Experimental comparison of ultrasonic properties of shaft lining concrete and surrounding rock in Xincheng Gold Mine

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Abstract. Based on the design of the wall rock and concrete lining of the new main shaft in Xincheng gold mine and the ultrasonic test as the main research method, the ultrasonic performance characteristics and influencing factors of the surrounding rock specimen and concrete specimen of the new main shaft are compared. It is concluded that the mechanical properties of rock specimens of metal mine surrounding rock are better than those of concrete lining. The complete surrounding rock segment of concrete lining does not play the role of rigid support. The two cube specimens have a significant influence on the attenuation of longitudinal wave. It is suggested to convert the cube specimen with a side length of 150mm into or directly use the cylinder specimen with a diameter of 50mm and a height of 100mm when determining the indoor ultrasonic parameters of rock and concrete in the shaft wall design of ultra-deep shafts of metal ore. The research results are of great significance to the design of shaft lining in mines.

1. Introduction

A new shaft is under construction in Xincheng Gold Mine with a designed shaft diameter of 6.7m and a depth of 1527m. C25 concrete shaft wall shall be used above 1300m depth and the thickness of shaft wall shall be 300mm. The surrounding rock of the new main shaft of Xincheng gold mine is hard granite. To solve this problem, it is necessary to make a comparative study on the mechanical properties of lining and surrounding rock. The ultrasonic velocity parameters obtained in laboratory rock ultrasonic nondestructive tests are important parameters for evaluating rock mass grade. Indoor ultrasonic non-destructive testing is also widely used in the detection of concrete specimens. In the process of obtaining the mechanical parameters of the two kinds of materials, it was found that the mechanical parameters of the two kinds of materials corresponded to different test specifications, and the size of the standard specimens of the two kinds of specifications were inconsistent. Therefore, it was necessary for different materials to study the influence of the size effect on the test data under the size of the two kinds of standard specimens.

At present, the research on size effect of concrete and rock is based on the fitting of test data to predict the change of mechanical properties caused by specific size change. Since there is no accurate analytical formula for the conversion of mechanical parameters between different geometric dimensions, in order to understand the mechanical properties of the two materials, it is still necessary to make a comparative analysis of the mechanical properties of the two materials under the test conditions of the same geometric size.

Research status of ultra-wave ultrasonic testing of concrete and rock specimens: Research on the shape and dynamic elastic modulus of specimens [1]. At present, there are many researches on ultra-
ultrasonic testing rocks, and the main research direction is the relationship between wave velocity and dynamic elastic modulus [2-6], dynamic elastic modulus and static elastic modulus comparison [7], saturated water and saturated air, porosity and fracture [8-9], damage variable, load and temperature [10-15]. At present, the research on ultrasonic testing has been relatively comprehensive. The dynamic elastic modulus and wave velocity can be calculated by analytical formula, but when it comes to the relationship with other conditions such as size, temperature, pore fracture, static elastic modulus and so on, all empirical formulas are based on the fitting of test data. The relationship between the dynamic elastic modulus of two standard specimens of different materials used in the design of metal mines has not been studied at present.

2. Experimental purpose and design

2.1. Purpose of the experiment
In order to compare the ultrasonic mechanical properties of the two kinds of wall rocks and concrete, it is necessary to test the two kinds of materials at the same size to obtain the shear wave velocities and longitudinal wave velocities of the same material with different sizes.

2.2. Experimental methods and standards
According to GB50107-2010 concrete strength inspection and assessment standard and GBT 50266-2013 engineering rock mass test method standard, the processing test of the specimen is carried out by using the test methods of strength test and deformation test in "Rock Mechanics Test Course". In this test, the concrete raw materials are from the construction site of the new city main shaft, and the raw materials are poured into C25 concrete test blocks according to the mix ratio used in the site. The raw material of the rock test block is from the waste rock after blasting in 680m of the main shaft of Xincheng gold mine. In order to facilitate the comparison of the ultrasonic properties of the two materials, it should be processed in accordance with the standard size of the concrete compressive test specimen and the standard size of the rock compressive test, respectively. However, it is difficult to process the rock into a 150mm cube, so we chose a 100mm cube with side length.

