

RESEARCH ARTICLE

ROCK MASS CLASSIFICATION SYSTEMS AND KINEMATIC ANALYSIS OF SLATES FROM DIR GROUP, NW, HIMALAYA, PAKISTAN; IMPLICATION FOR SLOPE STABILITY

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ABSTRACT

Slope stability is an important issue for the construction of roads on hill slopes. 24 slopes cuts have been investigated to determine the slope instability issues and mode of failure along the newly constructed road of Dir-Sheringal Khyber-Pakhtunkhwa, Pakistan. The major rocks are slates and tuffaceous siltstone which are weak to moderately strong in strength. The main objective of this study is to assess the application of rock mass classification systems and kinematic analysis which affects the slopes. The investigation shows that rock mass rating (RMR-basic), and slope mass rating (SMR) values range from 0 to 73 which is poor to normal while geological strength index (GSI) analysis classified the rock mass from poor to good conditions. The Kinematic analysis shows that three types (plane, wedge and topple) of failure mode are present in these slopes. Most of the slopes are unstable and weak where perspective tools and proper installation provide support and prevent future failure. This study shows a good relationship between RMR-basic, SMR, and GSI for different locations.

KEYWORDS

Slope, Kinematic Analysis, Stability RMR, SMR, GSI, Failure mechanism

1. INTRODUCTION

Rock slopes are one of the most important issues of road construction, especially in hilly and mountainous areas. Slopes are more liable to instability problems due to differences in the rock mass conditions, presence of different discontinuities, shear zones, fault, thrusts, unscientific way of slope cutting, heavy rainfall seismic and neo-tectonic activities (Bieniawski et al., 1979; Bieniawski, 1989; Ahmad et al., 2003). However, plane, wedge failures, rock topples, and rockfalls are common slope failures (Evert et al., 1981). A detailed geological investigation of any slope helps the civil engineer to design the proper support system to provide and mitigate the slope failures. A proper slope design not only leads to improvements in slope stability and safety but also reduces costs, extends the life of mines, and decreases the stripping ratio (Bieniawski, 1984; Bye et al., 2001).

Many researchers around the world have a great interest and widely used different classification techniques and methods for slope stability and rock mass classification systems. Rock mass classifications systems are frequently used methods by engineers that provide quantitative data and a good way for engineering purposes to provide original descriptions of rock mass from different structural parameters (Pantelidis, 2009). Rock mass classification systems have been commonly utilized in the field of engineering geology, particularly for the design purpose of the slope. They are widely used due to their simplicity and the limited need for detailed information (Duran et al., 2000). Various classification systems such as Rock Mass Rating; RMR Slope Mass Rating; SMR, Continuous Slope Mass Rating; CoSMR and Geological Strength Index; GSI are extensively used

methods for Rock Mass Classification (Bieniawski et al., 1979; Romana, 1985; Tomás et al., 2007; Evert et al., 1997).

In this study, three methods of rock mass classification system have been used which are Rock Mass Rating (RMR), Slope mass rating (SMR), and Geological Strength Index (GSI) (Hoek et al., 2013). Kinematic analysis can explain the possible mode of failure and potential along the slopes.

The current study has focused to investigate the slope cuts along the newly constructed road of Dir-Sheringal valley. Geological studies have been reported by many authors but, no work of engineering assessment is reported from the Dir group (Khan, 1979; Sullivan et al., 1993). Due to the poor blasting and mechanical excavation, many slopes and risky cuts have been generated along the road. Assessment of the selected slope has been conducted through different classification methods which give us different categories and descriptions of the selected slope cuts. Kinematic analysis was aimed to reveal the possible mode of failure and direction. All the results of the slope cut were examined to mark various zones that are prone to instability and determine failure reasons adversely affecting the newly constructed Dir-Sheringal Road.

2. LOCATION AND GEOLOGY OF THE STUDY AREA

Study area is located in northwestern Kohistan Island Arc (KIA), northern Pakistan (Figure 1. b). The selected slopes are located in a highly mountainous zone of [latitude 35°13' 03.43" N and longitude 71°58'25.73"E, an Elevation of 4220 feet] (Figure. 2) This road stretched specifically along the main road of Dir-Sheringal (N-45), near the village of Doon Payeen village in upper Dir, Khyber-Pakhtunkhwa (KP), Pakistan,

