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A Practical Classification to Sustainable Road Slope Stability Assessment, Alanya-Konya Roadway, Turkey: Case Study

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Abstract: Today, a vast range of slope stability analysis tools exist for both rock and mixed rocksoil slopes. As is well known, Rock mass classification systems (RMR, SMR,GSI, Q, CSMR..etc), can be used to assess rock slope stability, hence, this paper intended to employing SMR classification, to prove that a rigorous rock mass classification will give more reliable if uncertain parameters are dropped and considered indirectly. The present study was carried out of 14 rock cuts in which 3 different causes of instability (Planer, Wedge, Toppling) along Hadim – Gevne dam segment of the Konya –Alanya roadway,this road distingueshed with existence of different lithological units. However, the cut slopes are located within recrystallized limestone, hard to extremely hard and highly jointed. In order to determine engineering geological properties of the rocks exposed along the roadway, then assess stability of the cut slopes, fourteen cut slopes were detailed identified. During field investigation all field observations/measurements parameters were recorded, which involved a detailed discontinuity surveys discontinuity conditions, geometrical relationship between slope and rock discontinuities (dips angles and slope), slope excavation methods; and underground water condition. Based on the field observations, stability analyses of the cut slopes and SMR values concluded that the slopes can be categorized into partially stable (50%), unstable (30%) and completely unstable (20%) with probable planar failure mode (20%), toppling failure mode (27%) and wedge failure mode (53%) . To ensure slope stability of road cuts against failure, flattening with different angles, sometimes constructing rock block walls may also be adopted beneficially.
Keywords: Slope Stability analysis, Rock mass classification, SMR, field observations, Alanya-Konya roadway.

INTRODUCTION

Despite improvements in recognition, prediction and mitigative measures, slope stability failure is a part of landslides, still exact a heavy social, economic and environmental toll in mountainous regions [1].

Today, a vast range of slope stability analysis tools exist for both rock and mixed rock-soil slopes, in general. Slope stability failure occur due to many factors such as weathering effects, nature of slope geometry,discontinuities,weather condition (heavy and rainfall); and ongoing activity, in addition to seismicity could play a significant role in slope failure. Rock mass classification systems are a paramount importance to estimate rock mass conditions, provides results which correspond well with real stability conditions,then quantitatively classify the quality of the exposed rock mass slope stability to failure. One of most frequently used classification system, being the object of discussion in the present paper is Slope Mass Rating (SMR).

SMR is a geomechanics classification applied worldwide, developed by (Romana, 1985) for rock slope stability evaluation. Many researchers [2,3,4,5,6]; and consequently, several techniques and methods for slope stability evaluation have been proposed. This paper intended to employing SMR classification to prove that a rigorous rock mass classification will give more reliable if uncertain parameters are dropped and considered indirectly.

To fulfil this purpose,and then in order to determine engineering geological properties of the rocks exposed along the roadway, then assess stability of the cut slopes, fourteen cut slopes were detailed identified. During field investigation all field measurements parameters were recorded.

The present study was carried out of 14 rock cuts in which 3 different causes of instability (Planer, Wedge, Toppling) along Hadim – Gevne dam segment of the Konya – Alanya roadway,this road distingueshed with existence of different lithological units. The rock slopes of the selected case study are in rugged mountainous terrain (Taurus) well known with complex geological features.

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RMR_{basic} determination is made by rating five parameters are :1) rock strength, 2) rock quality, 3) Spacing, 4) Condition of discontinuities; and 5) groundwater conditions, Once the basic RMR_{basic} has been calculated, four new factors (f1, f2, f3, and f4) have to be taken into account to calculate the SMR index. These four factors depend on geometrical relationship between slope,rock discontinuities; and slope excavation methods. On based the field obsevations and SMR study results concluded that failure modes were controlled by discontinuities then can be categorized into partially stable, unstable and completely unstable with probable planar failure mode, toppling failure mode and wedge failure mode.

As a remedial measurements to ensure slope stability of road cuts against failure, flattening with different angles and sometimes constructing of rock block walls may also be adopted beneficially.

