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Experimental Study on the Anisotropy of the Tensile and Shearing Strength of Coal Rock

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Abstract

The tensile and shearing strength of coal rock accurately obtained by test can provide important parameters for the design of coal seam fracturing and main support system. Due to coal bedding and cleat developed, the experimental results will exist voluminous discreteness and can't accurate determine the tensile and shearing strength, ignoring the influence of loading direction and bedding and cleat development direction, In this paper, the tensile and shearing strength is measured by laboratory experiment, counting and analyzing divergence of different direction according to experimental results, obtaining the relationship between the tensile and shearing strength and the bedding and cleat development direction. This research confirms that the tensile and shearing strength of coal rock exists the characteristic of anisotropy and it should not only take the average value of the test results of different direction simply in engineering application. On the other hand, it can supply experimental consideration and method to confirm the tensile and shearing strength required by the relevant construction design.

Key words: Coal rock; Tensile strength; Shearing strength; Anisotropy

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INTRODUCTION

The tensile and shearing strength of coal rock accurately obtained by test can provide important parameters for the design of coal seam fracturing and mine support system. Due to coal bedding and cleat developed[1-5], the tensile and shear strength of coal rock acquired by test frequently existing voluminous discreteness, many previous researches simply taking average experimental value as the corresponding numerical strength, there is a big deviation between the average value and the actual value. Many scholars carried out the experiment to obtain the tensile and shear strength of coal rock[6-8], but they ignored the bedding and cleat system influence on the tensile strength and the experimental results existed voluminous discreteness. Yan Lihong[9], Wu Jiwen[10], Yan Zhifeng[11] and other scholars carried out a large number of tensile test and draw a conclusion that the tensile strength is quite different in the vertical and parallel direction of bedding, but the relationship between the cleat development direction and the tensile and shear strength can't be confirmed, and the mechanical parameters had obvious differences while the included angle between the cleats direction and principal stress was different. Therefore, the tensile and shearing strength with different direction is examined by laboratory test, and the variety regulation of parameters will be achieved. It can accurately calculate and analyze the relationship between the tensile and shearing strength and the direction of bedding and cleat, and supply reference to calculation of the tensile and shearing strength required by the relevant construction design.

1. PREPARATION OF LABORATORY CORE

The coal samples came from Dextral Roadway 4 West Block 22, Jixi mining area, Hei Longjiang province, and coal seam dip angle is 15°, and buried depth is 870 m. The coal samples dimensions is greater than 400 × 300 × 180 mm, and the pictures of the coal samples shot in laboratory is shown in Figure 1.

