Application of SMR and Stereographic Projection Method in the Highway Slope Stability

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Abstract. With the development of the highway construction in mountain areas, the accidents such as landslide, collapse of high slope stability of highway occurred frequently, and even caused heavy casualties and property losses, the problems become more and more prominent. Therefore, much significance to be studied the stability of high slope. In this paper, we focus on a high slope of the Musun road, Shunyi District, Beijing as the research object, carry out the SMR and stereographic projection method to analyze and evaluate the slope stability, then propose suitable reinforcement measures according to the analysis results.

Keywords: SMR, Stereographic projection method, Stability analysis.

1. Introduction

The rock mass rating (RMR) and slope mass rating (SMR) are very important methods to evaluate the high slope stability. The SMR is a kind of the rock slope stability evaluation method proposed by Romana (1985) [1]. On the basis of the rock mass rating (RMR) method, he proposed extra four specific factors to impact directly on the stability of slope. The four factors include: (1) F1 reflects the relationship between the structure plane inclination and slope inclination; (2) F2 reflects the influence of structural plane sliding surface angle; (3) F3 reflects the relationship between slope angle and the dip angle of structure plane; (4) F4 reflects the influence of excavation on slope stability [2].The calculation formula shown as follows: $SMR=RMR-F1\times F2\times F3+F4$ [2]. SMR method for evaluation of slope stability classification standard is shown in table 1.

Table 1. The slope stability classification standard of the SMR method

Classification	V	IV	III	II	I
The SMR score	0~20	21~40	41~60	61~80	81~100
The character of rock mass	Very poor	Difference	General	Good	Very good
Stability	The extremely unstable	Instable	Part of the stable	Stable	The most stable
Failure mode	Plane sliding, similar soil slope	Large scale planar or wedge	A small plane or wedge	Off the block	No
Reinforcement method	Reconstruction	Large scale reinforcement	Reinforcement system	Local reinforcement	No

Table 2 The rock mass quality classification standard of RMR

The value of RMR	100~81	80~61	60~41	40~21	<20
Classification	I	II	III	IV	V
The description of the quality	Very good	Good	General	Difference	Very poor
The cohesion of rock mass (kPa)	>400	400~300	300~200	200~100	<100
The internal friction angle of rock mass (°)	>45	45~35	35~25	25~15	<15

The RMR is a comprehensive classification method including several parameters, so it can be applied for both quantitative and qualitative evaluation [3]. It mainly considered the characteristics of rock strength (R1), rock mass integrity (R2), surface density(R3), rock and soil structure (R4), water surface station (R5) and structural plane geometry and engineering (R6) [4].The calculation formula described as follows: $RMR=R1+R2+R3+R4+R5+R6$. The RMR classification standard of Rock mass quality is shown in table 2.

2. Slope engineering geological conditions

The study object is an artificial cut slope 33.00 m in height, trends toward 92 °, slope angle is about 50 °. The slope is mainly composed of dolomite with the occurrence of 230 °∠60 °, medium thickness to thick layered structure, fissures and joints are developed.

Through the engineering geological mapping, dolomite mainly contains two sets of joints: the first joint shows factors as follows: the occurrence is 105 °∠45 °, structural surface is rough, extend about 0.30 to 0.40 meters long, spacing of about 0.30 to 0.6 m, for the rigid structural plane; anther joint is a the rigid structural plane, displays the occurrence of 335 °∠80 °, structural surface is also rough, extension range is about 0.50~0.80m, space about 0.40~0.50m. Structural surface cohesion of both joints (C value) yielded about 90 kPa, the internal friction angle is 27 °.

According to the test results, the saturated uniaxial compressive strength of medium altered dolomite is 22.3MPa.The data suggest that there may be the bedrock fissure water in the fracture site.

3. Evaluation of slope stability

3.1 SMR method for slope stability evaluation

According to the principle and the engineering geological conditions of slope rock mass quality, we firstly calculate the RMR, consider the effect of structural plane, and the excavation of slope stability calculation of SMR. The process of evaluation and the results are shown in Tables 3~5.