GEOLOGY

The investigated road segment is located within Central Taurus Belt, it is part of Konya – Alanya roadway,southwest of Turkey, between coordinates (36°58'52" N;52°32'32"E) and (36°44'54" N;32°27'55"E) as shown in Fig.1. Geologically, Hadim region was covered by shallow marine that resulted deposition of dolomite, dolomitic limestone and bioclastic limestones during the Early-Middle Cambrian, these units ranged in age from Upper Permian – Upper Jurassic [7] . The studied segment was a problematic due to the existence of lithological units with variable characters which mainly comprised of recrystallized and micritic limestone, dolomite – limestone, reefal limestone, conglomerate and Quaternary deposits. However, during field studies the observed cut slopes are located within recrystallized limestone, fossiliferous limestone, reefal limestone and dolomite – limestone with some clayey limestone, these units characterized with light gray to white, massive, hard to extremely hard and highly jointed. While the conglomerate beds consist of dominantly conglomerate with local sandstone and lacustrine marl layers. The conglomerate was reddish green, fine grained with subangular shape, slightly- moderately weathered and medium strong. Also, the researched stretch was an extensively deformed, this observed obviously by having major thrust fault named' Gevne thrust fault" which extrapolated by deeply valley named Gevne stream, as a weakness planes causing most of slope instabilities along this road. Therefore, most of the observed failure modes (planer, wedge, toppling) in the field were controlled by discontinuities. In addition to, there are a lot of critical climatic factors widely impact on roadways directly and indirectly such as seasonal rainfall events and snow coverage on open spaces [12]. These factors combined with the erosion and man-made activity,water courses and groundwater mainly causes to slope deformations.

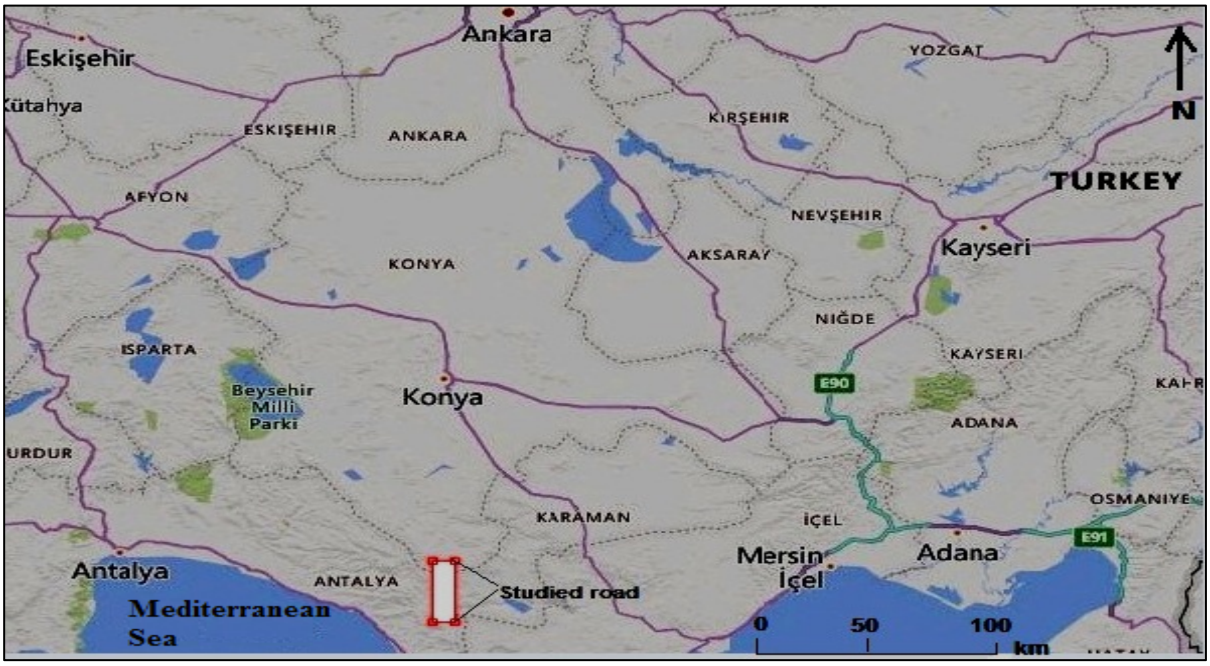

Figure 1. Locatio map of the studied road segment.

