International Journal of Mining Science and Technology 25 (2015) 489–495

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Experimental research on hydrophilic characteristics of natural soft rock at high stress state

Guo Hongyun [a,*], Lei Xiangyang [a], Zhang Yumei [b], Yang Guoxing [a], Niu Zhang [c]

[a] The Engineering Design Research Institute of Equipment of PLA, Beijing 100028, China
[b] Astronaut Center of China, Beijing 100094, China
[c] China Taiyuan Satellite Launch Center, Taiyuan 036300, China

ARTICLE INFO

Article history:
Received 18 September 2014
Received in revised form 22 November 2014
Accepted 26 December 2014
Available online 21 April 2015

Keywords:
Natural soft rock
Water absorption tests
X-ray diffraction
Mercury injection test
Hydrophilic characteristics

ABSTRACT

In order to study features of rock–water interaction, a self-developed experimental system called Intelligent Testing System for Water Absorption in Deep Soft Rocks (ITSWADSR) was utilized to analyze the hydrophilic behaviors of natural soft rock at high stress state. Combining X-ray diffraction and mercury injection test, main influencing factors on hydrophilic characteristics were studied. According to the results, it could be concluded as the following: (1) the effective porosity, and the content of illite, illite/smectite formation (S = 5%) and kaolinite have positive correlation with the water absorption capacity of rock; meanwhile, the initial moisture content, fractal dimension of effective pores, illite/smectite formation (S = 30%) and chlorite present negative correlation; (2) among the positive factors, the ascending order is kaolinite, illite/smectite formation (S = 5%) and illite; (3) the descending order among the negative factors are chlorite, illite/smectite formation (S = 30%) and fractal dimension of the effective pores; (4) influence of effective porosity on the pressurized water absorbing capacity of rock is minimal, while it is maximal in the process of no pressurized water absorption.

1. Introduction

High stress soft rock is referred to as an engineering rock mass with the characteristics of considerable deformation under condition of high stress level ($\sigma_c > 25$ MPa). Its geological feature is that the argillaceous ingredient is less while the sandy ingredient is more. In addition, its mechanical characteristics can be described by either hard rock mass at shallow layer or softening rock at deep seam. Presently, most of coal mines in China are being excavated under the condition of deep mining. Thus mining disasters caused by high stress level are frequently reported [1]. Moreover, large deformation among mining wall is usually observed, which has seriously affected route mining of many mines in China. Consequently, the understanding of such failure phenomena for softening rock has been seriously concerned nowadays [2,3].

The mining wall with high-stress is referred to as a mining wall that is formed under the condition of initial high stress in rock mass. After excavating, the compressed stress surrounding the wall will change so that the structural planes will cause the variation of hydro-geological environment for the surrounding rock masses, where water can flow through and chemo-physical reactions between water and surrounding minerals can be yielded to make the clayed minerals in the skeletons slop and swell [4–7]. These reactions also weaken rock layers and enhance rock deformation. Therefore, rock–water interaction plays an important role in the large deformation of soft rock wall under the condition of high stress.

A lot of work has been devoted to rock–water interaction. For example, the mechanical properties and dynamical response for rock containing water have been studied [8,9]. Rock–water chemical interaction has been investigated to understand its mechanical effect [10]. Microstructure characteristics and softening mechanism of soft rock interacting with water have also been analyzed recently [11,12]. However, it is noted that little attention has been paid to study the characteristics of absorbing water in deep soft-rock, and the flooding method was adopted in the researches mentioned above, in which rock specimens were completely immersed in water.

2. Experimental

After the excavation of deep tunnels, the surrounding rock environment changes lead structural plans or fissure surfaces to

* Corresponding author. Tel.: +86 13311015171.
E-mail address: guohongyun0415@126.com (H. Guo).

http://dx.doi.org/10.1016/j.ijmst.2015.03.025
2095-2686/© 2015 Published by Elsevier B.V. on behalf of China University of Mining & Technology.

extend and open in the surrounding rock, and then the hydrogeology conditions change, resulting in the increase of the possibility of water absorption in rock with various forms. The mechanics performance of soft rock at high stress state in natural state is well; however, after absorbing a certain volume of water, the mechanical properties of rock mass will be dramatically decreased, which leads to a series of engineering problems such as large deformation and collapse of soft rock tunnels [13–16].

