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Relationships between Field, Experimental Strengths or Their Ratios and Excavating Depths of Rock Masses in Datun Coal Mining Area

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***Abstract*--By experimental results for mudstone under the seventh coal seam and sand mudstone of the eighth coal seam in Datun mining area, their uniaxial compression strengths have no relationship with mining depth. Field compression strengths of these strata are not only no more than their experimental strengths, but also all descending with increasing excavation depths. Especially, the rock masses will represent soft rock in engineering as mining depth has been beyond 800 meters. That determining compression strength ratios of rock masses in situ to that in laboratory is an important reference for experimental results being used in real engineering, especially in deeper underground engineering. Strength ratios of rock masses in Datun coal mining area are about 75% in depth range from 300 to 600 meters and only 30% in depth range from 800 to 900 meters respectively. To mudstone under the seventh coal seam which mining depth is particularly deep or property is relatively weak, characteristic of strength ratio's decline with mining depth's increase should be more distinct. Studying results involving rock strata under coal seams in Datun coal mining area may be used to determine their strengths in situ.**

Keywords--field strength, experimental strength, strength ratio, mining depth, relationship

I. Introduction

Stress concentrated on rock masses must become higher with increasing mining depth of coal resources. Rheology will be main mechanical characteristics of hard rock in concentrated stress field, which is named soft engineering rock. Stability of underground engineering may depend on rheology of soft rock masses in situ[1]-[9]. Therefore, studying relationships between field, experimental strengths or their ratio and excavating depth of rock masses is a basic subject.

For typical destroyed mode on tunneling boundary of underground engineering closed with hard rock masses must be brittle split, reasonable strength of rock masses in their initial positions is determined to international rock mechanics and engineering. Stabilities of rock masses in situ would decrease because of primary crack, new fracture and failed effective surrounding pressure. Generally, uniaxial compressing strength ratios of rock mass in situ and in laboratory should have been range from 30% to 50%. While, based on numerical simulation or Kirsch analytic solution of smooth excavation boundary, rock stresses producing new joints in uniaxial compressing test could be equivalent to the ultimate strength of rock masses in situ, which is not very perfect without considering irregular boundary of underground engineering[10]-[15]. Assuming actual strength of rock mass in situ is almost its uniaxial compressing strength in laboratory in same scale space, Ming Cai represents that ratios between long term strength of entirely crystalline rock mass and its uniaxial compressing strength are range from 70% to 80% when involving scale effect and time effect, and the ratio must be beyond 30% if covering mineral structures of rock masses. These conclusions should depend on correct excavation boundary of underground engineering, which provides an important field to study strength distribution of rock mass in situ adjoining the excavating boundary of underground engineering[16]. However, because research background is circle tunnel of Mine-by laboratory in Canada whose mining depth is 420 m, surrounding rock is granite and tunneling method is mechanical excavation with little damage to rock mass, all these causes strictly limit application of scientific conclusions.

To localized underground engineering, that studying relationships between strength ratio of rock mass in situ and in laboratory and excavating depth will be useful to determine engineering application of laboratory strength of rock mass in situ with different mining depths. In Shanghai Datun Energy Resources Company Limited, China Coal Energy Company Limited, the seventh and eighth coal seams have been being excavated and covered depth range from 300 to 1000 meters. Actual coal production of four collieries in the company states softer rock mass under the coal seams could not be neglected to stability of underground engineering. For rock masses under the coal seams are determined to safety production of working face, roof rock mass control and support management, compressing strength test in situ with large scale mould may give true strength of rock masses in situ, especially to soft rock masses in deeper excavating position[17].

II. Strength Test in Laboratory of Rock under Coal Seam in Mining Zone

Suggestion to basic rock mechanical test has been certified by international rock mechanical standard committee with a published book suggestion method for rock mechanical test[18]. In China, series of rules and methods about rock mechanical tests had also been formulated by coal industry department and water conservancy department to clearly put forward specimen size, cutting accuracy and methods[19]-[20]. SAW 2000 electro-hydraulic servo-controlled rock mechanics testing system manufactured by Changchun Kexin Testing Instrument Co. LTD which is now equipped in Shandong Agricultural University is an ideal facility for mechanical tests of rock, concrete and cement mortar specimens, and stiffness of the machine frame is beyond 2×10^{10} N/m. Standard specimens are cut from rock masses under the seventh and eighth coal seams involving different mining depths. A stress-strain curve from rock mechanical test is illustrated in Fig. 1. Axial stress may be expressed with σ_v and ε_c stands for vertical strain.