Figure 1. The principle and test condition of ultrasonic velocity measuring device in room for rock and concrete specimen

| Block category | Size                                | Quantity |
|----------------|-------------------------------------|----------|
| Concrete       | 50mm*100mm (High* Diameter) (Cylinder) | 8        |
| Concrete       | 150mm*150mm*150mm (Cube)            | 6        |
| Rock           | 50mm*100mm (High* Diameter) (Cylinder) | 5        |
| Rock           | 100mm*100mm*100mm (Cube)            | 4        |
When selecting the transducer, the transmitting frequency of the transducer is required to meet the following formula: \( f \geq \frac{2V_p}{D} \), where \( f \) is the transmitting frequency of the transducer (Hz); \( V_p \) is rock compressional wave velocity (m/s); \( D \) is the diameter of the specimen (m). According to the diameter of the selected cylinder specimen is 5cm, the emission frequency of the transducer is calculated to be 200kHz. The test was carried out by direct penetration method. When the probe pressure is zero, there is no obvious wave form in the shear wave test result, so the wave velocity cannot be read from the wave form. Pressure is applied to the probe to measure the shear wave velocity. In the actual determination, only a layer of vaseline is applied evenly to the end face of the rock sample, and the longitudinal wave velocity can be measured one by one. When the probe pressure is zero, the measured p-wave velocity has obvious waveform in the test result, and the waveform can be read out. The compressive limit of the probe is 30MPa. In order to reflect the relationship between the wave velocity of the original rock and the depth, 5kN, 10kN, 15kN, 20kN, 25kN, 30kN and 35kN were selected for the test under pressure conditions. Assume that the average density of the rock is 2500kg/m³, and the corresponding depths are 100m, 200m, 300m, 400m, 500m, 600m and 700m respectively, and the original rock stress at about the depth.

2.3. Data processing and analysis

2.3.1. Rock ultrasonic test

The wave velocity of a cylindrical rock specimen. The test result is the same as that of the cylinder rock specimen, but the compressional wave velocity is not obviously affected by the pressure. At a pressure of 5kN, the longitudinal wave velocity of cylinder rock is 4728m/s~5167m/s, and that of cube rock is 5507m/s~5688m/s. At a pressure of 5kN, the shear wave velocity of cylindrical rock pieces ranges from 2754m/s to 3115m/s, while that of cubic rock pieces ranges from 2500m/s to 2878m/s. At a pressure of 35kN, the compressional wave velocity of cylinder rock pieces is 5154m/s~5434m/s, and that of cubic rock pieces is 5621m/s~599m/s.

At the pressure of 35kN, the shear wave velocity of cylindrical rock pieces is 3273m/s~3508m/s, and that of cubic rock pieces is 2624m/s~3177m/s.

2.3.2. Concrete ultrasonic

The longitudinal wave velocity of the cube rock specimen also conforms to the law that the wave velocity is little affected by pressure. According to the above law, the compressional wave velocity of cubic concrete specimen is used in the calculation of elastic modulus and shear modulus.

| Concrete cube specimen No. | 1     | 2     | 3     | 4     | 5     | 6     |
|----------------------------|-------|-------|-------|-------|-------|-------|
| Longitudinal wave velocity (m/s) | 4474  | 4477  | 4398  | 4385  | 4411  | 4360  |

The s-wave conversion relations of cylinder and cube specimens are calculated as 1.055 and 0.898, and 1.036 and 0.979 respectively. The larger the size of the rock specimen, the more obvious the defects contained, and the closer to the mechanical properties of rock mass, the smaller the dispersion of the test results. However, considering that it is difficult for the rock to be processed into a large cube specimen, it is suggested to use the cylinder specimen of rock and concrete for ultrasonic comparative test.

S-wave: When the specimen is a cylinder, the initial pressure has a great influence on the s-wave velocity, which increases rapidly. After 15kN, the s-wave velocity does not change significantly and tends to be stable. The corresponding stress is 7.5MPa and the depth is 300m. When the specimen is a cube, the pressure change has little influence on the shear wave velocity, and the wave velocity curve is relatively stable. Under the initial low stress condition, the original crack is closed, the size of the
circular specimen is close, and the s-wave attenuation decreases with the increase of pressure. At the later stage, the pressure-wave velocity curve tends to be stable and shows a horizontal line. The volume of the square specimen is more than 9 times that of the cylinder specimen, and the probability of refraction when the elastic wave propagates in the specimen meets micro-cracks will increase, which will cause attenuation, increase the wave propagation distance, and increase the row time. When the normal direction of the fracture is perpendicular to the propagation direction of the s-wave, the s-wave needs to pass through the fracture repeatedly, which will also cause attenuation. Moreover, the wave propagation direction of the concrete cube specimen is 5cm longer than that of the cylinder specimen, and the shear wave attenuation in the cube is more than that of the cylinder specimen under the same load. This is the reason why the shear wave velocity of the cube is lower than that of the cylinder.