2.1. Principle

There are two important kinds of forms for soft rock in water absorption, including pressurized and no pressurized water absorption. The former one is caused by the existence of fissure water, resulting in that a range of water head heights are exerted on the surrounding rock in soft rock tunnels. As shown in Fig. 1a, 1.5 m water head is exerted on one end face of rock specimens through touching the hard plastic material, which makes water device switch for water absorption with pressure. The latter is due to the damp environment and water using in the engineering, leading the surrounding rock to contact directly with the water environment. There is no pressure between the contact surfaces. The test of no pressurized water absorption is shown in Fig. 1b. The communicating vessel is formed by the glass funnel and metering tube connected with a rubber tube, and then keep the two water levels in the same height. When we put a rock sample on the glass funnel, one surface of the sample is contacting with water and there exists no pressure on the contacting surfaces.

2.2. System development

In order to meet the requirements of indoor experiments, a water absorption test system was designed by He et al. [12]. In 2010, the Intelligent Testing System for Water Absorption in Deep Soft Rocks (ITSWADSR) was developed by Prof. He Manchao, as shown in Fig. 2a. As for ITSWADSR, some improvements were made, in which dynamic monitoring and intelligent processes of data can be realized.

The improved system, ITSWADSR, can take two kinds of water absorption tests simultaneously. It is mainly composed of the box with good isolation of temperature and wetness, industrial panel PC, data acquisition system, and weight display instrument. Small cantilever sensor (accuracy ±0.01 g) is applied in this system to carry out real-time monitoring of the water quality change in the water tank, and then the water absorption quantity can be calculated automatically at different time. Moreover, it can real-time display the relation curve of water absorption Q (g) and time t (h). Through the relation between the water absorption w (%) and the time, the bibulous performance of the rock can be measured, and then the rock–water interaction can also be analyzed. The working principle of ITSWADSR is shown in Fig. 2b.

2.3. Procedures

Before water absorption tests, some basic data should be determined, including size, mass, initial moisture, quality, and porosity of the rock samples.

The main experimental procedures of pressurized water absorption test are as follows: (1) cement touching water device and cover the perspex cup on it to prevent water loss in the rock; (2) airproof the surrounding environments of the rock sample; (3) inject water into the water tank; (4) adjust the elevation of water tank; and (5) press the button of "start".

The main experimental procedures of no pressurized water absorption test are as follows: (1) inject water into the water tank; (2) adjust the elevation of water tank until the water height in the base remains a little higher than the water tank and then remove the air in tubes in time; (3) put the sample on the base of water tank and cover the perspex cup on it to prevent evaporation in the rock; and (4) press the button of "start".

3. Experimental rock samples

3.1. Rock samples preparation

Rock samples were taken at the depth of between −1351.42 m and −1478.44 m of Daqiang coal mine in Liaoning. The specimens were wrapped with ziplock bags in site and transported to the ground. Then, the rock samples were sealed with wax immediately to maintain the freshness. In the laboratory, all samples were cut and processed into the dimensions of ϕ 55 mm × 110 mm. The parallel deviated error between the two end surfaces is no more than 0.05 mm with deviation angle smaller than 0.25°.

3.2. Experimental design

The water absorption tests of the natural rock samples were grouped into two kinds: the pressurized water absorption tests

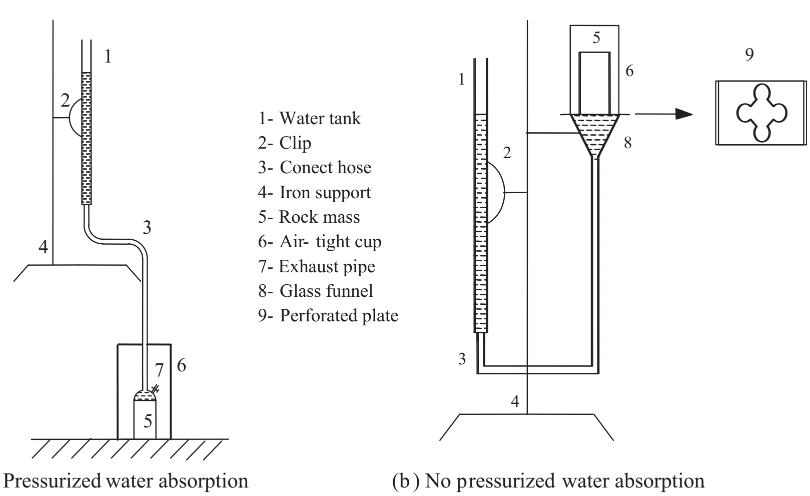

Fig. 1. Experimental methods for water absorption tests of soft rock.