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Research Article

Classification Method of Rock Structure and Rock Mass Quality of Surface Granite: Geological Disposal of High-Level Radioactive Waste in China

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The engineering quality of rock mass is a key factor to evaluate the long-term stability and safety of high-level radioactive waste (HLW) geological disposal engineering and is also the important basis for disposal site selection. Traditional rock mass quality classification methods, such as RMR and Q, can meet underground engineering but still should be studied further for the site evaluation in the HLW disposal engineering. In this study, rock mass structure rating (RMSG) was proposed based on the quantitative control index of rock mass structure which was from the rock mass quality classification methods. Based on the statistical results of rock mass structure, the relationship between the number of RMSG and the modified RMR (F_{RMR}) and Q (F_Q) was established, China, as a case study. Results from this study show that RMSG is linearly related to F_{RMR} and negatively exponential to F_Q. The research results can solve the evaluation of rock mass quality for HLW geological disposal engineering, and the addition of more engineering examples over time will enable further verification.

1. Introduction

The engineering quality of rock mass is a comprehensive reflection of the geological characteristics of rock masses. It not only objectively reflects various geological conditions and physical and mechanical properties of rock masses that affect the stability of rock masses but also provides a reliable basis for rock mass classification and grading as well as the correct selection of various rock mass mechanical parameters [1–3]. The quality index of engineering rock mass includes three factors: the integrity of rock mass, the shear characteristics of structural plane, and the strength of structure or rock block. The integrity of rock mass refers to the degree of cracking or fragmentation of rock mass, that is, the existence of structural planes in rock mass, which is expressed by integrity coefficient. The shear properties of structural planes are characterized by shear strength or friction coefficient. The strength of rock block refers to the resistance of rock block to deformation, which is expressed in the uniaxial compressive strength Rc of rock, and the strength coefficient is s, which is expressed in Rc/100. Therefore, the use of rock mass quality classifications is important to connect engineering surveys, design, and construction of rock masses [4].

In recent years, with the continuous development of science and technology, geotechnical engineering has developed from surface to underground. A variety of rock mass quality classifications methods have proposed according to the project category, and the evaluation factors and criteria are different [5, 6]. For the same project, different rock mass quality classifications method may have different evaluation result [7]. The most commonly used rock mass quality classification methods are RMR and Q [2, 3]. By comparing various types of evaluation methods, it is concluded that the factors affecting rock quality can be summarized as joint properties, rock strength, rock integrity and groundwater conditions (as in Table 1), while rock strength, joint properties, and rock integrity can be unified as rock structure [8–11]. Therefore, rock structure is fundamental factor to control the engineering quality of rock mass, which is also the theoretical basis for studying the correlation between rock structure and rock mass quality [5].

Studies on the correlation between rock structure and rock mass quality have increased over time. Liu and Dang [10] have studied the relationship between rock structure and rock mass quality and finally gave the quantitative relation and transformation formula. Tzamos and Sofianos [12] studied the common parameters of RMR, Q, GSI, and RMi and analyzed the correlation between rock structure and rock mass quality through testing the validity of the chart which placed the grading parameters of rock mass quality classification methods in the common fabric exponent graph for different projects. Tzamos and Sofianos and Wang et al. studied the structural surface grade, geometric characteristics, spatial distribution, properties, and rock structure types and established rock mass quality grading criteria from single-factor grading to multifactor grading to evaluate rock mass quality of Huokou Reservoir Dam [12–14].

However, as the high-level radioactive waste geological disposal project, there is no mature rock mass quality classifications method for the project. Andersson et al. [1] considered that rock mass engineering quality evaluation system should be established according to the characteristics of different stages of HLW disposal engineering such as site selection, engineering planning and design and engineering construction. Hagros [9] established the *HRC* Method to qualitative evaluate rock mass quality for HLW disposal engineering but has limitation for the engineering application due to the determining complexity of parameters [15–17]. Chen et al. [6] established Q_{HLW} method through introducing the surrounding rock characteristic factors that affect the long-term safety of the disposal project, which was the first quantitative evaluation method of rock mass suitability for HLW disposal [7, 18].

The underground project of burying high-level waste is called high-level waste repository. The high-level radioactive waste repository adopts the design of "multiple barrier system." That is, the waste is stored in the waste tank, wrapped with buffer materials, and then surrounded by surrounding rocks (granite, clay rock, tuff, rock salt, etc.). Generally, waste tanks and buffer materials are called engineering barriers, and the surrounding geological bodies are called natural barriers. Different countries have chosen different lithology as natural barriers according to different geological conditions. In the HLW geological disposal project, the site selection became the key to the factor for the success or failure of the geological repository because of surrounding rock as the natural barrier to prevent the migration of radionuclides [19, 20]. The current preselection area is often reaching tens or even hundreds of square kilometers, so how to quickly and reasonably conduct rock quality and site evaluation by analyzing the rock structure is a key problem that needs to be solved urgently [21]. Therefore, this paper put forward surface rock structure grading index *RMSG* based on the component factor of traditional rock mass quality classifications methods and established the function relationship between *RMSG* and the modified indexes of F_{RMR} and F_{Q} through surface structure surface investigation for rock mass around BS22 and BS23 boreholes in Beishan candidate area [4].

