Discreteness of Rock Strength Based on Acoustic Test

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ABSTRACT

In view of the characteristics of the complex composition and structure of coal rock whose strength has the discreteness, the wave velocity of coal rock specimen was measured by method of the ultrasonic pulse penetration. Meanwhile the relationship between the specimen wave velocity and mechanical parameters is obtained by regression analysis when using MTS815 testing machine for rock mechanics test. Results show that the strength differences of specimens which have similar wave velocity are small. Before the rock mechanics test, the wave velocity of specimens can be measured first. Then the strength of them can be expected and the specimens can also be classified according to the size of wave velocity, which will guide the rock mechanics test better, so as to provide a technical way for avoiding the blind trial from the discreteness of rock as far as possible.

KEYWORDS: coal rock; discrete; wave velocity; rock mechanics test

INTRODUCTION

Due to the complexity of sedimentary rock composition, structure and different sedimentary environment in thousands ways[1], the same kind of sedimentary rock strength is different, even in the same mining area. But in the study of rock mechanics test, the test result that the same kind of rock of strength and deformation characteristics under different stress state usually needs to be contrastively analyzed[2-3]. At the moment, the test should be taken by choosing the rock with similar physical properties, such as the strength. Otherwise, there is no comparability in the result of test. Therefore it is of great significance that how to eliminate the strength discreteness of sedimentary rock and avoid the test blindness before the similar rock mechanics test.

THE ELASTIC WAVE TEST METHOD AND TEST RESULTS

Elastic wave theory analysis and many field test results show that the sound velocities are related to elastic constants and rock mass density. If the P-wave velocity VP , shear wave velocity VS and the density of coal rock specimen is measured, the dynamic elasticity modulus Ed and dynamic Poisson's ratio Vd of them will be obtained according to the type[4].

$$E_d = \sqrt{\frac{\rho V_s^2 \left(3V_P^2 - 4V_S^2\right)}{V_P^2 - V_S^2}} \qquad (1)$$

$$V_d = \sqrt{\frac{V_P^2 - 2V_S^2}{2\left(V_P^2 - V_S^2\right)}} \qquad (2)$$

Therefore, sound velocity can comprehensively reflect the characteristics of the rock mass. Bedding, crackles or cracks of the rocks have great influences on the elastic wave, generally referring to the P-wave[5]. Therefore, the elastic wave of the rock specimen with different strength caused by different structure and weak sides inside them must be different. In engineering practice, detecting the rock mechanics parameter by elastic wave has been widely used, while the indoor rock mechanical parameters test are rare. Rock mechanics test are destructive test and it is feasible to test the acoustic velocity of the rock and select the coal rock specimen that have similar strength characteristics through analysis before the test.

Wave velocity measuring method

Coal specimens are collected from the two sides of coal mine roadway. The standard specimens should be cylindrical and the diameter of them is 50mm. Since the coal is soft, the height of specimens is between 81.1 mm and 100.2 mm after processing.

Figure 1: Coal specimens

Wave velocity was measured by method of the ultrasonic pulse penetration. The frequency of the transducer that is used by manual trigger and continuous sampling mode is 1 MHZ and sampling interval is 0.1μs. The waveform that is through the specimens can be recorded by acoustic detector connecting to a handheld computer and the penetration time t of P-wave velocity in the specimens can be automatically detected by the program. Then the P-wave velocity VP will be obtained with the sample length L divided by the penetration time t. Figure 2 shows the instrument for wave velocity test.

Figure 2: Wave velocity measuring instrument

Elastic wave test results

Elastic wave velocity was tested on 14 standard specimen by acoustic detector and the wave velocity test results has been measured by size, as shown in Table 1.

UNIAXIAL COMPRESSION TEST

Test method

The test was taken on the MTS815.03 electro-hydraulic servo-controlled rock mechanical test machine imported from the United States by Shandong University of Science and Technology, using axial strain as the control parameter and loading until the specimen destruction at a speed of 0.002 mm/s.

Test results

The test results are shown in Table 1.

Table 1: Specimen wave velocity and strength test results

Serial number	*Height /mm*	*P-wave velocity /m/s*	*Uniaxial compressive strength/MPa*	*Serial number*	*Height /mm*	*P-wave velocity /m/s*	*Uniaxial compressive strength/MPa*
1	84.9	1761	18.22	10	94.9	1998	23.32
2	83.4	1769	17.22	11	81.1	2003	24.23
3	88.7	1794	20.25	12	100	2007	24.36
4	82.7	1803	21.67	13	93.3	2008	22.09
5	99.9	1806	21.07	14	100.1	2114	25.87
6	85.1	1821	22.95	15	99.6	2188	25.68
7	88.3	1878	23.76	16	100	2208	26.18
8	94.5	1905	22.98	17	100.2	2210	27.74
9	96.6	1947	23.14	18	98.9	2267	26.94

TEST RESULTS ANALYSIS

Trend analysis

A scatter plot has been made and the index trend line could be added, using P-wave velocity as x axis, and specimen uniaxial compressive strength as y axis, as shown in Figure 3.

