 250 MPa	Pr :	Presiyometre Den.	/ *Pressuremeter Test*
			R6	Aşırı Derecede Sağlam Kayaç	*Ext.Strong Rock*	q_u = > 250 MPa			

NOTLAR / *REMARKS*

Sondör / *Driller*	Ziya YAMAN	Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	2 / 7
		İstasyon / *Station* (KM)	399+600
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	90.00

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı / *# of Blows* (15 / 30 / 45)	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Profil / *Symbol*	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-10 – -11	5	10.00 – 11.20	RC	96	114				63.5	75	-	>50	W3 / W4	R1 / R0	
-11 – -12	6	11.20 – 12.50	RC							73	-	>50	W3 / W4	R1 / R0	
-13	7	12.50 – 14.00	RC							60	17	>50	W3 / W4	R1 / R0	
-14 – -15	8	14.00 – 15.50	RC							57	-	4-10	W3	R1	
												>50	W4	R0	
-16	9	15.50 – 16.00	RC							36	-	>50	W3 / W4	R1 / R0	
-17	10	16.00 – 17.30	RC							58	-	>50	W4 / W5	R1 / R0	
-18	11	17.30 – 18.80	RC							73	48	4-10	W4 / W5	R1 / R0	
-19	12	18.80 – 19.50	RC							54	-	>50	W4 / W5	R1 / R0	
-20	13	19.50 – 20.00	RC							70	-	>50	W4 / W5	R1 / R0	
	14	20.00 – 20.50	RC							56	-	>50	W4 / W5	R1 / R0	
-21	15	20.50 – 21.50	RC							72	-	>50	W3 / W4	R1	
-22	16	21.50 – 23.00	RC							63	-	>50	W3 / W4	R1	
-23	17	23.00 – 24.00	RC							62	-	>50	W3 / W4	R1	
-24	18	24.00 – 24.50	RC							60	-	>50	W3 / W4	R1	
	19	24.50 –	RC							57	-	>50	W3 / W4	R1 / R0	

Jeoteknik Tanımlama / *Geotechnical Description*

BREŞİK METAKUMTAŞI;
Siyahımsı - koyu gri renkli,
9.60 - 25.00 m'ler arası;
genelde orta derecede - çok ayrışmış,
yer yer tamamen ayrışmış,
çok zayıf - aşırı derecede zayıf dayanımlı,
genelde parçalanmış, yer yer kırıklı,
25.00 - 32.00 m'ler arası;
genelde çok ayrışmış, yer yer az ayrışmış,
genelde aşırı derecede zayıf dayanımlı,
yer yer orta derecede sağlam dayanımlı,
genelde parçalanmış,
yer yer çok çatlaklı - kırıklı,
foliasyonlu.

Foliasyonlar;
70°, dalgalı, kaygan,
genelde kapalı.

Çatlaklar;
45° - 50° arasında,
dalgalı, pürüzlü,
yer yer kapalı,
kalsit damarlı.

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	3 / 7
		İstasyon / *Station* (KM)	399+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	90.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15 / 30 / 45	N₃₀ Grafiği *Graph of N30*	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi RQD (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-25	19	26.00	RC	96	114					63.5	57	-	11-50 >50	W2 W4	R3 R0	
-26	20	27.00	RC								23	-	>50	W4	R0	
-27	21	28.00	RC								33	-	11-50 >50	W2 W4	R3 R0	
-28	22	29.50	RC						Yukarısı gibidir.		43	-	>50	W4	R0	
-30	23	30.50	RC								38	-	>50	W4	R0	
-31	24	31.50	RC								55	-	>50	W4	R0	
-32	25	32.50	RC						32.00 m.		45	-	>50	W3 W4	R1 R0	
-33	26	34.00	RC								59	6	>50	W3 W4	R2 R1	
-34	27	35.00	RC								44	-	>50	W4 W5	R1 R0	
-35	28	36.00	RC								45	-	>50	W3 W4	R1 R0	
-36	29	37.50	RC								60	17	4-10 >50	W2 W4	R3 R2 R1	
-38	30	38.80	RC								69	39	4-10 >50	W2 W4	R3 R1	
-39	31		RC								66	-	>50	W3 W4	R1 R0	

GRAFİT ŞİST - METAKUMTAŞI ARDALANMASI;
Siyahımsı - gri - koyu gri renkli,
32.00 - 51.70 m'ler arası;
genelde orta derecede - çok ayrışmış,
yer yer az ayrışmış,
nadiren tamamen ayrışmış,
genelde zayıf - çok zayıf dayanımlı,
yer yer aşırı derecede zayıf dayanımlı,
yer yer orta derecede sağlam dayanımlı,
genelde parçalanmış,
yer yer çok çatlaklı - kırıklı, kırıklı,

Foliasyonlar;
70°, dalgalı, kaygan, parlak,
genelde kapalı,
yer yer breşik yapılı.

Çatlaklar;
45° - 50° arasında,
dalgalı, pürüzlü,
yer yer kapalı,
kalsit damarlı.

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	4 / 7
		İstasyon / *Station* (KM)	399+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	90.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}*	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-40	31	40.30	RC	96					Yukarısı gibidir.	63.5	66	-	>50	W3 / W4	R1 / R0	
-41	32	41.50	RC	96						63.5	79	28	>50	W3 / W4	R1 / R0	
-42	33	43.00	RC	96						63.5	63	-	>50	W3 / W4	R1 / R0	
-43 / -44	34	44.20	RC	96						63.5	79	26	>50	W3 / W4	R1 / R0	
	35	45.00	RC	96						63.5	58	-	>50	W3 / W4	R1 / R0	
-45	36	45.50	RC	96						63.5	76	-	>50	W3	R2 / R1	
-46	37	46.90	RC	96						63.5	68	-	>50	W3 / W4	R2 / R1	
-47 / -48	38	48.20	RC	96						63.5	75	33	4-10	W2	R3 / R2	
-49	39	49.40	RC	96						63.5	75	-	>50	W3 / W4	R2 / R1	
-50	40	50.55	RC	96						63.5	78	48	11-50 / >50	W2 / W3 W4	R4 / R2 R1	
	41	51.00	RC	96						63.5	93	56	11-50	W3 W4	R3 R2	
-51	42	51.70	RC	76						47.6	61	-	>50	W4	R2 / R1	
-52	43	52.70	RC	76					51.70 - 81.30 m'ler arası; genelde çok - tamamen ayrışmış, yer yer orta derecede ayrışmış, genelde çok zayıf - aşırı derecede zayıf dayanımlı, yer yer zayıf dayanımlı, nadiren sağlam dayanımlı, genelde parçalanmış, yer yer çok çatlaklı - kırıklı,	47.6	35	-	>50	W4 / W5	R1 / R0	
-53	44	53.20	RC	76						47.6	28	-	>50	W4 W5	R1 R0	
	45	54.00	RC	76						47.6	44	-	>50	W4 / W5	R1 / R0	
-54	46		RC	76						47.6	36	-	>50	W4 / W5	R1 / R0	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No	/ *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa	/ *Sheet*	5 / 7
		İstasyon	/ *Station* (KM)	399+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri	/ *BH Location*	Tünel
		Kuyu Derinliği	/ *BH Depth (m)*	90.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}* 10 20 30 40 50	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-55	47	55.00	RC	76					Yukarısı gibidir.	47.6	35	-	>50	W4 / W5	R1 / R0	
-56	48	56.00	RC								36	-	>50	W4 / W5	R1 / R0	
-57	49	57.00	RC								56	-	>50	W4 / W5	R1 / R0	
-58, -59	50	58.00	RC								71	-	>50	W4 / W5	R1 / R0	
	51	59.30	RC								73	-	>50	W4 / W5	R1 / R0	
-60	52	60.10	RC								33	-	>50	W4 / W5	R1 / R0	
-61	53	61.00	RC								35	-	>50	W4 / W5	R1 / R0	
-62	54	62.00	RC								52	-	>50	W4 / W5	R1 / R0	
-63, -64	55	63.00	RC								73	-	>50	W4 / W5	R1 / R0	
-65	56	64.30	RC								64	-	>50	W4 / W5	R1 / R0	
-66	57	65.50	RC								81	-	>50	W4 / W5	R1 / R0	
-67	58	66.80	RC								47	-	>50	W4 / W5	R1 / R0	
-68	59	67.50	RC								52	-	>50	W4 / W5	R1 / R0	
-69	60	68.60	RC								73	-	>50	W4 / W5	R1 / R0	
		69.90														

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG			
İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 805
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	6 / 7
		İstasyon / *Station* (KM)	399+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	90.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15	30	45	N₃₀ Grafiği *Graph of N₃₀* (10 20 30 40 50)	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-70	61	71.00	RC	76							Yukarısı gibidir.	47.6	66	-	>50	W4 / W5	R1 / R0	
-71, -72	62	72.50	RC										75	-	>50	W4 / W5	R1 / R0	
-73	63	73.40	RC										78	-	>50	W4 / W5	R1 / R0	
	64	74.00	RC										50	-	11-50	W3	R2	
-74	65	75.00	RC										65	-	>50	W4 / W5	R1 / R0	
-75, -76	66	76.20	RC										58	-	>50	W4 / W5	R1 / R0	
	67	77.00	RC										60	-	>50	W4 / W5	R0	
-77	68	78.00	RC										65	-	>50	W4 / W5	R0	
-78, -79	69	79.40	RC										68	-	>50	W4 / W5	R0	
	70	80.00	RC										78	-	>50	W4 / W5	R0	
-80, -81	71	81.30	RC										62	-	>50	W4 / W5	R0	
-82	72	82.15	RC								81.30 - 90.00 m'ler arası; tamamen ayrışmış, aşırı derecede zayıf dayanımlı, parçalanmış.		67	-	>50	W5	R0	
	73	82.60	RC										71	-	>50	W5	R0	
-83	74	83.80	RC										75	-	>50	W5	R0	
-84	75	84.80	RC										79	-	>50	W5	R0	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / Administration	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No	/ Borehole No	SK- 805
Proje İsmi / Project Name	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa	/ Sheet	7 / 7
		İstasyon	/ Station (KM)	399+600
Görevli Şirket / Appointed Company	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri	/ BH Location	Tünel
		Kuyu Derinliği	/ BH Depth (m)	90.00

Kuyu Derinliği / BH Depth (m)	Örnek No / Sample No	Örnek Derinliği / Sample Depth (m)	Örnek Türü / Sample Type	Matkap Tipi/Çapı / Bit Type/Diameter (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı / # of Blows 15	30	45	N_{30} Grafiği / Graph of N_{30} (10 20 30 40 50)	Profili / Symbol	Jeoteknik Tanımlama / Geotechnical Description	Karot Çapı / Core Diameter (mm)	Örnek Yüzdesi / Core Recovery (%)	Kaya Kalitesi / RQD (%)	Kırıklar / Fractures (#-m)	Ayrışma / Weathering	Dayanım / Strength	Yerinde Deneyler / In-situ Tests
-85	76		RC	76							Yukarısı gibidir.	47.6	61	-	>50	W5	R0	
		85.70																
-86	77		RC										66	-	>50	W5	R0	
		86.60																
-87	78		RC										61	-	>50	W5	R0	
		87.20																
	79												80	-	>50	W5	R0	
		87.60																
-88	80		RC										51	-	>50	W5	R0	
		88.50																
-89	81		RC										66	-	>50	W5	R0	
		89.20																
	82		RC										59	-	>50	W5	R0	
-90		90.00									90.00 m. KUYU SONU							
-91																		
-92																		
-93																		
-94																		
-95																		
-96																		
-97																		
-98																		
-99																		

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ, 17. BÖLGE MÜDÜRLÜĞÜ — OTOYOL YATIRIM VE İŞLETME A.Ş.	
	SONDAJ NO : SK-806
	SONDÖR : Mustafa YAMALI
	LOGU YAPAN : Uğur ÜNVER

Proje : YÜKSEL DOMANİÇ MÜHENDİSLİK LTD.ŞTİ.	Sondaj : ÖZTAY GRUP SONDAJ	Otoyol Yatırım ve İşletme A.Ş. Teknik Danışmanı : SİAL YERBİLİMLERİ MÜŞAVİRLİK VE MÜHENDİSLİK LTD.ŞTİ.
TEKNİK DANIŞMAN / KONTROL MÜH. : Süleyman B. PARLAK		REVİZYON : 000

PROJE ADI	: Gebze-İzmir Otoyolu	İŞVEREN	: Yüksel Domaniç Müh. Ltd. Şti.
SONDAJ YERİ	: Belkahve Tüneli	MAKİNA TÜRÜ	: D-900
KİLOMETRE	: 400+850	MUH. BOR. DER.	: 7,50 m
SONDAJ DER.	: 45,00 m	MUH. BOR. ÇAPI	: 114 mm
SONDAJ KOTU	: 200,00 m	DELİK ÇAPI	: 0,00-16,00m; 96mm / 16,00-45,00m; 76mm
YERALTI SUYU	: ~~8,00 m~~ 5.46m	KOORDİNAT D	: 527202
BAŞ. - BİT. TAR.	: 07.03.2011/11.03.2011	KOORDİNAT K	: 4256972
		SAYFA	: 1 / 3

Lugeon (l/m/dk)	Numune Derinliği	Numune Türü	STANDART PEN. DEN. DARBE SAYISI (15, 30, 45, N)	GRAFİK (10 20 30 40)	KAROT YÜZDESİ %	RQD %	Kot (m)	Derinlik (m)	Jeolojik Profil	Sür.Oryantasyonu	JEOLOJİK TANIMLAMA	Ayrışma (W) 123456	Dayanım (R) 1234567	Süreksizlik Aralığı (S) 1234567	YASS (m)
	0.00				40	0	200	0			0.00 - 1.00 m; Gri-Kahverengi renkli, orta derecede ayrışmış, zayıf dayanımlı METAKUMTAŞI - oldukça zayıf dayanımlı ŞİST 0,00 - 1,00 m; Düzensiz, çok sık çatlaklı				
	1.00				65	10	199	1			1.00 - 8.50 m; Gri renkli, az-orta derecede ayrışmış, orta-sağlam dayanımlı METAKUMTAŞI - çok zayıf dayanımlı ŞİST				
	2.00				20	0	198	2							
	3.00				25	0	197	3							
	4.00				30	0	196	4			4,50 - 5,10 m; 5,50 - 6,00 m; 7,00 - 8,50 m; Ezik Zon : Kil matriks içerisinde, ince-orta taneli, çakıl boyutlu				
	5.00				55	0	195	5							
	6.00				35	0	194	6							
	7.00				40	0	193	7							
	8.00						192	8							

SÜREKSİZLİK TÜRLERİ

Co	Dokanak	*C*	Dilinim (Klivaj)
B	Tabakalanma	*V*	Damar
FZ	Fay Zonu	*S*	Şistozite
F	Fay	*Fi*	Fisür
SZ	Makaslanma Zonu		
J	Çatlak		
Fo	Foliasyon		

PÜRÜZLÜLÜK-DÜZLEMSELLİK

P	Düzlemsel
U	Dalgalı
S	Basamaklı
Po	Kaygan - Parlak
Sl	Kayma izi
Sm	Düz

STANDART PENETRASYON DENEYİ

İNCE DANELİ		*KABA DANELİ*	
N : 0 - 2	Çok Yumuşak	*N : 0 - 4*	Çok Gevşek
N : 3 - 4	Yumuşak	*N : 5 - 10*	Gevşek
N : 5 - 8	Orta Katı	*N : 11 - 30*	Orta Sıkı
N: 9 - 15	Katı	*N : 30 -50*	Sıkı
N : 16 - 30	Çok Katı	*N > 50*	Çok Sıkı
N > 30	Sert		

AYRIŞMA DERECESİ

W1 Taze : Kayanın bozunduğuna ilişkin gözle ayırdedilebilir bir belirti gözlenmez

W2 Az Ayrışmış : Kaya malzemesinde ve süreksizlik yüeylerinde renk değişimi gözlenir

W3 Orta derecede Ayrışmış : Kayanın yarısından az bir kısmı toprak zemine dönüşerek

W4 Çok Ayrışmış : Kayanın yarısından fazla bir kısmı toprak zemine dönüşerek ayrışmış veya parçalanmış

W5 Tamamen Ayrışmış : Kayanın tümü toprak zemine dönüşerek ayrışmış ve/veya parçalanmış

W6 Artık Zemin : Kayanın tümü toprak haline dönüşmüştür.

KAYAÇ DAYANIMI

R1 Aşırı derecede zayıf kaya	UCS= 0.25 - 1.0 MPa
R2 Çok zayıf kaya	UCS= 1.0 - 5.0 MPa
R3 Zayıf kaya	UCS= 5.0 - 25 MPa
R4 Orta derecede sağlam kaya	UCS= 25 - 50 MPa
R5 Sağlam kaya	UCS= 50-100 MPa
R6 Çok sağlam kaya	UCS= 100 - 250 MPa
R7 Aşırı derecede sağlam kaya	UCS >250 Mpa

SÜREKSİZLİK ARALIĞI

S1	<20	Çok dar aralıklı
S2	20-60	Dar aralıklı
S3	60-200	Yakın Aralıklı
S4	200-600	Orta derecede Aralıklı
S5	600-2000	Geniş Aralıklı
S6	2000-6000	Çok Geniş Aralıklı
S7	>6000	Aşırı derecede geniş

DOLGU MALZEMESİ

K	Kil	*M*	Matrks / Kaya Parç.
Cl	Klorit	*R*	Breş
L	Limonit	*X*	Silt
I	Demir Oksit	*O*	Kum
C	Karbonat	*Py*	Pirit
Q	Quartz / Silikat	*D*	Diğer

GEÇİRİMLİLİK

Lugeon l/m/dk	*Kaya Sınıfı*
K1 <1	Geçirimsiz
K2 1-5	Az Geçirimli
K3 5-25	Geçirimli
K4 >25	Çok Geçirimli

Tünel Tavanı

Tünel Tabanı

T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-806
LOGU YAPAN : Uğur ÜNVER
SAYFA : 2 / 3

Numune Derinliği	Karot Yüzdesi %	RQD %	Kot (m)	Derinlik (m)
	70	15		
9.00	40	0	191	9
10.00	25	0	190	10
11.00	35	0	189	11
12.00	40	10	188	12
13.00	45	13	187	13
14.00	35	0	186	14
15.00	35	0	185	15
16.00	20	0	184	16
17.00	30	0	183	17
18.00	30	0	182	18
19.00	15	0	181	19
20.00	20	0	180	20
21.00	15	0	179	21
22.00	25	0	178	22
23.00	35	0	177	23
24.00	40	10	176	24
25.00	50	28	175	25
26.00	40	0	174	26
27.00	35	0	173	27
28.00	20	0	172	28
29.00	25	0	171	29
30.00			170	30

Column headings: Lugeon (l/m/dk) · Numune Derinliği · Numune Türü · STANDART PEN. DEN. (DARBE SAYISI 15 30 45 N; GRAFİK 10 20 30 40) · KAROT YÜZDESİ % (20 40 60 80) · RQD % (20 40 60 80) · Kot (m) · Derinlik (m) · Jeolojik Profil · Sür. Oryantasyonu · JEOLOJİK TANIMLAMA · Ayrışma (W) 123456 · Dayanım (R) 1234567 · Süreksizlik Aralığı (S) 1234567 · YASS (m)

JEOLOJİK TANIMLAMA

Metakumtaşı - Şist parçalı

1,20 - 8,50 m; J1 : V, (S1-S2), U, Po- yer yer Ro, K

1,20 - 8,50 m; J2 : 20-30° , (S1-S2), P, Ro, C - yer yer K

1,00 - 1,20 m; J2 : 20-30° , (S3), P, Ro, C - yer yer K

1,20 - 8,50 m; J3 : 40-50° , (S1-S2), P, Ro, C - yer yer K

8.50 - 45.00 m; Geri renkli, az derecede ayrışmış, orta-sağlam dayanımlı METAKUMTAŞI - çok zayıf dayanımlı ŞİST

14,75 - 15,25 m; Ezik Zon : Kil matriks içerisinde, ince-orta taneli, çakıl boyutlu Metakumtaşı - Şist parçalı

8,50 - 9,00 m;
13,00 - 13,50 m; /
14,25 - 14,50 m; /
22,00 - 22,20 m; /
23,80 - 24,25 m; /
24,75 - 25,00 m; /
25,70 - 26,00 m; /
26,90 - 27,00 m; /
31,00 - 31,50 m; /
32,50 - 33,00 m; /
35,00 - 36,50 m; /
38,80 - 39,70 m; /
40,20 - 41,50 m; /
42,00 - 42,50 m; /
43,25 - 43,50 m; /
44,75 - 45,00 m;

J1: V, (S3-S4), U, Po- yer yer Ro, K

J2 : 20-30° , (S3-S4), P, Ro, C - yer yer K

J3: 40-50° , (S3-S4), P, Ro, C - yer yer K

9,00 - 13,00 m;
13,50 - 14,25 m; /
14,50 - 22,00 m; /
22,20 - 23,80 m; /
24,25 - 24,75 m; /
25,00 - 25,70 m; /
26,00 - 26,90 m; /
27,00 - 31,00 m; /
31,50 - 32,50 m; /
33,00 - 35,00 m; /

Not: Zemin koşullarından dolayı BST yapılamadı.