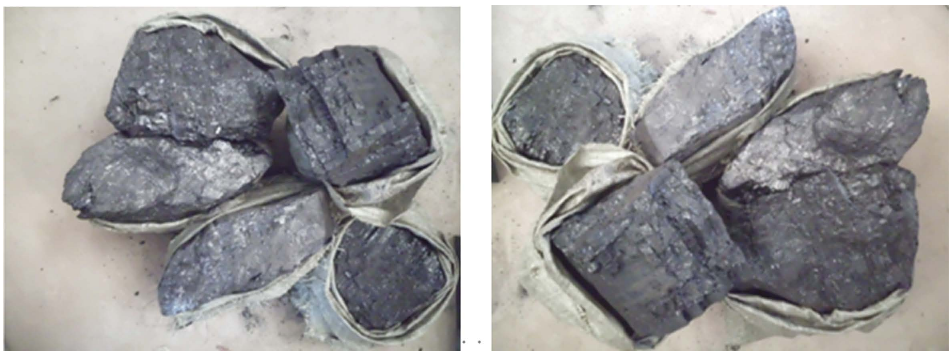


Figure 1
The Coal Samples From Dextral Roadway 4 West Block 22

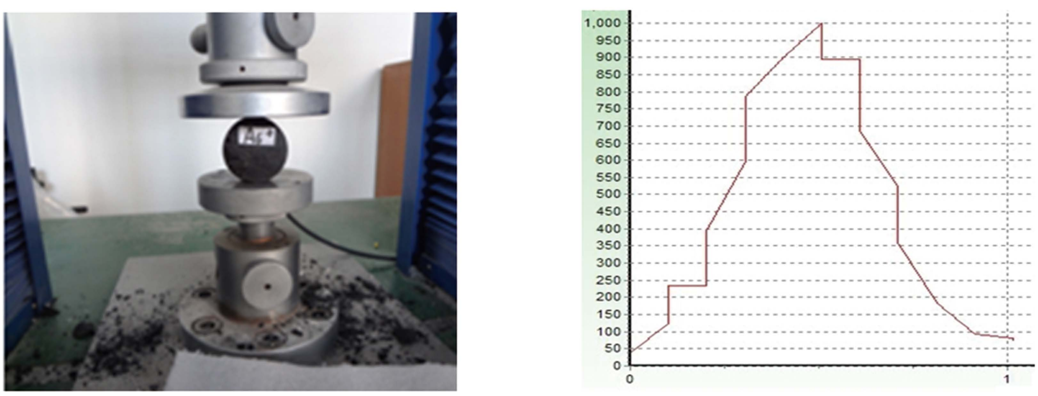
The dimension of test samples applied to tensile and shear test is Φ50 × 25~50 mm. according to the test requirements, preparation of coal standard samples is shown in Figure 2.

Figure 2
The Coal Sample of Tension Test and Shear Test (Φ50 mm)

2. EXPERIMENTAL TEST OF TENSILE STRENGTH

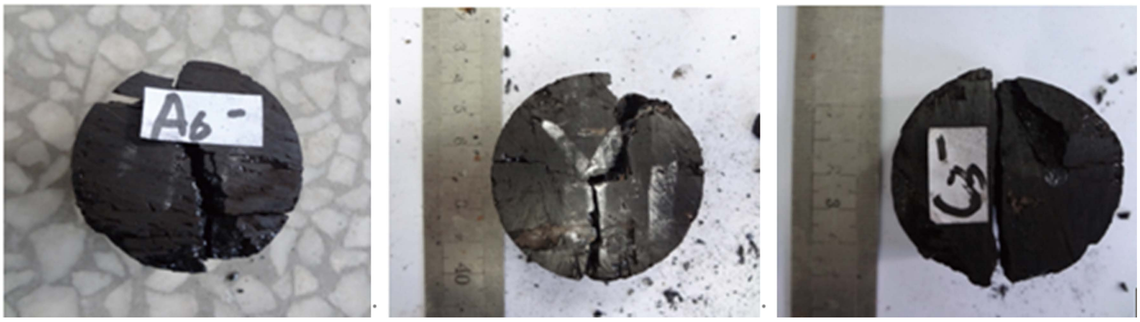
Due to coal bedding and cleat system developed, cut by joints and fractures, the coal structure complicated and the strength precipitous reduced. Uniaxial tensile strength acquired by Brazilian test, due to the loading direction being different, it may lead to values difference of tensile strength and show the strong anisotropy of tensile strength. This test designs and measures the tensile strength change under different conditions along with the cleat and splitting loading direction, and verifies and analyzes the characteristic of anisotropy of coal tensile strength according to laboratory findings.

The situation changes of loading process and the varying loads of coal sample is shown in Figure 3, and the failure mode of coal sample after test is shown in Figure 4.



(a) The Loading Process of Coal Sample A6 (b) The Load-Time Curve of Coal Sample A6

Figure 3
The Loading Process of Brazilian Test of Coal Samples From West Block 22



(a) Failure Form of Brazilian Test of Coal Sample A6 (b) Failure Form of Brazilian Test of Coal Sample Y1 (c) Failure Form of Brazilian Test of Coal Sample C3

Figure 4
Failure Form of Brazilian Test of Coal Samples From West Block 22

According to laboratory findings, calculated coal tensile strength with different direction of coring is shown in Table 1. From the laboratory findings, we can draw a conclusion that coal tensile strength presents large difference when the direction of coal rock coring and stress loading is different, and it also illustrates that the tensile strength of coal rock has directivity. The average value of tensile strength of coring coal sample along with the direction of perpendicular to the bedding and paralleled to face cleat and butt cleat is 0.45 MPa, and the average value of tensile strength of coring coal sample along with the direction of paralleled to bedding and perpendicular to face cleat is 0.51 MPa, and the average value of tensile strength of coring coal sample along with the direction of paralleled to bedding and face cleat is 0.58 MPa.