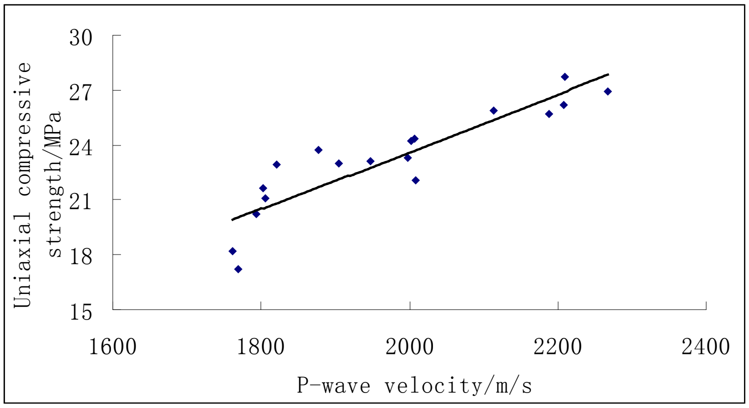

Figure 3 *Scatter plot of the relation between uniaxial compressive strength and P-wave velocity*

Figure 3 shows the measured results that the relation between coal rock specimens acoustic velocity VP and their uniaxial compressive strength σc. As can be seen from the figure, although axial compressive strength of individual specimens don't increase strictly with the wave velocity, the overall trend is that the axial compressive strength generally increase with the increase of specimen wave velocity, which is consistent with the theory that the rock mass with the higher compressive strength will have a higher wave velocity, otherwise will lower. They obey exponential function relationship and the correlation coefficient of them is 0.767, whose formula is showed as follow.

$$\sigma_c = 0.0019\exp\left(1.3255V_p\right)$$

If the data of No.1 and No.2 with large discreteness have been eliminated, the correlation coefficient will be 0.824.The formula is showed as follow.

$$\sigma_c = 0.0101\exp\left(1.0217V_p\right)$$

Therefore, it is feasible to predict a quasi strength for the rock specimen according to the elastic wave velocity.

Analysis of mean square error

The specimen with similar wave velocity were divided into the same group according to the different size of them, and the 18 pieces of specimen would be divided into three groups, calculating the average wave velocity and strength, as shown in Table 2.（1）Crustal stress measurement

The mean square error of wave velocity and strength on each group were respectively calculated and the results are as follows.

Wave velocity variance:

$$D_{v1} = 21.02 \;;\; D_{V2} = 50.18 \;;\; D_{V3} = 49.31$$

Strength variance:

$$D_{\varepsilon 1} = 2.495 \;;\; D_{\varepsilon 2} = 0.7276 \;;\; D_{\varepsilon 3} = 0.7617$$

Table 2: Average wave velocity and strength of specimen

Group	*Group One*	*Group Two*	*Group Three*
The specimen inside	1~6	7~13	14～18
Average wave velocity/m/s	1792.3	1963.7	2179.4
Average strength/MPa	19.92	23.41	26.48

The mean square error can be obtained as follows with each of them divided by the mean respectively.

$$d_{v1} = 0.0117 \;;\; d_{v2} = 0.0255 \;;\; d_{v3} = 0.0224$$

$$d_{\varepsilon 1} = 0.125 \;;\; d_{\varepsilon 2} = 0.0311 \;;\; d_{\phi 3} = 0.0288$$

If the No.2 specimen with obviously large deviation in Group One has been eliminated, the mean square error will be only 0.0756.

It is visible that a set of specimens with similar wave velocity vary little in the strength. Before the rock mechanics test, the wave velocity of specimens can be measured first. Then the strength of them can be expected and the specimens can also be classified according to the size of wave velocity, which will guide the rock mechanics test better.

CONCLUSION

Due to the complexity and variety of components, structure and sedimentary environment, there are great difference in the strength of the same kind of sedimentary rock. On contrastively study of strength and deformation characteristics of the same kind of rock under different loading, the rock specimens with similar strength should be chosen as far as possible to test for mechanical property and make analysis. Adopting the method of measuring the elastic wave velocity of specimens can classify the similar strength of specimen so as to guide the similar rock mechanics test, avoid the blindness of testing and obtain the ideal results.

ACKNOWLEDGEMENT

Much of the work presented in this paper was supported by the Youth Foundation Award for Scientific Innovation of Shandong Agricultural University, The author would like to express appreciation to the reviewers for their valuable comments and suggestions that helped to improve the quality of the paper.

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Editor’s note.
This paper may be referred to, in other articles, as:

Ma Depeng: “Discreteness of Rock Strength Based on Acoustic Test” *Electronic Journal of Geotechnical Engineering*, 2017 (22.01), pp 275-280. Available at ejge.com.