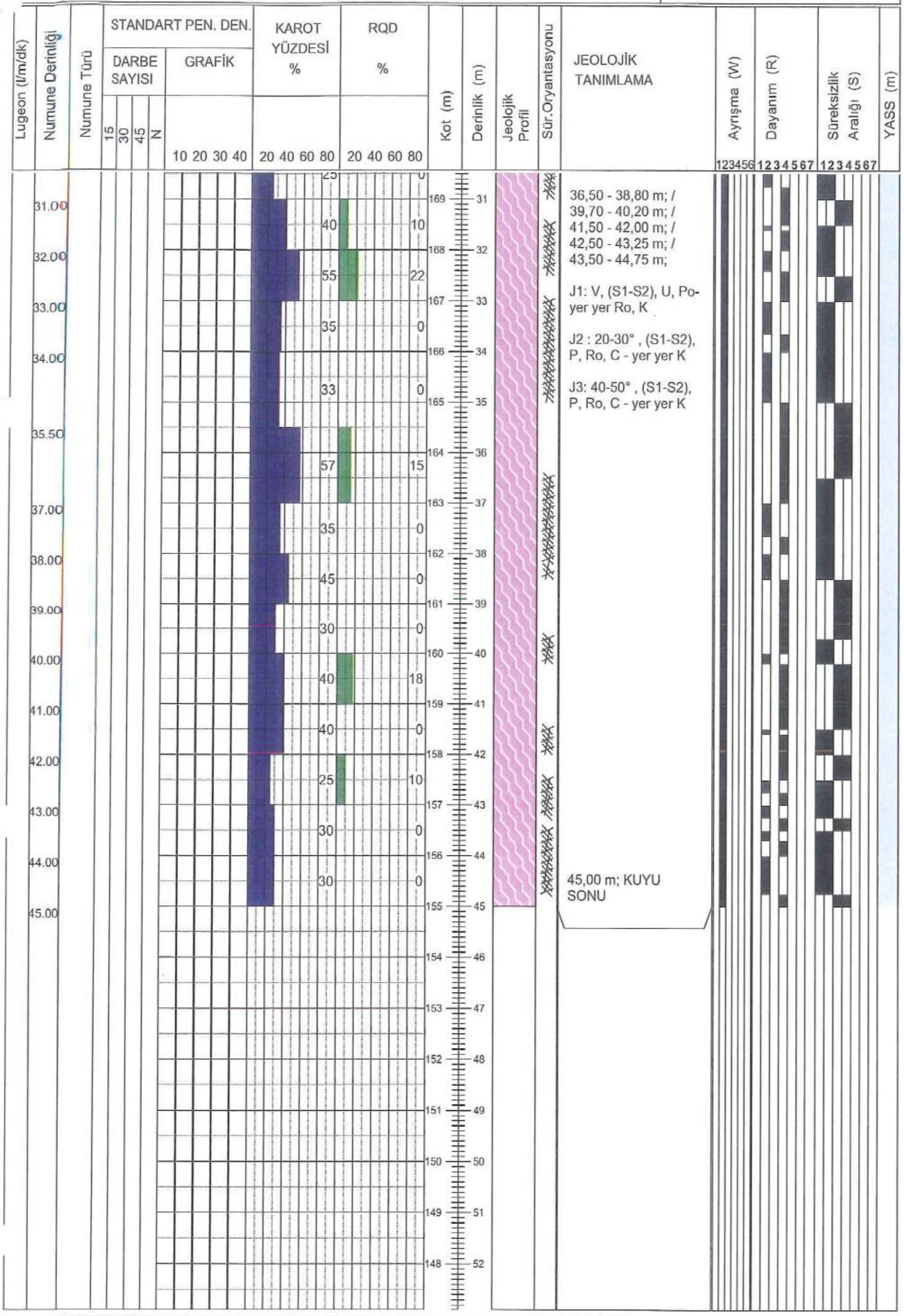
T.C. ULAŞTIRMA BAKALNLIĞI KARAYOLLARI GENEL MÜDÜRLÜĞÜ,
17. BÖLGE MÜDÜRLÜĞÜ

OTOYOL YATIRIM VE İŞLETME A.Ş.

SONDAJ NO : SK-806

LOGU YAPAN : Uğur ÜNVER

SAYFA : 3 / 3



Not: Zemin koşullarından dolayı BST yapılamadı.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	1 / 9
		İstasyon / *Station* KM.	399+850
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği, m / *BH Depth (m)*	128.00
Proje Firması / *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.	Başlangıç Tarihi / *Start Date*	02.07.2012
		Bitiş Tarihi / *Finish Date*	26.07.2012
Teknik Danışman / *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Kot, m / *Ground Elevation*	329.92
Yöntem / *Drill Method*	ROTARY SULU	Koordinatlar, m / *Coordinates* (ED-50/27-6°) N	4 259 315
Makine / *Drill Rig*	TSM-1000	E	527 944
		Sapma, m / *Offset*	

Tarih / *Date*	Derinlik / *Depth*, m	YAS Der. / *GW depth*, m	Açıklama / *Remarks*
28.07.12		65.50	-
18.09.12		59.00	-

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı / *# of Blows* (15 / 30 / 45)	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Profili / *Symbol*	Jeoteknik Tanımlama / *Geotechnical Description*	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-1	1	1.50	RC						*YOL DOLGUSU* Açık yeşilimsi - kahverenkli, az bloklu, çakıllı, kumlu KİL.		73	-				
-2	2	3.00	RC						1.50 m.		60	16	>50	W3 W4	R3 R2 R1	
-3	3	4.00	RC						METAKUMTAŞI; Koyu yeşil - yeşilimsi gri renkli, orta derecede - çok ayrışmış, çok zayıf - zayıf dayanımlı,		55	-	>50	W3 W4	R2 R1	
-4 -5 -6	4	6.30	RC	96	114				parçalanmış, yer yer yapraklanmalı, genelde bireşik yapılı. *Foliasyonlar;* düşeye yakın, çok dar aralıklı. Foliasyon yüzeyleri; düzlemsel, dalgalı, yer yer kapalı.	63.5	89	-	>50	W3 W4	R2 R1	
-7	5	7.40	RC						*Eklemler - 1;* düşeye yakın, 2 - 20 cm arasında tekrarlı, çatlak yüzeyleri; dalgalı, pürüzlü, demiroksit sıvamalı.		86	-	>50	W3 W4	R2 R1	
-8	6	9.00	RC						*Eklemler - 2;* 20°, 2 - 20 cm arasında tekrarlı, çatlak yüzeyleri; dalgalı, pürüzlü, demiroksit sıvamalı.		87	-	>50	W3 W4	R2 R1	
-9	7		RC								91	-	>50	W4	R1	

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / FINE GRAINED			İRİ DANELİ / *COARSE GRAINED*			KAYA KALİTESİ / *RQD*			KIRIKLAR / *FRACTURES* (# m)		
N_{30}: 0 - 2	Çok yumuşak	/ *Very soft*	N_{30}: 0 - 4	Çok Gevşek	/ *Very Loose*	0 - 25 %	Çok Zayıf	/ *Very Poor*	< 1	Masif	/ *Massive*
N_{30}: 3 - 4	Yumuşak	/ *Soft*	N_{30}: 5 - 10	Gevşek	/ *Loose*	25 - 50 %	Zayıf	/ *Poor*	2 - 3	Az çatlaklı-kırıklı	/ *S.cracked-frac.*
N_{30}: 5 - 8	Orta Katı	/ *M. Stiff*	N_{30}: 11 - 30	Orta Sıkı	/ *M. Dense*	50 - 75 %	Orta	/ *Fair*	4 - 10	Kırıklı	/ *Fractured*
N_{30}: 9 - 15	Katı	/ *Stiff*	N_{30}: 31 - 50	Sıkı	/ *Dense*	75 - 90 %	İyi	/ *Good*	11 - 50	Çok çatlaklı-kırıklı	/ *H.cracked-frac.*
N_{30}: 16 - 30	Çok Katı	/ *Very Stiff*	N_{30}: >50	Çok Sıkı	/ *Very Dense*	90 - 100 %	Çok İyi	/ *Excellent*	> 50	Parçalanmış	/ *Crushed*
N_{30}: >30	Sert	/ *Hard*									

AYRIŞMA / *WEATHERING*			DAYANIM / *STRENGTH*				KISALTMALAR / *ABBREVIATIONS*			NOTLAR / *REMARKS*
W1	Taze	*Fresh*	R0	Aşırı Derecede Zayıf Kayaç	*Ext. Weak Rock*	q_u = 0.25 - 1.0 MPa	UD :	Şelbi Tüp	/ *Shelby Tube*	
W2	Az Ayrışmış	*Slightly Weathered*	R1	Çok Zayıf Kayaç	*Very Weak Rock*	q_u = 1.0 - 5.0 MPa	RC :	Karot Numune	/ *Core Sample*	
W3	Orta Derecede Ayrışmış	*Moderately Weat.*	R2	Zayıf Kayaç	*Weak Rock*	q_u = 5.0 - 25 MPa	SPT :	St. Penetrasyon Den.	/ *St. Penetration Test*	
W4	Çok Ayrışmış	*Highly Weathered*	R3	Orta Derecede Sağlam Kayaç	*Medium Strong Rock*	q_u = 25 - 50 MPa	PD :	Paker Deneyi	/ *Packer Test*	
W5	Tamamen Ayrışmış	*Completely Weat.*	R4	Sağlam Kayaç	*Strong Rock*	q_u = 50 - 100 MPa	GD :	Geçirgenlik Deneyi	/ *Permeability Test*	
W6	Rezidüel Zemin (Toprak)	*Residual Soil*	R5	Çok Sağlam Kayaç	*Very strong Rock*	q_u = 100 - 250 MPa	Pr :	Presiyometre Den.	/ *Pressuremeter Test*	
			R6	Aşırı Derecede Sağlam Kayaç	*Ext.Strong Rock*	q_u = > 250 MPa				

Sondör / *Driller*	Ziya YAMAN	Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	2 / 9
		İstasyon / *Station* (KM)	399+850
		Sondaj Yeri / *BH Location*	Tünel
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Kuyu Derinliği / *BH Depth (m)*	128.00

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı / *# of Blows* (15 / 30 / 45)	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-10												W4	R1	
-10 – -11	7	– 11.40	RC	96				63.5	91	-	>50	W3 / W4	R2 / R0	
-12	8	11.40 – 12.30	RC	96				63.5	88	-	>50	W4	R0	
-13 – -14	9	12.30 – 14.40	RC	96				63.5	100	12	>50 / 11-50 / >50	W4 / W2 / W3 / W4	R0 / R3 / R2 / R0	
-15	10	14.40 – 15.50	RC	96				63.5	54	-	>50	W3 / W4	R2 / R1	
-16	11	15.50 – 16.65	RC	96				63.5	70	-	>50	W2 / W3	R2 / R1	
-17 – -18	12	16.65 – 18.50	RC	96				63.5	76	-	>50	W3 / W4	R1 / R0	
-19	13	18.50 – 19.65	RC	96				63.5	82	-	>50	W4 / W3	R0 / R1	
-20	14	19.65 – 20.65	RC	96				63.5	90	17	>50	W2	R2 / R1	
-21	15	20.65 – 21.35	RC	96				63.5	64	-	>50	W3	R1	
-22	16	21.35 – 22.50	RC	96				63.5	96	17	>50	W4 / W2	R0 / R1	
-23	17	22.50 – 23.50	RC	96				63.5	92	27	2-3 / >50	W1 / W2 / W3	R4 / R2 / R1	
-24	18	23.50 – 24.20	RC	96				63.5	97	43	11-50	W2 / W3	R2 / R1	
	19	24.20 –	RC	96				63.5	100	36	>50	W3	R1	

Jeoteknik Tanımlama / *Geotechnical Description*

Yukarısı gibidir.

——— 10.50 m. ———

GRAFİT ŞİST - METAKUMTAŞI ARDALANMASI;
Siyahımsı - gri renkli,
10.50 - 25.90 m'ler arası;
genelde orta derecede - çok ayrışmış,
yer yer az ayrışmış,
nadiren taze ayrışmış,
genelde çok zayıf - aşırı derecede zayıf day.,
yer yer zayıf - orta derecede sağlam day.,
genelde parçalanmış,
yer yer çok çatlaklı - kırıklı, kırıklı,
yer yer foliasyonlu,
yer yer breşik yapılı.

Foliasyonlar;
70°,
Foliasyon yüzeyleri;
düzlemsel, dalgalı, kaygan, parlak,
genelde kapalı.

Çatlaklar - 1;
6 - 20 cm arasında tekrarlı,
çatlak yüzeyleri; düz.

Çatlaklar - 2;
20° - 30°,
6 - 20 cm arasında tekrarlı,
düzlemsel, dalgalı, pürüzlü,
yer yer kalsit dolgulu,
yer yer kapalı.

EZİK ZON;
11.00 - 13.00 m'ler,
14.20 - 14.40 m'ler
18.50 - 19.50 m'ler
21.35 - 22.00 m'ler arası;
ince kil matriks içerisinde metakumtaşı - şist kaya parçalı.

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	3 / 9
		İstasyon / *Station* (KM)	399+850
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	128.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}* 10 20 30 40 50	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-25	19	25.90	RC	96					25.90 - 47.80 m'ler arası; genelde az - orta derecede ayrışmış, yer yer çok ayrışmış, genelde zayıf - orta derecede sağlam dayanımlı, yer yer çok zayıf dayanımlı, nadiren sağlam dayanımlı, genelde çok çatlaklı - kırıklı, yer yer parçalanmış, nadiren kırıklı,	63.5	100	36	4-10 >50	W2 W4	R3 R2 R0	
-26, -27	20	27.70	RC								94	16	>50 11-50 >50	W3 W2 W2 W3	R1 R3 R2 R1	
-28	21	28.90	RC								83	-	>50	W2 W3	R2 R1	
-29, -30	22	30.50	RC								75	16	>50 4-10 >50	W3 W2 W3	R1 R3 R1	
-31	23	31.50	RC								85	13	>50	W2 W3	R2 R1	
-32	24	33.00	RC								81	33	11-50 >50	W2 W3	R3 R2 R1	
-33, -34, -35	25	36.00	RC								93	22	>50 11-50	W3 W2 W3	R1 R3 R2	
-36, -37, -38	26	39.00	RC								90	-	11-50	W2 W3	R3 R2	
-39	27		RC								95	15	11-50	W2 W3	R3 R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Şektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	4 / 9
		İstasyon / *Station* (KM)	399+850
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	128.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15	30	45	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-40	27	41.00	RC										95	15	11-50	W2 W3	R3 R2	
-41 -42	28	42.70	RC										95	19	11-50	W2 W3	R3 R2	
-43 -44	29	44.10	RC								Yukarısı gibidir.		85	11	11-50 >50	W3 W4	R2 R1	
-45	30	45.10	RC										89	42	4-10 >50	W2 W4	R3 R1	
-46 -47	31	47.20	RC										90	-	>50	W2 W3	R3 R2	
	32	47.80	RC	96								63.5	83	30	>50 4-10	W3 W2	R2 R4	
-48 -49	33	49.20	RC								47.80 - 55.50 m'ler arası; çok ayrışmış, genelde zayıf - çok zayıf dayanımlı, nadiren aşırı derecede zayıf dayanımlı, parçalanmış,		79	-	>50	W4	R1 R0	
-50	34	50.50	RC										85	-	>50	W4	R2 R1	
-51	35	51.80	RC								EZİK ZON; 47.60 - 49.20 m'ler, ince kil matriks içerisinde metakumtaşı - şist kaya parçalı.		92	-	>50	W4	R2 R1	
-52	36	53.00	RC										96	-	>50	W4	R2 R1	
-53 -54	37	54.80	RC										88	-	>50	W4	R2 R1	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	5 / 9
		İstasyon / *Station* (KM)	399+850
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	128.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}* 10 20 30 40 50	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-55	38	55.50	RC	96						63.5	71	-	>50	W4	R2 R1	
-56	39	56.80	RC	96					55.50 - 65.00 m'ler arası; genelde orta derecede - çok ayrışmış, yer yer az ayrışmış, genelde zayıf - orta derecede sağlam dayanımlı, yer yer çok zayıf dayanımlı, genelde parçalanmış, yer yer çok çatlaklı - kırıklı,	63.5	85	-	>50	W3 W4	R3 R2	
-57	40	57.50	RC	96						63.5	80	-	>50	W3 W4	R3 R2	
-58	41	58.30	RC	96						63.5	71	-	>50	W3 W4	R3 R2	
-59	42	59.50	RC	96						63.5	85	-	>50	W3 W4	R3 R2	
-60	43	60.50	RC	96						63.5	80	-	>50	W3 W4	R3 R2	
-61	44	62.00	RC	76					Yukarısı gibidir.	47.6	67	10	>50	W3 W4	R3 R2	
-62	45		RC	76						47.6	100	17	>50	W3 W4	R2 R1	
-63													11-50	W3	R3 R2	
-64		64.60											>50	W3 W4	R2 R1	
-65	46	65.00	RC	76						47.6	100	-	>50	W4	R1	
-66	47	67.00	RC	76					65.00 - 82.00 m'ler arası; genelde orta derecede - çok ayrışmış, yer yer az ayrışmış, genelde çok zayıf - zayıf dayanımlı, yer yer aşırı derecede zayıf dayanımlı, genelde parçalanmış, yer yer çok çatlaklı - kırıklı,	47.6	100	-	>50	W3 W4	R1 R0	
-67 / -68	48	69.00	RC	76						47.6	100	23	>50	W3 W4	R2 R1	
-69	49		RC	76						47.6	96	-	>50	W3 W4	R2 R1	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A/Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Bursa - Orhangazi Kesimi, Bursa - Susurluk Kesimi	Sayfa / *Sheet*	6 / 9
		İstasyon / *Station* (KM)	399+850
		Sondaj Yeri / *BH Location*	Tünel
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Kuyu Derinliği / *BH Depth (m)*	126.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* (15 / 30 / 45)	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-70	49	70.40	RC	76					Yukarısı gibidir.	47.6	96	-	>50	W3 W4	R2 R1	
-71	50	72.00	RC								100	18	11-50 / >50	W3	R2 R1	
-72	51	72.70	RC								91	-	>50	W3	R1	
-73, -74, -75	52	75.20	RC								100	46	11-50	W2 W3	R2 R1	
-76	53	76.20	RC								100	22	11-50 / >50	W2 / W3 W4	R2 / R2 R1	
	54	77.00	RC								96	-	>50	W3 W4	R2 R1	
-77, -78	55	79.00	RC								100	5	>50	W3 W4	R2 R1	
-79, -80, -81	56	82.00	RC								100	-	>50	W3 W4	R2 R1	
-82, -83	57	83.20	RC								100	25	11-50 / >50	W2 / W3	R4 R3 / R2 R1	
-84	58	84.40	RC								100	-	>50	W3 W4	R2 R1	
	59		RC								92	-	>50	W3 W4	R2 R1	BST - 1

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare	/ Administration	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / Borehole No	SK- 807
Proje İsmi	/ Project Name	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Bursa - Orhangazi Kesimi, Bursa - Susurluk Kesimi	Sayfa / Sheet	7 / 9
			İstasyon / Station (KM)	399+850
Görevli Şirket	/ Appointed Company	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / BH Location	Tünel
			Kuyu Derinliği / BH Depth (m)	128.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-85	60	85.00	RC					92	-	>50	W3	R3 R2	BST - 1
-86	61	85.70	RC					100	-	>50	W3 W4	R2 R1	
	62	86.40	RC					100	-	>50	W3	R3 R2	
-87	63	87.00	RC					95	-	>50	W3	R2 R1	
-88	64	87.40	RC					100	20	>50	W4 W2 W3	R2 R5 R3	
-89	65	88.30	RC			82.00 - 128.00 m'ler arası;		100	-	>50	W3 W4	R3 R2	
	66	89.30	RC			genelde orta derecede - çok ayrışmış, yer yer az ayrışmış,		98	-	>50	W3 W4	R2 R1	
-90 -91	67	90.00	RC			genelde zayıf - orta derecede sağlam dayanımlı, yer yer çok zayıf dayanımlı, nadiren sağlam - çok sağlam dayanımlı, genelde parçalanmış, yer yer çok çatlaklı - kırıklı, nadiren az çatlaklı - kırıklı.		100	8	>50	W2 W3	R3 R2	BST - 2
-92	68	92.00	RC	76			47.6	67	-	>50	W3	R3 R2	
	69	92.30	RC					83	-	>50	W3	R3 R2	
-93	70	92.60	RC					63	-	>50	W4	R3 R2	
-94	71	93.00	RC					77	-	>50	W3 W4	R2 R1	BST - 3
-95	72	94.50	RC					98	-	>50	W3 W4	R2 R1	
-96	73	95.50	RC					92	-	>50	W3 W4	R2 R1	
	74	96.00	RC					80	-	>50	W3 W4	R2 R1	
-97	75	97.00	RC					100	-	>50	W3 W4	R3 R2	
-98 -99	76	98.00	RC					100	-	>50	W3 W4	R2 R1	
	77	99.20	RC					100	-	>50	W3 W4	R2 R1	

Standart Penetrasyon Deneyi / Standard Penetration Test (SPT): Darbe Sayısı / # of Blows (15, 30, 45); N_{30} Grafiği / Graph of N_{30} (10 20 30 40 50); Profili / Symbol

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Bursa - Orhangazi Kesimi, Bursa - Susurluk Kesimi	Sayfa / *Sheet*	8 / 9
		İstasyon / *Station* (KM)	399+850
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	128.00

Matkap Tipi/Çapı / *Bit Type/Diameter* (mm): 76 — Muhafaza Borusu (mm): – — Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT): Darbe Sayısı / *# of Blows* 15 / 30 / 45; N_{30} Grafiği / *Graph of N_{30}* 10 20 30 40 50: – — Karot Çapı / *Core Diameter* (mm): 47.6

Jeoteknik Tanımlama / *Geotechnical Description*: Yukarısı gibidir.