2. Geology Settings and Structural Surface Survey

A suitable "site" should consider many factors. From the geological point of view alone, the region should have flat terrain, stable crust, undeveloped surface water system, poor groundwater, complete rock mass, excellent rock mass engineering quality, and appropriate engineering geological conditions. For example, if the earth's crust is stable, there will be no big movement and damage to the underground repository. At the same time, surface water and groundwater are easy to penetrate and erode the underground disposal repository, so a dry and water deficient natural environment is very important. In addition, economic conditions and social effects need to be comprehensively considered. The area should be sparsely populated, with convenient transportation, no arable land value, and poor animal and plant resources and mineral resources, so as to avoid affecting the future regional economic and social development. Suan Jingzi section, as shown in Figure 1, is one of the favorable candidate sites in the preselection area of Gansu North Mountain for China's HLW geological disposal. It is located 200 kilometers north west of Jiayuguan City, which is low to medium mountain topography. The area is dry and water-scarce, no perennial flowing water, a typical continental climate, dry, and windy. The annual precipitation is less than sixty millimeters, while the evaporation is as high as 3039 millimeters. Because of the low precipitation, the vegetation is underdevelopment. There are few residents in the area, and most of them are not settled Mongolian herdsmen. These are the favorable geological and hydrological conditions as HLW disposal [8].

The geological investigation shows that the lithology of Suan Jingzi rock mass is single, mainly granite, widely developed in a large area of lithosphere, which is buried depth more than ten kilometers. However, the different scale structural surfaces developed within the granite rock mass are unfavorable conditions for the construction of HLW geological repository. Therefore, different geological investigation methods were used to analyze the geometric features of faults and joints. The investigation of joints and the distribution of faults in the 4 km^2 scope around BS22 and BS23 boreholes are shown in Figure 2.

2.1. Joint Investigation Method. In order to make more accurate the joint investigation results, the selected outcrops are flat, undisturbed, and no weather-worn and plant growth. At the same time, it should not be frequent change of personnel, equipment, and methods in the measurement process. After selecting outcrops in the study area, the location was determined by GPS; then, the comprehensive method was used to

Table 1: The component parameters of different rock mass quality classification methods.

Method	Rock structure								
	Joint properties			Rock strength	Rock integrity		Groundwater	Levels	Applications
	No.	Interval	Status		RQD	Integrity			
RQD								Five	Rock cores
RSR		✓	✓	✓			✓	Five	Tunnel support
RMR		✓	✓	✓	✓		✓	Five	Tunnel mining
Q	✓	✓	✓	✓	✓		✓	IX	Tunnel chamber
Z				✓		✓		Five	Underground engineering
Za						✓		Five	Underground engineering
China engineering Rock classification National standard		✓	✓	✓	✓	✓	✓	Five	Underground surface slopes

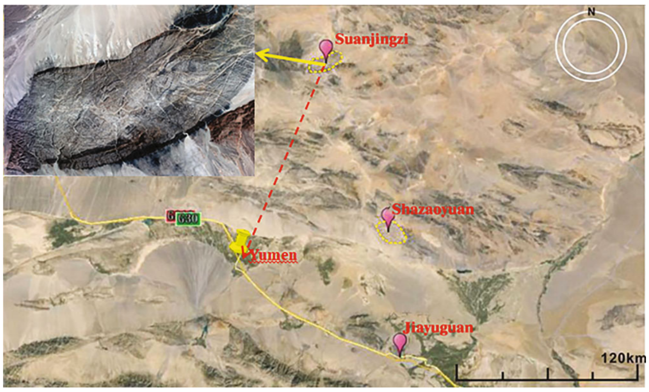

Figure 1: The location and area of Suan Jingzi section (form Google Earth).

