Influence of Different Joint Angles on Elastic P-wave Velocity Attenuation

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Abstract

In view of the attenuation phenomenon of elastic wave passing through a joint, the effect of joint strike Angle on the attenuation of elastic longitudinal wave velocity was studied. Considering the anisotropy of rock mass itself, a more reasonable test scheme is designed to explore the attenuation law of wave velocity. The results show that the anisotropy of rock mass leads to the anisotropy of compressional wave velocity, and the difference of wave velocity varies with different lithologies. This factor should be considered when exploring the influence of joint strike Angle on wave velocity attenuation. When this effect is fully taken into account, no matter what the joint Angle is, its existence has a certain damping effect on the elastic longitudinal wave velocity, and the wave velocity decreases linearly with the increase of the joint strike Angle.

Keywords

Elastic P-wave; Jointed rock mass; Joint angles of strike; Anisotropic.

1. INTRODUCTION

Joints are widely found in natural rock masses and have an important influence on the strength and dynamic mechanical properties of rock masses [1]. When elastic wave propagates to the joint surface, wave phenomena such as reflection and transmission will occur, resulting in energy attenuation, which further affects its propagation speed. Joint, on the other hand, the volatility of the problem involves the ultrasonic wave velocity test, blasting disturbance, ride and imitation of the earthquake, and many other geotechnical engineering [2], in such a frequent earthquakes and a lot of people use under the background of elastic wave testing technique, the effects of joint properties of elastic wave propagation attenuation has become the focus of the domestic and foreign scholars on the subject. Many scholars have made fruitful research on the characteristics of elastic compressional waves. Scholars at home and abroad have carried out a lot of research work from theoretical analysis, experiment and numerical simulation. L. R. Myer [3] established a discontinuous model of linear elastic displacement on the joint plane, believing that when the stress wave passes through the joint plane, the stress field is continuous, while the displacement is discontinuous. Moreover, they gave the exact solutions of the transmission and reflection coefficients of the stress wave (P wave, S wave and SH wave) incident on the joint plane at any Angle. X. B. Zhao et al [4] established a nonlinear model of stress waves passing through multi-layer joints, and discussed the effects of joint surface opening size and stiffness coefficient on the transmission performance of joint planes. Han Song and Cai Meifeng [5-6] conducted ultrasonic wave velocity test on the joint surface at different incidence angles, and analyzed the influence of different joint inclination angles on the wave velocity. Deng Tao and Yang Linde [7] studied the characteristics of wave velocity ratio of longitudinal and transverse waves in anisotropic rocks, and established the wave equation of transversely isotropic elastic media. Li Huanqiu et al[8] studied the propagation law of stress wave in the rock medium with underground composite structure. Wang Weihua et al [9] analyzed the influence of nonlinear normal deformed joints on elastic compressional wave propagation. However, due to the large differences between different types of rocks, the properties of rocks vary significantly with the different environments in which they are located, so the study of elastic compressional wave characteristics of various types of rocks does not have a wide range of applications.

As you can see from the research present situation, the current for each joint characteristics to study the influence of the elastic wave velocity, article explore joint, joint spacing and joint, joint filling medium table surface roughness joint properties such as the nature of the research on the effects of wave velocity attenuation is more, and for different joint Angle to research on the influence of wave velocity is less, Moreover, the influence of rock mass anisotropy on wave velocity has not been fully considered and eliminated, resulting in large discretization of data results. Generally speaking, even if the specimen is taken from the same rock, there is a certain difference in the wave velocity of the rock mass. The size of the difference is related to the lithology. If the difference cannot be effectively considered, together with the errors caused by the instrument and operation in the test, the test results will be greatly affected. Researchers currently existing [10-11] on the experimental study is carried out on the one hand, through the preparation of sandstone specimen under different joint Angle and the wave velocity test, many adopt the method of wave velocity distribution statistics to explore the effect of joint Angle of wave velocity attenuation, but the attenuation degree of wave velocity is not obvious, there cannot be completely ruled out the possibility of other error. Therefore, this paper takes the more compact rock-like structure as the test object, designs a more reasonable test scheme, and explores the influence of joint strike Angle on wave propagation attenuation under the premise of fully considering the influence of rock mass anisotropy on wave velocity. The research results can provide some reference for the attenuation characteristics of wave in jointed rock mass and the application of elastic wave testing technology in engineering.