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-100 – -101	78	100.00 – 101.00	RC	100	-	>50	W3 W4	R2 R1	
-101 – -102	79	101.00 – 102.10	RC	100	-	>50	W3 W4	R2 R1	
-102 – -103	80	102.10 – 103.50	RC	96	-	11-50	W2 W3	R5 R4	
-104	81	103.50 – 104.30	RC	69	-	>50	W3 W4	R3 R2	BST - 4
-105	82	104.30 – 105.60	RC	81	7	>50 11-50	W4 W3	R2 R1 R3	BST - 4
-106	83	105.60 – 106.50	RC	67	11	11-50 >50	W4 W4	R1 R0 R1	BST - 4
	84	106.50 – 107.00	RC	66	-	>50	W4	R2 R1	BST - 5
-107 – -108	85	107.00 – 108.20	RC	83	-	>50	W3 W4	R3 R2	BST - 5
-109	86	108.20 – 109.50	RC	77	-	>50	W3 W4	R3 R2	BST - 5
-110	87	109.50 – 110.50	RC	80	12	>50 11-50	W3 W2	R2 R4	BST - 6
-111 – -112	88	110.50 – 112.50	RC	75	25	>50 2-3 >50	W3 W2 W3	R2 R4 R2	BST - 6
-113	89	112.50 – 113.70	RC	100	8	2-3 >50	W2 W4	R4 R3 R2	
-114	90	113.70 –	RC	81	-	>50	W3 W4	R2 R1	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 807
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Bursa - Orhangazi Kesimi, Bursa - Susurluk Kesimi	Sayfa / *Sheet*	9 / 9
		İstasyon / *Station* (KM)	399+850
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	128.00

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı / *# of Blows* 15	30	45	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Profil / *Symbol*	Jeoteknik Tanımlama / *Geotechnical Description*	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-115	90	115.60	RC	76							Yukarısı gibidir.	47.6	81	-	>50	W3 W4	R2 R1	
-116	91	116.30	RC										97	-	>50	W3 W4	R2 R1	
-117	92	117.30	RC										100	-	>50	W3 W4	R2 R1	
-118	93	118.30	RC										100	20	11-50 >50	W2 W3 W4	R5 R4 R3 R2	
-119	94	119.30	RC										100	15	>50	W3 W2 W4	R2 R4 R3	
-120	95	120.30	RC										100	-	>50	W3 W4	R2 R1	
-121	96	121.30	RC										100	-	>50	W3 W4	R2 R1	
-122	97	122.30	RC										100	25	2-3 >50	W2 W3 W4	R4 R2 R1	
-123	98	123.30	RC										100	-	>50	W3 W4	R3 R2	
-124	99	124.30	RC										100	15	>50	W3 W4	R3 R2	
-125	100	125.50	RC										83	-	>50	W3 W4	R3 R2	
-126	101	126.50	RC										100	-	>50	W3 W4	R3 R2	
-127	102	128.00	RC										87	-	>50	W3 W4	R3 R2	
-128											128.00 m. KUYU SONU							
-129																		

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*		SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*		1 / 7
		İstasyon / *Station*	KM.	400+400
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*		Tünel
		Kuyu Derinliği, m / *BH Depth (m)*		100.00
Proje Firması / *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.	Başlangıç Tarihi / *Start Date*		25.06.2012
		Bitiş Tarihi / *Finish Date*		02.07.2012
Teknik Danışman / *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Kot, m / *Ground Elevation*		281.38
Yöntem / *Drill Method*	ROTARY SULU	Koordinatlar, m / *Coordinates*	N	4 258 979
Makine / *Drill Rig*	TSM-1000	(ED-50/27-6°)	E	527 505
		Sapma, m / *Offset*		

Tarih / *Date*	Derinlik / *Depth, m*	YAS Der. / *GW depth, m*	Açıklama / *Remarks*
8.07.12		59.65	-
18.09.12		47.00	-

Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*
1	0.00 - 1.50	RC		114		19	-			
2	1.50 - 3.00	RC		114		22	-			
3	3.00 - 4.50	RC		114		22	-			
4	4.50 - 6.00	RC	96	114	63.5	56	-	>50	W4	R1 / R0
5	6.00 - 7.00	RC	96		63.5	97	-	>50	W4	R1 / R0
6	7.00 - 7.70	RC	96		63.5	83	-	>50	W4	R1 / R0
7	7.70 - 9.00	RC	96		63.5	100	-	>50	W4	R1 / R0
8	9.00 -	RC	96		63.5	100	-	>50	W4	R1 / R0

Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT): Darbe Sayısı / *# of Blows* (15, 30, 45); N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)

Jeoteknik Tanımlama / *Geotechnical Description*

0.00 - 4.00 m:

YOL DOLGUSU

Yeşilimsi kahve - açık kahverenkli, çakıllı, kumlu, killi BLOK.

Bloklar ve çakıllar; köşeli, kireçtaşı kökenlidir.

— 4.00 m. —

GRAFİT ŞİST;
Koyu gri - gri renkli,
genelde çok ayrışmış,
yer yer orta derecede ayrışmış,
çok zayıf - aşırı derecede zayıf dayanımlı,
parçalanmış,
foliasyonlu.

Foliasyon Düzlemleri;
30° - 40° arası,
2 - 6 cm arasında tekrarlı,
düzlemsel, dalgalı, yer yer kapalı.

Çatlaklar;
yer yer düşey - düşeye yakın,
yer yer 30° - 40° arası,
düzlemsel, dalgalı, pürüzlü,
demiroksit sıvamalı,
açık - kapalı.

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / *FINE GRAINED*	İRİ DANELİ / *COARSE GRAINED*	KAYA KALİTESİ / *RQD*	KIRIKLAR / *FRACTURES (# m)*
N_{30}: 0 - 2 Çok yumuşak / *Very soft*	N_{30}: 0 - 4 Çok Gevşek / *Very Loose*	0 - 25 % Çok Zayıf / *Very Poor*	< 1 Masif / *Massive*
N_{30}: 3 - 4 Yumuşak / *Soft*	N_{30}: 5 - 10 Gevşek / *Loose*	25 - 50 % Zayıf / *Poor*	2 - 3 Az çatlaklı-kırıklı / *S.cracked-frac.*
N_{30}: 5 - 8 Orta Katı / *M. Stiff*	N_{30}: 11 - 30 Orta Sıkı / *M. Dense*	50 - 75 % Orta / *Fair*	4 - 10 Kırıklı / *Fractured*
N_{30}: 9 - 15 Katı / *Stiff*	N_{30}: 31 - 50 Sıkı / *Dense*	75 - 90 % İyi / *Good*	11 - 50 Çok çatlaklı-kırıklı / *H.cracked-frac.*
N_{30}: 16 - 30 Çok Katı / *Very Stiff*	N_{30}: >50 Çok Sıkı / *Very Dense*	90 - 100 % Çok İyi / *Excellent*	> 50 Parçalanmış / *Crushed*
N_{30}: >30 Sert / *Hard*			

AYRIŞMA / *WEATHERING*	DAYANIM / *STRENGTH*	KISALTMALAR / *ABBREVIATIONS*	NOTLAR / *REMARKS*
W1 Taze *Fresh*	R0 Aşırı Derecede Zayıf Kayaç *Ext. Weak Rock* q_u = 0.25 - 1.0 MPa	UD : Şelbi Tüp / *Shelby Tube*	(*) Kırıklar - ayrışma - dayanımının boş olduğu yerlerde kil dolgusu geçilmiştir.
W2 Az Ayrışmış *Slightly Weathered*	R1 Çok Zayıf Kayaç *Very Weak Rock* q_u = 1.0 - 5.0 MPa	RC : Karot Numune / *Core Sample*	
W3 Orta Derecede Ayrışmış *Moderately Weat.*	R2 Zayıf Kayaç *Weak Rock* q_u = 5.0 - 25 MPa	SPT : St. Penetrasyon Den. / *St. Penetration Test*	
W4 Çok Ayrışmış *Highly Weathered*	R3 Orta Derecede Sağlam Kayaç *Medium Strong Rock* q_u = 25 - 50 MPa	PD : Paker Deneyi / *Packer Test*	
W5 Tamamen Ayrışmış *Completely Weat.*	R4 Sağlam Kayaç *Strong Rock* q_u = 50 - 100 MPa	GD : Geçirgenlik Deneyi / *Permeability Test*	
W6 Rezidüel Zemin (Toprak) *Residual Soil*	R5 Çok Sağlam Kayaç *Very strong Rock* q_u = 100 - 250 MPa	Pr : Presiyometre Den. / *Pressuremeter Test*	
	R6 Aşırı Derecede Sağlam Kayaç *Ext.Strong Rock* q_u = > 250 MPa		

Sondör / *Driller*		Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	2 / 7
		İstasyon / *Station* (KM)	400+400
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	100.00

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT) – Darbe Sayısı / *# of Blows* (15 / 30 / 45)	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Profil / *Symbol*	Jeoteknik Tanımlama / *Geotechnical Description*	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-10	8	10.50	RC								100	-	>50	W4	R1 R0	
	9	11.00	RC								80	-	>50	W4	R1 R0	
-11	10	11.50	RC						Yukarısı gibidir.		90	-	>50	W4	R1	
	11	12.00	RC								100	-	>50	W3 W4	R1	
-12	12	13.00	RC						12.80 m.		90	10	>50 11-50	W3 W4	R2 R1	
-13	13	13.75	RC						BREŞİK METAKUMTAŞI; Siyahımsı - gri renkli, genelde az - orta derecede ayrışmış,		100	69	11-50	W2 W3	R3 R2	
-14	14	14.45	RC						yer yer çok ayrışmış, genelde zayıf - orta derecede sağlam dayanımlı, yer yer çok zayıf dayanımlı,		86	-	11-50	W3 W4	R2 R1	
-15	15	15.80	RC						genelde çok çatlaklı - kırıklı, yer yer az çatlaklı - kırıklı, kalsit damarlı. 15.30 m. METAKUMTAŞI; Koyu yeşil - gri renkli, az - orta derecede ayrışmış, zayıf dayanımlı,		96	60	2-3 11-50	W2 W2 W3	R3 R2	
-16 -17	16	17.15	RC						çok çatlaklı - kırıklı, parçalanmış. *Çatlaklar;* 40° düşeye yakın, 2 - 6 cm arasında tekrarlı, dalgalı, pürüzlü, demiroksit sıvamalı, kapalı. 16.50 m.		89	10	>50	W2 W3	R2	
-18	17	18.35	RC	96					GRAFİT ŞİST; Siyahımsı - gri renkli, genelde az - orta derecede ayrışmış, yer yer çok ayrışmış, genelde zayıf dayanımlı, yer yer çok zayıf dayanımlı,	63.5	100	22	11-50 -	W2 W3 -	R2 R1 -	
-19	18	20.00	RC						nadiren aşırı derecede zayıf dayanımlı, genelde çok çatlaklı - kırıklı, kırıklı, yer yer parçalanmış, foliasyonlu. *Foliasyonlar;*		91	19	- 4-10	- W2 W3	- R2 R1	
-20 -21	19	21.30	RC						20° - 30° arası, 2 - 6 cm arasında tekrarlı, düzlemsel, dalgalı, yer yer kapalı. *Çatlaklar;*		100	-	11-50 - 11-50	W2 W3 - W2 W3	R2 - R2	
-22	20	22.35	RC						yer yer düşey - düşeye yakın, yer yer 25° - 35° arası, düzlemsel, dalgalı, pürüzlü, demiroksit sıvamalı, kapalı.		100	30	4-10	W2 W3	R2	
-23	21	23.45	RC						16.50 - 24.50 m'ler arası; breşik yapılı.		100	-	4-10 - 11-50	W2W3 - W2 W3	R2 - R2	
-24	22	24.65	RC						*EZİK ZON;* 18.20 - 18.65 m'ler, 20.50 - 20.75 m'ler 22.50 - 22.70 m'ler arası.		100	10	11-50	W2 W3	R2	
	23		RC								100	-	11-50	W2W3	R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	3 / 7
		İstasyon / *Station* (KM)	400+400
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	100.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* (15 / 30 / 45)	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-25	24	25.00	RC	96				~ ~ ~		63.5	83	-	11-50 -	W2 W3 -	R2 -	
-26	25	25.90	RC					~ ~ ~			67	-	11-50	W2 W3	R2	
	26	26.20	RC					~ ~ ~			89	-	>50	W2 W3	R2	
-27	27	27.10	RC					~ ~ ~			89	-	>50	W3	R2 R1	
-28	28	27.55	RC					~ ~ ~			90	-	11-50 -	W2 W3 -	R2 -	
-29	29	28.55	RC					~ ~ ~	*KAYMA ZONU;* 25.10 - 25.90 m'ler, 28.15 - 28.55 m'ler, 29.00 - 29.35 m'ler, 30.30 - 32.50 m'ler, 38.80 - 40.20 m'ler arası; siyahımsı gri - koyu gri renkli, KİL matriks içerisinde meta kumtaşı-şist kaya parçalı.		100	13	>50 -	W2 W3 -	R2 R1 -	
-30	30	29.35	RC					~ ~ ~			100	-	>50 -	W3 -	R2 R1 -	
-31	31	30.55	RC					~ ~ ~			100	-	-	-	-	
-32	32	31.70	RC					~ ~ ~			100	-	-	-	-	
-33	33	32.50	RC					~ ~ ~	Yukarısı gibidir.		88	10	11-50	W2 W3	R2	
-34	34	33.80	RC					~ ~ ~			100	30	11-50	W2 W3	R2	
-35 / -36	35	35.15	RC					~ ~ ~			100	15	11-50	W2 W3	R2	
-37 / -38	36	36.30	RC					~ ~ ~			100	46	4-10 >50	W2 W3 W3	R2 R1	
-39	37	38.50	RC					~ ~ ~			98	28	4-10 >50	W2 W3 W4	R2 R0	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	4 / 7
		İstasyon / *Station* (KM)	400+400
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	100.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15	30	45	N_{30} Grafiği *Graph of* N_{30} (10 20 30 40 50)	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-40 – -40.50	37	40.50	RC							~ ~ ~ ~	Yukarısı gibidir. — 40.20 m. —		98	28	- / 4-10	- / W1 W2	- / R4	
-40.50 – -43.50	38	43.50	RC										100	55	4-10	W1 / W2	R4	
-43.50 – -45.50	39	45.50	RC								KİREÇTAŞI; Gri - açık gri renkli, genelde taze - az ayrışmış, nadiren orta derecede ayrışmış, genelde sağlam dayanımlı, yer yer orta derecede sağlam dayanımlı, genelde kırıklı, yer yer az çatlaklı - kırıklı, parçalanmış.		95	59	4-10	W1 / W2	R4	
-45.50 – -48.50	40	48.50	RC	96							*Çatlaklar;* yer yer düşey - düşeye yakın, 40° - 50° arası, düzlemsel, dalgalı, pürüzlü, kil ve kalsit dolgulu, yer yer erime boşluklu, kapalı.	63.5	100	70	4-10	W1 / W2	R4	
-48.50 – -51.50	41	51.50	RC								51.30 - 51.50 m'ler, 52.10 - 52.40 m'ler, 52.90 - 53.05 m'ler, 55.00 - 55.40 m'ler, 56.00 - 56.15 m'ler, 57.00 - 57.15 m'ler, 57.70 - 58.10 m'ler, 58.40 - 59.50 m'ler arası; sarımsı kahverenkli çakıllı KİL DOLGUSU geçilmiştir.		100	67	4-10 / -	W1 / W2 / -	R4 / -	
-51.50 – -54.50	42	54.50	RC										100	46	4-10 / - / 4-10 / - / 4-10	W1 / - / W1 / - / W1	R4 / - / R4 / - / R4	BST - 1
-54.50 –	43		RC										100	20	>50	W3	R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	5 / 7
		İstasyon / *Station* (KM)	400+400
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	100.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-55	43	55.40	RC	96		Yukarısı gibidir.	63.5	100	20	-	-	-	BST - 1
-56	44	56.00	RC					100	58	4-10	W2	R4	BST - 1
-57	45	57.70	RC					100	-	- 4-10 - 4-10	- W2 - W2	- R4 - R4	
-58, -59	46	59.60	RC					97	18	- 4-10 - 4-10	- W2 - W2W3	- R4 - R2	
-60, -61	47	62.00	RC					100	68	2-3 4-10	W1 W2 W2	R4 R3 R4	BST - 2
-62, -63, -64	48	65.00	RC					98	66	2-3 4-10	W1 W2	R4	
-65, -66, -67	49	68.00	RC					100	63	4-10	W1 W2	R4	BST - 3
-68, -69	50		RC					100	53	4-10 >50 4-10	W1 W2	R4	

Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT): Darbe Sayısı / *# of Blows* (15, 30, 45); N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50); Profili / *Symbol*

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	6 / 7
		İstasyon / *Station* (KM)	400+400
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	100.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15	30	45	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-70	50	71.00	RC										100	57	4-10 >50 4-10	W1 W2	R4	
-71, -72, -73	51	74.00	RC										100	82	2-3	W1 W2	R4	BST - 4
-74, -75, -76	52	77.00	RC										100	72	2-3	W1 W2	R4	
-77, -78, -79	53	80.00	RC	96							Yukarısı gibidir.	63.5	100	58	4-10	W1 W2	R4 R3	BST - 5
-80, -81, -82	54	83.00	RC										99	61	4-10	W1 W2	R4 R3	
-83, -84	55		RC										97	53	4-10	W1 W2	R4 R3	BST - 6

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No	/ *Borehole No*		SK- 808
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa	/ *Sheet*		7 / 7
		İstasyon	/ *Station*	(KM)	400+400
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri	/ *BH Location*		Tünel
		Kuyu Derinliği	/ *BH Depth (m)*		100.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* (15 / 30 / 45)	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-85 – -86	55	86.00	RC	96						63.5	97	53	4-10	W1 / W2	R4 / R3	BST - 6
-86 – -89	56	89.00	RC								100	64	4-10	W1 / W2	R4 / R3	
-89 – -90	57	90.00	RC						Yukarısı gibidir.		100	57	4-10	W1 / W2	R4 / R3	
-90 – -93	58	93.00	RC						90.95 - 91.45 m'ler arası; bloklu, kumlu, çakıllı KİL birimi geçilmiştir.		100	63	4-10 / - / 4-10	W1 / W2 / - / W1 / W2	R4 / - / R4 / R3	
-93 – -96	59	96.00	RC								100	68	4-10	W1 / W2	R4 / R3	
-96 – -99	60	99.00	RC								100	65	4-10	W1 / W2	R4 / R3	
-99 – -100	61	100.00	RC						KUYU SONU 100.00 m.		100	75	4-10	W1 / W2	R4 / R3	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare	/ *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No	/ *Borehole No*	SK- 809
Proje İsmi	/ *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa	/ *Sheet*	1 / 5
			İstasyon	/ *Station* KM.	400+600
Görevli Şirket	/ *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri	/ *BH Location*	Tünel
			Kuyu Derinliği, m	/ *BH Depth (m)*	59.00
Proje Firması	/ *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.	Başlangıç Tarihi	/ *Start Date*	01.07.2012
			Bitiş Tarihi	/ *Finish Date*	15.07.2012
Teknik Danışman	/ *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Kot, m	/ *Ground Elevation*	237.89
Yöntem	/ *Drill Method*	ROTARY SULU	Koordinatlar, m (ED-50/27-6°)	/ *Coordinates* N	4 258 845
Makine	/ *Drill Rig*	D-900		E	527 374
			Sapma, m	/ *Offset*	

Tarih *Date*	Derinlik *Depth, m*	YAS Der. *GW depth, m*	Açıklama *Remarks*
2.09.12		7.30	-
18.09.12		7.50	-

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}* 10 20 30 40 50	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-1	1		RC								52	-				
-2	2	1.50	RC						*YAMAÇ MOLOZU* Yeşilimsi - sarımsı açık kahverenkli, kumlu, çakıllı, bloklu KİL. Çakıllar ve bloklar; köşeli, kumtaşı, kireçtaşı kökenlidir.		47	-				
-3	3	3.00	RC								67	-				
-4	4	4.00	RC						4.00 m.		92	-	>50	W2 W3	R4	
-5	5	4.60	RC	96	114				METAKUMTAŞI; Koyu gri - gri renkli, genelde az - orta derecede ayrışmış, yer yer çok ayrışmış,	63.5	60	-	11-50	W2 W3	R5 R4	
-6	6	5.60	RC						genelde sağlam - çok sağlam dayanımlı, yer yer zayıf - orta derecede sağlam dayanımlı, çok çatlaklı - kırıklı, parçalanmış.		83	20	>50	W2 W3	R5 R4	
-7	7	6.80	RC						*Çatlaklar;*		88	-	>50	W2 W3	R4 R3	
	8	7.20	RC						45° - 50° arasında, yer yer düşey - yatay, düz, dalgalı, demiroksit sıvamalı.		58	-	>50	W3 W4	R3 R2	
-8	9	7.80	RC						8.20 m. Tanımlama arka sayfadadır.		56	-	>50	W3 W4	R3 R2	
-9	10	9.50	RC								40	-	>50	W2	R4	