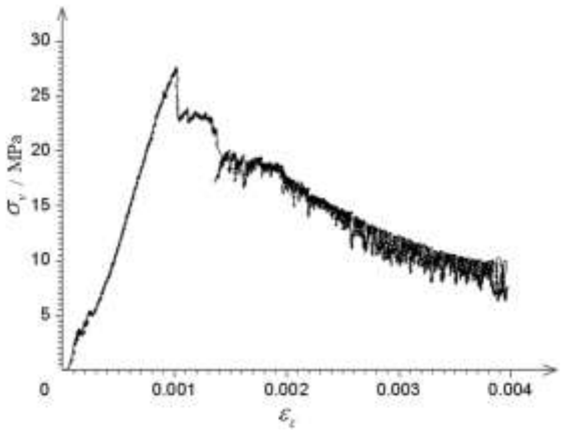

Fig. 1. Strain-stress curve of rock specimen

From the rock mechanical test curve, uniaxial compressing strength of the rock in laboratory is 27.64 MPa which stands for σ_c. Other experimental results of each group specimens are same as the illustration, while their even value may be used in this subject.

III. Monitoring Compressing Strength of Rock Mass under the Coal Seam in Situ

Many working faces distributed in Datun coal mining field to excavate the seventh and the eighth coal seams lie in different mining depths. Monitoring positions in those working faces are determined to get compressing strengths of rock masses under the coal seams in situ by specific pressure meter. Specific pressure instrument based statics is illustrated in Fig. 2, and in Fig. 3 monitoring positions for field strengths have been represented.

Immediate floor of the 7th coal seam in 340 m depth is mudstone, immediate floor of the 8th coal seam in 350 m depth is sandy mudstone, immediate floor of the 7th coal seam in 360 m depth is mudstone, immediate floor of the 8th coal seam in 577 m depth is sandy mudstone, immediate floor of the 7th coal seam in 578 m depth is mudstone, immediate floor of the 7th coal seam in 800 m depth is mudstone, immediate floor of the 8th coal seam in 810 m depth is sandy mudstone, and immediate floor of the 7th coal seam in 858 m depth is mudstone respectively. Compressing strengths in situ of every rock masses under the coal seam in different mining depths should be determined by tests.

Fig. 2. Specific pressure instrument based on statics

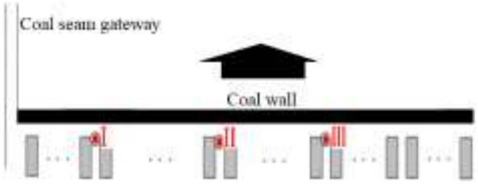

Fig. 3. Monitoring positions for field strengths

According to real conditions of rock masses under coal seams, compressing templates with appropriate diameters are chosen to receive strengths of rock in situ. Relationship between compressed distance h_i of the template and its specific pressure q_{mi} is illustrated in Fig. 4.

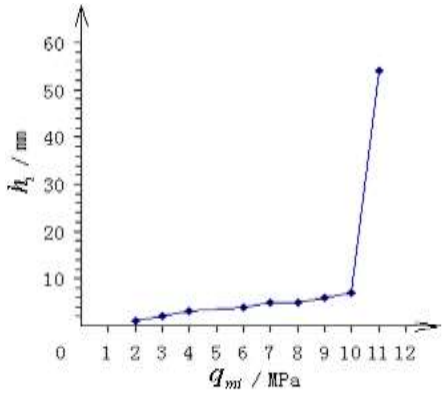

Fig. 4. Field relationship between h_i and q_{mi}

Among them,

$$q_{mi} = \left(\frac{D}{d_m}\right)^2 \cdot q_{zi} \tag{1}$$

Where: D—inner diameter of hydro-cylinder, mm;

d_m—diameter of template, mm;

q_{zi}—pumping pressure of each time, MPa.

Analyzing h_i - q_{mi} curve of rock mass in situ, its compressing strength σ_s is about 10.00 MPa. Other monitoring results in situ are same as this illustration and will be usable with the average value.

IV. Distribution of Strengths and Their Ratio of Rock Masses under the Coal Seams in Mining Zone

Mudstone is main rock mass under the seventh coal seam and sandy mudstone is that under the eighth coal seam, which excavation depths are range from 340 to 858 meters. Uniaxial compressing strengths of these rock masses in laboratory have been listed in Table 1 to compare with results of rock masses in situ.