Table 3. The rock mass quality classification standard of RMR

	The parameters and weights	Grading and score					Score
R1	The uniaxial compressive strength(MPa)	>250	100~250	50~100	25~50	5~25 1~5 <1	15
	Weight	15	12	7	4	2 1 0	
R2	RQD (%)	90~100	75~90	50~75	25~50	<25	13
	Weight	20	17	13	8	3	
R3	The structure of space (cm)	>200	60~200	20~60	6~20	<6	10
	Weight	20	15	10	8	5	
R4	Roughness	Very rough	Rough	Rough	Smooth		20
	Filling /mm				<5	Soft filling more than 5	
	Opening width /mm	Not open	<1	<1	1~5	5 or more	
	Continuity	Discontinuous			Continuous	Continuous	
	The two walls of the weathering degree of rock	Weathered	The breeze	Strong weathering			
	Weight	30	25	20	10	0	
R5	Groundwater conditions	Completely dry	Compared with the wet	Moist	Drop	Flow	10
	Weight	15	10	7	4	0	
R6	The geometric relationship between structural plane and slope	Very good	Favorable	General	Adverse	Very bad	-5
	Weight	0	-5	-25	-50	-60	
	RMR=R1+R2+R3+R4+R5+R6=15+13+10+20+10-5=63						

According to the structure of negative evaluation, the excavation for the pre splitting blasting, so the SMR value is 43.25. The formula shown below.

SMR= RMR-F1×F2×F3+F4 =63-0.7×0.85×50+10=43.25 (Table4).

Besides, the high slope belongs to type III and part of the stable slope, rock mass quality is general (Table1). It means that the slope will probably create a small plane or wedge. Therefore, the high slope on the Musun road need to make a systematic reinforcement.

Table 4 Factors affecting the classification standard of SMR structures

Failure mode	The calculated value	Very good	Favorable	General	Adverse	Very bad	Score
P	$\gamma_1 = \left|\alpha_j - \alpha_s\right|$	>30°	30~20°	20~10°	10~5°	<5°	
T	$\gamma_1 = \left|\alpha_j - \alpha_s - 180°\right|$						
P/T	F1	0.15	0.40	0.70	0.85	1.0	0.7
P	$\gamma_2 = \left|\beta_j\right|$	<20°	20~30°	30~35°	35~45°	>45°	
P	F2	0.15	0.40	0.70	0.85	1.0	0.85
T		1.0	1.0	1.0	1.0	1.0	
P	$\gamma_3 = \beta_j - \beta_s$	>10°	10~ 0°	0°	0~ -10°	< -10°	
T	$\gamma_3 = \beta_j + \beta_s$	<110°	110~120°	>120°			
P/T	F3	0	5	25	50	60	50

Table 5. Effect of grading standards of SMR excavation method.

Slope excavation	The natural slope	Pre splitting blasting	Smooth blasting	Mechanical excavation	No controlled blasting
F4	15	10	8	0	-8

3.2 Stereographic projection method for slope stability evaluation

The stereographic projection method is an important method to study of the stability of rock slope, including the natural slope and artificial slope. It not can only describe the spatial relationship among structures of the slope surface, show the geometric shape, size, and their spatial location and distribution of the unknown and unstable masses in the slope, but also determine the deformation displacement direction, and then make decision of the slope stability conditions and stability evaluation. The qualitative analysis on slope stereographic projection using Lizheng software shows in fig.1.

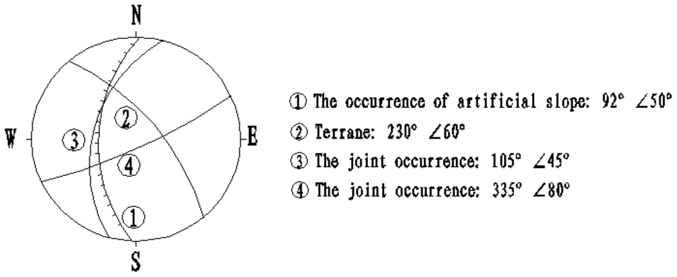


Fig. 1 The slope stereographic projection

According to Fig.1, we can see that the rock layer ② and the artificial slope ① is tangential intersection, this shape is favorable for slope stability. Besides, there is little effect on the slope stability, because a high angle tangent intersection locates between joint ④ and the artificial slope ①. However, certain influence on the slope stability should be concerned, due to a small angle forward intersection lies in between joint ③ and artificial slope. In a word, the whole slope is stable, but at the cutting action of rock layer and two sets of joints, after the slope excavation, a local wedge may form (Fig.2).