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which is easily accessible through the main Dir-Sheringal Road from Dir town (Figure 1. b). The climate of Sheringal and surrounding areas are humid to subtropical having moderate to severely cold temperatures in the winter season. From December to February a heavy snowfall occurs that causing a sudden drop in the temperature up to -4°C. Whereas in June to September the temperature ranges from 25°C-35°C with annual rainfall is recorded about 1468.8 mm (Pakistan Metrological Department, PMD). Due to this rainfall, different instability problems and failure mechanisms are present. Geologically, the Baraul Banda slate is a part of the Dir group of early Eocene age which is confined to the western half of the Kohistan arc terrain in northern Pakistan (Figure 1. c); (Kakar et al., 1971; Khan, 1979; Tahirkheli, 1979). The terrain forms a 10-15 km wide; 120 km long stretch from the Upper Swat valley southwestward. Dir group is moderate to steeply dipping, gently folded belt (Tahirkheli, 1979; Shah et al., 1999). Baraul Banda slates are greenish-grey, light grey, thin-bedded, fine, and silty in texture which is striking in the east-west while dipping in the North. Shiringal and Baraul Banda stream running along strike of the slates which also shows isoclinal fold and faulted contact with lower Shou Quartzite (Figure 1. c) (Tahirkheli, 1979).

3. MATERIALS AND METHODS

The investigated areas have been divided into six major zones which are represented as zone 1, 2, 3, 4, 5, and 6 respectively. Each major zone has been divided into subzones based on structural properties, alluvium cover, and shear zones (Figure 2). The total area of the selected zones is consisting of structural and nonstructural slopes. Structural slopes are divided into 24 subzones based on slope and discontinuities orientation (Table 1). All the zones are present along the newly constructed road of Dir-Sheringal (Figure 2). Methods used in this study depend upon the different classification systems of rock (RMR-basic, SMR, and GSI) which are further analyzed and compared with RMR values. In this study, 6 major zones were selected to find out the failure mode and stability condition of cut slopes along the roadside. The methodology used in this study starts from site selection of different slopes and rock cuts along the newly constructed road which show some failures (planner, wedges, and slides) mode (Figure 3). Field investigation includes the details of slope properties (height, location, orientation), (Table 1), rock type, joint spacing, alteration, and joint condition (infilling, aperture, roughness, weathering, water condition) (Table 1; Table 2).

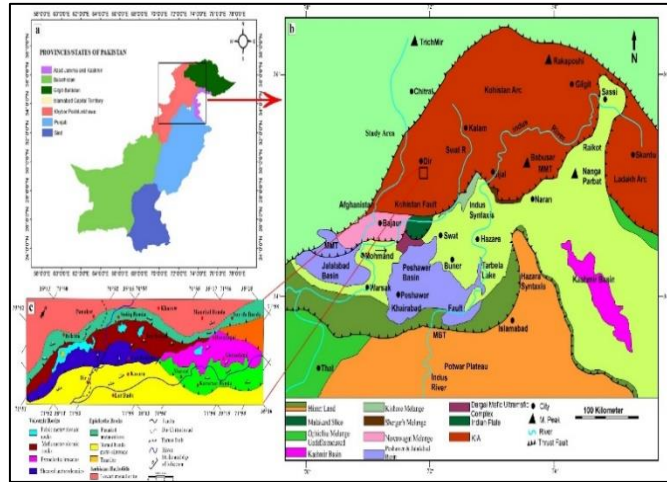


Figure 1: Show location of the study area and regional tectonic map of North Pakistan; (a) Provincial division of Pakistan after (Hassan et al., 2019); (b) Regional geology and tectonic map of Northwestern Pakistan modified after (Ahmad, Jan, & DiPietro, 2003); (c) Local geology and tectonic of Dir valley after (Shah and Shervais, 1999; Sullivan et al., 1993)

Table 1: Dip and strike of discontinuities and slopes.

Site No	Slope height (m)	Slope face [dip in (°)/ dip direction (°)]	Discontinuity [dip(°)/dip direction(°)]			
			J1	J2	J3	J4
Z1A	12	70/ 35	42/255	48/290		
Z1B	12	70/ 35	41/295	45/135	42/292	
Z1C	12	70/ 35	72/85			
Z1D	12	70/ 35	45/8	40/100	79/230	
Z1E	18	65/ 330	34/322			
Z1F	18	65/ 330	88/255	39/289	26/310	
Z1G	18	65/ 330	30/28	10/100		
Z1H	18	65/ 330	50/332	70/166	34/148	
Z2A	15	80/40	50/70	35/308		
Z3A	3	57/58	46/290	38/108		
Z3B	3	57/58	50/278	78/217	58/109	
Z4A	9	58/28	30/333	90/18		
Z4B	9	58/28	10/8	90/20		
Z4C	9	58/28	78/41			
Z4D	9	58/28	24/131	44/28		
Z5A	9	58/28	40/314	45/325	67/235	
Z5B	9	58/28	86/38	40/292		
Z5C	13	80/70	42/214	70/200		
Z5D	8	78/70	39/15	60/77	42/100	
Z5E	20	58/40	86/38	40/202		
Z5F	6	58/40	44/300	85/205		
Z5G	6	58/40	39/15	60/77	42/170	
Z6A	6	58/40	48/322	28/252	40/313	77/62
Z6B	6	58/40	41/295	45/135	42/292	