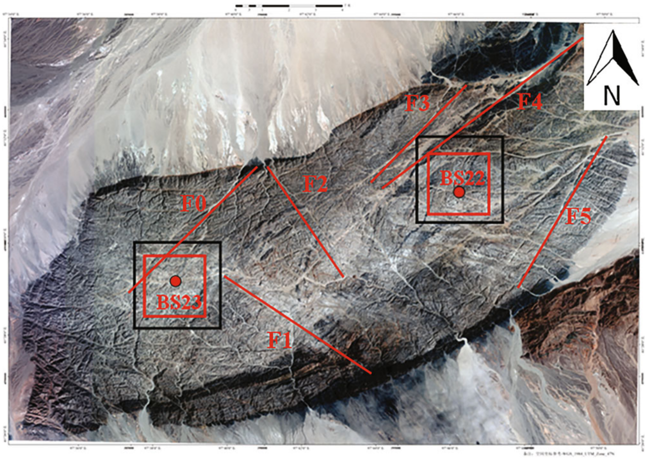

Figure 2: Joint investigating area and fault distribution for Suan Jingzi section.

survey joint. Joints, fissures in rocks, and a type of fault structures refer to those in which the rocks are cracked, and there is no obvious relative displacement on both sides of the fracture surface (opposite to the fault with obvious displacement). This is a crack caused by the stress of the rock, but there is no obvious displacement (which can be seen clearly by the eyes) on both sides of the crack surface. Geologically, this kind of crack is called joint, and joints can be seen everywhere on the rock outcrop. First of all, measuring line, intersecting each joint as far as possible, is arranged on the outcrop; then, statistical joint geometric characteristics are shown in Figure 3 [16, 17]. According to the relative location between joints and measuring line, joints are divided into I, II, and III; then, survey the location and occurrence of outcrops, measuring line direction, joint type, occurrence, trace length, aperture, and filler, as shown in Table 2.

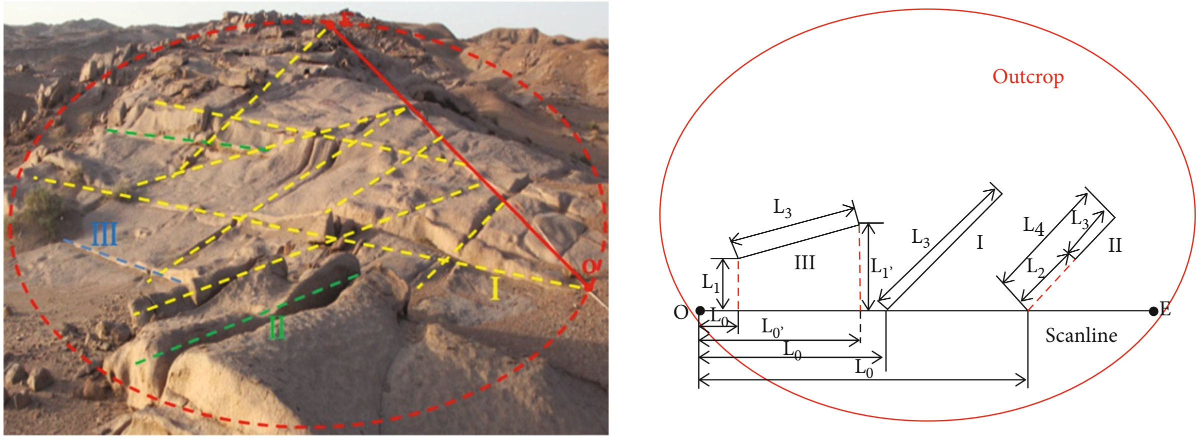

Figure 3: Comprehensive joint investigation.

Table 2: Record chart of joint geometry characteristics.

(a)

Outcrop position	97°46′4.3″, 41°30′59.4″	Outcrop occurrence	225°∠21°
Outcrop area	85.2m^2	Measuring line direction	144°
Lithology	Second-length granite		

(b)

Structural surface No.	Location (m)	Dip direction (°)	Dip angle (°)	Length (m)	Aperture (mm)	Filler	Type
1	0.00	205	54	7.665	200	Aplitic dyke	I
2	1.05	232	76	2.654	0	None	I
3	2.23	60	80	3.619	0	None	I
4	2.78	65	79	9.487	0	None	I
5	3.45	185	61	7.792	0	None	I
6	4.60	60	76	1.031	0	None	I
7	5.60	233	76	10.991	0	None	I
8	5.50	212	77	6.323,12.002	0	None	II
9	4.70	202	74	7.804,12.809	0	None	II
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
22	19.40	192	65	10.398	0	None	I

2.2. Fault Investigation Method. Faults are structures in which rock strata or rock masses are obviously displaced along the fracture surface. Faults are widely developed in the crust and are one of the most important structures in the crust. In terms of landform, large faults often form rifts and steep cliffs, such as the famous East African Rift Valley and the great cliff on the northern slope of Mount Hua in China. Since the fault is too long to be directly measured by instruments, the geological investigation of the faults was firstly interpreted from satellite remote sensing images, then determined the fault plane occurrence and fracture bandwidth according to the characteristics of fault gouge on the exploratory trench in Figure 4, and counted the length of fault used GPS and imagery interpretation to point by point to track the extension of fault; finally, the fault influence zone was determined by investigating the development pattern of joints around the fault. Therefore, the statistical parameters of the fault include fault occurrence, length, fragmentation zone, and influence zone.