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / *FINE GRAINED*			İRİ DANELİ / *COARSE GRAINED*			KAYA KALİTESİ / *RQD*			KIRIKLAR / *FRACTURES* (# m)		
N_{30}: 0 - 2	Çok yumuşak	/ *Very soft*	N_{30}: 0 - 4	Çok Gevşek	/ *Very Loose*	0 - 25 %	Çok Zayıf	/ *Very Poor*	< 1	Masif	/ *Massive*
N_{30}: 3 - 4	Yumuşak	/ *Soft*	N_{30}: 5 - 10	Gevşek	/ *Loose*	25 - 50 %	Zayıf	/ *Poor*	2 - 3	Az çatlaklı-kırıklı	/ *S.cracked-frac.*
N_{30}: 5 - 8	Orta Katı	/ *M. Stiff*	N_{30}: 11 - 30	Orta Sıkı	/ *M. Dense*	50 - 75 %	Orta	/ *Fair*	4 - 10	Kırıklı	/ *Fractured*
N_{30}: 9 - 15	Katı	/ *Stiff*	N_{30}: 31 - 50	Sıkı	/ *Dense*	75 - 90 %	İyi	/ *Good*	11 - 50	Çok çatlaklı-kırıklı	/ *H.cracked-frac.*
N_{30}: 16 - 30	Çok Katı	/ *Very Stiff*	N_{30}: >50	Çok Sıkı	/ *Very Dense*	90 - 100 %	Çok İyi	/ *Excellent*	> 50	Parçalanmış	/ *Crushed*
N_{30}: >30	Sert	/ *Hard*									

AYRIŞMA / *WEATHERING*			DAYANIM / *STRENGTH*				KISALTMALAR / *ABBREVIATIONS*			NOTLAR / *REMARKS*
W1	Taze	*Fresh*	R0	Aşırı Derecede Zayıf Kayaç	*Ext. Weak Rock*	q_u = 0.25 - 1.0 MPa	UD :	Şelbi Tüp	/ *Shelby Tube*	
W2	Az Ayrışmış	*Slightly Weathered*	R1	Çok Zayıf Kayaç	*Very Weak Rock*	q_u = 1.0 - 5.0 MPa	RC :	Karot Numune	/ *Core Sample*	
W3	Orta Derecede Ayrışmış	*Moderately Weat.*	R2	Zayıf Kayaç	*Weak Rock*	q_u = 5.0 - 25 MPa	SPT :	St. Penetrasyon Den.	/ *St. Penetration Test*	
W4	Çok Ayrışmış	*Highly Weathered*	R3	Orta Derecede Sağlam Kayaç	*Medium Strong Rock*	q_u = 25 - 50 MPa	PD :	Paker Deneyi	/ *Packer Test*	
W5	Tamamen Ayrışmış	*Completely Weat.*	R4	Sağlam Kayaç	*Strong Rock*	q_u = 50 - 100 MPa	GD :	Geçirgenlik Deneyi	/ *Permeability Test*	
W6	Rezidüel Zemin (Toprak)	*Residual Soil*	R5	Çok Sağlam Kayaç	*Very strong Rock*	q_u = 100 - 250 MPa	Pr :	Presiyometre Den.	/ *Pressuremeter Test*	
			R6	Aşırı Derecede Sağlam Kayaç	*Ext. Strong Rock*	q_u = > 250 MPa				

Sondör / *Driller*	Mustafa CEYLAN	Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 809
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	1 / 5
		İstasyon / *Station* KM.	400+600
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği, m / *BH Depth (m)*	59,00
Proje Firması / *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.	Başlangıç Tarihi / *Start Date*	01.07.2012
		Bitiş Tarihi / *Finish Date*	15.07.2012
Teknik Danışman / *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Kot, m / *Ground Elevation*	237,89
Yöntem / *Drill Method*	ROTARY SULU	Koordinatlar, m / *Coordinates* N	4 258 845
Makine / *Drill Rig*	D-900	(ED-50/27-6°) E	527 374
		Sapma, m / *Offset*	

Tarih / *Date*	Derinlik / *Depth*, m	YAS Der. / *GW depth*, m	Açıklama / *Remarks*
2.09.12		7.30	-
18.09.12		7.50	-

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Matkap Tipi/Çapı / *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Darbe Sayısı / *# of Blows* (15 / 30 / 45)	N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50)	Profil / *Symbol*	Jeoteknik Tanımlama / *Geotechnical Description*	Karot Çapı / *Core Diameter* (mm)	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
0–1.50	1	1.50	RC	96	114				YAMAÇ MOLOZU	63.5	52	-				
1.50–3.00	2	3.00	RC								47	-				
3.00–4.00	3	4.00	RC								67	-				
4.00–4.60	4	4.60	RC						METAKUMTAŞI		92	-	>50	W2 W3	R4	
4.60–5.60	5	5.60	RC								60	-	11-50	W2 / W3	R5 / R4	
5.60–6.80	6	6.80	RC								83	20	>50	W2 / W3	R5 / R4	
6.80–7.20	7	7.20	RC								88	-	>50	W2 W3	R4 R3	
7.20–7.80	8	7.80	RC								58	-	>50	W3 W4	R3 R2	
7.80–9.50	9	9.50	RC								56	-	>50	W3 / W4	R3 / R2	
9.50–	10		RC								40	-	>50	W2	R4	

YAMAÇ MOLOZU
Yeşilimsi - sarımsı açık kahverenkli, kumlu, çakıllı, bloklu KİL.

Çakıllar ve bloklar; köşeli, kumtaşı, kireçtaşı kökenlidir.

——— 4.00 m. ———

METAKUMTAŞI;
Koyu gri - gri renkli,
genelde az - orta derecede ayrışmış,
yer yer çok ayrışmış,
genelde sağlam - çok sağlam dayanımlı,
yer yer zayıf - orta derecede sağlam dayanımlı,
çok çatlaklı - kırıklı, parçalanmış.

Çatlaklar;
45° - 50° arasında, yer yer düşey - yatay, düz, dalgalı, demiroksit sıvamalı.

——— 8.20 m. ———

Tanımlama arka sayfadadır.

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / FINE GRAINED			İRİ DANELİ / *COARSE GRAINED*			KAYA KALİTESİ / *RQD*			KIRIKLAR / *FRACTURES* (# m)		
N_{30}: 0 - 2	Çok yumuşak	/ *Very soft*	N_{30}: 0 - 4	Çok Gevşek	/ *Very Loose*	0 - 25 %	Çok Zayıf	/ *Very Poor*	< 1	Masif	/ *Massive*
N_{30}: 3 - 4	Yumuşak	/ *Soft*	N_{30}: 5 - 10	Gevşek	/ *Loose*	25 - 50 %	Zayıf	/ *Poor*	2 - 3	Az çatlaklı-kırıklı	/ *S.cracked-frac.*
N_{30}: 5 - 8	Orta Katı	/ *M. Stiff*	N_{30}: 11 - 30	Orta Sıkı	/ *M. Dense*	50 - 75 %	Orta	/ *Fair*	4 - 10	Kırıklı	/ *Fractured*
N_{30}: 9 - 15	Katı	/ *Stiff*	N_{30}: 31 - 50	Sıkı	/ *Dense*	75 - 90 %	İyi	/ *Good*	11 - 50	Çok çatlaklı-kırıklı	/ *H.cracked-frac.*
N_{30}: 16 - 30	Çok Katı	/ *Very Stiff*	N_{30}: >50	Çok Sıkı	/ *Very Dense*	90 - 100 %	Çok İyi	/ *Excellent*	> 50	Parçalanmış	/ *Crushed*
N_{30}: >30	Sert	/ *Hard*									

AYRIŞMA / *WEATHERING*			DAYANIM / *STRENGTH*				KISALTMALAR / *ABBREVIATIONS*			NOTLAR / *REMARKS*
W1	Taze	*Fresh*	R0	Aşırı Derecede Zayıf Kayaç	*Ext. Weak Rock*	q_u = 0.25 - 1.0 MPa	UD :	Şelbi Tüp	/ *Shelby Tube*	
W2	Az Ayrışmış	*Slightly Weathered*	R1	Çok Zayıf Kayaç	*Very Weak Rock*	q_u = 1.0 - 5.0 MPa	RC :	Karot Numune	/ *Core Sample*	
W3	Orta Derecede Ayrışmış	*Moderately Weat.*	R2	Zayıf Kayaç	*Weak Rock*	q_u = 5.0 - 25 MPa	SPT :	St. Penetrasyon Den.	/ *St. Penetration Test*	
W4	Çok Ayrışmış	*Highly Weathered*	R3	Orta Derecede Sağlam Kayaç	*Medium Strong Rock*	q_u = 25 - 50 MPa	PD :	Paker Deneyi	/ *Packer Test*	
W5	Tamamen Ayrışmış	*Completely Weat.*	R4	Sağlam Kayaç	*Strong Rock*	q_u = 50 - 100 MPa	GD :	Geçirgenlik Deneyi	/ *Permeability Test*	
W6	Rezidüel Zemin (Toprak)	*Residual Soil*	R5	Çok Sağlam Kayaç	*Very strong Rock*	q_u = 100 - 250 MPa	Pr :	Presiyometre Den.	/ *Pressuremeter Test*	
			R6	Aşırı Derecede Sağlam Kayaç	*Ext. Strong Rock*	q_u = > 250 MPa				

Sondör / *Driller*	Mustafa CEYLAN	Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 809
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	2 / 5
		İstasyon / *Station* (KM)	400+600
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	59.00

Matkap Tipi/Çapı / *Bit Type/Diameter*: 96 mm; Muhafaza Borusu: 114 mm; Karot Çapı / *Core Diameter*: 63.5 mm

Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT): Darbe Sayısı / *# of Blows* (15 / 30 / 45); N_{30} Grafiği / *Graph of N_{30}* (10 20 30 40 50) — no entries

Kuyu Derinliği / *BH Depth* (m)	Örnek No / *Sample No*	Örnek Derinliği / *Sample Depth* (m)	Örnek Türü / *Sample Type*	Örnek Yüzdesi / *Core Recovery* (%)	Kaya Kalitesi / *RQD* (%)	Kırıklar / *Fractures* (#-m)	Ayrışma / *Weathering*	Dayanım / *Strength*	Yerinde Deneyler / *In-situ Tests*
-10	10	10.50	RC	40	-	>50	W3	R5	
	11	11.00	RC	36	-	>50	W3 W4	R3 R2	
-11	12	12.50	RC	50	-	>50	W2 W3	R5 R4	
-12	13	13.00	RC	46	-	>50	W3 W4	R3 R2	
-13	14	14.00	RC	35	-	>50	W3 W4	R3 R2	
-14	15	14.60	RC	25	-	>50	W3 W4	R3 R2	
	16	15.20	RC	23	-	>50	W3 W4	R3 R2	
-15	17	16.00	RC	73	-	>50	W3 W4	R3 R2	
-16	18	16.70	RC	54	-	>50	W3 W4	R3 R2	
	19	17.10	RC	35	-	>50	W3 W4	R3 R2	
-17	20	17.50	RC	50	-	>50	W3 W4	R3 R2	
-18	21	18.50	RC	40	-	>50	W3 W4	R3 R2	
	22	19.00	RC	40	-	>50	W3 W4	R3 R2	
-19	23	19.30	RC	33	-	>50	W3 W4	R3 R2	
	24	19.90	RC	50	-	>50	W3 W4	R3 R2	
-20	25	20.40	RC	70	-	>50	W3 W4	R3 R2	
	26	21.10	RC	79	26	>50	W3 W4	R3 R2	
-21	27	22.30	RC	83	-	>50	W3 W4	R3 R2	
-22	28	23.00	RC	79	-	>50	W3 W4	R3 R2	
-23	29	23.40	RC	100	-	>50	W3 W4	R3 R2	
	30	24.00	RC	83	-	>50	W3 W4	R3 R2	
-24	31	24.50	RC	100	25	11-50	W3	R3 R2	
	32		RC	93	20	11-50	W3	R3	

Jeoteknik Tanımlama / *Geotechnical Description*

METAKUMTAŞI;
Siyahımsı - koyu gri renkli,

8.20 - 30.00 m'ler arası;
genelde orta derecede - çok ayrışmış,
yer yer az ayrışmış,
genelde zayıf - orta derecede sağlam dayanımlı,
yer yer sağlam - çok sağlam dayanımlı,
nadiren çok zayıf dayanımlı,
genelde parçalanmış,
yer yer çok çatlaklı - kırıklı.

Foliasyonlar;
70° - 75° arasında,
dalgalı, kaygan, parlak,
yer yer kapalı.

Çatlaklar;
45° - 50° arasında, yer yer düşeye yakın,
dalgalı, kaygan, parlak,
yer yer kapalı,
kalsit dolgulu.

8.20 - 17.50 m'ler arası;
Breşik metakumtaşının kaplayıcısı aşırı derecede zayıf dayanımlı (Grafit Şist) olduğundan bağlayıcısını su eritmiştir.

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 809
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	3 / 5
		İstasyon / *Station* (KM)	400+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	59.00

Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*
32	25.20	RC	96		63.5	93	20	>50	W4	R2
33	25.50	RC				30	-	>50	W3 W4	R3 R2
34	26.50	RC				88	14	11-50	W4	R2 R1
35	27.00	RC				50	-	11-50	W3 W4	R2
36	28.00	RC				88	14	11-50	W2 W3	R3
37	28.40	RC				50	-	>50	W3	R2
38	29.20	RC				81	-	>50	W3 W4	R2
39	30.00	RC				56	-	>50	W3 W4	R2 R1
40	31.00	RC		30.00 - 48.50 m'ler arası; çok - tamamen ayrışmış, yer yer az - orta derecede ayrışmış, genelde çok zayıf dayanımlı, yer yer zayıf - aşırı derecede zayıf dayanımlı, nadiren sağlam - çok sağlam dayanımlı, parçalanmış,		90	-	>50	W4 W5	R1
41	32.00	RC				60	-	>50	W4 W5	R1
42	32.70	RC				72	-	>50	W4 W5	R1
43	33.30	RC				75	-	>50	W4 W5	R1
44	34.20	RC				76	60	>50	W4 W5	R1
45	35.80	RC				81	36	>50	W4 W5	R1
46	36.60	RC				75	30	>50	W4 W5	R1
47	37.40	RC				69	-	>50	W4 W5	R1
48	38.00	RC				67	-	>50	W4 W5	R1
49	38.50	RC				64	32	>50	W4 W5	R2 R1
50	39.50	RC				100	84	>50	W4 W5	R2 R1
51		RC				100	51	>50	W4 W5	R2 R1

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 809
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	4 / 5
		İstasyon / *Station* (KM)	400+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	59.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of N_{30}* 10 20 30 40 50	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-40	51	40.50	RC	96						63.5	100	51	>50	W4 W5	R2 R1	
-41	52	41.50	RC	96						63.5	90	62	>50	W4 W5	R1	
-42	53	42.10	RC	96						63.5	93	22	>50	W4 W5	R1	
	54	42.50	RC	96						63.5	100	-	>50	W4 W5	R1 R0	
-43	55	43.10	RC	96						63.5	68	-	>50	W4 W5	R1 R0	
	56	44.00	RC	96					Yukarısı gibidir.	63.5	72	-	>50	W3 W4	R4 R3	
-44	57	44.50	RC	76						47.6	78	-	11-50	W2 W3	R5 R4	
-45	58	45.20	RC	76						47.6	93	-	>50	W4 W5	R2 R1	
	59	45.70	RC	76						47.6	90	-	>50	W3 W4	R3 R2	
-46	60	46.50	RC	76						47.6	72	-	>50	W4 W5	R2 R1	
-47	61	47.50	RC	76						47.6	65	12	>50 11-50	W4 W5 W2 W3	R2 R1 R4	
	62	47.90	RC	76						47.6	75	-	>50	W4 W5	R1 R0	
-48	63	48.50	RC	76						47.6	80	-	>50	W4 W5	R2 R1	
	64	49.00	RC	76						47.6	100	20	11-50	W3 W4	R2 R1	
-49	65	50.00	RC	76						47.6	100	66	4-10 >50	W3 W3 W4	R2	
-50	66	51.00	RC	76					48.50 - 59.00 m'ler arası; orta derecede - çok ayrışmış, genelde çok zayıf - zayıf dayanımlı, yer yer orta derecede sağlam dayanımlı, genelde kırıklı - parçalanmış, yer yer çok çatlaklı - kırıklı.	47.6	55	-	>50	W3 W4	R2 R1	
-51 -52	67	52.50	RC	76						47.6	63	-	11-50	W3	R2 R1	
-53	68	53.50	RC	76						47.6	66	-	4-10 >50	W3	R3 R2	
-54	69	54.50	RC	76						47.6	80	-	>50	W3	R3 R2	
	70		RC	76						47.6	100	30	4-10	W3	R3 R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 809
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	5 / 5
		İstasyon / *Station* (KM)	400+600
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Tünel
		Kuyu Derinliği / *BH Depth (m)*	59.00

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* 15	30	45	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-55	70		RC	76							Yukarısı gibidir.	47.6	100	30	4-10	W3	R3 R2	
		55.50																
-56	71		RC										100	52	4-10	W3	R3 R2	
		56.50																
-57	72		RC										100	-	4-10	W3	R2	
		57.50																
-58	73		RC										100	-	>50	W3 W4	R2 R1	
		58.50																
	74		RC										100	-	>50	W3 W4	R2 R1	
-59		59.00									59.00 m. KUYU SONU							
-60																		
-61																		
-62																		
-63																		
-64																		
-65																		
-66																		
-67																		
-68																		
-69																		

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü			Kuyu No / *Borehole No*	SK- 810
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)			Sayfa / *Sheet*	1 / 4
				İstasyon / *Station* KM.	400+923
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.			Sondaj Yeri / *BH Location*	Portal
				Kuyu Derinliği, m / *BH Depth (m)*	47.50
Proje Firması / *Designer*	YD Yüksel Domaniç Mühendislik Ltd. Şti.			Başlangıç Tarihi / *Start Date*	28.08.2012
				Bitiş Tarihi / *Finish Date*	01.09.2012
Teknik Danışman / *Technical Consultant*	Fugro Sial Yerbilimleri Müş.ve Müh. Ltd. Şti.	Tarih *Date* / Derinlik *Depth, m*	YAS Der. *GW depth, m* / Açıklama *Remarks*	Kot, m / *Ground Elevation*	214.23
Yöntem / *Drill Method*	ROTARY SULU	2.09.12	6.10 / -	Koordinatlar, m / *Coordinates* N	4 258 583
Makine / *Drill Rig*	D-900	18.09.12	6.40 / -	(ED-50/27-6°) E	527 189
				Sapma, m / *Offset*	

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* (15 / 30 / 45)	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi RQD (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
0–1	1	1.50	RC	96	114			63.5	67	-	>50	W3 / W4	R2 / R1	
2	2	2.50	RC						95	10	>50 / 4-10	W3 W4 / W2	R2 / R3	
3	3	3.50	RC						95	12	4-10 / >50	W2 / W3	R2 / R1	
4	4	4.50	RC						98	25	11-50	W2	R2	
5	5	5.50	RC						95	10	11-50 / >50	W2 / W3	R2	
6	6	6.50	RC						95	34	>50 / 11-50	W3 / W2	R2	
7	7	7.50	RC						95	-	11-50 / >50	W2 / W3	R2 / R1	
8	8	8.50	RC						90	-	>50	W3	R2	
9	9	9.10	RC						83	-	>50	W3	R2	
	10	9.80	RC						90	-	>50	W3	R2	

Jeoteknik Tanımlama / *Geotechnical Description*

METAKUMTAŞI;
Yeşilimsi gri - açık kahverenkli,
genelde orta derecede - çok ayrışmış,
yer yer az ayrışmış,
genelde zayıf - çok zayıf dayanımlı,
yer yer orta derecede sağlam dayanımlı,
genelde parçalanmış,
yer yer çok çatlaklı - kırıklı, kırıklı,

Çatlaklar;
45° - 50° arasında, yer yer düşeye yakın,
çatlak düzlemleri; dalgalı, pürüzlü,
açık - kapalı,
yer yer kalsit damarlı,
9.10 m'ye kadar;
demiroksit sıvamalı.

Foliasyonlar;
düşeye yakın,
dalgalı, kaygan, parlak,
kapalı.