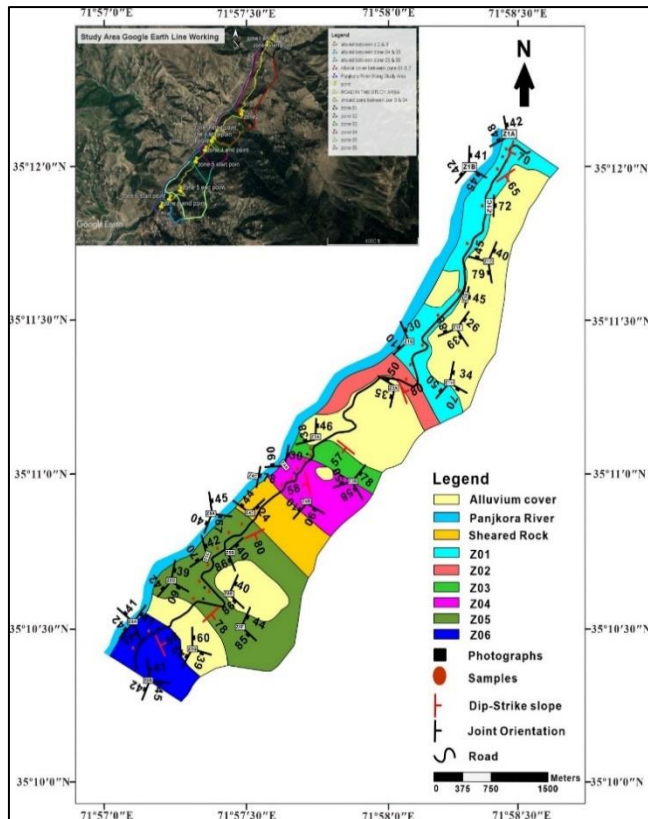


Figure 2: Google earth map and zonal division of the slopes in the study area.

Table 2: Show rating values for Rock Mass Classification of a slope.

Site No.	UCS	RQD %	Spacing (m)	Joints Condition					W.C	T. RMR	C. N	R. Q
				P	A	I	R	W				
Z1A	42	75	1.57	4.1	1.95	6	3	5	15	55	III	F
Z1B	35	72	1.17	3.42	2.66	4	3	5	15	48	III	F
Z1C	52	91	0.72	4.6	9.2	2	3	5	15	64	II	G
Z1D	34	100	3.35	6.78	3.75	6	3	5	15	76	II	G
Z1E	59	88	0.91	5.21	2.2	6	3	5	15	46	III	F
Z1F	31	95	0.89	18.13	3.6	2	6	5	15	40	IV	P
Z1G	65	62	0.73	10.81	1.96	4	1	5	15	30	IV	P
Z1H	42	75	0.52	4.1	2.35	4	2	5	15	17	V	V.P
Z2A	30	78	0.64	2.71	5.83	2	1	2	15	33	IV	P
Z3A	44	91	2.5	3.16	5.2	2	1	6	15	34	IV	P
Z3B	36	72	0.77	3.4	5.35	2	2	4	15	40	IV	P
Z4A	38	78	1.62	4.85	4.13	2	4	3	15	51	III	F
Z4B	49	75	0.55	5.54	3.4	6	6	5	15	57	III	F
Z4C	55	75	0.58	8.54	7.75	4	3	4	15	50	III	F
Z4D	60	65	0.7	5.54	3.4	6	6	5	15	47	III	F
Z5A	25	95	1.34	4.11	3.3	3	5	1	15	63	II	G
Z5B	43	75	0.5	3.36	7.11	4	3	5	15	20	IV	P
Z5C	51	65	0.71	2	8.5	6	1	6	15	40	IV	P
Z5D	40	72	0.53	7.45	5.43	6	1	6	15	53	III	F
Z5E	52	58	1.1	1.16	9.45	4	3	5	15	39	IV	P
Z5F	58	52	0.89	5.33	8.45	4	1	5	15	36	IV	P
Z5G	57	55	0.33	3.36	2.93	6	0	5	15	52	III	F
Z6A	31	49	1.27	4.54	6.42	6	1	5	15	45	III	F
Z6B	24	65	0.59	5.07	2.45	2	1	1	15	37	IV	P

(P*) persistence, (A) alteration, (I) infilling (R) roughness, (weathering) (W.C) water condition, (T.R.M.R) total rock mass rating, (C.N) class number, (R.Q) rock quality, (F) fair, (G) good, (P) poor (V.P) very poor.