2.3. Characterization and Rating of Rock Mass Structure. Faults are widely distributed on the earth's surface, which destroy the continuity of rock masses, reduce their integrity, weaken their mechanical properties, and increase their permeability. Fracture zones are mainly composed of the fracture zones and influence zones which form the groundwater flow and accumulation and lead to low strength and permeability of the rock mass. Therefore, faults

Figure 4: Exploratory trench and fault gouge.

Table 3: Classification of fracture zones.

Fracture zone scale	Location requirement	Safety distance
≥10 km	No part of the disposal bank can intersect directly with the fracture zone	>500 m
[3 km, 10 km)	Disposal pits and disposal tunnels connecting disposal pits should not intersect directly with the fracture zone	>100 m
[100 m, 3 km)	Disposal pits cannot intersect directly with such fissures	

are one of safety hazards for underground works such as HLW geological repositories [13].

Wang et al. [15] concluded that the classification of fracture zones needs to consider the seismic, hydraulic conductivity, and construction performance, and the potential seismic-induced fracture misalignment has a greater impact on the long-term safety of the HLW disposal project. Therefore, the classification of fracture zones is based on seismic impact. As shown in Table 3, the scale of the fracture zones is divided into 10 km, 3 km, and 100 m. The distribution of fracture zones needs to be given priority for the HLW geological disposal project. Figure 2 can be seen that the distribution of fracture zones is greater than 500 m from the borehole which meets the requirements of HLW geological disposal project.

In the *RMR* system, *RQD* and structural face spacing are used to characterize rock structure. In the *Q* system, *RQD* and joint groups are used to characterize rock structure. In the Chinese national standard for engineering rock classification, the degree of rock integrity is used to characterize rock structure. In the analysis of various rock mass quality evaluation methods, it is concluded that the characterization factors of rock structure mainly include *RQD*, joint spacing, number of joint groups, and rock integrity. In view of this, considering the influence of joint connectivity on the migration of nuclides, *RMSG*, a relatively comprehensive and integrated surface rock structure grading index, was proposed. The expression of *RMSG* is as follows:

$$\mathrm{RMSG} = B_1 + B_2 + B_3, \tag{1}$$

where B_1, B_2, and B_3 are the score values of joint groups J_n, joint spacing D, and joint trace length L.

According to the fracture description recommended by the International Society for Rock Mechanics, using the 20-point system and the equal-point system, the *RMSG* values and characteristic description of rock mass structure were obtained, as shown in Table 4.

2.4. Rock Mass Quality Evaluation Correction Index

2.4.1. Rock Quality Evaluation Correction Index F_{RMR}.

The RMR method proposed by Bieniawski includes the geological factors such as R_1 rock strength, R_2 rock quality index, R_3 joint spacing, R_4 condition, R_5 groundwater, and R_6 joint direction on the corresponding engineering factors. The expression of RMR is as follows:

$$\mathrm{RMR} = R_1 + R_2 + R_3 + R_4 + R_5 + R_6. \tag{2}$$

In the selection stage of HLW geological disposal project, granite is mainly studied. Granite is the preferred surrounding rock for the geological disposal of high-level radioactive waste in China, and there are a large number of structural planes in its rock mass. The fracture network formed by these structural planes is the main channel for nuclides to diffuse to the biosphere with groundwater flow. At the same time, the structural plane is also the main factor affecting the stability of rock mass, especially playing a decisive role in the safety and stability of the chamber of the future disposal repository. Therefore, it is necessary to conduct in-depth study on the structural plane characteristics of granite rock mass in the preselection area of high-level radioactive waste geological disposal. The uniaxial compressive strength of granite is between 150 and 200 MPa, and R_1 was identified as 12. Because the groundwater-poor area is the essential condition as the HLW geological disposal candidate area, R_5 was considered as 15. For evaluation of surface rock mass quality, it can be ignored the influence of the direction of structural plane on HLW geological disposal engineering. In the light of the above, the correction index F_{RMR} was proposed to evaluate the rock quality of HLW geological

Table 4: *RMSG* values and characteristic description of rock structure.

RMSG	Rock structure characteristic description						Level
	J_n (No.)	Score values	D (m)	Score values	L (m)	Score values	
20	0	0	⊳2	10	<1	10	I Overall shape
40	1	10	0.6~2	15	1~3	15	II Blocky
60	2	20	0.2~0.6	20	3~10	20	III More broken shape
80	3	30	0.06~0.2	25	10~30	25	IV Crumbly
100	4	40	<0.06	30	⊳30	30	V Dispersion-like

Table 5: Description and rating F_{RMR} for rock mass quality.