METHODOLOGY

In the present paper, Slope Mass Rating (SMR) after [8] had been used to determine the slope stability. To fulfil this purpose, a detailed field investigation has been carried out in the different selected localities of the study area. This investigation involved both quantitative and qualitative recording of various rock masses with an emphasis on collect all the geological and geotechnical data/measurements for both RMR and SMR assessment.RMRb index calculation include determination of the six parameters related to RMRb for an investigated slope, consequently, finding SMR values.

Accordingly, investigate and record, then finding Romana's rating adjustments (F1,F2,F3) and assess excavation method (F4) parameters, to determine the respective Slope Mass Rating, SMR values.

ROCK MASS CLASSIFICATIONS

Rock mass classifications are a universal communication system for engineers which provide quantitative data and guidelines for engineering purposes that can improve originally abstract descriptions of rock mass from inherent and structural parameters [9] by simple arithmetic algorithms. Some of rock mass classifications such as Q, RMR and MRMR systems have been applied successfully in tunneling and underground excavations. Some of these systems have been used for slopes (e.g. Q and RMR system) or have been modified for slopes (e.g. the RMS, SMR, SRMR and CSMR systems comprise modifications of the RMR system). Here, only the system used in the current study will be addressed.

Slope Mass Ratıng (SMR)

Slope Mass Rating (SMR) is a system of classification developed for slope stability by [1] as an application of RMR_{basic} [10,11]‘. RMR_{basic} Rating is computed by adding the ratings of five parameters are: Rock strength (UCS), rock quality designation (RQD), joint or discontinuity spacing, joint condition and ground water condition. Romana (1985) established a relationship to find ‘Slope Mass Rating ‘depending on the RMRbasic index [11] and a factorial adjustment factors that depict the geometrical relationship between discontinuities affecting the rock mass and the slope (F1,F2,F3); and the slope excavation method (F4). The final calculation is of the form:

$$SMR = RMRbasic + (F1.F2.F3) + F4 \qquad \text{(Equation 1)}$$

Where: (RMRbasic) is computed according to Bieniawski proposal by adding rating values [10] Adjustment rating for joints in rock slopes is a product of three factors:

F1 – depends on the angle between the discontinuity dip direction and slope dip direction. Values range from 1.00 to 0.15.

F2 – depends on the discontinuity dip angle, angle of inclination of the plane. It's value ranges from 1.00 to 0.15 . For the toppling mode of failure F2 remains 1.00.

F3 – depends on the difference (between the discontinuity and the slope dip angles for plane failure),and refers to relationship between dip of joint or plunge of intersection of two joints and the dip of slope. The adjustment factor for the method of excavation F4 depends on the excavation method. Based on the SMR results, the slopes are classified into different instability classes with risks descriptions according to Table.1.

Table 1. Description of SMR classes [8].

Class	SMR	Description	Stability	Failure probability
V	0- 20	Very bad	Completely unstable	0
IV	21-40	Bad	unstable	0.2
III	41-60	Fair	Partially stable	0.4
II	61-80	Good	stable	0.6
I	81-100	Very good	Completely stable	0.9

RESULTS AND DISSCUSION

The current study was meant to evaluate or assessment of slope stability with employing SRM classification system along secondary rodway, southwest of Turkey. Based on the obtained SMR results , then classified their stability and according to Table 1.

To fulfil this purpose a detailed field work was carried out during summer season (2018,2019) Year; regarding SRM joints slope measurements parameters at different studied locations is given in Table 2, After that,a calculated RMR_{basic} rating values were inserted in table 3 (ranges from **61** to **72**). İn the same Table, the obtained SMR results show that there is a noticeable decrease in the SMR scores , where most of the stability conditions have switched from unstable to partially stable.

Also,in this study, the stability condition of only three sites,5 and 6 sites changed from partially stable to unstable (see Table 4.).