Compressional wave: Pressure has a certain effect on the compressional wave. The compressional wave velocity changes slightly and uniformly with the increase of load, showing a linear relationship. In the process of 5kN~35kN, the longitudinal wave velocity of the four specimens increased by 200~300m/s, or 6%~7%. The longitudinal wave velocity of the two specimens is higher than that of the cylinder, and the volume of the cube is about ten times that of the cylinder. The larger the specimen is, the more obvious the material uniformity is. Concrete aggregate maximum size is close to the cylinder of diameter, the cube after processed into cylindrical specimen inside will exist with traveling wave direction vertical interface, this interface with cylindrical cross section size close, longitudinal wave refraction must also spread through this interface, after the total reflection, most of the energy of incident wave into the reflection, through the projection of the interface wave and converted into by him refraction will become very weak, can make the longitudinal wave attenuation obviously. However, because of the large volume of the cube specimen, the transmitted wave path will become a curve or broken line when it encounters an obvious interface, and the reflected wave and refracted wave can no longer propagate through this interface.

The longitudinal and shear wave velocities of concrete specimens are lower than those of rock specimens. The defects such as holes and cracks in the specimen have a great influence on the s-wave propagation. The comparison test shows that the cracks and other defects in C25 concrete are more than those in the complete rock specimen, and are weaker than the rock. The concrete aggregate used in the test is processed from underground blasting waste rock, and the material properties of the rock specimens used in the test are basically the same. Rock specimens are more uniform and denser than concrete specimens. Due to the inhomogeneity of the matrix and aggregate inside the concrete test block, the wave will be refracted at the interface between the matrix and aggregate during the propagation process, changing the propagation route and attenuation of the wave velocity. It shows that the fracture and other defects have little influence on the longitudinal wave, but are related to the uniformity and density of the specimen. The main reason why the wave velocity in concrete is slower than that in rock is the matrix, which has poor properties. It can be inferred that the mechanical properties of concrete specimens are significantly lower than those of rock specimens.

The rock specimens were gradually pressurized on a pressure machine, and eventually the transverse and longitudinal wave velocities tended to be stable, indicating that the ultrasonic mechanical properties of the complete surrounding rocks tended to be stable after reaching a certain depth. It also provides some reference for the judgment of rock mass ultrasonic wave test results.

3. conclusion
The test methods for the indoor ultrasonic mechanical properties of the lining and surrounding rock for metal mines are summarized through experimental research. The two materials, rock and concrete, were compared under the same size according to the standard specimen size in the code for processing rock mechanics and the standard specimen size in the concrete test code. A set of conversion methods of mechanical parameters for nondestructive testing of laboratory specimens were developed. The ultrasonic parameters of the two materials were unified under the condition of the same size specimen. Proposed to the cube specimens through the relationship between coefficient of concrete and rock into
the cylinder specimen or direct use of cylinder specimen on ultrasound contrast test, rock cylinder specimen and cube specimen of shear wave conversion coefficient is 1.055 and compressional wave conversion coefficient is 0.898, rock cylindrical specimen and cube specimen of shear wave conversion coefficient is 1.036 and compressional wave conversion coefficient is 0.979.

When testing the shear wave velocity of the specimen, it is recommended to test the load of the original rock stress to the corresponding depth. For the complete rock extracted from the deep mine below 300 meters and the concrete lining designed for the corresponding depth, the cylinder specimen and the cube specimen of the two materials can be pressurized to 7.5MPa and 2.5MPa respectively during the shear wave velocity test. The compressional wave can be tested without pressure.

The transverse and longitudinal wave velocities of C25 concrete used in the current design of Xincheng Gold mine are lower than those of rocks, and the mechanical properties of C25 concrete are worse than those of surrounding rocks. The concrete lining of the complete section of surrounding rock in the metal mine shaft cannot play the role of rigid support.

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