Geological factors									Rock mass quality classification characteristics
R_1	RQD (%)	R_2	Spacing (cm)	R_3	R_4	R_5	R_6	F_{RMR} value	
1 2	90~100	20	>200	20	2 5	1 5	0	84~92	I The rock quality is very good and stable
	75~90	17	60~200	15				75~84	II Good and stable rock quality
	50~75	13	20~60	10				68~75	III Rock quality is medium, basically stable
	25~50	8	6~20	8				60~68	IV Poor and unstable rock quality
	0~25	3	<6	5				52~60	V The rock quality is very poor and unstable

Table 6: Description and rating F_Q for rock mass quality.

Geological factors								Surface rock quality classification characteristics
RQD (%)	No.	J_n	J_r	J_a	SRF	J_w	F_Q value	
90~100	1	1	3.9	0.88	1	1	133~443	I The rock quality is very good and stable
75~90	2	3					66~133	II Good and stable rock quality
50~75	3	5					32~66	III Rock quality is medium, basically stable
25~50	4	7					12~32	IV Poor and unstable rock quality
0~25	>4	9					1~12	V The rock quality very poor and unstable

disposal candidate area. The value of each parameter and the scoring standard for F_{RMR} is shown in Table 5.

2.4.2. Rock Quality Evaluation Correction Index F_Q. Barton [2] proposed the *Q* system which includes six parameters to quantitatively describe the rock mass quality in 1974. The expression of *Q* is as follows:

$$Q = \frac{\mathrm{RQD}}{J_n} \bullet \frac{J_r}{J_a} \bullet \frac{J_w}{\mathrm{SRF}}, \tag{3}$$

where *RQD* is rock quality index, J_n is the number of joint groups, J_r is joint roughness, J_a is joint alteration coefficient, J_w is joint water discount factor, and *SRF* is the stress discount factor.

In the selection stage of HLW geological disposal project, granite is the mainly subject. Therefore, J_r was identified as 3.9, and J_a was identified as 0.88 [6]. According to the double embolism field hydrological test system, the permeability characteristics of granite are less than 10^{-9} m/s, and J_w was identified as 1. Through laboratory tests and deep borehole hydraulic fracturing tests, most of the strength stress ratio data for granite was greater than 5, which was conducive to engineering construction, and SRF was identified as 1. In the light of the above, a modified rock quality evaluation index F_Q was proposed to evaluate the rock quality of HLW geological disposal candidate area. The value of each parameter and the scoring standard for F_Q is shown in Table 6.

2.5. Quantitative Relationship between Rock Structure and Rock Mass Quality

2.5.1. The Statistical Data of RMSG, F_{RMR}, and F_Q. The evaluation of rock structure is much faster than the evaluation of rock mass quality. If the quantitative relationship between rock structure and rock mass quality can be established, the purpose of rapid evaluation of geological disposal sites of high-level radioactive waste can be achieved.

Suan Jingzi section is one of the favorable candidate sites in the preselection area of Gansu North Mountain for China's HLW geological disposal. The intrusive rocks in the Suan Jingzi section (Suan Jingzi rock mass) are the products of magmatic activities in the middle of Variscan, mainly acidic rocks, which occur in rock foundation shape. The rock mass intrudes into the Baishan formation of the lower Carboniferous system and Gongpoquan group of the middle Silurian system. The contact zone in the rock mass is strongly contaminated and lithified, and roof-shaped surrounding rock residues are common at the top, indicating that the denudation degree of the rock mass is poor. Joint survey was carried out, and the geometric parameters were obtained for the outcrops within 4 km^2 of the surface rock

Table 7: RMSG values of the outcrops around BS22 and BS23 boreholes.

BS22 borehole	No.	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15
	RMSG	34	23	20	29	20	28	25	20	23	30	36	18	16	22	41
BS23 borehole	No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
	RMSG	22	20	16	36	17	21	12	18	32	20	33	40	17	28	22

Table 8: F_{RMR} values of the outcrops around BS22 and BS23 boreholes.

BS22 borehole	No.	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15
	F_{RMR}	92	77	70	90	77	84	82	84	63	84	84	89	92	85	92
BS23 borehole	No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
	F_{RMR}	70	66	84	72	78	72	84	92	84	72	71	83	68	85	80

Table 9: F_Q values of the outcrops around BS22 and BS23 boreholes.

