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Study of triaxial compression test on mechanical parameters of coal rock

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Abstract: *The stability problem of the coal seam roof and bottom slab has been an important issue for mine safety in the process of coal mine workings in the recovery process. To solve this problem, rock mechanics tests are needed to study the mechanical properties of coal seams and top and bottom plates. In this paper, triaxial compression tests were applied to the No. Coal-two seam and top and a bottom slab of Wangjiazhai coal mine, and the compressive strength, residual strength and cohesive force C, and internal friction angle of coal rocks under different circumferential pressure were measured. φ values. The test results show that the residual strength of the rock is higher than that of the coal sample and decays faster with the increase of strain, and the axial bearing limit of the coal rock is generally linear with the surrounding pressure, which generally conforms to Coulomb's strength criterion. The findings of the study are of great significance for the support design of the roadway and the study of other reinforcement mechanisms.*

Keywords: *triaxial compression test, stress-strain, support*

1. Introduction

Rock mechanics tests have always been the main means to understand the mechanical properties of rocks under different stress states, and also the main basis for establishing strength theory and intrinsic structure relations[1-2] . Due to the limitation of science and technology development level and experimental means, the fruitful research on the mechanical properties of rocks is only about half a century, and rock mechanics experiments are the basis for the study of rock mechanics theory and engineering technology, and the accuracy of test results determines the reliability of rock mechanics problem calculation and engineering design. Therefore, rock mechanics tests are of great importance to the study of rock mechanics theory and related engineering calculations and designs. To this end, triaxial compression tests were conducted on the No. 2 coal seam and top and bottom slabs of Wangjiazhai coal mine to provide scientific and accurate basic parameters for the design of roadway support.

2. Test procedure

To study the triaxial compression characteristics of coal seams in mines, the compressive strength, residual strength and cohesive force C, internal friction angle of coal rocks under different circumferential pressure are derivedφ The values of[3-4] . The test was carried out in the ROCK600-50 rock test system according to the ministerial standard. The tests were carried out on the ROCK600-50 rock test system according to the ministerial standard. Stress-strain curves were obtained from the test results at[5] , where the strains from rock compression were positive and the strains from rock expansion were negative.

3. Calculation of experimental data

3.1 Calculation of axial stress under different lateral pressure conditionsσ=P/A

Where: σ—the axial stress under different lateral pressure conditions, MPa;

P—axial breaking load of the specimen, kN;

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A—Area of the specimen, mm2.

3.2 Determination of internal friction angle φ and bonding force C for coal and rock

(1)Cylindrical specimen under axial stressσ_1 and the surrounding pressureσ_3 under the joint action of the inclination angle of θ of the section is subjected to the positive stress σ and shear stress τ are as follows

$$\sigma = \sigma_1 cos^2\theta + \sigma_3 sin^2\theta = (\sigma_1 - \sigma_3)cos^2\theta + \sigma_3$$

$$\tau = (\sigma_1 - \sigma_3)\sin\theta\cos\theta$$

According to Coulomb's criterion, the condition for this section not to produce damage is

$$\tau < \mu\sigma + C$$

namely: $cos^2\theta(\tan\theta - \mu)\sigma_1 < (\sin\theta\cos\theta + \mu sin^2\theta)\sigma_3 + C$

It is clear that the $\tan\theta \le \mu$, $\theta \le \varphi = \arctan\mu$At time, the above equation holds constant. Axial stress σ_1 increase causes the shear stressτincreases, but the positive stressσ and friction increase more, so the rock sample will not be a shear slip.

in$tan\,\theta > \mu$ or tilt angle$\theta > \varphi = arctan\mu$ when:

$$\sigma_1 < [(\sin\theta\cos\theta + \mu sin^2\theta)\sigma_3 + C]/cos^2\theta(\tan\theta - \mu)$$

The right side of the above equation is the maximum axial stress that the section can carry, and the influencing parameters are the inclination angle, the friction coefficient, the cohesion ,and the surrounding pressure.

Mathematical analysis of equation shows that the dip angle$\theta_0 = 45° + \frac{\varphi}{2}$

The bearin capacity of the cross section is the smallest. in the case of homogeneous rock samples and no obvious damage, the rock samples along the inclination angle θ0 The damage of the cross-section of the dip angle, as shown in Figure 1.

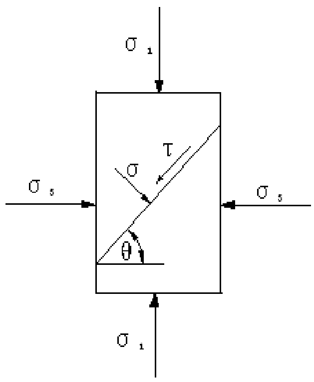

Figure 1: Triaxial bearing capacity of rock samples with different inclination sections

(2) Calculation of internal friction angle and bonding coefficient C Rock strength equation:

$$\tau = \sigma tg\varphi + C$$

Triaxial test linear regression equation: $\sigma_1 - \sigma_3 = \sigma_3 tg\alpha + k$

where: φ — angle of internal friction of the rock;

C —rock cohesion;

$tg\alpha$ —slope of the linear regression equation;

k—Intercept of the vertical axis of the linear regression equation.