We can also consider that the value of tensile strength when the direction of the axis of loading is vertical to bedding is larger than the value when the direction of the axis of loading is parallel to bedding, which are consistent with existing research results[9,11]. However, under the condition of evenly bedding coring, the value of tensile strength of coal rock paralleled to face cleat is larger than the value of coal rock vertical to face cleat, and deviation of the average tensile strength is 13.73%.

Table 1
The Test Data of Brazilian Test of West Block 22

Coal rock sample No.	Sampling direction	Maximum breaking load N	Tensile strength MPa	The average value of tensile strength MPa
A4		957.52	0.49	
A5	Vertical to bedding paralleled to face cleat and butt cleat	1,098.10	0.56	0.45
A6		999.04	0.51	
X2		433.50	0.22	
Y1		1,058.10	0.54	
Y2	Paralleled to bedding vertical to face cleat	1,116.81	0.57	0.51
B5		773.45	0.40	
B6		1,050.49	0.53	
C3		1,158.08	0.59	
C5	Paralleled to bedding paralleled to face cleat	1,217.90	0.62	0.58
Z2		852.51	0.43	
Z5		1,295.74	0.66	

3. EXPERIMENTAL TEST OF SHEARING STRENGTH

Experimental test of shearing strength applied to variable angle shear test, and the test carried out many groups of experiment, including different, shear angle including respectively 35°, 45°, 55° and 65°. The conditions of loading process is shown in Figure 5.

According to laboratory findings, calculated coal shearing strength with different direction of coring is shown in Table 2. The shearing strength of coal rock has directivity, and the divergence of the shearing strength values with different coring directions is apparently various. From Mohr envelope (Figure 6) of different direction, we can consider that the cohesion and angle of internal friction of coring coal sample along with the direction of vertical to the bedding and paralleled to face butt cleat is 4.42 MPa, 18.35°; and the cohesion and angle of internal friction of coring coal sample along with the direction of paralleled to bedding and vertical to face cleat is 4.06 MPa, 17.07°; and the cohesion and angle of internal friction of coring coal sample along with the direction of paralleled to bedding and face cleat is 4.11 MPa, 19.84°; drawing Mohr envelope ignoring directions, calculated the cohesion and angle of internal friction are 4.32 MPa and 17.42°.

45° Shear Test of Coal Sample A10 55° Shear Test of Coal Sample A7 65° Shear Test of COAL SAMple X3

Figure 5
The Loading Process of Shear Test of Coal Samples From West Block 22

Table 2
The Test Data of Shear Test of West Block 22

Coal rock sample No	Cleat direction	Shear direction	Load N	Normal stress MPa	Shear stress MPa	The average value of shear strength MPa
X4	Vertical to bedding paralleled to face cleat and butt cleat	35°	18,679.49	12.11	8.51	6.41
A10		45°	9,488.27	5.39	5.34	
A7		55°	6,324.66	2.92	4.13	
X3		65°	10,590.35	3.62	7.66	
Y5	Paralleled to bedding paralleled to face cleat	35°	18,942.89	12.46	8.63	6.35
Y6		45°	11,389.48	6.47	6.41	
B7		55°	6,462.48	2.97	4.22	
B8		65°	8,488.87	2.9	6.14	
Z3	Paralleled to bedding vertical to face cleat	35°	15,869.88	10.44	7.23	5.78
Z4		45°	10,287.85	5.85	5.79	
C6		55°	8,514.55	3.93	5.56	
C7		65°	6,249.14	2.14	4.52	

This test illustrates that the value of shearing strength of coal rock paralleled to face cleat is larger than the value of coal rock vertical to face cleat, and the shearing strength paralleled to face cleat is 6.35 MPa, and the shearing strength vertical to face cleat is 5.78 MPa, and the difference is 0.57 MPa, and the percentage of disparity is 9.86%.