BS22 borehole	No.	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15
	F_Q	45	19	31	18	119	5	15	40	19	11	81	106	129	31	16
BS23 borehole	No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
	F_Q	38	14	57	7	22	10	41	64	21	41	17	11	19	61	47

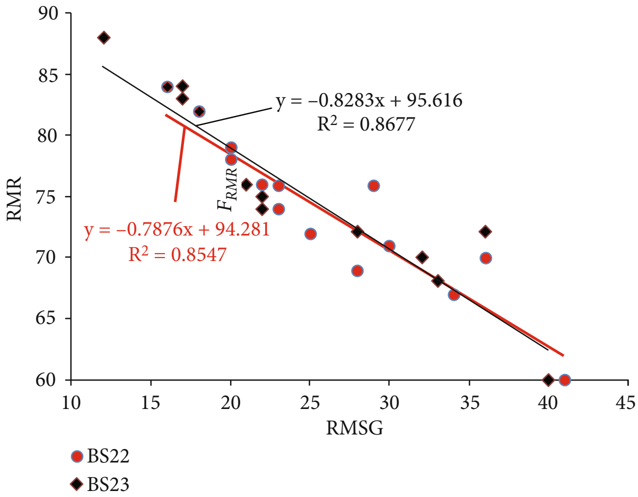

Figure 5: Relationship between RMSG and F_{RMR} of outcrops around BS22 and BS23 boreholes.

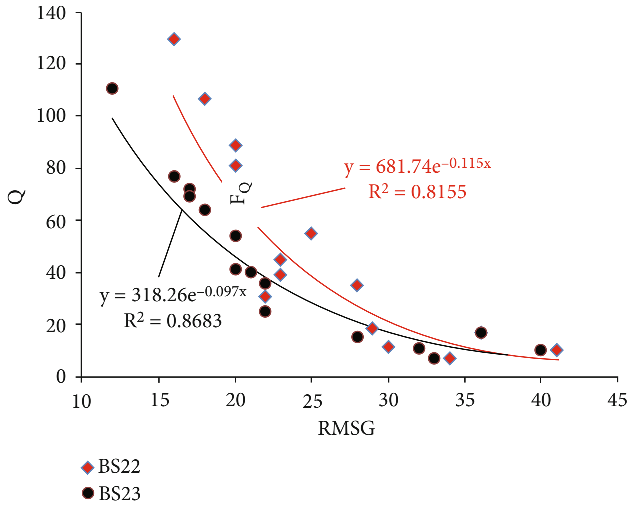

Figure 6: Relationship between RMSG and F_Q values of outcrops around BS22 and BS23 boreholes.

mass centered on boreholes BS22 and BS23 [14]. Therefore, RMSG, F_{RMR}, and F_Q can be calculated, as shown in Tables 7–9.

2.6. The Quantitative Relation of RMSG, F_{RMR}, and F_Q. Using the F_{RMR} and F_Q as the Y-axis and the RMSG as the X-axis, point-to-point relationships between F_{RMR} and F_Q and RMSG were established in a right-angle coordinate system along with the fitted curves, as shown in Figures 5 and 6. It can be seen that RMSG and F_{RMR} are linearly related, and RMSG and F_Q are negatively exponential, so F_{RMR} and F_Q are logarithmically related, which is consistent with Bieniawski's statistics (Figures 5 and 6). It can also be seen that RMSG-F_{RMR} and RMSG-F_Q of the outcrops around BS23 borehole are slightly better fitted than BS22 borehole. The quantitative correspondence between F_{RMR} and F_Q and RMSG was expressed as

$$F_{RMR} = 95.616 - 0.8283\text{RMSG}, \tag{4}$$

$$F_Q = 318.26e^{-0.097\text{RMSG}}. \tag{5}$$

For the other outcrops around BS23 borehole, the theoretical and actual values of F_{RMR} and F_Q were compared

Table 10: Comparison of theoretical and actual values of F_{RMR} and F_Q.

Outcrop No.	F_{RMR}		F_Q		Outcrop No.	F_{RMR}		F_Q	
	Theoretical	Actual	Theoretical	Actual		Theoretical	Actual	Theoretical	Actual value
16	83	83	76	70	36	69	68	21	12
17	65	66	38	10	37	80	80	41	49
18	89	88	133	125	38	88	88	93	125
19	65	67	24	11	39	85	88	94	125
20	92	88	111	125	40	84	80	31	49
21	80	83	63	70	41	92	88	108	125
22	71	71	29	17	42	70	75	18	28
23	87	83	76	70	43	80	80	46	49
24	61	68	22	12	44	71	71	21	17
25	63	62	14	6	45	66	68	21	12
26	73	77	20	35	46	71	67	17	11
27	84	80	45	49	47	81	85	81	88
28	68	68	11	12	48	77	76	41	31
29	90	88	106	125	49	78	74	27	25
30	66	68	21	12	50	73	76	20	31
31	80	80	57	49	51	87	90	123	158
32	68	68	7	12	52	80	79	31	44
33	69	74	22	25	53	66	64	19	8
34	70	68	10	12	54	77	78	23	39
35	60	59	16	4	55	83	80	32	49

Table 11: Contrast with the classification result of rock mass quality and rock mass structure.