From the Mohr stress circle relationship the equation for φ , C can be derived:

$$\varphi = 2tg^{-1}\sqrt{tg\alpha + 1} - 90$$

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$$C = \frac{k(1-\sin\varphi)}{2\cos\varphi}$$

4. Triaxial compression test of coal seam and top and bottom slab and results

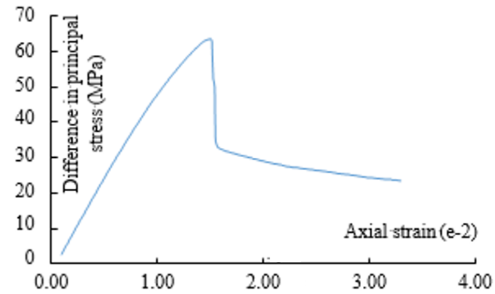
The mechanical parameters such as triaxial strength and residual strength of coal seam 2 in Wangjiazhai coal mine were obtained through the test, and the specific test results are shown in Table 3.2. In the process of coal rock coring, the strength of the coal rock specimens measured in the laboratory was higher than that of the coal body because the coal mine contained more joints and the coal rock cores that could be taken contained fewer laminated fissures[6].

1) The results of triaxial compression tests on coal -two seams and top and bottom plates are shown in Table 1

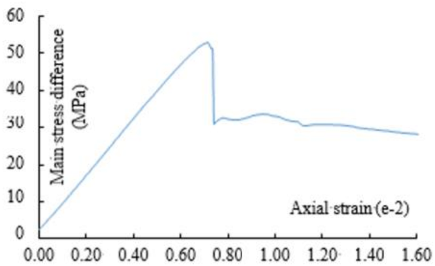
Table 1: Coal seam and top and bottom plate triaxial compression test results

Rockiness	Surrounding pressure (MPa)	Damage load (kN)	Triaxial strength limit (MPa)	Residual strength (MPa)	Full Stress-Strain Curve Chart No.
Coal-two	5	124.58	63.48	23.48	Fig.2(1)
	10	100.32	51.12	28.08	Fig.2(2)
	15	112.77	57.46	2.56	Fig.2(3)
Coal-two Roof plate	5	201.29	102.57	28.37	Fig.2(4)
	10	147.48	75.15	46.44	Fig.2(5)
	15	194.88	99.30	53.19	Fig.2(6)
Coal-two Base plate	5	86.51	44.08	22.57	Fig.2(7)
	10	215.62	109.87	44.58	Fig.2(8)
	15	252.02	128.42	59.34	Fig.2(9)

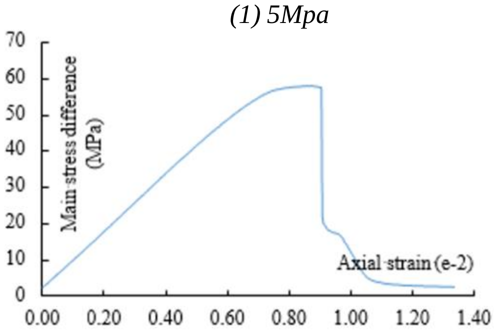
2) The full stress-strain curves under triaxial compression of the coal seam and the top and bottom plates are shown in Figure 2.



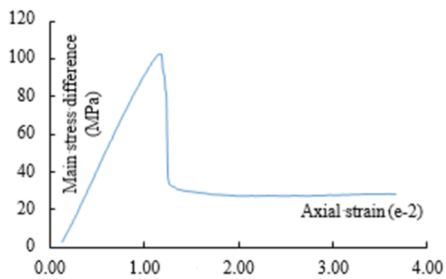
(1) 5Mpa



(2) 10Mpa



(3) 15Mpa



(4) 5Mpa

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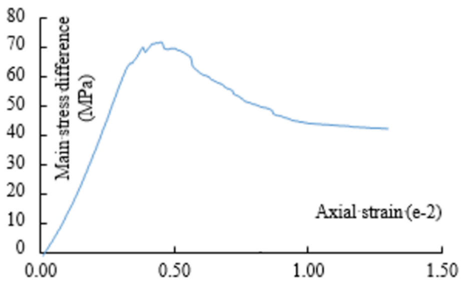
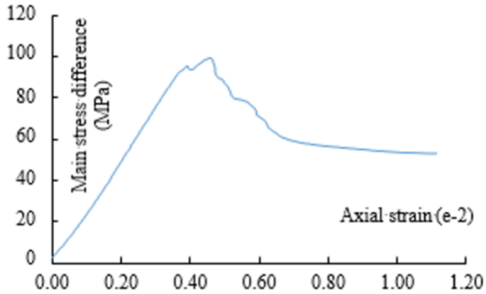
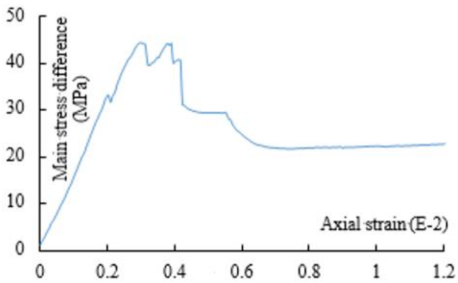