Figure 3: Field photographs of the investigated area; (a) Planar failure condition, here foliation plane dipping towards the road at zone Z3A; (b) foliation plane dipping towards the slope and a set of vertical to sub-vertical joint intersection the rock mass at Z4D which is failed due to planar failure; (c) foliation plane dipping towards slope at >45° angle and an inclined valley dipping joint intersecting the exposure that is giving the birth to topple failure at Z5E location; (d) field photograph is showing wedge failure condition between joints set1, set2, and bedding plane at Z2A location; (e) a planar failure condition due to joint set1 and set2 in which both are dipping in the same direction of slope which cause planner failure which is already failed at Z6A location; (f): a wedge failure condition due to joint set2 and set3 which is already failed at Z5G location.

The assembled data were transported for different laboratory tests and analyses to find out the stability condition and mode of failure for each zone. Contacts and attitude data were plotted in google earth and then moved to GIS software to finalize the geological map of the investigated location (Figure 2). Bulk samples of rock were collected and brought into the geotechnical laboratory of Shaheed Benazir Bhutto University Dir upper to find out the mechanical strength of the intake rock. Rock samples were prepared in the rock cutting lab to perform the Uniaxial Compressive Strength (UCS) test on core samples to determine the strength of the collected samples by (UCS) machine (ASTM-D-2938-95, 1995). The Schmidt hammer strength was also found and then converted into uniaxial compressive strength (UCS) after the method of International Society of Rock Mechanics (ISRM) (Bieniawski, 1989; Hatheway, 2009; Aydin, 2015). The value and rating of Rock Quality Designation (RQD) are found through the volumetric joints count method (RQD=115-3.3 Jv) by (Deere, 1963).

3.1 Rock Mass Rating (RMR) System

Rock mass rating was first introduced by Bieniawski (Bieniawski, 1973; Bieniawski, 1984; Bieniawski, 1989). This system depends upon five basic parameters of the discontinuities present in the rock. By adding rating values for these five parameters: (I) Strength of intact rock, (II) RQD values (measured or estimated), (III) spacing of discontinuities, (IV) condition of discontinuities, and (V) water inflow through discontinuities which is shown in equation 1.

$$RMR_{-basic} = UCS + RQD + DS + DC + GW \tag{1}$$

The RMR values were calculated for all the five parameters after the proposed method of Bieniawski (Bieniawski, 1989). By adding the rating values of five parameters the final rating from each slopes cuts range from 0 to 100 (Table 1). The sixth parameter of RMR, which is not mentioned here is based on the orientation of discontinuities. However, these parameters can only be applied for the dam and tunnel but not for the slope (Aksoy, 2008). In case of considering the orientation of discontinuities in slope, we need to apply a correction related to discontinuities orientation in rock slopes by the SMR system (Romana, 1985; Bieniawski, 1989).

3.2 Slope Mass Rating System (SMR)

This classification system is for the geo-mechanical classification of rock slopes. It is derived from the RMR_{basic} classification with the addition of four adjustment factors as shown in Equation 2 (Bieniawski, 1989; Romana, 1985).

$$SMR = RMR_{basic} + (F1, F2, F3) + F4 \tag{2}$$

The adjustment factors named by Romana (Romana et al., 2003; Romana et al., 2015) as F1, F2, F3 are related to discontinuity orientation compared

to slope direction is given in (Table 3). Rating for (F4) was assigned to be 0 because all the slope cuts were excavated by mechanical method (Romana et al., 2003). That's why most of the cut slopes come under unstable conditions (Table 3). These adjustment factors based on discontinuity orientation are corrections to SMR classification, which is discrete and more decision-based (Table 1). SMR is suitable for the assessment of slope stability including heavily jointed rock masses. The SMR value, stability classes, and description are described in detail after Romana (Romana, 1985) shown in (Table 3). All the data were analyzed by SMRTTool software (Riquelme et al., 2014).

Table 3: SMR and GSI values for each zone.

