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Hydrophilic characteristics of soft rock in deep mines

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ABSTRACT

A series of water absorption tests on dried soft rock have been conducted by the intelligent testing system for water absorption tests in deep soft rock, including tests of water absorption with and without pressure. The results show that the water absorbing capacity of rock with a certain pressure is larger than that of rock without pressure; however, the relationship between the water absorbing percentage and the time can be expressed by $w(t) = a(1 - e^{-bt})$. In bi-logarithmic coordinates, the hydrophilic relationship with time in tests with pressure could be characterized by linearity, while they present concave or convex in tests without pressure. Based on the hypothesis that each influential factor is irrelevant and they have a linear correlation with the water absorbing capacity, we calculated the weight coefficient of each factor according to experimental results under different conditions. The calculations demonstrate that the effective porosity, content of smectite and kaolinite are all positively correlated with the water absorption capacity of rock; meanwhile, the fractal dimension of the effective pores presents a negative correlation with the water absorption capacity of rock. The water absorption capacity with pressure increases with increasing illite, chlorite and chlorite/smectite formation and a decrease in illite/smectite formation and the fractal dimension of the effective pores, while it is opposite in tests without pressure. The weight coefficient of smectite is smallest among positive factors, and the fractal dimension of the effective pores is the smallest amongst the negative factors.

1. Introduction

Water is one of the most active factors in inducing various kinds of geological disasters. In addition, it is an important carrier during the evolution of geological disasters [1]. The mechanical performance of deep soft rock in its natural state is good; however, when absorbing a certain volume of water, the mechanical performance of the rock mass will be dramatically decreased, which can lead to a number of engineering problems, for example: large deformation and collapse of soft rock tunnels [2].

Many researchers have found that the mechanical properties of rocks are deteriorated to various degrees with increasing saturation ratios [3–6]. In particular, clayey rocks show a significant reduction in strength as a result of the swelling clayey minerals contained in rocks having a strong absorption and swelling capacity. Therefore, the study of the characteristics of water absorption of rock masses is significantly important, allowing for understanding of the deformation mechanism of deep soft rocks and the determination of successful support systems. Microstructure characteristics and softening mechanisms of rocks after interacting with water have also been widely studied [7–16]. It is noted that the flooding method was adopted in the above-mentioned researches, in which rock specimens were completely immersed in water.

Much work has been devoted to the rock-water interaction. It is, however, noted that little attention has been paid to studies of the characteristics of the absorption of water in deep soft-rocks. In this study, rock samples were obtained from the Daqiang coal mine at Liaoning province of China. The hydrophilic characteristics of the rock samples were investigated by a self-developed testing system (the intelligent testing system for water absorption in deep soft rocks) (ITSWADSR). To study the correlation between various factors on water absorbing capacity, X-ray diffraction and mercury injection tests were employed.

2. Experimental

2.1. Principle

Following excavation of deep tunnels, the environment in the surrounding rock changes, which causes structural planes or fissure surfaces to extend and open in the surrounding rock. As a result, the hydrogeological conditions change, resulting in an

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increase in the potential for rock water absorption by different mechanisms. There are two very important mechanisms including water absorption under pressure and without pressure. The former is caused by the existence of fissure water, resulting in a range of water head heights (1.5 m) exerted on the surrounding rock in soft rock tunnels. The latter is due to a damp environment and water used in engineering and results in direct contact between the surrounding rock and the water environment with no pressure between the contact surfaces.

2.2. Method

As shown in Fig. 1a, 1.5 m water head is exerted on one end face of the rock specimens by touching the water device switch, which is made of hard plastic material, for water absorption with pressure. The testing of water absorption without pressure is shown in Fig. 1b. The communicating vessel is formed by the glass funnel and metering tube which are connected with a rubber tube, and then keeping the two water levels at the same height. When the rock sample is placed on the glass funnel, one surface of the sample is in contact with water and there exists no pressure on the contacting surfaces.

