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Research Article

The Application of Dynamic Shock Mechanics Test in Engineering Blasting

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Abstract: With the continuous advancement of China's infrastructure construction to the west, according to the geographic situation in the southwest region, such as mountainous areas and complex terrain, the road construction process is inevitably accompanied by earth and rock blasting. To improve the quality and safety of the project, this paper addresses the problems of land and rock blasting faced in the construction of mountain road projects, taking the research of rock dynamic mechanics test as the starting point, and using a combination of theoretical analysis and experimental research methods. The specific research content includes the following parts: dynamic impact compression test (SHPB), dynamic splitting tensile test, and stress-strain curve analysis of the test results, which provides the theoretical basis and numerical parameters for the numerical simulation of future engineering blasting.

Keywords: Earth and stone blasting; Dynamic impact compression test (SHPB); Dynamic splitting tensile test; Stress-strain curve analysis.

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1 Dynamic shock compression test (SHPB)

1.1 Test equipment and principles

Rock impact compressive strength is tested using a Hopkinson Pressure Bar (SHPB), the basic idea of which is to separate from obtaining the strain rate effect of the material by decoupling the wave propagation effect as well as the strain rate effect of the content. In a typical SHPB device, as shown in Figure 1, at the beginning of the test, the bullet strikes the incident rod through the firing device at a set velocity. The incident pulse generated by the impact will create transmission and reflection of waves due to the difference in wave impedance between the Hopkinson rod and the rock specimen. The transmitted and reflected waves are recorded by strain gauges on the incident and transmitted rods, respectively. Based on the measured data (including event, indicated and sent waves), the necessary deformation and failure conditions of the specimen are copied and processed to obtain the dynamic mechanical properties of the rock specimen.

The SHPB test is based on two underlying assumptions: (1) the assumption of a one-dimensional stress wave in the rod and (2) the assumption of a uniform distribution of stress/strain along the length of the short specimen.

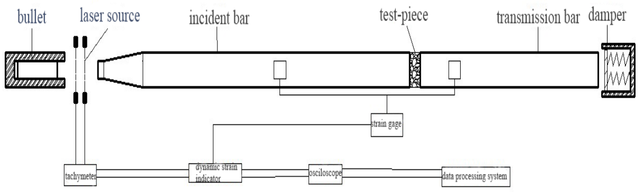

Figure 1. Schematic diagram of Hopkinson rod device

1.2 SHPB formula

The simplified three-wave formula (1-1) is used for the processing of the test data, i.e., the three-wave method is used to calculate the strain rate and strain, and the transmission wave is used to calculate the specimen stress, which can effectively reduce the calculation error brought about by the processing of the classical two-wave formula.

$$\begin{cases} \dot{\varepsilon}(t) = \frac{1}{l_s}(v_I - v_{II}) = \frac{C_0}{l_s}[\varepsilon_i(t) - \varepsilon_r(t) - \varepsilon_t(t)] \\ \varepsilon(t) = \frac{C_0}{l_s}\int_0^t [\varepsilon_i(t) - \varepsilon_r(t) - \varepsilon_t(t)]dt \\ \sigma(t) = \frac{EA}{A_s}\varepsilon_t(t) \end{cases} \qquad (1\text{-}1)$$

1.3 Test results and analysis

The test air pressure setting values are 0.2MPa, 0.4MPa, 0.6MPa, and 0.7MPa.

Figure 2 shows the strain rate time-course curves for different impact air pressures in SH2 group, as shown in the picture: the strain rate time-course curve in general rises rapidly, then decreases slowly, with a relatively stable flat zone, and finally decreases sharply. Figure 3 shows the stress-strain curves of a single group of rocks under different impact air pressures; it is evident that under the same strain, the stress increases as the impact air pressure increases. The typical failure mode of impact compression test of rock specimen is shown in Figure 4.