Site No:	Adjustment Factors				Smr Rating			Geological Strength Index	
	F1	F2	F3	F4	Romana	Thomas	Condition	GSI	Condition
Z1A	0.15	1	-60	0	46	45	Normal	45	Fair
Z1B	0.15	0.85	-60	0	40	38	Normal	41	Fair
Z1C	0.15	0.85	-60	0	56	55	Bad	57	Fair
Z1D	0.4	1	-6	0	73	72	Normal	67	Good
Z1E	0.15	0.85	-60	0	38	36	Good	39	Poor
Z1F	0.15	0.7	-60	0	4	0	Bad	37	Poor
Z1G	0.4	0.4	-60	0	20	17	Very Bad	28	Poor
Z1H	0.15	0.4	-60	0	13	10	Very Bad	15	Very poor
Z2A	0.15	1	-60	0	24	23	Very Bad	40	Poor
Z3A	0.7	1	-50	0	0	0	Bad	29	Poor
Z3B	0.15	1	-60	0	31	31	Very Bad	37	Poor
Z4A	0.4	1	-50	0	31	22	Bad	44	Fair
Z4B	0.15	0.4	-60	0	53	48	Bad	49	Fair
Z4C	0.15	1	-60	0	48	47	Normal	45	Fair
Z4D	0.7	0.85	-60	0	11	8	Normal	41	Fair
Z5A	0.15	1	0	0	60	59	Very Bad	69	Good
Z5B	0.7	0.85	-6	0	20	20	Normal	35	Poor
Z5C	0.4	1	-25	0	30	31	Very Bad	48	Fair
Z5D	0.15	1	-60	0	44	39	Bad	63	Good
Z5E	0.4	1	-25	0	29	32	Bad	35	Poor
Z5F	0.65	0.85	0	0	0	0	Very Bad	28	Poor
Z5G	0.15	1	-6	0	51	51	Normal	48	Fair
Z6A	0.15	0.4	-60	0	36	37	Bad	37	Poor
Z6B	0.7	0.85	-60	0	1	0	Very Bad	32	Poor

3.3 Geological Strength Index (GSI)

A method used directly for the closely spaced joints and heterogeneous rock mass. GSI depends on the discontinuities condition, rock mass structure, surface condition of joints, and rock blocks which can be directly applied in the field (Evert et al., 1997). Therefore, this system of classification is applied to overcome the encountered deficits present in the RMR-basic system (Hoek et al., 2013). The proposed formula to calculate GSI values is shown in (Equation. 3) which is based on field observation of joint surface conditions, composition, and structure of each slope cut (Table 2). Analysis of Geological Strength Index (GSI) for each zone has been assessed through RocLab software (Goodman et al., 1989).

$$GSI = 1.5 (\text{Joint wall condition}) + 0.5 RQD \tag{3}$$

3.4 Kinematic Analysis

Kinematic analysis was aimed to inspect the geological discontinuities and slope to determine the potential and failure mechanisms in structurally controlled areas (Table 1). Discontinuities and slope data (Dip, Dip direction) for each zone were measured through Brunton Compass. The angle of internal friction was assigned as 25°-35° for slope after (Evert et al., 1981). The measured data were further analyzed for the mechanism of failure based on discontinuities and slope orientation through DIPS

software (Rocscience, 2004; Goodman et al., 1989).

4. RESULTS AND DISCUSSION

4.1 Rock Mass Rating

To consider the RMR-basic rock mass rating was conducted which assigned the rating for each parameter to all locations in the study area. Rating for each parameter was calculated according to average values (spacing (mm), roughness, separation, continuity of joints, and groundwater condition) of discontinuities to calculate the final value of RMR (Table 2). The groundwater of each zone is in completely dry condition. RQD% is calculated from joint spacing which shows the block pattern of each zone. Variation in RQD% is present due to the irregular and varying space between different discontinuities sets. Rock mass classification of selected slope cuts (Table 2) shows that most of the zones have RMR values between 40-60 which is classified as a fair rock (Z1A, Z1B, Z1E, Z4A, Z4B, Z4C, Z4D, Z5D, Z5G, and Z6A). The same number of locations show the poor quality of rocks whose RMR values range from 20-40 (Z1F, Z1G, Z2A, Z3A, Z3B, Z5B, Z5C, Z5E, Z5F, and Z6B). Three locations (Z1C, Z1D, and Z5A) show good quality of rock whose RMR values range from 60 to 80. One location (Z1H) shows a very poor quality of rock having RMR values are 17.