ZEMİN - KAYA DEĞERLENDİRMESİ / *SOIL - ROCK EVALUATION*

İNCE DANELİ / *FINE GRAINED*			İRİ DANELİ / *COARSE GRAINED*			KAYA KALİTESİ / *RQD*			KIRIKLAR / *FRACTURES (# m)*		
N_{30}: 0 - 2	Çok yumuşak	/ Very soft	N_{30}: 0 - 4	Çok Gevşek	/ Very Loose	0 - 25 %	Çok Zayıf	/ Very Poor	< 1	Masif	/ Massive
N_{30}: 3 - 4	Yumuşak	/ Soft	N_{30}: 5 - 10	Gevşek	/ Loose	25 - 50 %	Zayıf	/ Poor	2 - 3	Az çatlaklı-kırıklı	/ S.cracked-frac.
N_{30}: 5 - 8	Orta Katı	/ M. Stiff	N_{30}: 11 - 30	Orta Sıkı	/ M. Dense	50 - 75 %	Orta	/ Fair	4 - 10	Kırıklı	/ Fractured
N_{30}: 9 - 15	Katı	/ Stiff	N_{30}: 31 - 50	Sıkı	/ Dense	75 - 90 %	İyi	/ Good	11 - 50	Çok çatlaklı-kırıklı	/ H.cracked-frac.
N_{30}: 16 - 30	Çok Katı	/ Very Stiff	N_{30}: >50	Çok Sıkı	/ Very Dense	90 - 100 %	Çok İyi	/ Excellent	> 50	Parçalanmış	/ Crushed
N_{30}: >30	Sert	/ Hard									

AYRIŞMA / *WEATHERING*			DAYANIM / *STRENGTH*				KISALTMALAR / *ABBREVIATIONS*			NOTLAR / *REMARKS*
W1	Taze	Fresh	R0	Aşırı Derecede Zayıf Kayaç	Ext. Weak Rock	q_u = 0.25 - 1.0 MPa	UD :	Şelbi Tüp	/ Shelby Tube	
W2	Az Ayrışmış	Slightly Weathered	R1	Çok Zayıf Kayaç	Very Weak Rock	q_u = 1.0 - 5.0 MPa	RC :	Karot Numune	/ Core Sample	
W3	Orta Derecede Ayrışmış	Moderately Weat.	R2	Zayıf Kayaç	Weak Rock	q_u = 5.0 - 25 MPa	SPT :	St. Penetrasyon Den.	/ St. Penetration Test	
W4	Çok Ayrışmış	Highly Weathered	R3	Orta Derecede Sağlam Kayaç	Medium Strong Rock	q_u = 25 - 50 MPa	PD :	Paker Deneyi	/ Packer Test	
W5	Tamamen Ayrışmış	Completely Weat.	R4	Sağlam Kayaç	Strong Rock	q_u = 50 - 100 MPa	GD :	Geçirgenlik Deneyi	/ Permeability Test	
W6	Rezidüel Zemin (Toprak)	Residual Soil	R5	Çok Sağlam Kayaç	Very strong Rock	q_u = 100 - 250 MPa	Pr :	Presiyometre Den.	/ Pressuremeter Test	
			R6	Aşırı Derecede Sağlam Kayaç	Ext.Strong Rock	q_u > 250 MPa				

Sondör / *Driller*	Mustafa CEYLAN	Mühendis / *Engineer*	Hakan OKUR

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 810
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	2 / 4
		İstasyon / *Station* (KM)	400+923
Görevli Şirket / *Appointed Company*	OTOYOL Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Portal
		Kuyu Derinliği / *BH Depth (m)*	47.50

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	Standart Penetrasyon Deneyi *Standard Penetration Test* (SPT) Darbe Sayısı *# of Blows* 15 / 30 / 45	N_{30} Grafiği *Graph of* N_{30} 10 20 30 40 50	Profil *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-10	11		RC						Yukarısı gibidir.		83	-	>50	W3	R2	
		10.50							10.50 m.							
	12		RC		114						100	-	>50	W5	R1 R0	
-11		11.00														
	13		RC								83	-	>50	W4 W5	R2 R1	
-12		12.20														
	14		RC								78	-	>50	W3 W4	R2 R1	
-13		12.90														
	15		RC								77	-	>50	W3 W4	R2 R1	
		13.50														
	16		RC								93	-	>50	W3 W4	R2 R1	
-14		14.20														
	17		RC						GRAFİT ŞİST; Siyahımsı gri renkli,		86	-	>50	W3 W4	R2 R1	
-15		15.20							genelde orta derecede - çok ayrışmış,							
	18		RC						yer yer az ayrışmış, nadiren tamamen ayrışmış,		50	-	>50	W3 W4	R2 R1	
-16		16.00							genelde zayıf - çok zayıf dayanımlı, nadiren aşırı derecede zayıf dayanımlı,							
	19		RC						genelde parçalanmış, nadiren çok çatlaklı - kırıklı, kil matriks içerisinde metakumtaşı		45	-	>50	W3 W4	R2 R1	
-17		17.00							kaya parçalı.							
	20		RC	96					*Foliasyonlar;*	63.5	50	-	>50	W3 W4	R2 R1	
-18		18.00							düşeye yakın, düzlemsel.							
	21		RC								56	-	>50	W3 W4	R2 R1	
		18.50														
-19	22		RC								80	-	>50	W3 W4	R2 R1	
		19.50														
-20	23		RC								81	-	>50	W3 W4	R2 R1	
		20.30														
-21	24		RC								95	-	>50	W3 W4	R2 R1	
		21.30														
-22	25		RC								97	18	11-50	W2 W3	R2	
		22.50														
-23	26		RC								88	-	>50	W3 / W4	R2 / R1	
-24		23.90														
	27		RC								73	-	>50	W2 W3	R3 R2	
		24.50														
	28		RC								57	-	>50	W3	R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No / *Borehole No*	SK- 810
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa / *Sheet*	3 / 4
		İstasyon / *Station* (KM)	400+923
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri / *BH Location*	Portal
		Kuyu Derinliği / *BH Depth (m)*	47,50

Kuyu Derinliği *BH Depth* (m)	Örnek No *Sample No*	Örnek Derinliği *Sample Depth* (m)	Örnek Türü *Sample Type*	Matkap Tipi/Çapı *Bit Type/Diameter* (mm)	Muhafaza Borusu (mm)	SPT Darbe Sayısı *# of Blows* (15 / 30 / 45)	N_{30} Grafiği *Graph of N_{30}* (10 20 30 40 50)	Profili *Symbol*	Jeoteknik Tanımlama *Geotechnical Description*	Karot Çapı *Core Diameter* (mm)	Örnek Yüzdesi *Core Recovery* (%)	Kaya Kalitesi *RQD* (%)	Kırıklar *Fractures* (#-m)	Ayrışma *Weathering*	Dayanım *Strength*	Yerinde Deneyler *In-situ Tests*
-25	28	25.40	RC								57	-	>50	W3	R2	
-26	29	26.40	RC						23.50 - 23.90 m'ler,		66	-	>50	W3 W4	R2	
	30	26.80	RC						25.40 - 26.40 m'ler, 27.70 - 28.20 m'ler arası;		62	-	>50	W3 W4	R1 R0	
-27	31	27.80	RC						*EZİK ZON* kil matriks içerisinde metakumtaşı kaya parçalı.		71	-	>50	W3 W4 W5	R2 R1 R1	
-28	32	28.30	RC								56	-	>50	W3 W4	R2 R1	
-29	33	29.30	RC								66	-	>50	W2 W3	R2	
	34	30.00	RC						Yukarısı gibidir.		71	-	>50	W2 W3	R2	
-30	35	31.00	RC								76	16	>50	W2 W3	R2	
-31 -32	36	32.50	RC	96						63.5	73	-	>50	W2 W3	R2	
-33	37	33.50	RC								82	-	>50	W2 W3	R2	
-34	38	34.10	RC								75	-	>50	W2 W3	R2	
	39	34.30	RC						34.30 m.		100	-	>50	W2	R2	
	40	35.00	RC								67	-	>50	W4	R1	
-35	41	35.50	RC								98	-	>50	W4	R1	
	42	36.00	RC						BREŞİK METAKUMTAŞI; Yeşilimsi açık kahverenkli,		74	-	>50	W4	R1	
-36 -37	43	37.50	RC						genelde orta derecede - çok ayrışmış, nadiren az ayrışmış, zayıf - çok zayıf dayanımlı, parçalanmış, çok zayıf kil bağlayıcılı,		82	-	>50	W4	R1	
	44	38.00	RC								88	-	>50	W4	R1	
-38	45	38.50	RC								90	-	>50	W3	R2	
	46	39.00	RC								84	-	>50	W3	R2	
-39	47	39.50	RC								60	-	>50	W3	R2	
	48		RC								46	-	>50	W2	R2	

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

SONDAJ LOGU / BORING LOG

İdare / *Administration*	T.C. Ulaştırma Denizcilik ve Haberleşme Bakanlığı Karayolları Genel Müdürlüğü, Kamu Özel Sektör Ortaklığı Bölge Müdürlüğü	Kuyu No	/ *Borehole No*	SK- 810
Proje İsmi / *Project Name*	Gebze-Orhangazi-İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM:398+300-KM:402+500 Arası)	Sayfa	/ *Sheet*	4 / 4
		İstasyon	/ *Station* (KM)	400+923
Görevli Şirket / *Appointed Company*	Otoyol Yatırım ve İşletme A.Ş.	Sondaj Yeri	/ *BH Location*	Portal
		Kuyu Derinliği	/ *BH Depth (m)*	47.50

Column key: Kuyu Derinliği / *BH Depth* (m); Örnek No / *Sample No*; Örnek Derinliği / *Sample Depth* (m); Örnek Türü / *Sample Type*; Matkap Tipi/Çapı / *Bit Type/Diameter* (mm); Muhafaza Borusu (mm); Standart Penetrasyon Deneyi / *Standard Penetration Test* (SPT): Darbe Sayısı / *# of Blows* (15, 30, 45), N_{30} Grafiği / *Graph of* N_{30} (10 20 30 40 50); Profil / *Symbol*; Jeoteknik Tanımlama / *Geotechnical Description*; Karot Çapı / *Core Diameter* (mm); Örnek Yüzdesi / *Core Recovery* (%); Kaya Kalitesi / *RQD* (%); Kırıklar / *Fractures* (#-m); Ayrışma / *Weathering*; Dayanım / *Strength*; Yerinde Deneyler / *In-situ Tests*

Örnek No	Örnek Derinliği (m)	Örnek Türü	Matkap Çapı (mm)	Karot Çapı (mm)	Örnek Yüzdesi (%)	RQD (%)	Kırıklar (#-m)	Ayrışma	Dayanım
48	40.50	RC	96	63.5	46	-	>50	W3	R2
49	41.50	RC	96	63.5	53	-	>50	W3 / W4	R2 / R1
50	42.50	RC	96	63.5	52	-	>50	W3	R2
51	43.00	RC	96	63.5	60	-	>50	W3	R2
52	44.00	RC	96	63.5	50	-	>50	W3	R2
53	45.00	RC	96	63.5	59	-	>50	W3	R2
53	46.00	RC	96	63.5	62	-	>50	W3	R2
54	47.50	RC	96	63.5	52	-	11-50	W2 / W3	R3 / R2

Jeoteknik Tanımlama:

-40.00 – 46.00 m: Yukarısı gibidir.

46.00 m.

GRAFİT ŞİST;
Siyahımsı gri renkli,
az - orta derecede ayrışmış,
zayıf - orta derecede sağlam dayanımlı,
çok çatlaklı - kırıklı.

47.50 m.
KUYU SONU

LİMİT Teknik Araştırma Proje, Uygulama, Müşavirlik San. ve Tic. A.Ş.

APPENDIX B

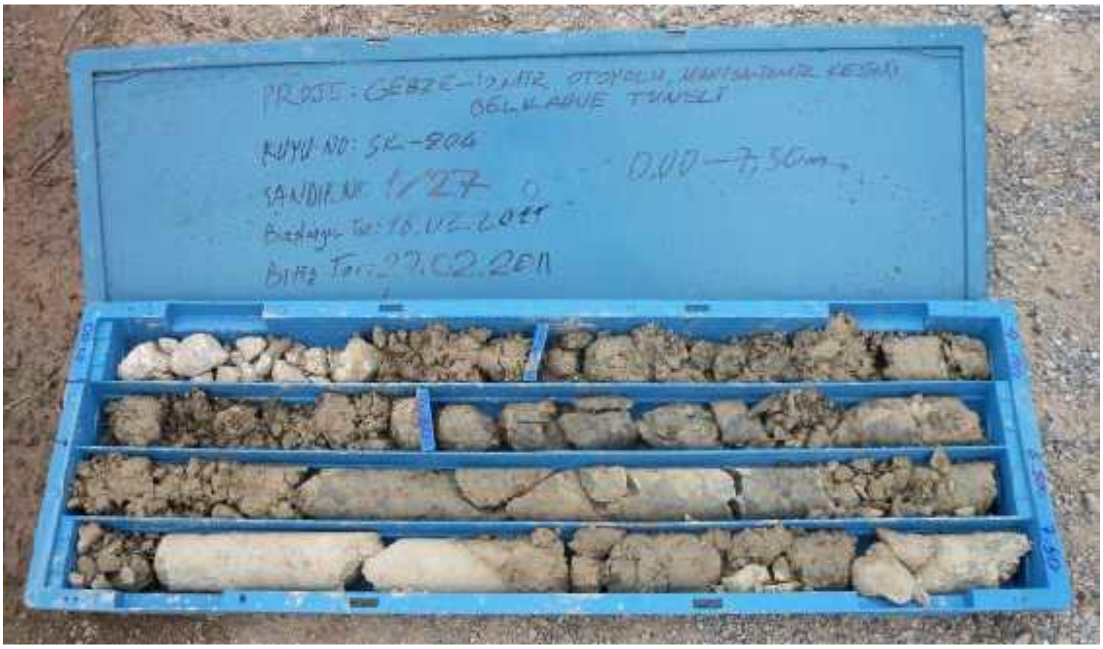
CORE BOX PICTURES

Sk- 802


KUYU = SK-802
SANDIK = 3/5
BİTİŞ TAR = 06.03.2011
15.00 - 23.00 m


SANDIK = 4/5
23.00 - 31,50

SK-804




PROJE: GEBZE - IZMIR OTOYOLU, MANISA-IZMIR KESIMI
BELKAHVE TÜNELİ
SANDIK: 2/27
7.50 - 12.00 m
Bitiş Tar: 27.02.2011


BELKAHVE TÜNELİ
SANDIK: 3/27
12.00 - 16.00 m
16-02-2011


PROJE = GEBZE - İZMİR OTOYOLU - MANİSA - İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU NO = 804
SANDIK = 4/27
16.00 - 20.00 m
BAŞLANGIÇ TAR = 16.02.2011
BİTİŞ TAR = 27.02.2011


PROJE = GEBZE - İZMİR OTOYOLU - MANİSA - İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU NO = 804
SANDIK = 5/27
20.00 - 24.00 m
BAŞLANGIÇ TAR = 16.02.2011
BİTİŞ TAR = 27.02.201


PROJE = GEBZE-İZMİR OTOYOLU - MANİSA - İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU NO = SK-804
SANDIK = 6/27
24.00 – 28.00m
BAŞLANGIÇ = 16.02.2011
BİTİŞ TAR = 28.02.2011


BELKAHVE TÜNELİ
KUYU NO SK 804
SANDIK = 7/27
28.00 – 32.00 m
BAŞLANGIÇ TAR = 16.02.2011
BİTİŞ TAR 27.02.2011


SANDIK = 8/27
32.00- 36.00 m


KUYU = SK 806
SANDIK = 9/27
36.00- 40.00m
BAŞLANGIÇ TAR = 16-02-2011
BİTİŞ TAR - 27.02.201


BELKAHVE TÜNELİ
SANDIK = 10/27
40.00 — 44.50 m
BAŞLANGIÇ TAR = 16.02.2011
BİTİŞ TAR = 27.02.2011


BELKAHVE TÜNELİ
KUYU = SK 804
SANDIK = 11/27
44.50 — 49.50 m
BİTİŞ TAR = 27.02.2011


PROJE = GEBZE-İZMİR OTOYOLU
BELKAHVE TÜNELİ
KUYU = SK-804
SANDIK = 12/27
BASLANGIC TAR = 16.02.2011
BITIS TAR = 27.02.2011


PROJE = GEBZE-İZMİR OTOYOLU MANİSA-İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU = SK-804
SANDIK = 13/27
54.50-60.50 m
BASLANGIC TAR = 16.02.2011
BITIS TAR = 27.02.2011


PROJE=GEBZE-İZMİR OTOYOLU
KUYU=SK-804
SANDIK=14/27
60.50-63.00 M
BAŞLANGIÇ TAR=16.02.11
BİTİŞ TAR=27.02.2011


PROJE=GEBZE-İZMİR OTOYOLU
KUYU=SK-804
BELKAHVE TÜNELİ
SANDIK=15/27
63.00 -
BAŞLANGIÇ TAR=16.02.11


69.00-74.00m
16.02.11
27.02.2011


74.00 - 80.00m
16.02.11
27.02.2011


PROJE = GEBZE-İZMİR OTOYOLU MANİSA - İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU = SK 804
SANDIK = 18/27
80.00 – 85.00 m
BAŞLANGIÇ TAR = 16-02-2011
BİTİŞ TAR = 27.02.2011


PROJE = GEBZE-İZMİR OTOYOLU MANİSA - İZMİR KESİMİ
BELKAHVE TÜNELİ
KUYU = SK 804
SANDIK = 19/27
85.00 – 90.00 m
BAŞLANGIÇ TAR = 16 02 2011
BİTİŞ TAR = 27.02.2011


KUYU-SK-804
SANDIK-20/27
90.00-95.00m
BİTİŞ TAR=27.02.2011


KUYU=SK-804
SANDIK-21/27
95.00-100 m
BİTİŞ TAR-27.02.2011


KUYU = SK-804
SANDIK = 22/27
BELKAHVE TÜNELİ
100 – 105 m


KUYU = SK-804
SANDIK = 23/27


MANİSA-İZMİR KESİMİ
BELKAHVE TÜNELİ
109.50 - 114.50
SANDIK=24/27


PROJE=GEBZE-İZMİR OTOYOLU
MANİSA-İZMİR KESİMİ
BELKAHVE TÜNELİ
SANDIK=25/27
114.50-119.50 m
BAŞLANGIÇ TAR= 16.02.2011
BİTİŞ TAR=27.02.2011


…ROJE=GEBZE-İZMİR OTOYOLU
MANİSA-İZMİR KESİMİ
KUYU=SK-804
BELKAHVE TÜNELİ
SANDIK=26/27
119.50-125.00 m
BAŞLANGIÇ TAR=16.02.2011
BİTİŞ TAR=27.02.2011


PROJE=GEBZE-İZMİR OTOYOLU
MANİSA-İZMİR-KESİMİ
KUYU=SK-804
BELKAHVE TÜNELİ
SANDIK=27/27
125.00-130.00 m
BAŞLANGIÇ TAR=16.02.2011
BİTİŞ TAR=27.02.2011

SK-805

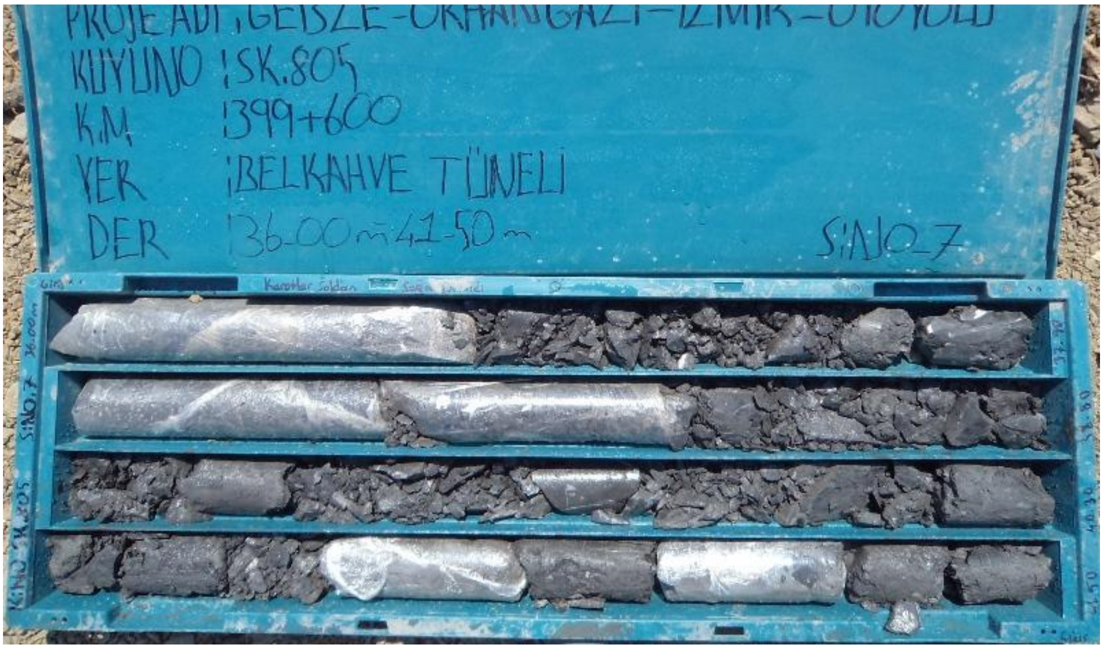

KUYU NO SK =805
YER = BELKAHVE TÜNELİ
DER 0.00m 5.00m
S.NO =1


K.NO = SK-805
K.M. = 399+600
YER = BELKAHVE TÜNELİ
DER = 5.00m 10.00m
S.NO = 2


PROJE ADI =GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO =SK.805
K.M =399+600
YER =BELKAHVE TÜNELİ
DER =15.50m 21.50m
S.NO =4
18.80m
19.50m
20.00
20.50


KUYUNO=SK.805
K.M =399+600
YER =BELKAHVE TÜNELİ
DER =21-50 m
S.NO =5


KUYUNO:SK.805
K.M :399+600
DER :28-50 m-36-00m
YER :BELKAHVE TÜNELİ
S.NO :6


KUYU NO ; SK.805
K.M 1399+600
YER ;BELKAHVE TÜNELİ
DER 36.00 m - 41.50 m
S.NO-7


PROJE ADI ; GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO ; SK-805
K.M 1399+600
YER ;BELKAHVE TÜNELİ
DER ;41.50 m - 46.90 m
S.NO-8


PROJE ADI ;GEBZE-ORHANGAZI- IZMIR-OTOYOLU
KUYU NO ;SK-805
K.M ;399+600
YER ;BELKAHVE TÜNELI
DER ;46-90 m - 51-70 m
S.NO ;9
51.00


PROJE ADI ;GEBZE-ORHANGAZI-IZMIR-OTOYOLU
KUYU NO ;SK-805
K.M ;399+600
YER ;BELKAHVE TÜNELI
DER ;51.70 - 61,00
S.NO ;10
56.00m
61.00m