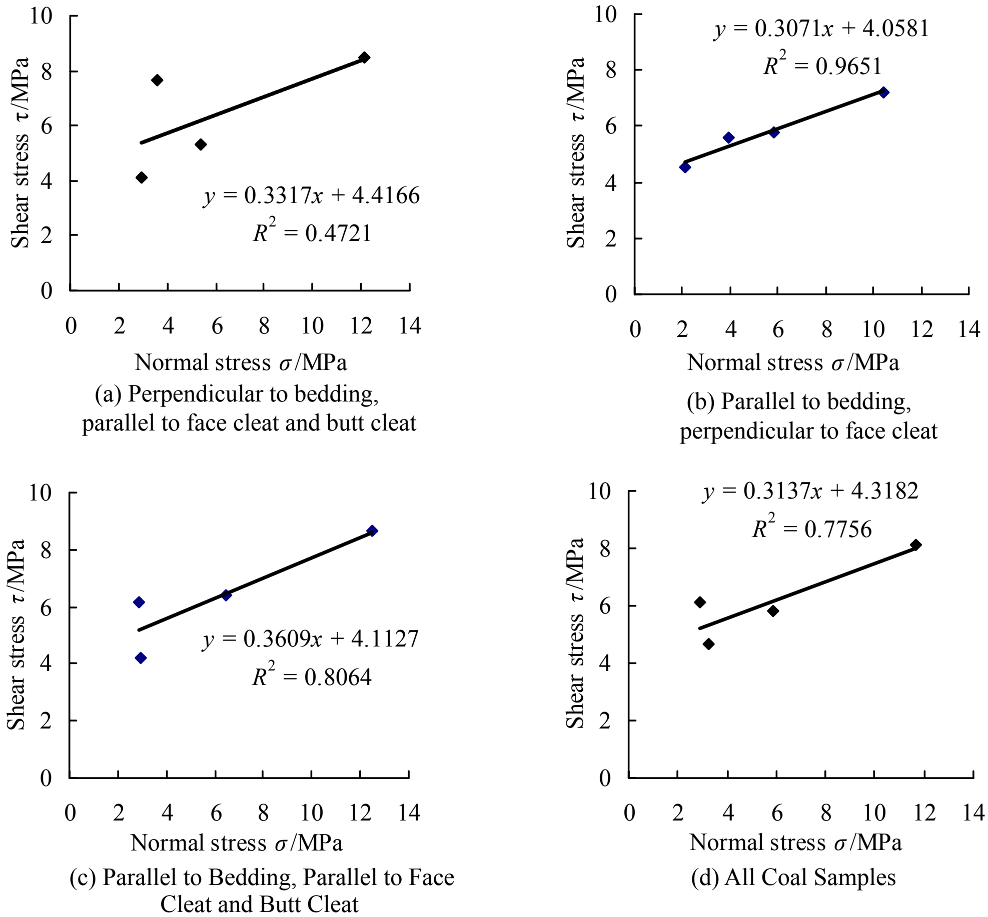


Figure 6
The Mohrenvelope of Shear Test of Coal Samples From West Block 22

CONCLUSION

(a) The tensile strength of coal rock has directivity, and the value of tensile strength when the direction of the axis of loading is vertical to bedding is larger than the value when the direction of the axis of loading is parallel to bedding; But in the direction of paralleled to bedding, the value of tensile strength of coal rock paralleled to face cleat is larger than the value of coal rock vertical to face cleat.

(b) The shearing strength of coal rock also has directivity. This test illustrates that in the direction of paralleled to bedding, the value of shearing strength of coal rock paralleled to face cleat is larger than the value of coal rock vertical to face cleat, and the shearing strength paralleled to face cleat is 6.35 MPa, and the shearing strength vertical to face cleat is 5.78 MPa, and the difference is 9.86%.

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