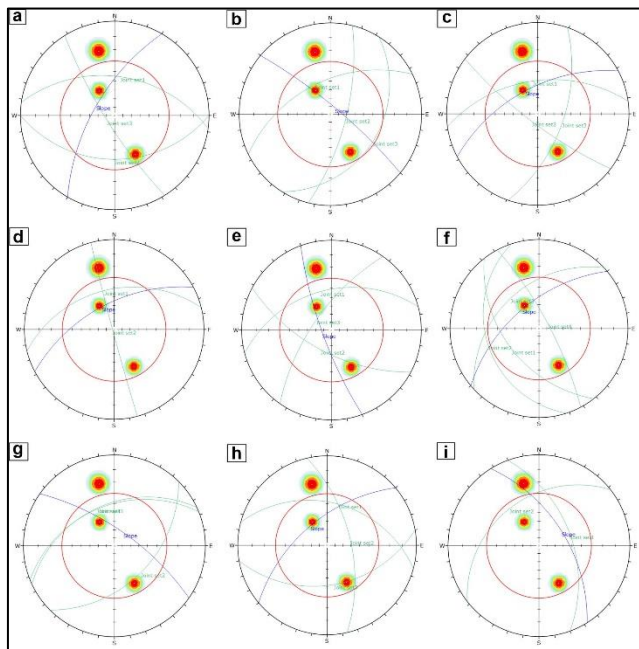


Figure 4: a: Z1E wedge failure along joint set1&3; b: Z2A show wedge failure along joint set1&2; c: Z4A show toppling failure along joint set3; d: Z4D show plane failure along joint set1; e: Z5D show wedge failure along with three sets of joints but joint set1&3 are very closer to failure; f: Z6A show planer failure along joint set3, also joint1&4 show wedge failure along jointset3 but not likely; g: Z1B is stable, No failure is present; h: Z5G show toppling along joint set3 also wedge along joint set 1&2 but not in the critical stage; i: Z3A show planner failure along joint set1 and also show wedge failure along joint set 1&2 but not likely.

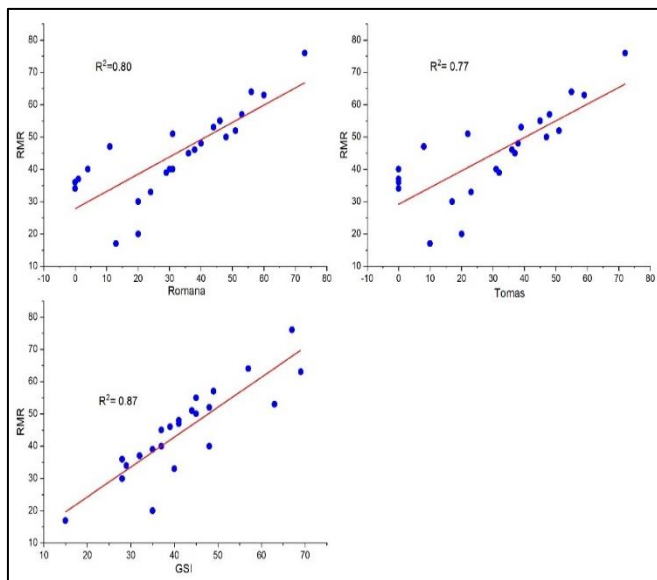


Figure 5: SMR results for adjustment factors after (M Romana, 1985; Tomás et al., 2007)

4.2 Slope Mass Rating

The slope stability assessment for each zone was conducted through different methods of classification systems which are developed for the slopes, like SMR (M Romana, 1985) and continuous SMR (Tomás et al., 2007). Original SMR is the combined result of RMR_{basic} and four adjustments (F1.F2.F3+F4) (Bieniawski, 1989; Romana et al., 2015) factors. By calculating the combined results of RMR_{basic} and adjustment factors shown in (Figure 6), the SMR quality ranges from very bad to normal (Table 3). Analysis for each slope was conducted through SMRTools (Riquelme et al., 2014). SMR rating for each zone show varying results and a decrease in values from the original RMR_{basic} due to applying four adjustment factors (F1, F2, F3, and F4) and orientation of discontinuities and slope. A cross plot is assigned between RMR_{basic} and SMR results of Romana and Tomas to find out the linear relationship between these parameters in which most of the values are scattered from

the regression line while some of them are following the line as shown in (Figure 5). According to SMR classification, eight zones (Z1F, Z1G, Z1H, Z3A, Z4D, Z4D, Z5B, Z5F, Z6B) show low rating ranges from 0 to 20 which comes under very bad conditions. (Figure 3. a, e) shows the location (Z3A, Z6B) which is already failed. Nine locations (Z1B, Z1E, Z2A, Z3B, Z4A, Z5C, Z5D, Z5E, Z6A) comes under the bad condition which the value of SMR values ranges from 20 to 40 (Figure 3. c) shows unstable conditions at Z5E where failure is possible. In five zones (Z1A, Z1C, Z4B, Z4C, Z5A, Z5G) the rating value ranges from 40 to 60 which comes under the normal condition but a small wedge is already failed at the Z5G location (Figure 3. f). One location (Z1D) shows the highest rating same as the original RMR which is in stable condition. Results for adjustment factors and stability conditions are shown in Table 3 and (Figure. 6, a-c).