KUYU NO:SK-805
KM =399+600
YER =BEIKAHVE TÜNELİ
DER =61.00 – 68,60m
S.NO =11


KUYU NO =SK-805
KM =399+600
YER =BEIKAHVE TÜNELİ
DER =68,60m – 75,00m
S.NO =12


PROJE ADI-GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO =SK-805
KM =399+600
YER =BELKAHVE TÜNELİ
DER =75,00m — 82,15m
S,NO =13

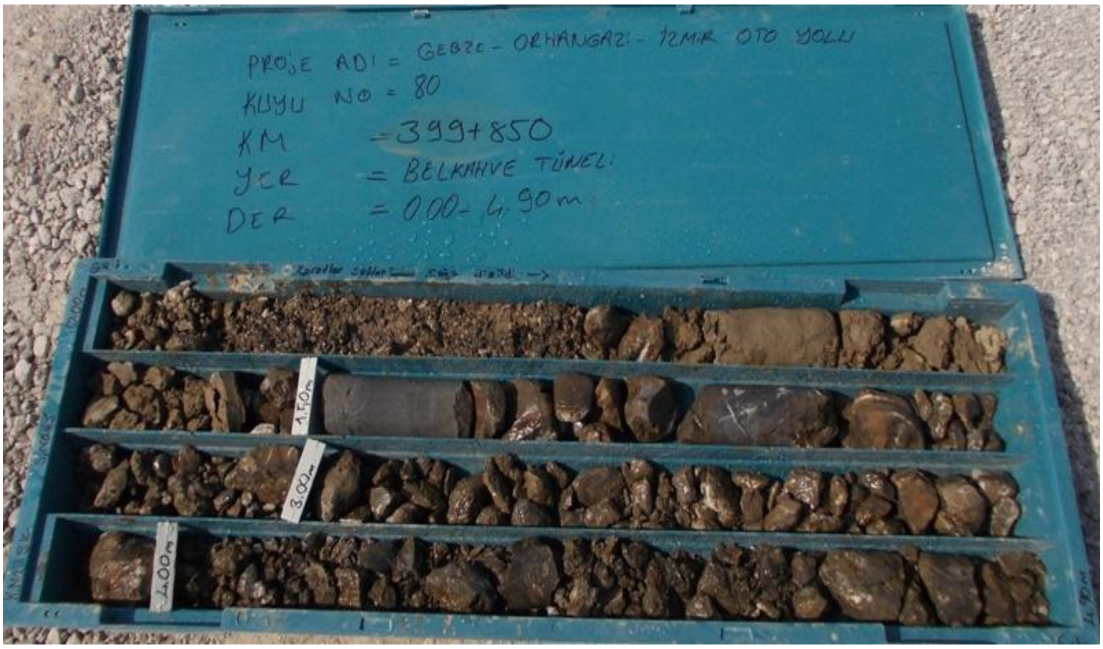

KUYU NO =SK-805
KM =399+600
YER =BELKAHVE TÜNELİ
DER =82,15 — 89,20m
S,NO =14


KUYU NO =SK-805
KM =399+600
DER =89.20— 90.00m
S.NO =15
BİTİŞ TARİHİ=15-08-2012

SK-806


SK-806

SK-807


PROJE ADI = GEBZE - ORHANGAZİ - İZMİR OTO YOLU
KUYU NO = 80
KM = 399+850
YER = BELKAHVE TÜNELİ
DER = 0.00 - 4.90m
1.50m
3.00m
4.00m


PROJE ADI = GEBZE - ORHANGAZİ - İZMİR OTO YOLU
KUYU NO =
KM = 399+850
YER = BELKAHVE TÜNELİ
DER = 4.90 - 9.00m
S.NO = 2/28
6.30m
7.60m


KUYU NO = 807
KM = 399+850
12.30


KUYU NO = 807
KM. = 399+850
YER = BELKAHVE TÜNELİ
14.40
16.65


PROJE ADI = GEBZE-ORHANGAZİ-İZMİR- OTOYOLU
KUYU- NO =807
KM 399+850
YER =BELKAHVE TÜNELİ
DER = 16.85 - 20.90m
18.50m
19.65
20.65


PROJE ADI=GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO=807
KM =399+850
YER =BELKAHVE TÜNELİ
DER =20.90-24.80
23.50m


PROJE ADI = GEBZE - ORHANGAZİ - IZMİR OTOYOLU
KUYU NO = 807
KM = 399+850
YER = BELKAHVE TÜNELİ
DER. = 24.80 - 28.90m
S NO / 7
25.90m
27.70

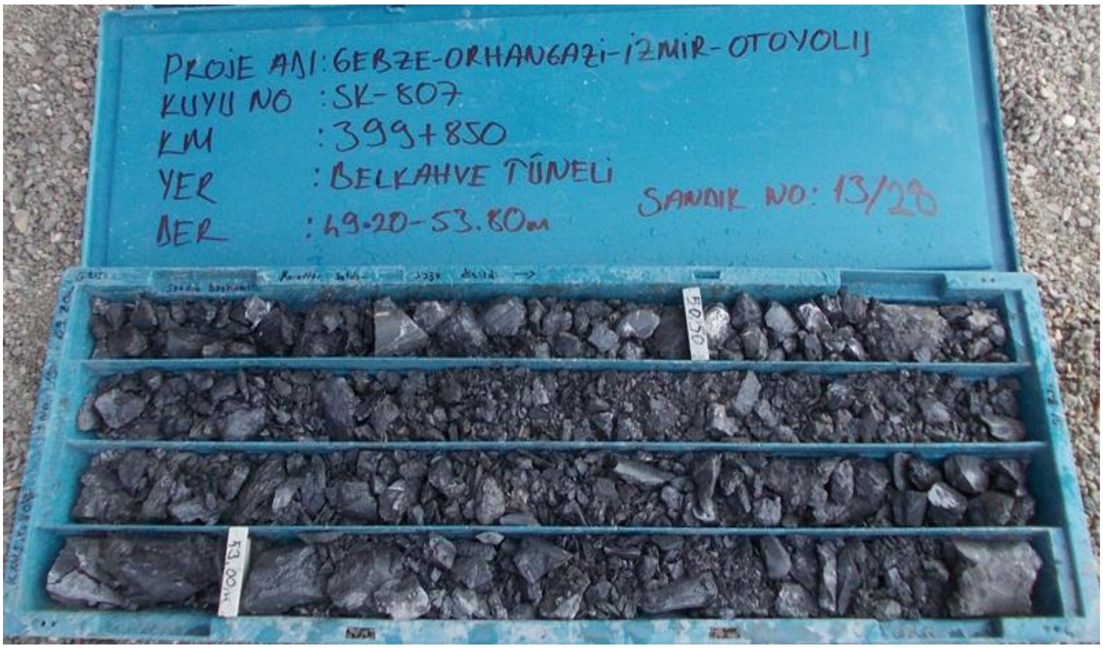

PROJE ADI = GEBZE
KUYU NO = 807
KM = 399+850
YER = BEIKAHVE TÜNELİ
DER = 28,90m - 33,00
S NO: 8
30.50
31.50m


PROJE ADI =GEBZE-ORHANGAZİ-İZMİR
KUYU NO =807
KM =399+850
DER =33,00m-37,00m
S.NO=9


KUYU NO =807
KM =399+850
DER =37.00-41.00m


PROJE ADI=GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO =807
KM 399+850
YER =BELKAHVE TÜNELİ
DER. =41.00-45.10 m.
S NO=11


PROJE ADI=GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO=807
KM 399+850
YER =BELKAHVE TÜNELİ
DER =45.10-49.20
S NO 12


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 49.20-53.80m
SANDIK NO: 13/28


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 53.80-57.90m
SANDIK NO: 14/28


PROJE ADI=GEBZE ORHANGAZİ İZMİR OTOYOLU
KUYU NO =807
KM
YER =BELKAHVE TÜNELİ
DER
5830
5850
6050


PROJE ADI=GEBZE ORHANGAZİ İZMİR OTOYOLU
KM =393.850
YER =BELKAHVE TÜNELİ
DER =62.00-67.00
S.NO=16/28


PROJE ADI = GEBZE ORHANGAZİ İZMİR OTOYOLU
KUYU NO SK = 807
KM = 399.850
YER = BELKAHVE TÜNELİ
DER = 67.00-72.00
S NO = 17/28


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO: SK-807
KM: 399+850
YER: BELKAHVE TÜNELİ
DER: 72.00-77.00m
SANDIK NO: 18/28


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 77.00-82.00m
SANDIK NO: 19/28


PROJE ADI: GEBZE-ORHANGAZİ- İZMİR- OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 82.00- 87.10m
SANDIK NO: 20/28

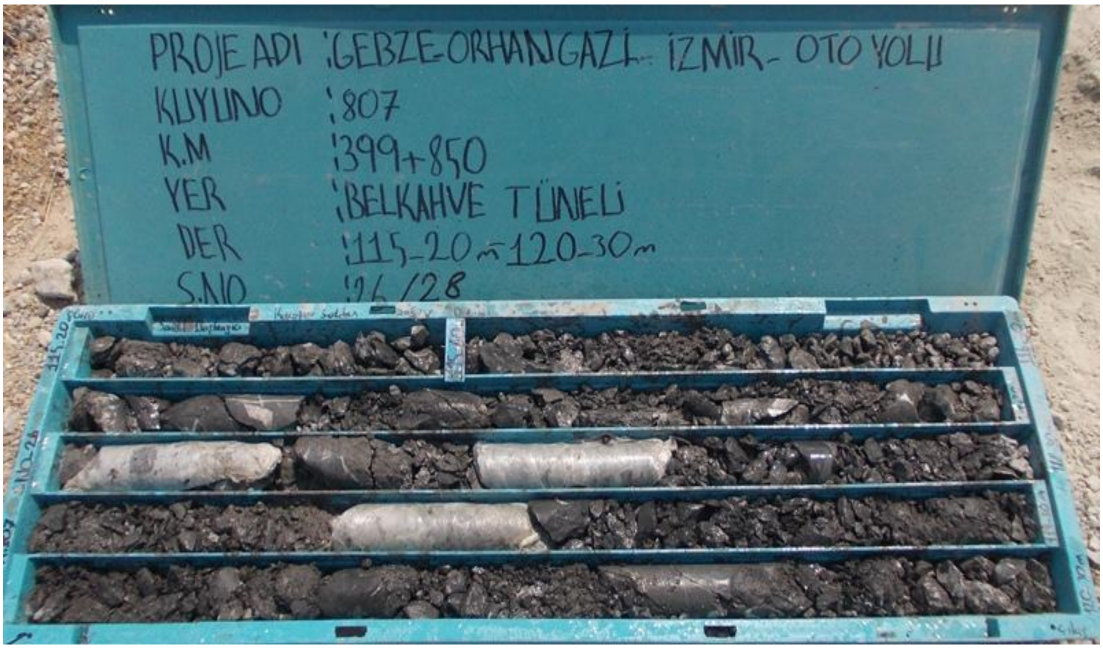

PROJE ADI : GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
KM :399+850
YER :BELKAHVE TÜNELİ
DER :87.10-92.00m
SANDIK NO: 21/28

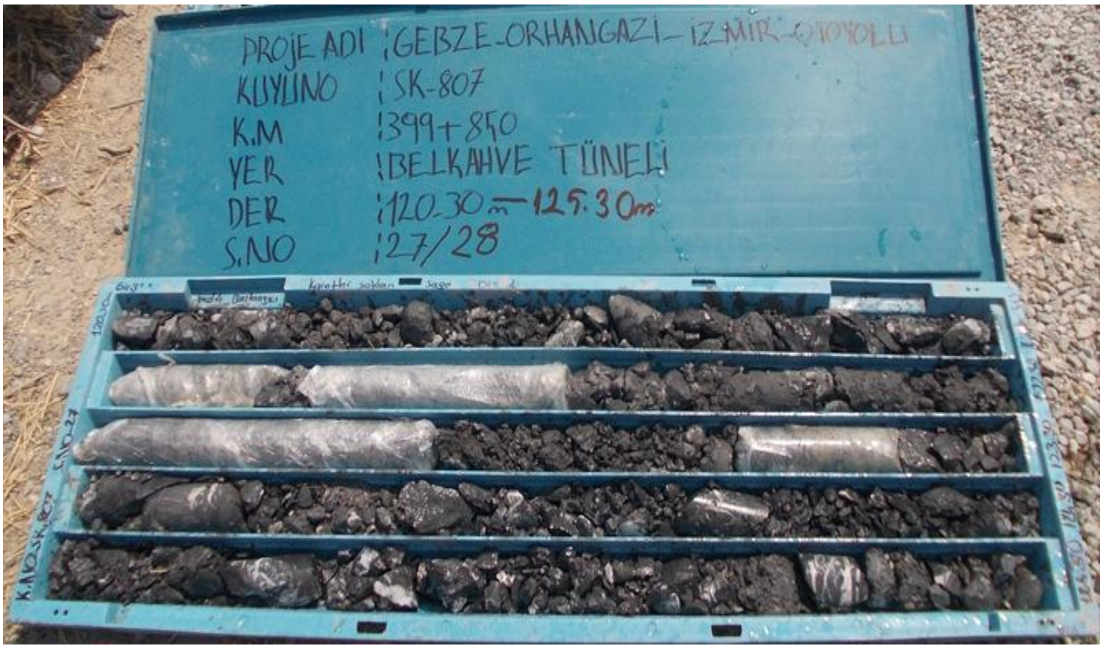

PROJE ADI : GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 92.00-97.80m.
SANDIK NO: 22/28


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
KM : 399+850
YER : BELKAHVE TÜNELİ
DER : 97.80 - 103.10m
SANDIK NO: 23/28


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-807
K.M : 399+850
YER : BELKAHVE TÜNELİ
DER : 103.10m - 109.50m
S.NO : 24/28

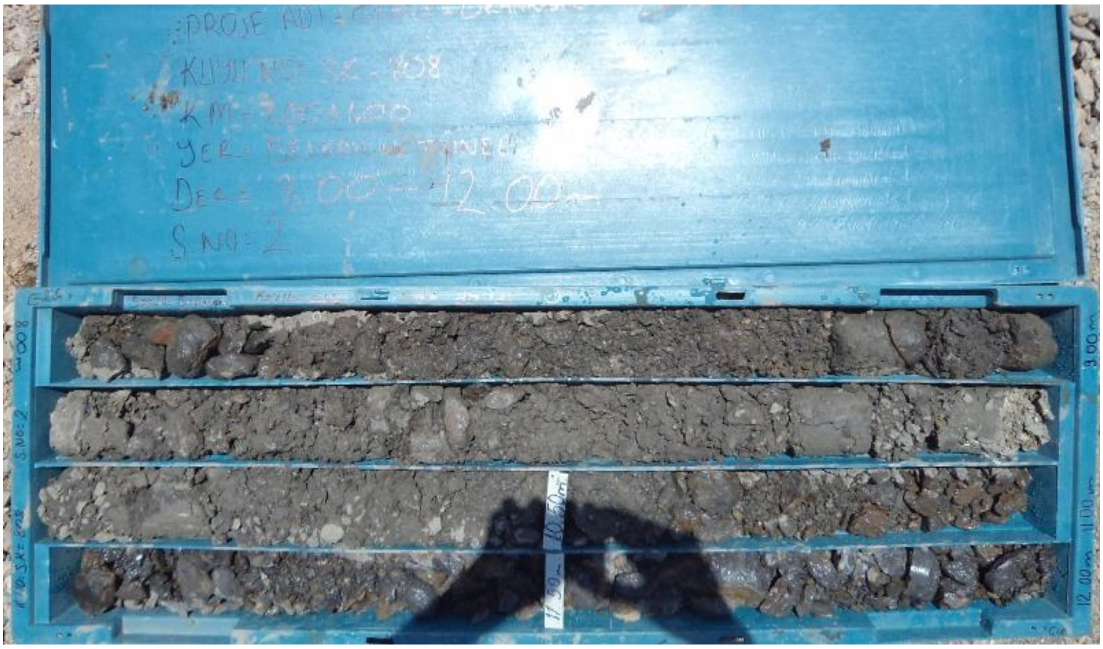

PROJE ADI :GEBZE-ORHANGAZİ- İZMİR-OTOYOLU
KUYUNO :SK-807
K.M :399+850
YER :BELKAHVE TÜNELİ
DER :109-50-115-20m
S.NO :25/28


PROJE ADI :GEBZE-ORHANGAZİ- İZMİR- OTO YOLU
KUYUNO :807
K.M :399+850
YER :BELKAHVE TÜNELİ
DER :115-20m-120-30m
S.NO :26/28


PROJE ADI : GEBZE-ORHANGAZI-IZMIR-OTOYOLU
KUYU NO : SK-807
K.M : 399+850
YER : BELKAHVE TÜNELI
DER : 120.30m – 125.30m
S.NO : 27/28


PROJE ADI : GEBZE-ORHANGAZI-IZMIR-OTOYOLU
KUYU NO : SK-807
K.M : 399+850
YER : BELKAHVE TÜNELI
DER : 125.50m – 128.00m
S.NO : 28/28 BİTİŞ TARİHİ = 26-07-2012.
128.00

SK-808




KUYU NO : SK-808
KM : 600+600
YER : BELKAHVE TÜNELİ
DER : 12.00-16.00m
SANDIK NO:
12.00m
13.00m
13.75
14.45m
15.00m
15.80m
16.00m


KUYU NO : SK-808
K.M : 600+600
YER : BELKAHVE
DER. 16.00-20.00m
SANDIK NO: 4
16.00
17.15m
18.35
20.00m


PROJE ADI
KUYU NO
SK-808
KM
YER
DER
21.70m
22.35
23.45


PROJE ADI
KUYU NO
KM
YER
DER
23.55
24.65
25.00m
25.90
26.20m
27.10
27.55


KUYU NO
K.M
YER
DER
27.55-31.50m
28.55m
29.35
30.55
31.50m


KUYU NO = 808
K.M = 400+400
YER = BELKAHVE TÜNELİ
DER = 31.50-35.30m
S NO = 8
31.50m
31.70m
32.50m
33.80m
35.15
35.30m


KM
YER
DER
S.NO- 9
38.50m
38.90


KM
YER
DER
S-NO-10
40.50m


43.50m


K.NO= 808
KM= 400+400
YER= BELKAHUE TÜNELİ
DFR=46.85m 50.85m
S.NO= 12
S.NO= 12


YER =DELKAHVE TÜNELİ
SANDIK NO =13
51.50m


S.NO. 14/25
55.40
56.00


PROJE ADI = GEBZE-
KUYU NO = 808
KM = 400+400
YER = BELKAHVE
DER = 58,50m - 62,50m
S.NO=15
59,60m
62,00m


PROJE ADI = GEBZE-ORHANGAZI-
KUYU NO = 808
KM = 400+400
YER = BELKAHVE
DER = 62,50m - 66,50m
S.NO=16
65,00m


PROJE ADI=GEBZE-
KUYU NO=808
KM =400+400
YER =BELKAHVE
DER =66.50-70.50
S.NO-17
68.00


PROJE ADI=GEBZE-ORHANGAZİ-İZMİR OTO YOLU
KUYU NO=808
KM =400+400
YER =BELKAHVE TÜNEL
DER =70.50-74.00 M
S.NO=18/25
71.00
74.00


PROJE ADI = GEBZE - ORHANGAZİ - İZMİR OTO YOLU
KUYU NO = 808
KM = 400+600
YER = BELKAHVE
DER = 74.00 - 78.00 m
S.NO = 19/25


PROJE ADI = GEBZE - ORHAN GAZİ - İZMİR OTOYOLU
KUYU NO = 808
KM = 400+600
YER = BELKAHVE TÜNELİ
DER = 78.00 — 82.00
SANDIK NO: 20/25


PROJE ADI =GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO =808
KM =400+400
YER =BELKAHVE TÜNELİ
DER =82.00—86.00
SANDIK NO: 21/25


PROJE ADI =GEBZE-ORHANGAZİ İZMİR
KUYU NO =808
KM =400+400
YER =BELKAHVE TÜNELİ
DER =86.00—90.00
S.NO: 22/25


PROJE ADI
KUYU
KM
YER
DER
S.NO=23


PROJE ADI = GEBZE- ORHANGAZİ - İZMİR - OTO YOLU
KUYU NO = 808
KM = 400+400
YER
TÜNEL
DER
98.00
S.NO:24/25


PROJE ADI = GEBZE-ORHANGAZİ-İZMİR OTO YOLU
KUYU NO = 808
KM = 400+400
YER = BELKAHVE TÜNELİ
DER = 98.00-100.00
S.NO=25/25 KUYU SONU
Bit. Tarihi: 01-07-2012
Baş. Tarihi = 25-06-2012

SK-809


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK: 0.00-6.10m
SANDIK NO: 1/
1.50
3.00
4.00
4.60
6.10


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK: 6.10-
SANDIK NO: 2/


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 13.00-21.10
SANDIK NO: 3/


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK: 21.10-25.50m
SANDIK NO: 4/
23.00
24.00


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK:
SANDIK NO: 5/
26.50
27.00


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR-OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 30.50-
SANDIK NO: 6/