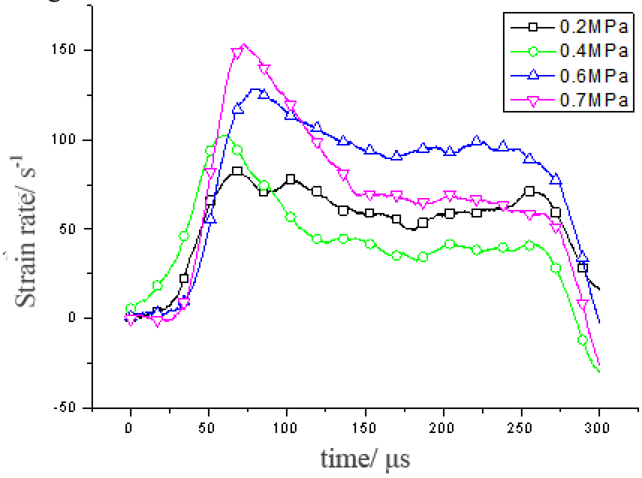

Figure 2. Strain rate time history curve of impact compression test

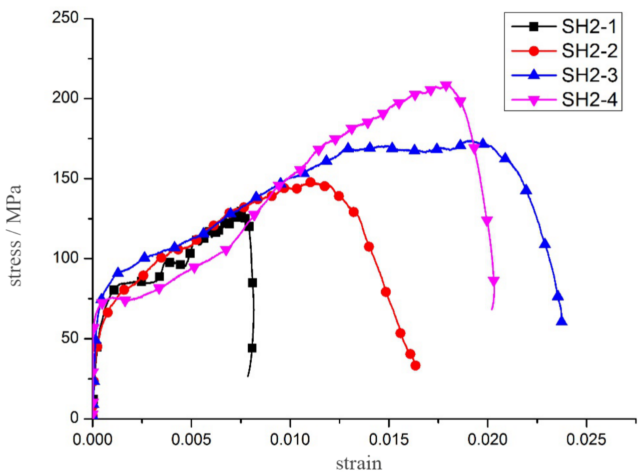

Figure 3. Stress-strain curves of different groups under different impact pressure

Figure 4. Typical failure modes of impact compression test specimens

2 Dynamic splitting tensile test

The tensile strength of rocks is an essential parameter in the mechanical properties test of stones, considering that the tensile strength of rocks is much smaller than the compressive strength and is mainly destroyed in the form of tensile under load. In the blasting process, the degree of rock fragmentation and the extent of damage depends mostly on the rock tensile properties. Therefore, the dynamic splitting and tensile test are carried out on the Brazilian disc specimen using SHPB to provide a reference and basis for studying the tensile properties of rocks under high strain rate.

The test air pressure setting values are 0.3MPa, 0.6MPa, 0.9MPa and 1.2MPa.

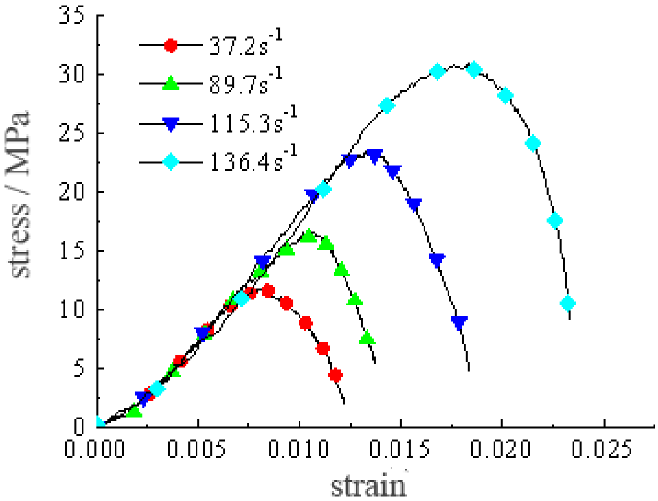

Figure 5. Typical stress-strain curves of the specimens under splitting tensile test

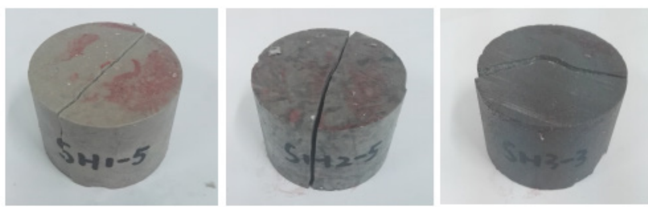

Figure 6. Typical failure modes of dynamic splitting test specimens

Figure 5 shows the typical stress-strain curve of splitting tensile, as shown in the picture: as the strain rate increases, the stress value also increases gradually;

the standard damage form of the dynamic splitting of the specimen is shown in Figure 6.

3 Conclusion

(1) The rock dynamic impact compression test was conducted by Hopkinson Pressure Bar (SHPB), and the simplified three-wave formula was used for the test data processing. The stress-strain curves of the rock specimens were analyzed at the set air pressure values (0.2MPa, 0.4MPa, 0.6MPa, 0.7MPa), and the test results showed that the stress value of the rock specimens increased with the increase of the impact air pressure.

(2) Dynamic rock splitting tensile test using SHPB to test a Brazilian disc specimen with test air pressure set at 0.3MPa, 0.6MPa, 0.9MPa and 1.2MPa, and analyzed a set of typical stress-strain curves at different strain rates. The results show that the stress value increases with the increase of strain rate.

(3) The test results can provide relevant data and theoretical bases for blasting scheme design and numerical calculations, and avoid the situation of extensive operation and inappropriate control techniques and measures in the construction process, to realize controlled blasting and refined construction.

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