The graphical SMR method results shows that some slopes have moderate to high RMR_{basic} values with good quality of rock mass,and it has positive correlation between joints - slope parameters and failure modes (planer, wedge, toppling).

In hence, and according to all obtained results, the probability of failure for all studied slopes have been estimated in table 4 too.

Finally,slope stability condition for all fourteen rock slopes were assessed and classified into three potential failure classes as illustrated in table 4., then represented in Figure 2.

It is worth mentioning,slope stability analysis were classified with taking into account multiple considerations of anticipated conditions during field study**.**

Table 2. Field observations for the selected fourteen cut slopes

Locations	**Slope orientation *DD / DA**	**Bedding plane**	**Joints orientation**		
		DD / DA	**J1 (DD / DA)**	**J2 (DD / DA)**	**J3 (DD / DA)**
L1-L2	089/41-68	210/34-35	322/70	045/80	098/90
L3-L6	087/30-37	180/30-35	180/82	030/83	140/87
L7-L8	105/34	255/37	125/80	040/72	115/ 70
L9-L11	115/44	270/40	135/87	045/56	085/85
L12-L14	112/40	220/31-40	325/82	055/85	030/64

*DD= *Dip direction*, DA = *Dip amount*.

Table 3 . Obtained SMR Rating values for studied rock cut slopes.

Locations	***RMR basic**	**The factorial adjustment factors**				**SMR rating**	**Obserefed failure modes**
		F1	F2	F3	F4		
L1-L2	69	0.85	0.85	-25	+8	58.93	Wedge
L3-L6	66	0.85	0.70*	-60	0	30.30	Planar
L7-L8	66	0.70	0.85	-50	0	36.25	Wedge
L9-L11	72	0.85	0.85	-25	0	53.93	Block failure
L12-L14	61	0.15	1.00	-6	+8	68.10	Toppling

RMR_b* = ∑(classification parameters) + Discontinuity orientation adjustment (R6).

Table 4: Slope stability analysis results of Hadim – Gevne roadway segment slopes.

Locations	**SMR** value**	**Class No.**	**Slope description**	**Stability**	**Failure Probability %**
L1-L2	58.93	III	Normal	Partially stable	40
L3-L6	30.30	IV	Bad	unstable	60
L7-L8	36.25	IV	Bad	unstable	60
L9-L11	53.93	III	Normal	Partially stable	40
L12-L14	68.10	II	Good	stable	20

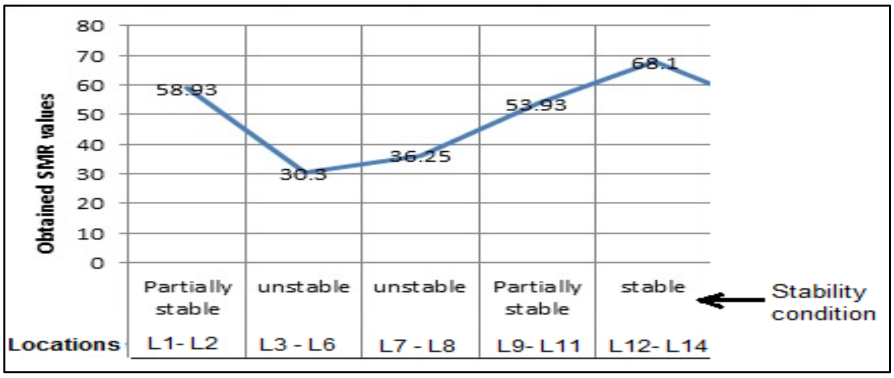

Figure 2. Slope stability condition for all fourteen rock slopes.

CONCLUSION

In present study, and by utilizing SMR classification (Romana,1985), the authors emphasize that the use of an SMR index is a very helpful tool in evaluating the quality of the exposed rock mass slope stability to failure.

Also, it was found that SMR can be applicable to thickly-massive and extremely rocks like massive limestone of this study, because this rock will need to a heavy blasting, this blasting creates new fractures in the rock slopes, So, the effects of the new fractures on rock slopes stability with (F4) factor can be estimated

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