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Comparison of mechanical properties in high temperature and thermal treatment granite

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Abstract: Static mechanical experiments were carried out on granite after and under different temperatures using an electro-hydraulic and servo-controlled material testing machine with a heating device. Variations in obvious form, stress−strain curve, peak strength, peak strain and elastic modulus with temperature were analyzed and the essence of rock failure modes was explored. The results indicate that, compared with granite after the high temperature treatment, the brittle−ductile transition critical temperature is lower, the densification stage is longer, the elastic modulus is smaller and the damage is larger under high temperature. In addition, the peak stress is lower and the peak strain is greater, but both of them change more obviously with the increase of temperature compared with that of granite after the high temperature treatment. Furthermore, the failure modes of granite after the high temperature treatment and under high temperature show a remarkable difference. Below 100 °C, the failure modes of granite under both conditions are the same, presenting splitting failure. However, after 100 °C, the failure modes of granite after the high temperature treatment and under high temperature present splitting failure and shear failure, respectively.

Key words: granite; thermal treatment; high temperature effect; static mechanical properties; failure properties

1 Introduction

A hot topic, namely the effect of temperature on rock properties, has drawn the attention of researchers, given an increasing mining depth of underground resources. Up to now, many studies have related to deep exploitation of hard rock metal mines [1−3]. And, it has been recognized that temperature is one of the vital factors influencing the mechanical behavior of rock. Temperature plays a significant role in many engineering practices [4−6], such as the disposal of highly radioactive nuclear waste, the underground storage and mining of petroleum and natural gas, the development and utilization of geothermal resources, and the post-disaster reconstruction of underground rocks engineering [7]. In order to solve the engineering problems, many researchers studied the effect of temperature on physical and mechanical properties of various rocks [8−15]. ZHAO et al [16] developed a servo-controlled triaxial rock testing system of high temperature and high pressure for rock testing. LAM DOS SANTOS et al [17] researched temperature effects on mechanical behaviour of engineered stones. The results reveal the different characteristics of the materials. CHEN et al [18] found that the peak stress and elastic modulus of heated granite decrease while the peak strain increases as the heating temperature increases. OZGUVEN et al [19] studied the temperature effect on properties of thermal treated limestone and marble and discovered that the structure of natural building stone becomes damaged or changes when heated above 800 °C. BROTÓNS et al [20] investigated the effect of high temperatures in the mechanical properties of a calcarenite. The results show that uniaxial compressive strength and elastic parameters decrease as the temperature increases for the tested range of temperatures. LIU and XU [21] studied the static mechanical properties of thermal treatment biotite granite by using an electro-hydraulic and servo-controlled material testing machine. The results show that the physical and mechanical characteristics are changed after thermal treatment.

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There were already some rock mechanical properties studies related to temperature, but barely came down to static mechanical properties of rocks under high temperature. And, the mechanical properties of rocks after high temperature treatment and under high temperature can certainly be different. Thus, research on the mechanical properties of rock after high temperature treatment and under high temperature is extremely urgent. By using an electro-hydraulic and servo-controlled material testing machine with a heating device, uniaxial compression tests on granite samples after high temperature treatment and under high temperature, from room temperature to 800 °C, were carried out. The variations in apparent form, stress−strain curve, compressive strength, peak strain, elastic modulus and failure modes under the two types of conditions with the change of temperatures are analyzed and compared. The results can provide a reference for problem-solving related to high temperature rock engineering.

2 Experimental

2.1 Sample preparation

Rock samples were processed into cylindrical specimens of *d*50 mm × 100 mm by cutting and polishing. In particular, to ensure parallelism and flatness, both ends of the samples were polished. Precision control of the specimens was exercised in accordance with the standard requirements of the International Society of Rock Mechanics [22] with the parallelism controlled within ±0.05 mm and surface flatness within ±0.02 mm. Samples of similar wave velocity were selected by wave velocity determination. According to the experimental program, the specimens were numbered and heated to designed temperatures by using an auxiliary heating device. Some prepared specimens are shown in Fig. 1. In addition, the main components of granite, as shown in Table 1, were obtained throughout the diffraction experiment and an experimental graph is given in Fig. 2.

2.2 Experimental equipment

The electro-hydraulic and servo-controlled material testing machine used here, as shown in Fig. 3, mainly consists of main equipment, a heating device, a control and data-processing device and a water pump. The main equipment includes a pressure device, a strut bar and support. The heating device with a maximum designed temperature of 1000 °C includes an insulating layer used as heat preservation, resistance used for heating and a temperature controller, which has three built-in thermocouples used for heating control. The control and data-processing device is used for test control and data processing. The water pump is used to cool the pressure bar. The auxiliary heating device of the type SX-4-10, with a rated power of 4 kW and a maximum designed temperature of 1050 °C mainly contains a high temperature furnace and a temperature controller.

2.3 Experimental procedure

The test temperature is classified into 6 groups: 25, 100, 200, 400, 600 and 800 °C. Each group is equipped with no less than five specimens. For the test of granite after the high temperature treatment, the wave velocity of the specimens is measured by using a rock and soil engineering mass detector of type CE9201 no less than three times, and the mass of specimens is measured by

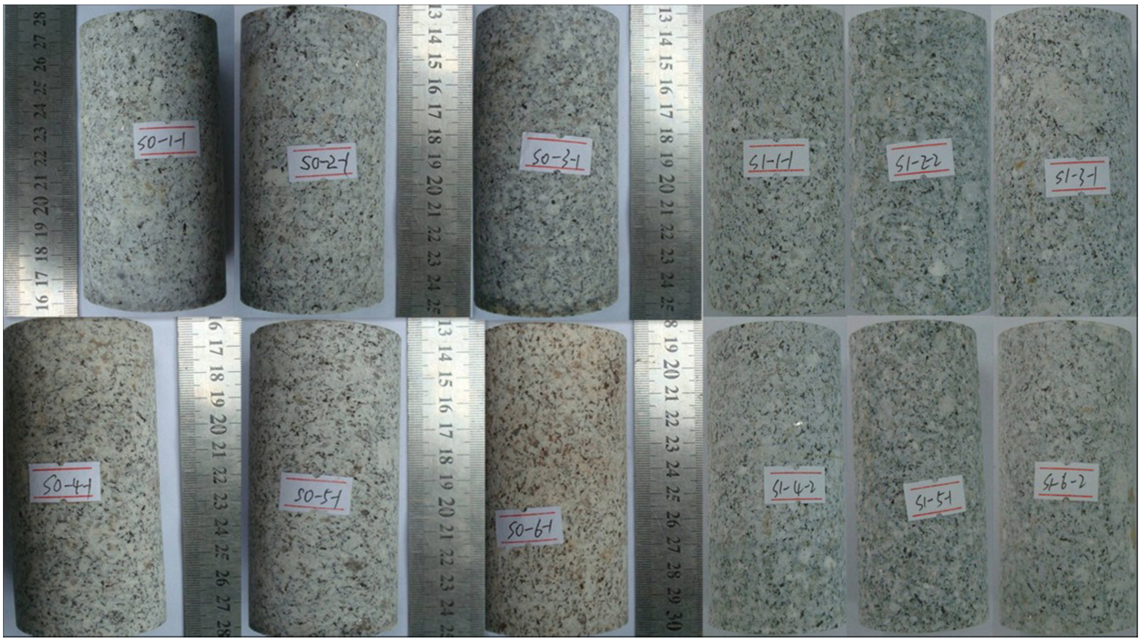

Fig. 1 Photos of some prepared specimens