Rock level	RMSG		Actual measurement of F_{RMR}		Theoretical calculation of F_{RMR}	
	Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)	Area (m^2)	Percentage (%)
I	0.79	39.6	0.46	22.9	0.38	19.2
II	1.21	60.4	1.54	77.1	1.60	79.9
III	0	0	0	0	0.02	0.9

based on the quantitative relationships Equations (4) and (5), as shown in Table 10. The error distribution of theoretical and actual values was plotted according to the data in Table 11, as shown in Figure 7. It can be seen that the F_Q value was a larger error than the F_{RMR} value, which was mainly due to the exponential function relationship between RMSG and F_Q 。 Because the error of F_{RMR} value is smaller, F_{RMR} is chosen as rock mass quality evaluation index.

2.7. Engineering Applications. The joint survey was carried out using the lineament method for the surrounding rock mass of about 2 km^2 around BS23 borehole, which obtains rock mass structure classification index and rock mass quality grade of each outcrop. According to the quantitative relationship between F_{RMR} and RMSG, RMSG, F_{RMR}, and the theoretically calculated F_{RMR} value were plotted in contour maps as Figures 8–10. It can be seen that F_{RMR} grading result is II about 1.6 km^2 and 79.9% of the total area, I is about 0.4 km^2 and 19.2% of the total area, and III is only distributed in a small area in the southwest of the measurement area. In general, the quality of the rock masses is good, and the distribution is relatively uniform.

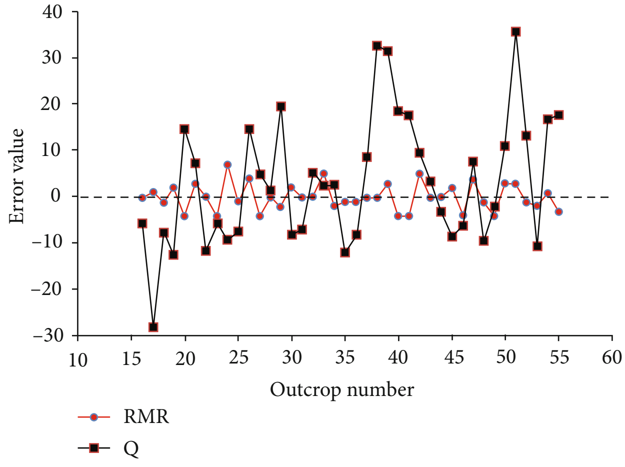

Figure 7: Error distribution chart.

The results of rock mass quality evaluation through F_{RMR} and theoretically F_{RMR} values and rock structure grading through *RMSG* are given in Table 11. The theoretically calculated F_{RMR} and RMSG were basically consistent that

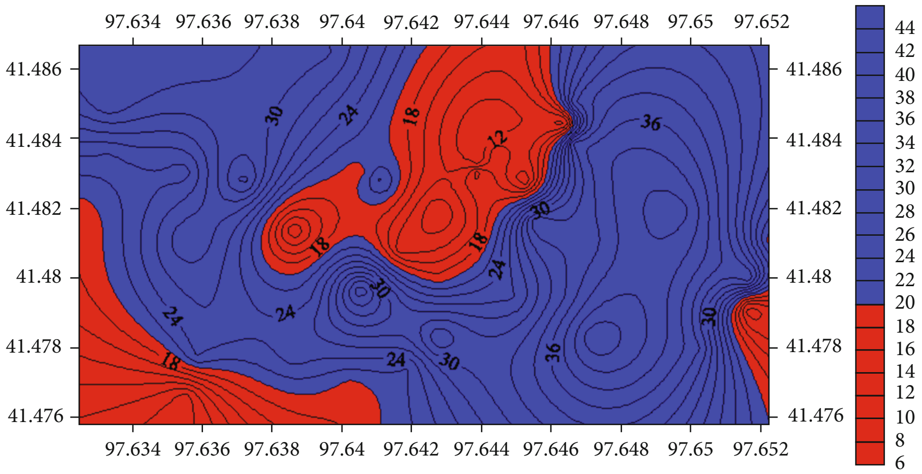

Figure 8: The contour map of RMSG around BS23 borehole.