4.3 Geological Strength Index (GSI)

The result shows that most of the slope cuts come under poor and fair conditions. Three zones (Z1D, Z5A, Z5D) have a rating >60, which comes under good condition while one location (Z1H) comes under very poor condition, which shows a very unstable condition of slope (Table 3). Various structure of rock mass was noted from blocky to crushed material (disintegrated). Discontinuous conditions (roughness, infilling, weathering) are also calculated most of which range from slightly rough to smooth while infilling is mostly soft materials (clay) to hard infilling (quartz). Weathering condition was almost slightly weathered while in some zone it is varying in condition (Table 2). All the calculated values were marked in the GSI chart by RocLab software (Evert et al., 2000; Goodman et al., 1989). A graphical representation was also established between RMR_{basic} and GSI values and a linear relationship has been carried out in which most of the slopes are not following the regression line (Figure. 5).

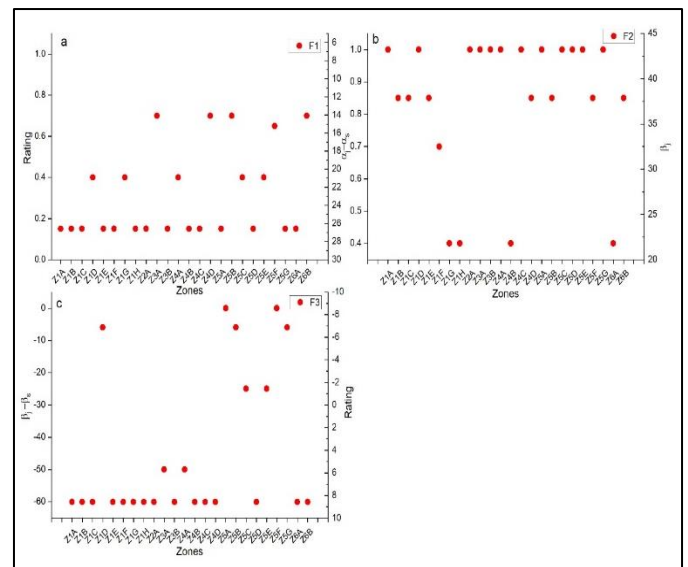


Figure 6: Cross-plot of RMR_{basic}, SMR, and GSI

4.4 Kinematic Analysis

Kinematic analysis is a geometrical assessment of discontinuities and slope orientation in a structural control area to determine the failure mode and potential for failure. During the investigation DIPS 7.0 software was used to determine the failure potential (Goodman et al., 1989). Three main results were defined through kinematic analysis for the selected slope cuts (planner, wedge, toppling) as shown in Table 4. Kinematic analysis shows that seven locations (Z1F, Z1G, Z3A, Z4D, Z5F, Z6A, Z6B) have the potential for planner failure in which site numbers Z3A, Z4D, Z6A are already failed in (Figure 3. a, b & e; Table 4). The stereographic projection of discontinuities and slope for planner failure zones (Z4A, Z4D, Z6A, Z3A) are shown in (Figure 4. c, d, f, & i). joint set1 is more preeminent to the potential of planner failure (Figure 4). Seven locations (Z1F, Z1G, Z2A, Z4D, Z5D, Z5G, Z6A), (Table 4) shows potential for wedge failure in which zone Z2A and Z5G are active (Figure 3. d, f). The kinematic analysis of wedge failure zones (Z1E, Z2A, Z5D, Z6A) is shown in (Figure 4. a, b, e & f). Toppling failure is present at six locations which most of which are not likely. (Figure 3. c) shows potential for toppling slope but no failure occurs. The kinematic result for, Z5G is shown (Figure 4.h). Eight locations show that there are no chances for potential failure. Zone Z5E shows stable condition (Figure 4. g). All the results for the kinematic analysis of slopes are present in (Table 4).

Table 4: Shows the failure mechanism in each zone.