2. VELOCITY THEORY OF ELASTIC COMPRESSIONAL WAVE PROPAGATION IN JOINTED ROCK MASS

When the elastic longitudinal wave propagates in the rock mass, the wave velocity of the wave can be known as:

$$v_p=\sqrt{\frac{\lambda+2\mu}{\rho}} \tag{1}$$

In the formula, Lame constant λ, μ, also known as volume elastic coefficient and shear elastic coefficient, can be expressed as

$$\lambda=\frac{Ev}{(1+v)(1-2v)},\mu=\frac{E}{2(1+v)} \tag{2}$$

Therefore, the propagation velocity formula of elastic compressional wave in rock mass can be obtained [12]:

$$V_p=\sqrt{\frac{(1-v)E}{(1-2v)(1+v)\rho}} \tag{3}$$

Where, V_p is the elastic longitudinal wave velocity in the intact rock mass, E is the elastic modulus, V is the Poisson's ratio, G is the shear modulus, and ρ is the density of the rock mass. When elastic compressional waves propagate in jointed rock mass, the wave velocity can be expressed by Equation (4) :

$$V_p = \frac{l}{t_1+t_2} \tag{4}$$

Where, L is the test length of the sample, T_1 and T_2 represent the propagation time of wave in rock mass and joint respectively.

3. EXPERIMENTAL STUDY ON THE EFFECT OF JOINT STRIKE ANGLE ON ELASTIC COMPRESSIONAL WAVE VELOCITY ATTENUATION

3.1. Selection and Preparation of Specimens

In this paper, the selection and preparation of intact rock samples and jointed rock samples are divided into three steps:

(1) Three groups of rock samples with different strength are layered pouring with the same batch of C30 cement and quartz sand, gypsum as raw material, which can preliminarily avoid the influence of cracks in the samples on the test results.

(2) Three standard specimens with joint horizontal Angle α (representing joint Angle) of 0°, 15°, 30°, 45°, 60°, 75° and 90° are taken by a coring machine. After the completion of coring, the uneven place is carefully polished to ensure the parallelism and smoothness of each end face. To improve the standard degree of the specimen and the easy operation of the sending and receiving probe during the wave velocity test, to ensure more accurate test results.

(3) Finally, the wave velocity test was carried out on each specimen, and one specimen was selected from each Angle with a small difference in the lower wave velocity.

The prepared specimens with different joint angles are shown in Figure 1. The basic mechanical parameters of complete rock mass are shown in Table 1.

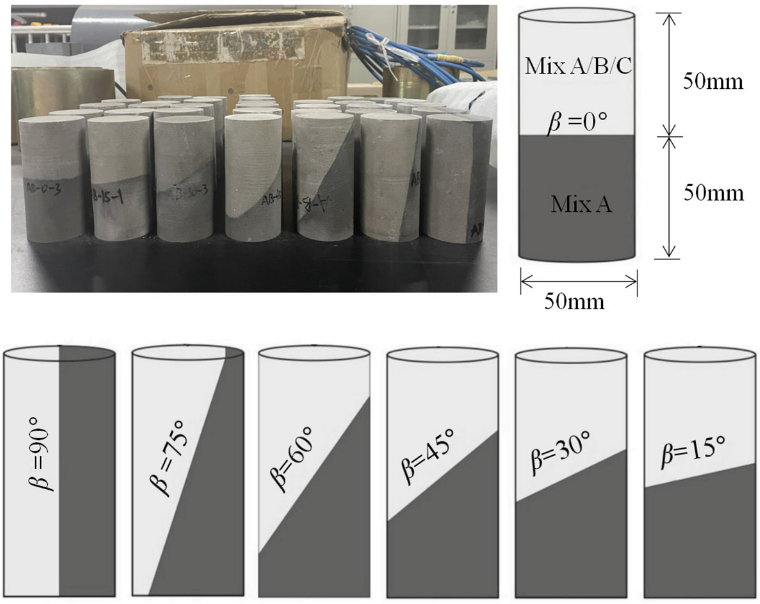

Figure 1. Specimens with different joint angles

Table 1. Physical and mechanical parameters

materials	ρ(g.cm-3)	σ_c (MPa)	E_c(GPa)	ν
A	2.07	34.42	9.87	0.19
B	1.85	16.50	4.93	0.21
C	1.64	6.91	1.79	0.25

3.2. Wave Velocity Test Scheme

The ZT801 rock parameter tester (as shown in Figure 2) produced by Zhongtuo Technology Company was adopted in this test.

Figure 2. Rock parameter tester

This intelligent instrument applies ultrasonic pulse detection technology and can conduct nondestructive testing on non-metallic materials and components such as rock, concrete, rock ceramics, graphite, plastic, etc.It integrates the functions of ultrasonic transmission, single channel synchronous reception, digital signal high-speed acquisition, automatic detection of acoustic parameters, data analysis and processing, real-time display of results, data storage and output.It can be used for wave velocity detection, strength detection, internal defects and cracks detection, homogeneity detection, damage layer thickness detection and material mechanics, physical properties detection, etc.In this test, the ultrasonic normal wave velocity test module was used to test the specimen.In order to eliminate the acoustic delay caused by the instrument and the transducer system during the test, the zero adjustment operation should be carried out before each test or after the replacement of the test conductor and transducer (the setting at zero sound).In order to avoid the error of test results caused by the tiny cracks between the receiving probe and the specimen, an appropriate amount of Vaseline was applied to the contact area between the probe and the rock as the coupling agent to reduce the acoustic impedance difference between the contact surfaces and the energy reflection loss at the interface, so as to improve the accuracy of test results.Finally, the wave velocity measured by the instrument test system is recorded.