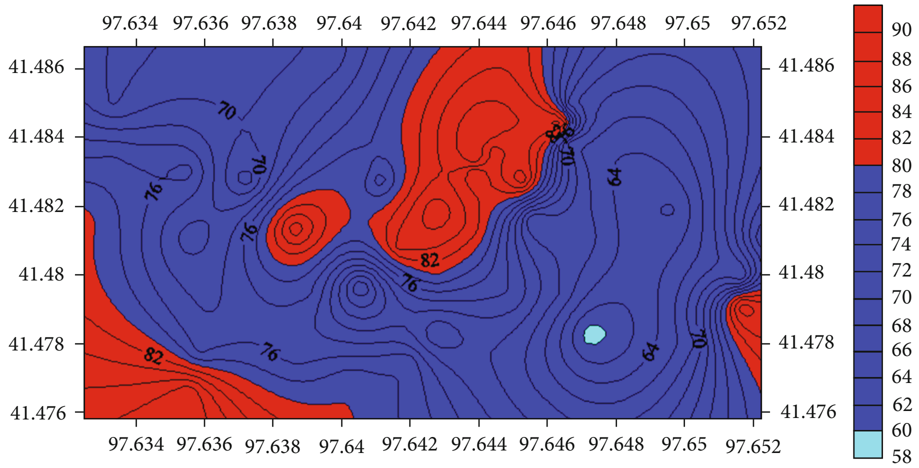

Figure 9: The contour map of F_{RMR} around BS23 borehole.

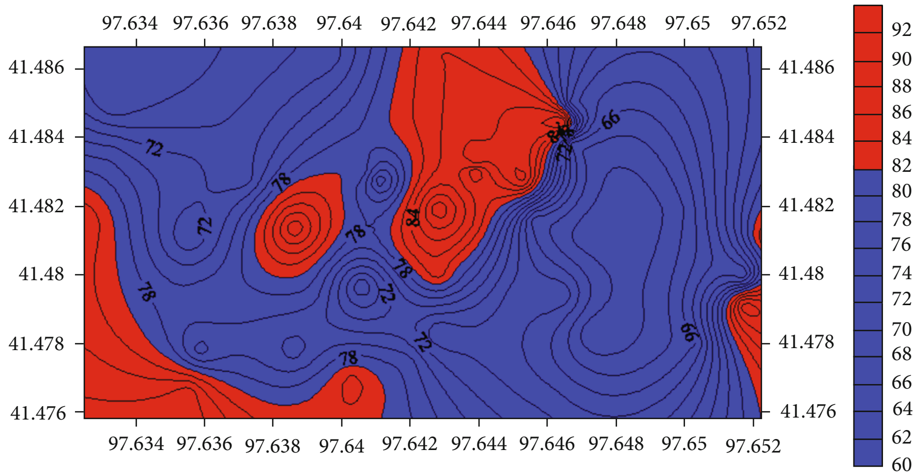

Figure 10: The contour map of theoretical F_{RMR} around BS23 borehole.

II is the most widely distributed, so it is feasible to use the quantitative relationship between F_{RMR} and RMSG for rock mass quality evaluation (see Table 11and Figures 8–10). At the same time, the rock mass structure grading determined through RMSG and the rock mass quality evaluation grades obtained through F_{RMR} have good consistency, and rock mass quality evaluation is also feasible through rock structure grade.

3. Conclusion

Rock mass engineering quality is a key factor in evaluating the long-term stability and safety of HLW geological disposal project and is also an important basis for the alternative site of repository. In this paper, based on the study of quantitative indicators for controlling rock structure in traditional rock mass engineering quality evaluation methods, the RMSG, a relatively comprehensive and comprehensive classification index for surface rock mass structure, was proposed. On the basis of the investigation and statistics of surface rock joints and the relationship between RMSG and F_{RMR}, F_Q was quantified, which was applied in the HLW geological disposal project. The results were as follows.

(a) Because the distribution of all fracture zones and the borehole was more than, the distribution of fracture zones meets the requirements of HLW geological disposal. The *RMSG* was used to grade the rock structure. The traditional rock mass quality evaluation correction indexes F_{RMR} and F_Q, was used to grade rock mass quality. RMSG was the linear relationship with F_{RMR} and the negative exponential relationship with F_Q

(b) The analysis of contour plots drawn from the RMSG, F_{RMR}, and theoretically calculated F_{RMR} showed that the rock structure grade is consistent with the rock mass structure grade. So it is feasible to use the rock structure grade for preliminary rock mass quality evaluation

(c) The rock structure is the main factor affecting the rock mass quality in the HLW disposal project, so it is feasible to use the correlation between rock structure and rock mass quality for repository site comparison. But the correlation still needs a lot of verification and supplementation, while further research is needed in whether it is applicable to the other projects

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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