Site No:	Plane Failure	Wedge Failure	Toppling Failure	Mass Failure
Z1A	No	No	Yes	Some Joints or many Wedges
Z1B	No	No	No	Planer or Big wedges
Z1C	No	No	No	Some Joints or many Wedges
Z1D	No	No	No	Some blocks
Z1E	No	Yes	No	Planer or Big wedges
Z1F	Yes	No	No	Big planner / Soil like
Z1G	Yes	Yes	No	Planer or Big wedges
Z1H	No	No	No	Big planner / Soil like
Z2A	No	Yes	No	Planer or Big wedges
Z3A	Yes	No	No	Big planner / Soil like
Z3B	No	No	No	Planer or Big wedges
Z4A	No	No	Yes	Some Joints or many Wedges
Z4B	No	No	No	Some Joints or many Wedges
Z4C	No	No	No	Some Joints or many Wedges
Z4D	Yes	Yes	No	Big planner / Soil like
Z5A	No	No	No	Some blocks
Z5B	No	No	Yes	Big planner / Soil like
Z5C	No	No	Yes	Planer or Big wedges
Z5D	No	Yes	No	Some joints or many Wedges
Z5E	No	No	Yes	Big planner / Soil like
Z5F	Yes	No	No	Big planner / Soil like
Z5G	No	Yes	Yes	Some Joints or many Wedges
Z6A	Yes	Yes	No	Planer or Big wedges
Z6B	Yes	No	No	Planer or Big wedges

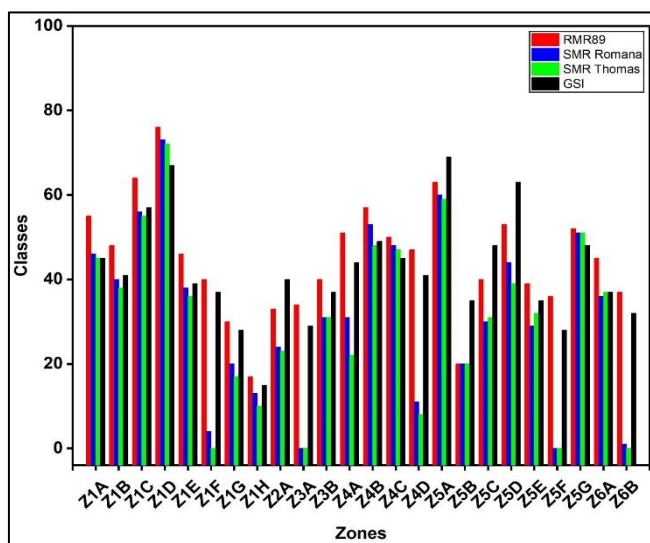


Figure 7: Bar diagram showing the comparison of classification method

All the methods applied for the rock mass classification system show different conditions and results for each slope cut, shown in (Figure 7). Histogram results show the confirmation of assessment for all the locations. The above methods and results suggest that most of the slopes are considered unstable which requires proper support. Planner slides, big wedges, and mass failures are possible to fail at many locations (Table 4). According to the above methods and results, installing rock-bolting, wire-mesh, and retaining walls is needed to prevent failure. The current study suggests that RMR_{basic} is not only applicable for slope investigation. For the detailed study we can use different classification methods which are specially designed for slope mass rating.

4. CONCLUSION

In this study, 24 locations were investigated through different classification methods (RMR_{basic}, SMR, GSI, and kinematic analysis) of rock

mass classification system. All the area were divided into six domains on the basis of geological and structural features. Different classification methods have been used to identify the risky and most vulnerable locations for a different mode modes of failure and slope conditions. From the current study, it is concluded that RMR_{basic} can only be applied to determine the Rock mass property and quality condition of rock but we cannot approach to find out the stability condition of the slope. The Geological Strength Index (GSI) method also describes the slope stability condition of rock in situ.

SMR methods are applied to determine the condition of rock mass and classify all the slopes into different classes which can be obtained by applying RMR_{basic}, with relation to dip and dip direction of slope and discontinuities. The deficiencies present in RMR_{basic}, which cannot determine the actual condition of the slope are recovered by the adjustment factors of F1, F2, F3, and F4. So, it is concluded that the SMR method can only be applied for the structurally controlled slope. RMR and SMR methods have almost same rating and condition of rock. Kinematic analysis confirms that three types of failure are present in the investigated slopes. Planner failure is more prominent to fail which is affected by joint set 1. Some of the slopes are stable which is affected by geology and stable structure. However, the experimental results concluded that most of the slopes are unstable while some of them are already failed. In addition, it can also be confirmed that all the investigated slopes are originated after the construction of the newly constructed road between Dir and Kumrat valleys which no research work has been reported before. Many authors have worked on rock mass classification system and kinematic analysis but there is no previous work reported on the newly constructed road. Due to the poor blasting and mechanical excavation, most of the slopes are unstable and vulnerable to failure which some of them are already failed. On the basis of the above study proper installation technique and support are required to stabilize all the slopes before failure.

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