TABLE I. EXPERIMENTAL AND FIELD STRENGTHS OF STRATA UNDER COAL SEAMS IN DATUN MINING AREA

No.	Colliery	Tunneling Position of Rock Mass in Situ	Rock Mass	Rock	H /m	σ_c /MPa	Working Face	σ_s /MPa	Strength Ratio/% σ_s/σ_c	Strength Ratio/% *Average*
1	Yao qiao	Exit of material roadway in working face 7717	Immediate floor of the 7th coal seam	Mudstone	340	45.63	7717	33.44	73.29	74.88
2	Yao qiao	Exit of material roadway in working face 7717	Immediate floor of the 8th coal seam	Sandy mudstone	350	50.98	8503	29.58	58.02	
3	Long dong	Material roadway of working face 7162	Immediate floor of the 7th coal seam	Mudstone	360	44.71	7162	32.24	72.11	
4	Xu zhuang	Material roadway of working face 8230	Immediate floor of the 8th coal seam	Sandy mudstone	577	36.04	8172	32.08	89.01	
5	Xu zhuang	Material roadway of working face 7199	Immediate floor of the 7th coal seam	Mudstone	578	38.88	7199	31.87	81.97	
6	Yao qiao	Exit of transportation roadway in working face 7269	Immediate floor of the 7th coal seam	Mudstone	800	43.99	7269	17.25	39.21	31.20
7	Kong zhuang	Exit of district dip Ⅲ5	Immediate floor of the 8th coal seam	Sandy mudstone	810	59.23	8353	22.20	37.48	
8	Kong zhuang	Material roadway of working face 17433 in Ⅳ district	Immediate floor of the 7th coal seam	Mudstone	858	28.03	7354	4.74	16.91	

From Table 1, uniaxial compressing strengths of rock masses under the seventh and the eighth coal seams in situ are all beyond 25 MPa when mining depths are no more than 600 meters, and all no more than 25 MPa if the excavating depths have been beyond 800 meters. That is, ultimate strength of sandy mudstone in laboratory from depth of 810 meters has been up to 60 MPa which may possess middle stability, but it is a typical soft rock mass in engineering for its compressing strength in situ is only 22.2 MPa. Experimental results may have proved that load bearing capacity of rock masses in situ is especially lower than it in laboratory, and also the stable rock will became soft rock mass in engineering for its decreased strength with increased excavation depth.

Uniaxial compressing strength ratios between strength of rock in situ and that in laboratory descend with increase of mining depths, which has been listed in table 1. From which the strength ratio may reach about 75% when excavating depth range from 300 to 600 meters, while it may not even achieve 30% if mining depth range from 800 to 900 meters. The above conclusions state uniaxial compressing strength of rock mass in situ is indeed no more than that in laboratory. Experimental results about rock mass have been given a suggested proportion to engineering application, which is one third in Datun mining area as excavating depth has been beyond 800 meters.

V. Relationships between Strengths or Their Ratio and Excavating Depth of Mudstone under the Seventh Coal Seam

Mudstone under the seventh coal seam in Datun coal mining area is soft rock mass in engineering, which relationships between uniaxial compressing strengths in laboratory, in situ or their ratios and mining depths are illustrated in Fig. 5 with curves.

Uniaxial compressing strengths of mudstone under the seventh coal seam in laboratory and that in situ are both descending with increasing excavation depths, and strength

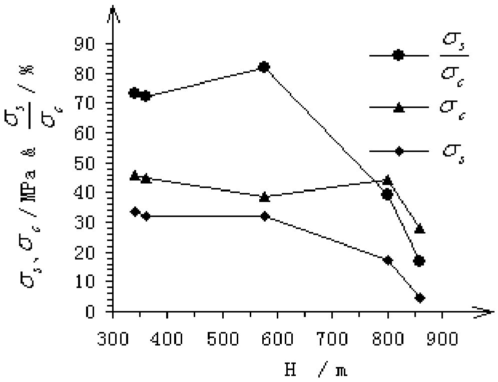

Fig. 5. Relationship between field, experimental strength or their ratio and mining depth of mudstone under the 7th coal seam

values of rock mass in laboratory are almost more than those in situ. Limited by mining depth of 600 meters the average strength ratio of the mudstone is about 75%, also the even strength ratio is only 28% when the excavating depths have been beyond 800 meters.

VI. Main Conclusions

Uniaxial compressing strengths of mudstone and sandy mudstone under coal seams in laboratory are all beyond 25 MPa, which have reached medium stability without influence of mining depths. Compressing strengths of the rock masses in situ are under those in laboratory, which represents typical instability in engineering with increasing excavation depths especially being beyond 800 meters.

Uniaxial compressing strength ratios between rock mass in situ and rock in laboratory descend with increasing excavation depths. The ratio may be about 75% when mining depths of rock masses are range from 300 to 600 meters, and it will be only 30% if excavating depths have been beyond 800 meters. This study provides valuable proportions about experimental results of rock masses being used in situ.

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