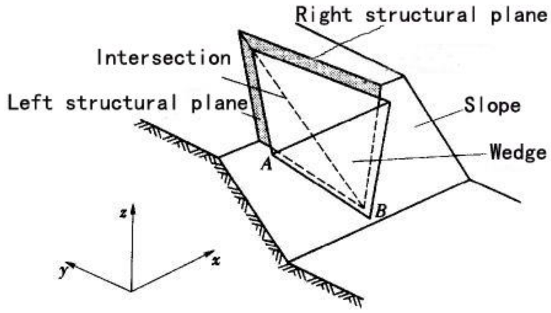
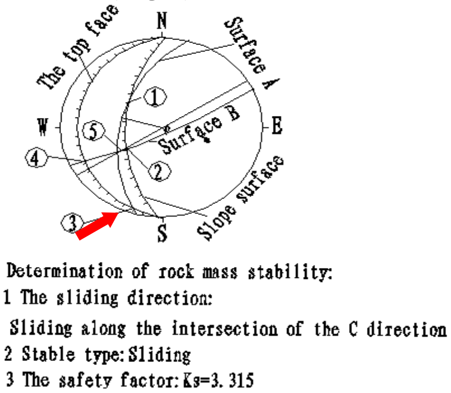


Fig. 2 The schematic diagram of the wedge stability analysis

Using Lizheng software to model all possible wedges on the slope, the stereographic projection analysis shows as follow (Fig.3).



Occurrence / Structural plane	Tendency (°)	Inclination (°)
The top face	90. 00	10. 00
Slope surface	92. 00	50. 00
Surface A	105. 00	45. 00
Surface B	335. 00	80. 00
Intersection ①	316. 02	40. 60
Intersection ②	225. 30	43. 70
Intersection ③	198. 15	3. 14
Intersection ④	243. 41	8. 96
Intersection ⑤	238. 08	34. 34

Fig. 3 Analysis of rock wedge slope stereographic projection

Seen from the Fig.3, intersection points of two structure planes drop inside the high slope in the stereographic projection. It is not conducive for the rock slope stability, and the slope probably slide along the direction of the red arrow. Moreover, the safety coefficient (Ks=3.315) in natural state meets the requirements of the national codes, but rain and fracture surface will reduce the safety factor of wedge, and decrease the slope stability.

4. Conclusion

In this paper, we present SMR method and stereographic projection method to calculate the slope stability in the Musun road. The results are consistent with each other, and verify the credibility of stability evaluation. If the slope is excavated follow the design elevation, the whole stability of slope will good, however, a local wedge will be created.

Based on the data and analysis, we recommend that cutting slope, and grade elimination will be helpful to keep the slope stability. The slope should be cut 2 to 3 grade, slope ratio of 1:1, and build a pack way to protect it. For a joint fissure of slope, it may adopt net-suspended spray anchor bracing or use lattice slope protection, set intercepting ditch, drainage at the slope top, dip slope drainage hole. Moreover, during the slope construction and operation, slope displacement monitoring should be strengthened, nip in the bud.

References

[1] Romana M. New adjustment ratings for application of Bieniawski classification to slopes [C], International Symposium on the Role of Rock Mechanics, 1985, p. 49-53.

[2] Enxi Qiu, Xie Qiang, Hi Yue, Application of modified SMR method in Redbed soft rock slopes, Rock and soil mechanics. 2009, 30(7), p. 2109-2113.

[3] Bieniawski Z T. The point-load test in geotechnical practice., Engineering Geology, 1975, 9(1), p. 1-11.

[4] Qing Miao. Application of SMR method in the stability classification of Dachaoshan Hydropower Station, Hydroelectric power generation, 2001(12), p. 23-25.