3. System

3.1. System development

In order to meet the requirements of indoor experiments, a small water absorption test system was designed by He et al. [17,18]. In 2010, the intelligent testing system for water absorption in deep soft rocks (ITSWADSR) was developed by He M C, as shown in Fig. 2. As for the ITSWADSR, some improvements were made in which dynamic monitoring of water absorption of rocks and intelligent processing of data can be achieved.

The improved system, ITSWADSR, can perform two kinds of water absorption tests simultaneously. It is mainly composed of a box with good isolation of temperature and wetness, industrial panel PC, data acquisition system, and weight display instrument. A small cantilever sensor (accuracy ±0.01 g) is applied in this system to take real-time monitoring of the water quality change in the water tank, so that the water absorption quantity can be calculated automatically at different times. Moreover, the relation curve of water absorption (Q/g) and time (t/h) can be displayed in real time. Through the relation between the water absorption (w/%) and the water absorption time of the rock sample, the bibulous performance of the rock can be measured, and then the interaction between rock and water can also be analyzed. The working principle of ITSWADSR is shown in Fig. 3.

3.2. Experimental procedure

Prior to carrying out water absorption tests, some basic data should be determined, including size, mass, initial moisture content, quality and the porosity of rock samples.

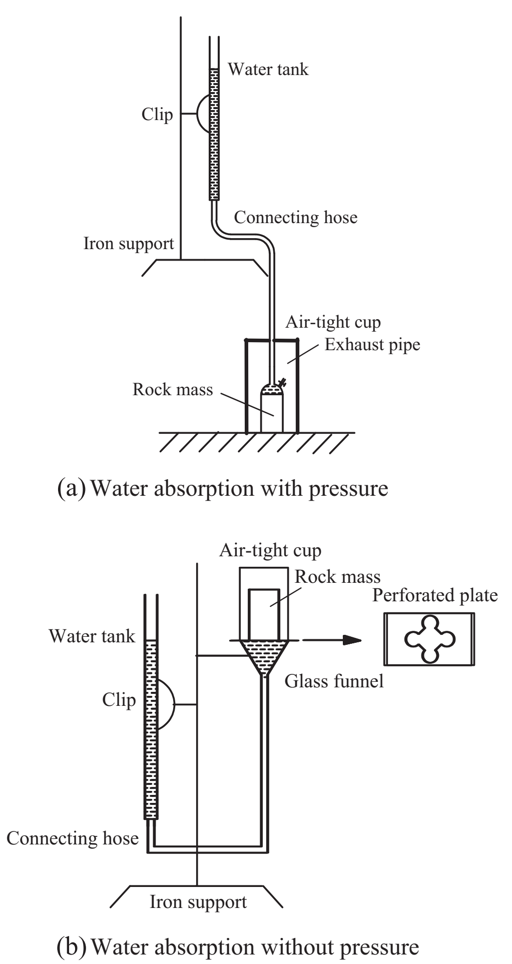

Fig. 1. Experimental methods for water absorption tests of rock.

Fig. 2. Intelligent testing system for water absorption in deep soft rock.

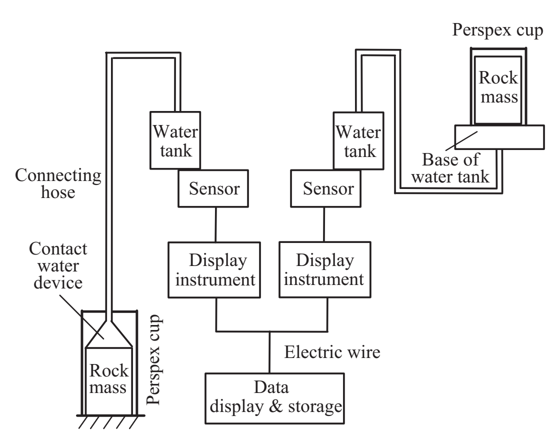

Fig. 3. Schematic diagram of the experimental system.