4. TEST RESULTS AND ANALYSIS

4.1. Wave Velocity Distribution Law of Intact Rock Specimen

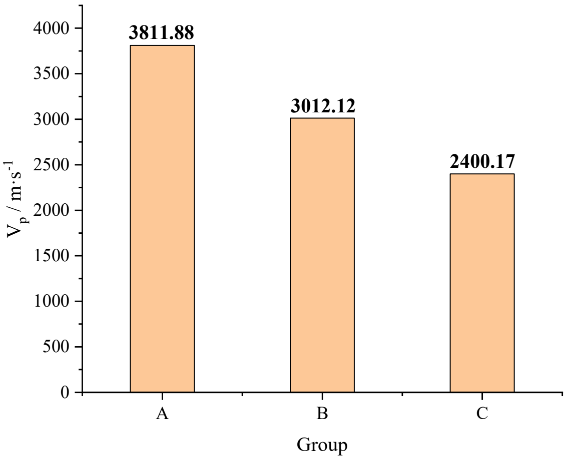

Figure 3. Wave velocity distribution of different rock masses

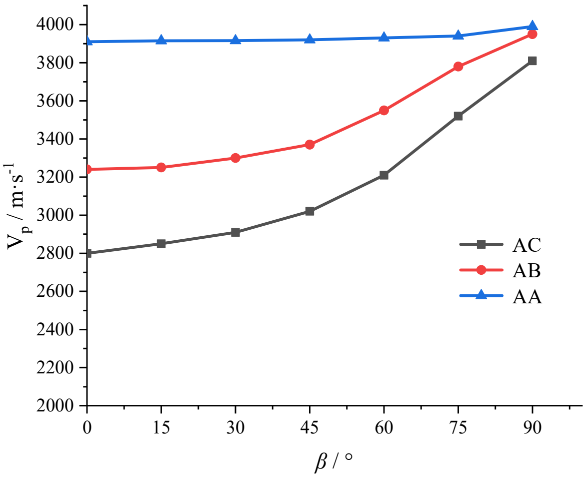

Figure 4. Wave velocity distribution of rock mass at different joint angles

It can be seen from the figure that the compressional wave velocities of the rock samples of the three groups of composite rock strata are between 2,800m /s and 4,000m /s, which is consistent with the measured compressional wave velocities of the three rock materials A, B and C. Experience of A large number of tests show that the density of the rock and there exists A positive correlation between the vertical wave linear relationship [13], namely rock increases with the increase of the density and vertical wave velocity, the material of A kind of rock sample density is the largest, material B A soupcon of gypsum, density is less than the material A, material C adding amount of gypsum is larger, the density is minimal. Therefore, the measured P-wave velocity of material A > B > C alternately propagates in the composite rock samples composed of them, and the propagation velocity is between the two.

On the other hand, we can also find from the figure that the longitudinal wave velocity of the three groups of samples increases with the increase of the strata dip Angle. The longitudinal wave velocity is smaller when the dip Angle is 0°, and the maximum when the dip Angle is 90°.Among them, AC group was the most obvious, AB group was the second, AA group was less obvious. As stated earlier, this is layered anisotropic characteristics of compound rock strata, the elastic wave propagation in rock medium, meet joint surface reflection and transmission will occur two kinds of circumstances, among them, the reflection will lose a lot of energy, make the weakened continued spread of elastic wave transmission in the past, hindered its continue to spread, therefore characterized by wave velocity slow down.

5. CONCLUSION

This article will bedded composite rock sample as the transverse isotropic body, when the formation dip Angle of 0 °, elastic wave in the joint plane and vertical direction, the reflection of the elastic wave energy most at this moment, the spread of the block, the largest minimum velocity, therefore, when grow large formation dip Angle, this kind of reflection of more and more small, wave velocity increases slowly, when strata dip Angle is 90 °,Elastic wave propagation in the direction parallel to the joint plane, the joint face of elastic wave has almost no effect, elastic wave can be directly in A, B, C two kinds of material spread at the same time, because the material of A wave speed is fast, in the inside of the elastic wave was the first to reach the receiving probe, so at this time of wave velocity measurement results and the material of A single type of rock sample measurement result is close to. According to the above analysis of the wave velocity measurement results, the anisotropy of layered composite rock strata is obvious, and the influence of the longitudinal wave velocity on the joint face decreases with the increase of the dip Angle of the rock strata.

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