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 35.80-40.50
SANDIK NO: 7/

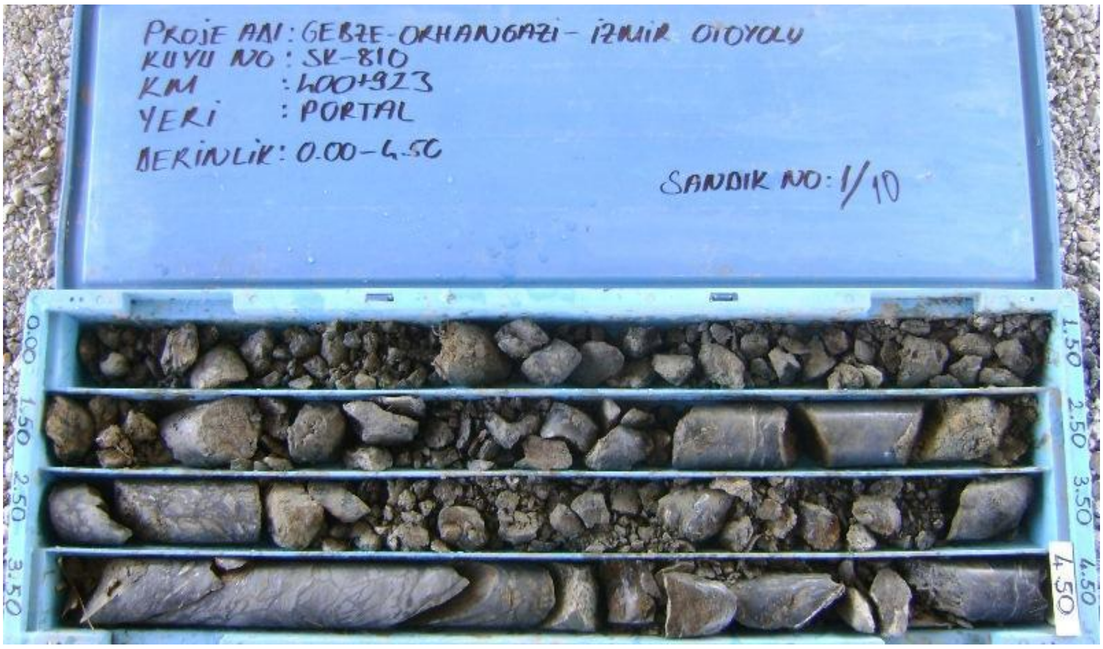

PROJE ADI : GEBZE-ORHANGAZİ-İZMİR OTOYOLU
SONDAJ NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 40.50-44.00m
SANDIK NO: 8/


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR OTOYOLU
SONDAJ NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 44.00-50.00m
SANDIK NO: 9/


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 50.00-56.50m
SANDIK NO: 10/
51.00
52.50
53.50


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-809
KM : 400+600
YERİ : BELKAHVE TÜNELİ
DERİNLİK : 56.50-59.00m
SANDIK NO: 11/
59.00

SK-810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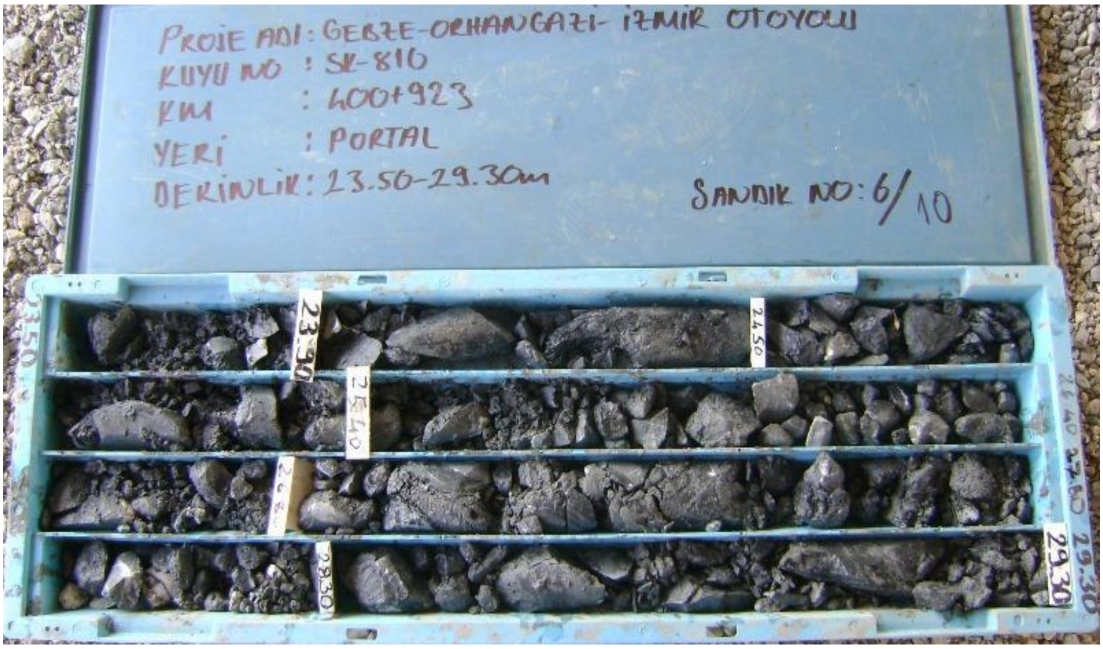
KUYU NO : SK-810
KM : 400+923
YERİ : PORTAL
DERİNLİK : 0.00-4.50
SANDIK NO: 1/10


PROJE ADI : GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO : SK-810
KM : 400+923
YERİ : PORTAL
DERİNLİK : 8.50-13.50
SANDIK NO: 3/10


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM : 400+923
YERİ : PORTAL
DERİNLİK: 13.50-19.30m
SANDIK NO: 4/10


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM: 400+923
YERİ : PORTAL
DERİNLİK: 19.30-23.50
SANDIK NO: 5/10


PROJE ADI: GEBZE-ORHANGAZİ- İZMİR OTOYOLU
KUYU NO : SK-810
KM : 400+923
YERİ : PORTAL
DERİNLİK: 23.50-29.30m
SANDIK NO: 6/10


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM: 400 + 923
YERİ: PORTAL
DERİNLİK: 29.30-34.30
SANDIK NO: 7/10


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM: 400+923
YERİ: PORTAL
DER: 34.30 - 39.00
SANDIK NO: 8
36.00
37.50
38.00
38.50
39.00


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM: 400+923
YERİ: PORTAL
DER: 39.00 - 46.00
SANDIK NO: 9/10
39.00
39.50
40.50
41.50
42.50
43.00
44.00
45.00
46.00


PROJE ADI: GEBZE-ORHANGAZİ-İZMİR OTOYOLU
KUYU NO: SK-810
KM: 400+923
YERİ: PORTAL
DER: 46,00 - 47,50
SANDIK NO: 10/10
47,50

APPENDIX C:

LABORATORY TEST RESULTS

limit

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90 312) 394 53 64 e-mail : lab@limitteknik.com

LABORATUVAR DENEYLERİNİN SONUÇLARI (KAYA)
RESULTS OF LABORATORY TESTS (ROCK)

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

Rapor Tarihi / *Report Date* : 10.10.2012
Numune Geliş Tarihi / *Sample Receive Date* : 15.09.2012
Lab. Kayıt No / *Lab. Registration No.* : LMT12-09-07
Bakanlık Kayıt No / *Ministry Registration No.* : 3368264

Kuyu / AÇ No *Borehole / T.Pit No*	Örnek No *Sample No*	Derinlik *Depth*		Su Muhtevası *Moisture Content*	Doğal Birim Hacim Ağırlık *Natural Unit Weight*	Kuru Birim Hacim Ağırlık *Dry Unit Weight*	Özgül Ağırlık *Specific Gravity*	Boşluk Oranı *Void Ratio*	Porozite *Porosity*	Su Emme *Water Absorbtion*	Görünür Porozite *Apparent Porosity*	Tek Eksenli Basınç Dayanımı *Uniaxial Compressive Strength*	Elastisite Modülü *Elastic Modulus*	Poisson Oranı *Poisson's Ratio*	Üç Eksenli Basınç Dayanımı Deneyi *Triaxial Compressive Strength Test*		Nokta Yük İndeksi *Point Load Index*	İndirek Çekme Day. (Brazilian) *Indirect Tensile Str. (by Brazilian) Test*	Notlar *Notes*
		m.'den *from*	m.'ye *to*	W_n	γ_n	γ_d	G_s	e	n	I_v	n_a	q_u	E	υ	c	ϕ	$I_{s(50)}$	σ_T	
				%	g/cm³	g/cm³	-	-	%	%	%	kg/cm²	GPa	-	kg/cm²	°	MPa	MPa	
SK-805	RC-11	17.30	18.80	3.14	1.64	1.59						1*					0.08		
SK-805	RC-26	32.50	34.00	1.20	2.65	2.62											0.30		
SK-805	RC-29	36.00	37.50	0.49	2.70	2.68						349.63	22.04	0.23					
SK-805	RC-33-34	41.50	44.20	1.09	1.90	1.88						1*	1*	1*			0.12		
SK-805	RC-38	46.90	48.20	3.79	1.64	1.58											0.66		
SK-805	RC-40	49.40	50.55	0.70	2.68	2.66						785.25	61.77	0.32					
SK-805	RC-44-48	52.70	57.00	0.12	2.72	2.72											2.65		
SK-805	RC-64-65	73.40	75.00	0.72	2.72	2.70											4.05		
SK-807	RC-17	22.50	23.50	0.42	2.66	2.65						546.83	57.11	0.18					
SK-807	RC-24	31.50	33.00	0.10	2.68	2.68											1.72		
SK-807	RC-27	39.00	41.00	0.65	2.65	2.63						459.60	36.50	0.24					
SK-807	RC-32	47.20	47.80	0.59	2.68	2.66						781.55	58.96	0.21					
SK-807	RC-37-39	53.00	56.80	0.17	2.70	2.69											1.64		
SK-807	RC-50	70.40	72.00	0.82	2.70	2.68											0.37		
SK-807	RC-52	72.70	75.20	0.43	2.82	2.81						132.93	5.18	0.21					
SK-807	RC-53-54	75.20	77.00	0.31	2.66	2.65											1.21		
SK-807	RC-57	82.00	83.20	0.15	2.66	2.66											3.28		
SK-807	RC-64	87.40	88.30	0.38	2.71	2.70						1575.09	52.10	0.21					
SK-807	RC-67	90.00	92.00	0.19	2.65	2.64											3.75		
SK-807	RC-75-76	97.00	99.20	0.37	2.74	2.73											3.45		
SK-807	RC-80	102.10	103.50	0.08	2.68	2.68											5.30		
SK-807	RC-83	105.60	106.50	3.86	2.33	2.24						1*	1*	1*					
SK-807	RC-86-87	108.20	110.50	0.26	2.64	2.63											4.47		
SK-807	RC-88	110.50	112.50	0.47	2.70	2.69						1086.72	50.92	0.19					
SK-807	RC-89-90	112.50	115.60	1.09	2.71	2.68											1.18		

Açıklamalar / *Remarks* : **Not 1* :** Örnek kesilirken kırıldığı için deney yapılamamıştır.

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :

1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

Sayfa / Page : 1 / 42

FORM No: K1

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

LABORATUVAR DENEYLERİNİN SONUÇLARI (KAYA)
RESULTS OF LABORATORY TESTS (ROCK)

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

Rapor Tarihi / *Report Date* : 10.10.2012
Numune Geliş Tarihi / *Sample Receive Date* : 15.09.2012
Lab. Kayıt No / *Lab. Registration No.* : LMT12-09-07
Bakanlık Kayıt No / *Ministry Registration No.* : 3368264

Kuyu / AÇ No *Borehole / T.Pit No*	Örnek No *Sample No*	Derinlik *Depth* m.'den *from*	m.'ye *to*	Su Muhtevası *Moisture Content* W_n (%)	Doğal Birim Hacim Ağırlık *Natural Unit Weight* γ_n (g/cm³)	Kuru Birim Hacim Ağırlık *Dry Unit Weight* γ_d (g/cm³)	Özgül Ağırlık *Specific Gravity* G_s (-)	Boşluk Oranı *Void Ratio* e (-)	Porozite *Porosity* n (%)	Su Emme *Water Absorbtion* I_v (%)	Görünür Porozite *Appearant Porosity* n_a (%)	Tek Eksenli Basınç Dayanımı *Uniaxial Compressive Strength* q_u (kg/cm²)	Elastisite Modülü *Elastic Modulus* E (GPa)	Poisson Oranı *Poisson's Ratio* υ (-)	Üç Eksenli Basınç Dayanımı Deneyi *Triaxial Compressive Strength Test* c (kg/cm²)	ϕ (°)	Nokta Yük İndeksi *Point Load Index* $I_{s(50)}$ (MPa)	İndirek Çekme Day. (Brazilian) *Indirect Tensile Str. (by Brazilian) Test* σ_T (MPa)	Notlar *Notes*
SK807	RC-93-94	117.30	119.30	1.59	2.68	2.64						1*					6.32		
SK807	RC-97-98	121.30	123.30	1.92	2.55	2.50						1*	1*	1*			3.67		
SK808	RC-18-20	18.35	22.35	0.88	2.60	2.57						131.30					0.16		
SK808	RC-31	30.55	31.70	3.15	2.37	2.30						1*	1*	1*					
SK808	RC-36	36.30	38.50	0.47	2.54	2.53						87.02	7.22	0.40					
SK-808	RC-40	45.50	48.50	0.74	2.68	2.66						813.82	69.73	0.32					
SK-808	RC-44	55.40	56.00	0.87	2.68	2.65						514.94	76.42	0.25			3.22		
SK-808	RC-47	59.60	62.00	0.84	2.69	2.67						320.17	52.05	0.33					
SK-808	RC-49-50	65.00	71.00	0.67	2.68	2.66						551.09	54.95	0.27			2.34		
SK-808	RC-52-53	74.00	80.00	0.84	2.67	2.65						462.53	44.77	0.26			3.35		
SK-808	RC-55	83.00	86.00	0.77	2.70	2.68						192.85	54.15	0.32					
SK-808	RC-58-59	90.00	96.00	0.78	2.54	2.52						270.28	38.17	0.40			3.05		
SK-809	RC-5-6	4.60	6.80	0.15	2.70	2.70											5.70		
SK-809	RC-10-12	9.50	12.50	0.20	2.72	2.72											5.46		
SK-809	RC-15-18	14.00	16.70	0.17	2.81	2.81											5.47		
SK-809	RC-26-27	20.40	22.30	0.78	2.65	2.63						454.34	31.39	0.20			7.57		
SK-809	RC-31	24.00	24.50	0.48	2.67	2.66						645.43	43.07	0.28					
SK-809	RC-36	27.00	28.00	0.23	2.67	2.66											3.59		
SK-809	RC-38-40	28.40	31.00	0.23	2.71	2.70											1.11		
SK-809	RC-44-45	33.30	35.80	2.45	2.14	2.09						1*	1*	1*			0.07		
SK-809	RC-50	38.50	39.50	3.49	2.28	2.21						55.11	1.93	0.27					
SK-809	RC-52	40.50	41.50	3.18	2.12	2.05						1*	1*	1*					
SK-809	RC-56-57	43.10	44.50	0.29	2.72	2.71											4.54		
SK-809	RC-59	45.20	45.70	0.35	2.65	2.64						1*	1*	1*					
SK-809	RC-61-63	46.50	48.50	0.21	2.68	2.67											3.41		

Açıklamalar / *Remarks* : **Not 1* :** Örnek kesilirken kırıldığı için deney yapılamamıştır.

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz / *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011 provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

Sayfa / Page : 2 / 42

FORM No: K1

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

LABORATUVAR DENEYLERİNİN SONUÇLARI (KAYA)
RESULTS OF LABORATORY TESTS (ROCK)

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

Rapor Tarihi / *Report Date* : 10.10.2012
Numune Geliş Tarihi / *Sample Receive Date* : 15.09.2012
Lab. Kayıt No / *Lab. Registration No.* : LMT12-09-07
Bakanlık Kayıt No / *Ministry Registration No.* : 3368264

Kuyu / AÇ No / *Borehole / TP No*	Örnek No / *Sample No*	Derinlik / *Depth*		Su Muhtevası / *Moisture Content*	Doğal Birim Hacim Ağırlık / *Natural Unit Weight*	Kuru Birim Hacim Ağırlık / *Dry Unit Weight*	Özgül Ağırlık / *Specific Gravity*	Boşluk Oranı / *Void Ratio*	Porozite / *Porosity*	Su Emme / *Water Absorbtion*	Görünür Porozite / *Appearant Porosity*	Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	Elastisite Modülü / *Elastic Modulus*	Poisson Oranı / *Poisson's Ratio*	Üç Eksenli Basınç Dayanımı Deneyi / *Triaxial Compressive Strength Test*		Nokta Yük İndeksi / *Point Load Index*	İndirek Çekme Day. (Brazilian) / *Indirect Tensile Str. (by Brazilian) Test*	Notlar / *Notes*
		m.'den / *from*	m.'ye / *to*	W_n	γ_n	γ_d	G_s	e	n	I_v	n_a	q_u	E	υ	c	ϕ	$I_{s(50)}$	σ_T	
				%	g/cm³	g/cm³	-	-	%	%	%	kg/cm²	GPa	-	kg/cm²	°	MPa	MPa	
SK-805	RC-11	17.30	18.80	3.14	1.64	1.59						1*					0.08		
SK-805	RC-26	32.50	34.00	1.20	2.65	2.62											0.30		
SK-805	RC-29	36.00	37.50	0.49	2.70	2.68						349.63	22.04	0.23					
SK-805	RC-33-34	41.50	44.20	1.09	1.90	1.88						1*	1*	1*			0.12		
SK-805	RC-38	46.90	48.20	3.79	1.64	1.58											0.66		
SK-805	RC-40	49.40	50.55	0.70	2.68	2.66						785.25	61.77	0.32					
SK-805	RC-44-48	52.70	57.00	0.12	2.72	2.72											2.65		
SK-805	RC-64-65	73.40	75.00	0.72	2.72	2.70											4.05		
SK-807	RC-17	22.50	23.50	0.42	2.66	2.65						546.83	57.11	0.18					
SK-807	RC-24	31.50	33.00	0.10	2.68	2.68											1.72		
SK-807	RC-27	39.00	41.00	0.65	2.65	2.63						459.60	36.50	0.24					
SK-807	RC-32	47.20	47.80	0.59	2.68	2.66						781.55	58.96	0.21					
SK-807	RC-37-39	53.00	56.80	0.17	2.70	2.69											1.64		
SK-807	RC-50	70.40	72.00	0.82	2.70	2.68											0.37		
SK-807	RC-52	72.70	75.20	0.43	2.82	2.81						132.93	5.18	0.21					
SK-807	RC-53-54	75.20	77.00	0.31	2.66	2.65											1.21		
SK-807	RC-57	82.00	83.20	0.15	2.66	2.66											3.28		
SK-807	RC-64	87.40	88.30	0.38	2.71	2.70						1575.09	52.10	0.21					
SK-807	RC-67	90.00	92.00	0.19	2.65	2.64											3.75		
SK-807	RC-75-76	97.00	99.20	0.37	2.74	2.73											3.45		
SK-807	RC-80	102.10	103.50	0.08	2.68	2.68											5.30		
SK-807	RC-83	105.60	106.50	3.86	2.33	2.24						1*	1*	1*					
SK-807	RC-86-87	108.20	110.50	0.26	2.64	2.63											4.47		
SK-807	RC-88	110.50	112.50	0.47	2.70	2.69						1086.72	50.92	0.19					
SK-807	RC-89-90	112.50	115.60	1.09	2.71	2.68											1.18		

Açıklamalar / *Remarks* : Not 1* : Örnek kesilirken kırıldığı için deney yapılamamıştır.

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

limit

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

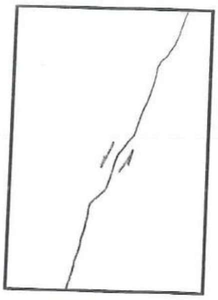
DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*
Firma Adı / *Company Name*	:	Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name*	:	Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date*	:	10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	:	SK-805
Örnek No / *Sample No*	:	RC-29
Derinlik / *Depth*	:	36.00 - 37.50

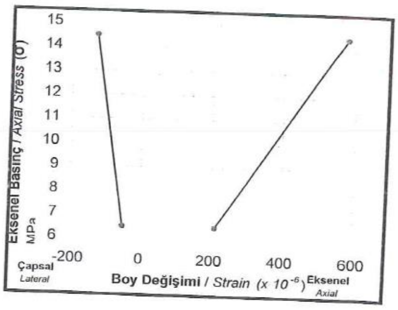
Örnek Çapı / *Sample Diameter*	:	6.30	cm
Örnek Boyu / *Sample Height*	:	14.44	cm
Örnek Alanı / *Sample Area*	:	31.17	cm²
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1214.40	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1208.50	gr
Örnek Hacmi / *Sample Volume*	:	450.13	cm³
Nem İçeriği / *Moisture Content*	:	0.49	%
Doğal BHA / *Natural Unit Weight*	:	2.70	gr/cm³
Kuru BHA / *Dry Unit Weight*	:	2.68	gr/cm³
Kırılma Yükü / *Failure Load*	:	10899.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**349.63**	kg/cm²

En Küçük Eksenel Basınç / *Min. Axial Stress,* σ_{min}	:	6.48	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain,* ε_{min}	:	214.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain,* $\varepsilon_{c\text{-}min}$	:	-48.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress,* σ_{max}	:	14.48	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain,* ε_{max}	:	577.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain,* $\varepsilon_{c\text{-}max}$	:	-132.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	22.04	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.23	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 15 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir.
Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.