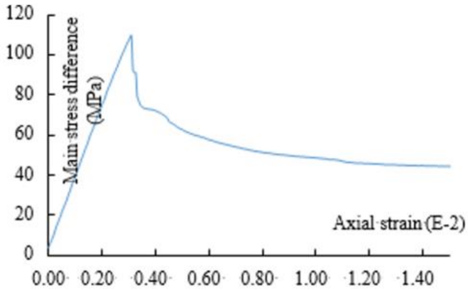
(5) 10Mpa



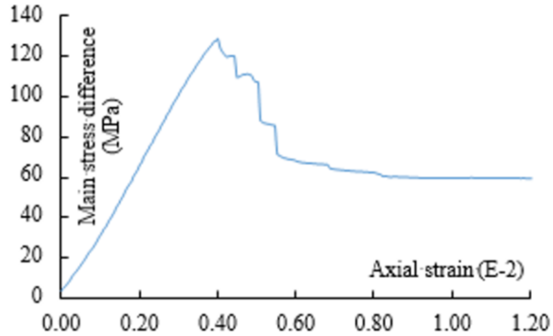
(6) 15Mpa



(7) 5Mpa



(8) 10Mpa



(9) 15Mpa

Figure 2: Tri-axial compression full stress-strain curve of No.2 coal and top and bottom plates

The internal friction angle and cohesive force C of coal seam and top and bottom slab rock is calculated in Table 2.

Table 2: Experimental results of internal friction angle φ and cohesion C in 2 coal seams and top and bottom plates

Rockiness	$\sigma_1-\sigma_3$ Linear regression equation	Correlationcoefficient	C (MPa)	$\varphi(^\circ)$
Coal-two	$\sigma_1-\sigma_3$=23.6637+2.1491σ_3	0.985186	6.667	31.19603
Roof plate	$\sigma_1-\sigma_3$=46.582+4.31214σ_3	0.99648	10.1054	37.0903
Base plate	$\sigma_1-\sigma_3$=26.621+6.3452σ_3	0.88426	12.0325	42.5

5. Analysis of experimental results

Figure 2 shows the stress-strain curves of No.coal-two seam and top and bottom slab under conventional triaxial compression test, from which it can be seen that the rupture process of the specimen can be roughly divided into five stages: compression-density stage, linear-elastic stage, fracture extension and expansion stage, unstable macroscopic rupture stage, and residual plastic stage.

(1)Compression stage: A large number of microfractures, pores and defects such as joints and laminae in the coal sample are gradually compressed and closed under the action of the load, which is up-concave in the axial stress-strain curve;

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(2)Linear elastic stage: from the axial stress-strain curve, the curve is macroscopically linear, and the specimen behaves as a seemingly continuous medium after the linear elastic stage, with $\varepsilon 1$ gradually increasing, while $\varepsilon 3$ changes less;

(3)Crack extension and expansion stage: after the online elastic stage, a large amount of energy is accumulated in the specimen, and it enters the plastic deformation stage, many micro-cracks are generated inside the specimen, with the development and convergence of cracks, the deformation starts to accelerate and increase, resulting in the expansion phenomenon, the load rises slowly, the rupture increases with the increase of load, the specimen enters the plastic yield state and gradually reaches the peak stress; after reaching the peak stress, the crack expansion penetration intensifies, macroscopic cracks increase, the deformation rate of the specimen increases, $\varepsilon 3$ grows steadily, and the dilation phenomenon is obvious;

(4)Unstable macro rupture stage: the specimen macro crack continues to develop, forming arupture surface, the specimen deformation increases sharply, the expansion is intense, and the stress-strain curve produces a sudden drop until damage.

(5)Residual plastic stage: the plastic deformation of the rock sample continues to develop and eventually reaches the residual strength of the rock sample.

6. Conclusion

(1)The average compressive strength of the No. 2 coal seam and the top and bottom plates of the Wangjiazhai coal mine was 11.70 MPa, with an average internal friction angle of 31.2° and an average cohesive force of 6.67 MPa; the average compressive strength of the top plate of the No. 2 coal seam was 49.43 MPa, with an average internal friction angle of 37.09° andan average cohesive force of 10.1 MPa; the average compressive strength of the bottom plate of the No. 2 coal seam was 76.85 MPa, with an average internal friction angle of 42.5° and an average cohesive force of 12.03 MPa. The average compressive strength of the bottom plate of coal seam 2 is 76.85 MPa, the average internal friction angle is 42.5°, and the average cohesive force is 12.03 MPa.

(2)According to the stress-strain curves under triaxial compression tests, the rupture process of the sample specimens can be roughly divided into five stages: compression-density stage, linear-elastic stage, fracture extension and expansion stage, unstable macroscopic rupture stage, and residual plasticity stage.

(3)The damage form of coal rock samples in triaxial compression conditions is relatively simple, generally shear damage from the morphological point of view, and the axial bearing limit is generally linearly related to the surrounding pressure, which is generally consistent with Coulomb strength criterion.

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