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The strength competition effect at different strain rates

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Abstract

The dynamic characterization of materials under intermediate and high strain rates is fundamental to understand the material behaviour in case of dynamic loadings. In this study dynamic tests of rocks in compression and splitting by the Kolsky method and its modification were analysed. The time dependence of the critical stress can predict by the incubation time of fracture criterion and these dependencies turned out to be in good agreement with experiments.

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Keywords: Dynamic loading, strength, incubation time;

1. Introduction

In selecting a material for construction is usually guided by the values of mechanical parameters obtained in quasi-static tests. For example, the strength of various buildings and structures has been defined according to the principle of the limiting force field for many years. Construction material is selected based on its ability to withstand a certain stress. There is a set of standards governing the determination of the ultimate strength of the material under quasi-static tension, compression, bending, etc. However tests of the strength of these materials under dynamic loading conditions show a essential difference in the dynamic strength characteristics of comparison with data of quasi-static tests. The dynamic characterization of materials under high loading rates is fundamental to understand the material behaviour in the case of dynamic events. The dynamic mechanical properties are very different from those exhibited in quasi-static conditions. In addition, a wide range of external loads could occur a strength inversion

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effect when take place change of the dominant strength between the two materials. A material, which has lower strength compared to another material in quasi-static tests, can have greater strength under dynamic loading a material may have a lower dynamic strength for a high static strength compared with other material.

Using the incubation time fracture criterion and experimental results for different materials were obtained some examples with the strength inversion effect characteristics of strength. The dynamic characterization was carried out by means of traditional Split Hopkinson Pressure Bar (SHPB) placed at the Laboratory of Dynamic Investigation of Materials of Nizhny Novgorod.

2. Experimental and analytical details

Progress in this area associated with the split Hopkinson bar (SHB). The experimental method originally proposed by Kolsky (1949) is today one of the most thoroughly developed and verified methods for obtaining the dynamic strain curves for materials. In recent decades many efforts were undertaken to develop experimental studies and new set-ups in order to analyse dynamic behaviour of different materials. For example, in work performed by Goldsmith and Sackman (1973) Kolsky method was used for some rock. In this work we show good compliance with the experimental method and theoretical investigation.

Dynamic compressive and splitting tests were performed in the Laboratory of Dynamic Investigation of Materials in Nizhny Novgorod by means of a SHPB shown in Fig. 1.

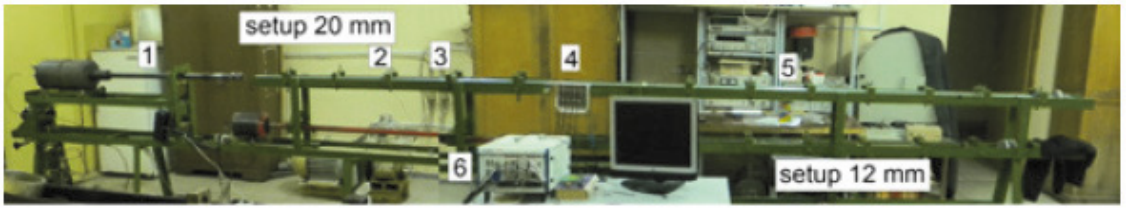

Fig. 1. Experimental apparatus realizing SHPB for compressive and splitting tests.

The experimental set-up consists of a compact gas gun (1), incident (2) and transmitter (5) steel (or duralumin) pressure bars with the specimen (3) sandwiched between them. Power supply and calibration of strain gauges was produced by an original scheme (4). In order to record the electrical signals from strain gauges, a multichannel digital oscilloscope (6) was used. The diameters of striker as well as pressure bar are 20 mm. The incident bar length was 1 m, while the length of the transmitter bar was 3 m in order to provide correct registration of possible additional cycles of loading during the experiment Rodriguez (1994).

The classical Kolsky scheme is used for compression tests. For dynamic tensile test, the modified Kolsky scheme – the Brazilian test is used. Splitting test disks is one of the available methods to measure the tensile strength of brittle materials (Bragov, 2001). Due to the stress-state of the disk, the failure is caused by tension when the tensile stresses reachs the tensile strength of the material at the diametric loading plane.

This article presents some results of dynamic compression and splitting tests of rocks: gabbro and two type of marble (Koelga and Pervouralsk). Gabbro - one of the most common intrusive rocks. This breed is composed of plagioclase and clinopyroxene in roughly equal proportions. Gabbro-diabase rock is the basic structure, with a massive texture, fine-medium grained, without cavities and irregularities uniformly painted in dark gray. Test specimens were taken from Drugoretskoe field (Republic of Karelia). Marble - durable, capable polished limestone. Marble deposits found in various parts of Russia. Above all, more than 20 fields, located in the Urals, but the stone is mined only from 8 deposits. Marble Koelga and Pervouralsk taken respectively from Chelyabinsk and Sverdlovsk region of Russia. Material properties are given in Table 1.

Test specimens in the form of rectangular parallelepipeds sawn diamond cutting discs from flat slabs of 20mm thick and length dimensions 20x20x10mm, 20x20x20mm, 20x20x30mm, 30x30x20mm. Samples of the first two sizes are used for high-speed tests on a simple compression and splitting under compression (Brazilian test). Samples with a size 20x20x30mm are mainly used for static testing in compression. Samples with a size 30x30x20mm - for dynamic tests with compression and splitting under compression in the quasi-static and dynamic tests.