FORM No: K5

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

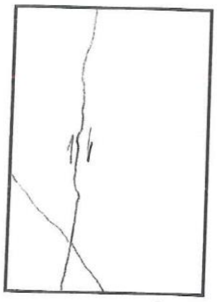
DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*
Firma Adı / *Company Name*	:	Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name*	:	Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date*	:	10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	:	SK-805
Örnek No / *Sample No*	:	RC-40
Derinlik / *Depth*	:	49.40 - 50.55

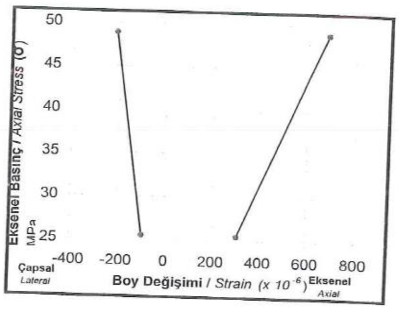
Örnek Çapı / *Sample Diameter*	:	6.32	cm
Örnek Boyu / *Sample Height*	:	13.40	cm
Örnek Alanı / *Sample Area*	:	31.37	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1126.50	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1118.70	gr
Örnek Hacmi / *Sample Volume*	:	420.37	cm^3
Nem İçeriği / *Moisture Content*	:	0.70	%
Doğal BHA / *Natural Unit Weight*	:	2.68	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.66	gr/cm^3
Kırılma Yükü / *Failure Load*	:	24634.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**785.25**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress,* σ_{min}	:	25.49	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain,* ε_{min}	:	307.00	x 10^{-6}
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain,* $\varepsilon_{c\text{-}min}$	:	-95.00	x 10^{-6}
En Büyük Eksenel Basınç / *Max. Axial Stress,* σ_{max}	:	48.90	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain,* ε_{max}	:	686.00	x 10^{-6}
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain,* $\varepsilon_{c\text{-}max}$	:	-215.00	x 10^{-6}
Elastisite Modülü / *Elastic Modulus* E	:	61.77	GPa
Poisson Oranı / *Poisson's Ratio* υ	:	0.32	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 2 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

limit — LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

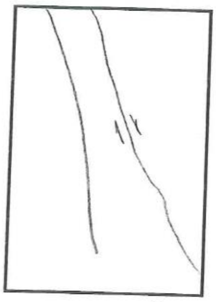
DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	: ISRM
Yöntem / *Method*	: Sünme ölçer ile / *With straingauge*
Firma Adı / *Company Name*	: Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name*	: Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date*	: 10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	: SK-807
Örnek No / *Sample No*	: RC-17
Derinlik / *Depth*	: 22.50 - 23.50

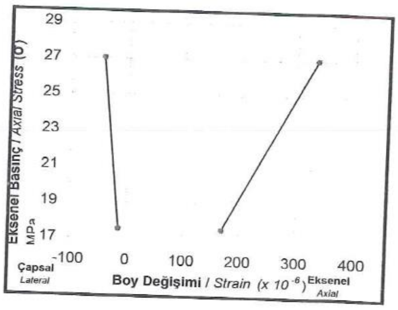
Örnek Çapı / *Sample Diameter*	:	6.30	cm
Örnek Boyu / *Sample Height*	:	13.22	cm
Örnek Alanı / *Sample Area*	:	31.17	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1095.30	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1090.70	gr
Örnek Hacmi / *Sample Volume*	:	412.10	cm^3
Nem İçeriği / *Moisture Content*	:	0.42	%
Doğal BHA / *Natural Unit Weight*	:	2.66	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.65	gr/cm^3
Kırılma Yükü / *Failure Load*	:	17046.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**546.83**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress*, σ_{min}	:	17.53	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain*, ε_{min}	:	170.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain*, $\varepsilon_{c\text{-}min}$	:	-13.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress*, σ_{max}	:	27.01	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain*, ε_{max}	:	336.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain*, $\varepsilon_{c\text{-}max}$	:	-43.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	57.11	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.18	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 18 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*	Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*	İnci GENÇ, Jeo. Müh./*Geo.Eng.*
	Belge / *Certificate* No:16275

Notlar / *Notes* :

1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 **Fax :** (90.312) 394 53 64 **e-mail :** lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No* : ISRM
Yöntem / *Method* : Sünme ölçer ile / *With straingauge*

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

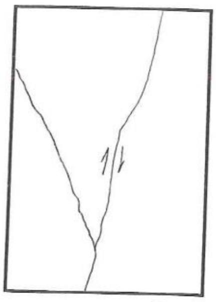
Rapor Tarihi / *Report Date* : 10.10.2012

Kuyu / Çukur No / *Borehole / T.Pit No* : SK-807 **Örnek No** / *Sample No* : RC-27 **Derinlik** / *Depth* : 39.00 - 41.00

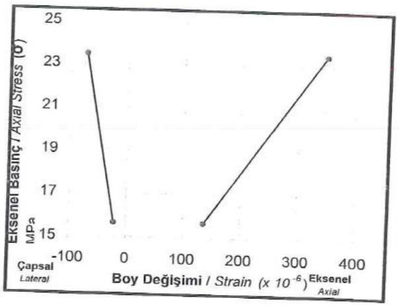
Örnek Çapı / *Sample Diameter*	:	6.32	cm
Örnek Boyu / *Sample Height*	:	14.56	cm
Örnek Alanı / *Sample Area*	:	31.37	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1208.70	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1200.90	gr
Örnek Hacmi / *Sample Volume*	:	456.76	cm^3
Nem İçeriği / *Moisture Content*	:	0.65	%
Doğal BHA / *Natural Unit Weight*	:	2.65	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.63	gr/cm^3
Kırılma Yükü / *Failure Load*	:	14418.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**459.60**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress, σ_{min}*	:	15.66	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain, ε_{min}*	:	137.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain, $\varepsilon_{c\text{-}min}$*	:	-21.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress, σ_{max}*	:	23.47	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain, ε_{max}*	:	351.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain, $\varepsilon_{c\text{-}max}$*	:	-73.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	36.50	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.24	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği / *Graph of Axial Stress - Axial/Lateral Strain*



Kırılma Açısı / *Failure Angle* : 11 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 **Fax :** (90.312) 394 53 64 **e-mail :** lab@limitteknik.com

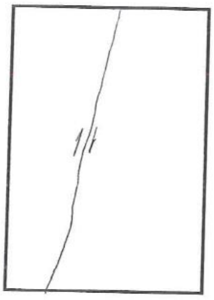
TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

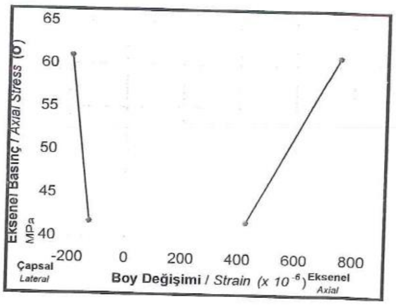
Standart No / *Standard No*	:	ISRM			
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*			
Firma Adı / *Company Name*	:	Yüksel Domaniç Mühendislik Ltd. Şti.			
Proje Adı / *Project Name*	:	Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)	**Rapor Tarihi** / *Report Date*	:	10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	:	SK-807	**Örnek No** / *Sample No*	:	RC-32
Derinlik / *Depth*	:	47.20 - 47.80			

Örnek Çapı / *Sample Diameter*	:	6.30	cm	**En Küçük Eksenel Basınç** / *Min. Axial Stress, σ_{min}*	:	41.74	MPa
Örnek Boyu / *Sample Height*	:	15.38	cm	**En Küçük Eksenel Birim Boy Değişimi** / *Min. Axial Strain, ε_{min}*	:	428.00	x 10^{-6}
Örnek Alanı / *Sample Area*	:	31.17	cm^2	**En Küçük Çapsal Boy Değişimi** / *Min. Lateral Strain, $\varepsilon_{c\text{-}min}$*	:	-124.00	x 10^{-6}
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1283.20	gr	**En Büyük Eksenel Basınç** / *Max. Axial Stress, σ_{max}*	:	60.96	MPa
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1275.70	gr	**En Büyük Eksenel Birim Boy Değişimi** / *Max. Axial Strain, ε_{max}*	:	754.00	x 10^{-6}
Örnek Hacmi / *Sample Volume*	:	479.43	cm^3	**En Büyük Çapsal Boy Değişimi** / *Max. Lateral Strain, $\varepsilon_{c\text{-}max}$*	:	-192.00	x 10^{-6}
Nem İçeriği / *Moisture Content*	:	0.59	%	**Elastisite Modülü** / *Elastic Modulus*	E :	58.96	GPa
Doğal BHA / *Natural Unit Weight*	:	2.68	gr/cm^3	**Poisson Oranı** / *Poisson's Ratio*	υ :	0.21	
Kuru BHA / *Dry Unit Weight*	:	2.66	gr/cm^3				
Kırılma Yükü / *Failure Load*	:	24363.00	kg				
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**781.55**	kg/cm^2				

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 8 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
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3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

limit

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 **Fax :** (90.312) 394 53 64 **e-mail :** lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	**Sünme ölçer ile** / *With straingauge*

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

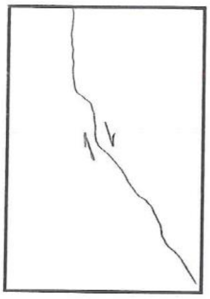
Rapor Tarihi / *Report Date* : 10.10.2012

Kuyu / Çukur No / *Borehole / T.Pit No*	: SK-807	**Örnek No** / *Sample No*	: RC-52	**Derinlik** / *Depth*	: 72.70 - 75.20

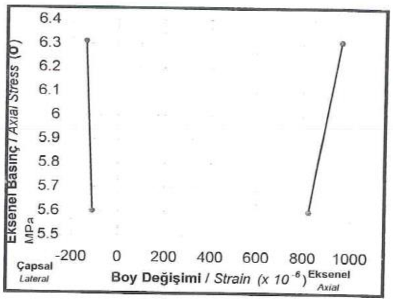
Örnek Çapı / *Sample Diameter*	:	4.72	cm
Örnek Boyu / *Sample Height*	:	10.30	cm
Örnek Alanı / *Sample Area*	:	17.50	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	509.10	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	506.90	gr
Örnek Hacmi / *Sample Volume*	:	180.22	cm^3
Nem İçeriği / *Moisture Content*	:	0.43	%
Doğal BHA / *Natural Unit Weight*	:	2.82	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.81	gr/cm^3
Kırılma Yükü / *Failure Load*	:	2326.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**132.93**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress,* σ_{min}	:	5.60	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain,* ε_{min}	:	825.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain,* $\varepsilon_{c\text{-}min}$	:	-109.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress,* σ_{max}	:	6.31	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain,* ε_{max}	:	962.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain,* $\varepsilon_{c\text{-}max}$	:	-138.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	5.18	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.21	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği / *Graph of Axial Stress - Axial/Lateral Strain*



Kırılma Açısı / *Failure Angle* : 17 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :

1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

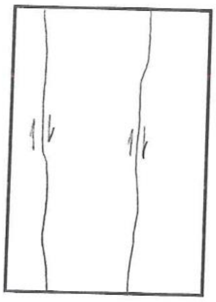
DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*
Firma Adı / *Company Name*	:	Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name*	:	Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date*	:	10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	:	SK-807
Örnek No / *Sample No*	:	RC-64
Derinlik / *Depth*	:	87.40 - 88.30

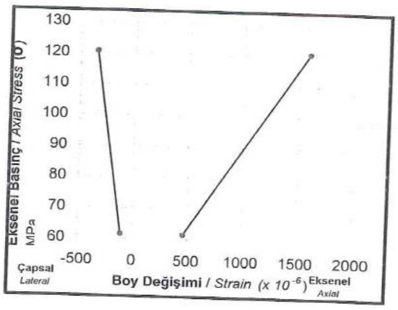
Örnek Çapı / *Sample Diameter*	:	4.72	cm
Örnek Boyu / *Sample Height*	:	13.92	cm
Örnek Alanı / *Sample Area*	:	17.50	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	659.60	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	657.10	gr
Örnek Hacmi / *Sample Volume*	:	243.56	cm^3
Nem İçeriği / *Moisture Content*	:	0.38	%
Doğal BHA / *Natural Unit Weight*	:	2.71	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.70	gr/cm^3
Kırılma Yükü / *Failure Load*	:	27560.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**1575.09**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress,* σ_{min}	:	61.48	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain,* ε_{min}	:	467.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain,* ε_{c-min}	:	-106.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress,* σ_{max}	:	120.61	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain,* ε_{max}	:	1602.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain,* ε_{c-max}	:	-348.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	52.10	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.21	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 1 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

limit

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 **Fax :** (90.312) 394 53 64 **e-mail :** lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.

Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)

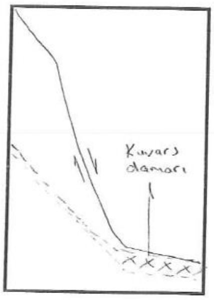
Rapor Tarihi / *Report Date* : 10.10.2012

Kuyu / Çukur No / *Borehole / T.Pit No* : SK-807 **Örnek No** / *Sample No* : RC-88 **Derinlik** / *Depth* : 110.50 - 112.00

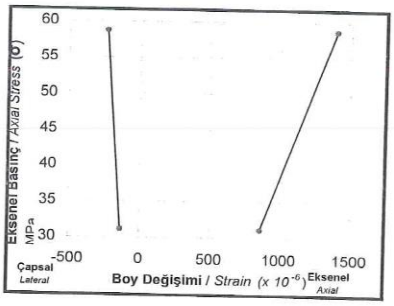
Örnek Çapı / *Sample Diameter*	:	4.70	cm
Örnek Boyu / *Sample Height*	:	12.66	cm
Örnek Alanı / *Sample Area*	:	17.35	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	593.20	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	590.40	gr
Örnek Hacmi / *Sample Volume*	:	219.64	cm^3
Nem İçeriği / *Moisture Content*	:	0.47	%
Doğal BHA / *Natural Unit Weight*	:	2.70	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.69	gr/cm^3
Kırılma Yükü / *Failure Load*	:	18854.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**1086.72**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress, σ_{min}*	:	31.13	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain, ε_{min}*	:	862.00	$x 10^{-6}$
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain, $\varepsilon_{c\text{-}min}$*	:	-132.00	$x 10^{-6}$
En Büyük Eksenel Basınç / *Max. Axial Stress, σ_{max}*	:	58.73	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain, ε_{max}*	:	1404.00	$x 10^{-6}$
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain, $\varepsilon_{c\text{-}max}$*	:	-233.00	$x 10^{-6}$
Elastisite Modülü / *Elastic Modulus*	E :	50.92	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.19	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 17 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :

1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5

LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 **Fax** : (90.312) 394 53 64 **e-mail** : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI DENEYİ (KAYA)
UNIAXIAL COMPRESSIVE STRENGTH TEST (ROCK)

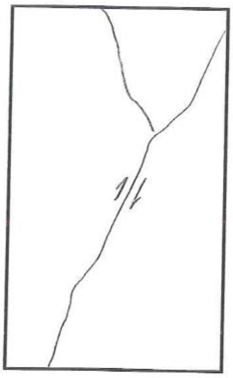
Standart No / *Standard No* : ISRM
Yöntem / *Method* : -

Firma Adı / *Company Name* : Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name* : Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date* : 10.10.2012

Kuyu / Çukur No / *Borehole / T.Pit No*	: SK-808	**Örnek No** / *Sample No*	: RC-18,19,20	**Derinlik** / *Depth*	: 18.35 - 22.35
Örnek Çapı / *Sample Diameter*	: 6.32 cm	**Örnek Boyu** / *Sample Height*	: 13.62 cm	**Örnek Alanı** / *Sample Area*	: 31.37 cm²
Yaş Örnek Ağırlığı / *Wet Sample Weight*	: 1109.00 gr	**Örnek Hacmi** / *Sample Volume*	: 427.27 cm³	**Nem İçeriği** / *Moisture Content*	: 0.88 %
Kuru Örnek Ağırlığı / *Dry Sample Weight*	: 1099.30 gr	**Doğal BHA** / *Natural Unit Weight*	: 2.60 gr/cm³	**Kuru BHA** / *Dry Unit Weight*	: 2.57 gr/cm³
Kırılma Yükü / *Failure Load*	: 4119.00 kg				

Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength* (q_u) : **131.30** kg/cm²

Kırılma şekli / *Mode of failure*



Kırılma Açısı / *Failure Angle* : 19 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :
1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir.
Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.

FORM No: K2

limit
LİMİT Teknik Araştırma, Proje, Uygulama, Müşavirlik, Sanayi ve Ticaret A.Ş.
İvedik OSB, 1354. Cadde, 1395. Sokak, No:1, 06378 Yenimahalle / Ankara / TÜRKİYE
Tel : (90.312) 394 53 63 Fax : (90.312) 394 53 64 e-mail : lab@limitteknik.com

TEK EKSENLİ BASINÇ DAYANIMI, ELASTİSİTE MODÜLÜ, POİSSON ORANI TAYİNİ DENEYİ (KAYA)

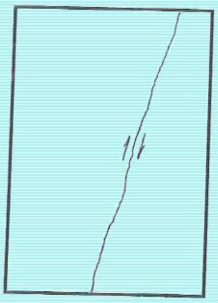
DETERMINATION OF UNIAXIAL COMPRESSIVE STRENGTH, ELASTIC MODULUS, POISSON'S RATIO (ROCK)

Standart No / *Standard No*	:	ISRM
Yöntem / *Method*	:	Sünme ölçer ile / *With straingauge*
Firma Adı / *Company Name*	:	Yüksel Domaniç Mühendislik Ltd. Şti.
Proje Adı / *Project Name*	:	Gebze - Orhangazi - İzmir (İzmit Körfez Geçişi ve Bağlantı Yolları Dahil) Otoyolu, Manisa - İzmir Kesimi, Belkahve Tüneli (KM: 398+300-402+500 Arası)
Rapor Tarihi / *Report Date*	:	10.10.2012
Kuyu / Çukur No / *Borehole / T.Pit No*	:	SK-808
Örnek No / *Sample No*	:	RC-40
Derinlik / *Depth*	:	45.50 - 48.50

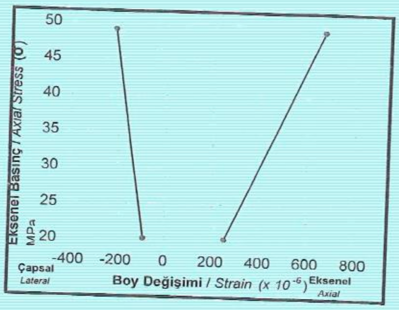
Örnek Çapı / *Sample Diameter*	:	6.32	cm
Örnek Boyu / *Sample Height*	:	14.34	cm
Örnek Alanı / *Sample Area*	:	31.37	cm^2
Yaş Örnek Ağırlığı / *Wet Sample Weight*	:	1205.00	gr
Kuru Örnek Ağırlığı / *Dry Sample Weight*	:	1196.20	gr
Örnek Hacmi / *Sample Volume*	:	449.86	cm^3
Nem İçeriği / *Moisture Content*	:	0.74	%
Doğal BHA / *Natural Unit Weight*	:	2.68	gr/cm^3
Kuru BHA / *Dry Unit Weight*	:	2.66	gr/cm^3
Kırılma Yükü / *Failure Load*	:	25530.00	kg
Tek Eksenli Basınç Dayanımı / *Uniaxial Compressive Strength*	:	**813.82**	kg/cm^2

En Küçük Eksenel Basınç / *Min. Axial Stress, σ_{min}*	:	20.14	MPa
En Küçük Eksenel Birim Boy Değişimi / *Min. Axial Strain, ε_{min}*	:	256.00	x 10^{-6}
En Küçük Çapsal Boy Değişimi / *Min. Lateral Strain, $\varepsilon_{c\text{-}min}$*	:	-88.00	x 10^{-6}
En Büyük Eksenel Basınç / *Max. Axial Stress, σ_{max}*	:	49.08	MPa
En Büyük Eksenel Birim Boy Değişimi / *Max. Axial Strain, ε_{max}*	:	671.00	x 10^{-6}
En Büyük Çapsal Boy Değişimi / *Max. Lateral Strain, $\varepsilon_{c\text{-}max}$*	:	-219.00	x 10^{-6}
Elastisite Modülü / *Elastic Modulus*	E :	69.73	GPa
Poisson Oranı / *Poisson's Ratio*	υ :	0.32	

Kırılma şekli / *Mode of failure*



Eksenel Basınç - Eksenel/Çapsal Boy Değişimi Grafiği
Graph of Axial Stress - Axial/Lateral Strain



Kırılma Açısı / *Failure Angle* : 7 °

Açıklamalar / *Remarks* :

Deney Sorumlu Mühendisi / *Test Responsible Engineer*
Karaca KARAKAŞ, Jeo. Müh./ *Geo.Eng.*

Lab. Denetçi Mühendisi / *Lab. Supervising Engineer*
İnci GENÇ, Jeo. Müh./*Geo.Eng.*
Belge / *Certificate* No:16275

Notlar / *Notes* :

1. Söz konusu deney sonuçları sadece test edilen deney numunelerine aittir. / *The test results belong only to the experimental samples brought to the laboratory.*
2. Deney sonuçları laboratuvarımız izni olmadan kısmen kopyalanamaz ve çoğaltılamaz./ *The test results can not be copied and reproduced without permission.*
3. Laboratuvarımız 4708 sayılı kanun gereği T.C.Çevre ve Şehircilik Bakanlığı Yapı İşleri Genel Müdürlüğü tarafından verilen 09/08/2011 tarih ve 316 No'lu laboratuvar izin belgesine sahiptir. *Our laboratory has permit number 316 dated 09/08/2011, provided by the General Directorate of Construction jobs ofMinistry of Environment and Urbanism in accordance with the Law 4708.*

FORM No: K5