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# Water-resisting ability of cemented broken rocks

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ABSTRACT

Using the self-designed testing system, the seepage tests for cemented broken rocks were conducted, and the impact of different factors on water-resisting ability was analyzed. The results show that (1) seepage process of the cemented broken rocks can be divided into two categories: in one category, seepage instability occurs after a period of time, in the other, the permeability decreases slowly and tends to be stable, and seepage instability does not occur; (2) cementing performance of cementing agent and grain size distribution are the decisive factors for water-resisting ability, with the increase of cementing performance and the mass percentage of large grains, the water-resisting ability of the specimen strengthens; (3) aggregate type has little effect on seepage stability, for the specimens with different aggregate types, the permeability and the duration of seepage instability have small difference; (4) initial porosity has a certain effect on the water-resisting ability of the specimen, but has no decisive role. With the increase of the initial porosity, the duration of seepage instability decreases.



## 1. Introduction

In the history of water hazards in coal mining engineering in China, there are hundred serious water inrush accidents, and most of the accidents are related to the broken geological structures, such as collapse column and fault [1]. However, engineering practice shows that not all broken geological structures connected with aquifers will cause water inrush, in other words, broken geological structures have a certain ability to resist groundwater. However, a relatively small number of studies have been performed regarding the water-resisting ability of broken geological structures. In terms of water-resisting ability of rock strata, many scholars have done much related researches. The water-resisting ability of rock strata and some influence factors have been studied [2–9]. Through indoor tests, the water-resisting ability and the water inrush risk of rock strata with different composition and structure have been investigated [10–13]. Miao et al. have established the basic mechanical model of composite waterproof key strata, and showed the methods to judge the water-resisting ability of key strata with different combinations [14–17]. Kong et al. have studied water inrush from coal seam floor [18,19]. However, all the above results focused on complete rock strata, and have not involved in the water-resisting ability of broken geological structure.

Meanwhile there are many results about the permeability of broken rocks [20–23]. Through experimental methods, Ma et al. have tested the seepage characteristics of broken rocks, and got the seepage parameters [24–29]. Based on the time sequence of water pressure gradient and seepage velocity, Chen et al. have established a kind of permeability parameters calculation for broken rocks [30]. However, the results, mentioned above, are only focused on discrete rock material, and the cementation among broken rock mass is ignored. In the engineering practice, broken geological structure, made up of broken rock mass and fillings after long-playing compaction and cementation, is a kind of porous media with complex structure. That is to say, broken geological structure is cementation body, and it not only can resist the pressure, but also can resist a certain amount of shear and minimal tension.

Due to the above problems, we used the self-designed testing system to conduct the seepage tests of cemented broken rocks with different cementing agents, aggregate type, grain size distribution and initial porosity. The impact of different factors on water-resisting ability was analyzed, and the seepage instability mechanism of cemented broken rocks was discussed.

## 2. Test method

### 2.1. Specimen preparation

A self-designed compacting device was used to fabricate the cemented broken rock specimens. The compacting device is mainly

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composed of a compacting rod, cylinder tube, felt, pedestal and other components, as shown in Fig. 1.

Rock grains were used as the aggregate for the seepage specimens. Before the test, the rocks were first crushed and separated into six different grain sizes: 0–2.5, 2.5–5, 5–8, 8–10, 10–12 and 12–15 mm, as shown in Fig. 2. The fabrication method of the specimens is described as follows: first, 900 g rock grains were taken and mixed with 100 g cementing agent, and the mass of the rock grains within each grain size range was calculated by Talbol theory [29]. Then, 60 g water was added and stirred evenly. Next, the mixture was poured into the cylinder tube, after which the mixture was pushed to the preset height by using the press machine to apply an axial pressure. Finally, maintaining the height, the specimen was taken out after seven days.

### 2.2. Seepage device

The self-designed testing system is mainly composed of four parts: the pore water pressure control apparatus, seepage device, press machine and data acquisition apparatus [29]. In this test, the original seepage device was improved. Fig. 3 shows the new seepage device.

### 2.3. Test scheme

Four groups of specimens were prepared to study the impact of cementing agent, aggregate type, grain size distribution and initial porosity on the water-resisting ability of cemented broken rocks, as shown in Table 1.

For different Talbol power exponents, the details of mass amount of rock grains in each diameter range to each specimen is shown in Table 2. From Table 2, we can observe that the mass percentage of large particles increases with an increase in the Talbol power exponent.

### 2.4. Testing procedure

A water pump was used to inject water into the lower cavity of the double-acting hydraulic cylinder. After the piston rod rose to the highest position, the hydraulic pump station was used to push the piston rod to move downward so as to drive the water in the lower cavity into the seepage loop, thereby achieving the seepage test. The entire testing procedure is shown in Fig. 4.

## 3. Analysis of test results

Because of the particles loss from specimens, the seepage parameters change over time. According to the pore water pressure and water flow rate obtained by data acquisition apparatus, we can calculate the permeability during seepage test through the seepage parameters algorithm for broken rocks concluded by Chen et al. [30].

### 3.1. Impact of cementing agent on water-resisting ability

In order to compare the strength of the specimens cemented by different cementing agents after encountering water, we soaked the four specimens cemented by different cementing agents in the water simultaneously. The results showed that: the specimen cemented by clay was quickly disintegrated; the specimen cemented by rock debris was disintegrated after approximate 30 min; the other two specimens were taken out after one hour to conduct the uniaxial compression test. The results showed that the strength of specimen cemented by gypsum is lower than that of specimen cemented by cement. Therefore, the cementing strength of the four specimens after encountering water is successively as follows: clay < rock debris < gypsum < cement.

The permeability of the specimens cemented by different cementing agents is respectively listed in Tables 3 and 4. Here '–' represents seepage instability, namely, large water channels are formed in the specimens, and the seepage changes into pipe flow.

Fig. 5 shows the time-varying curves of the permeability of the specimens cemented by different cementing agents. From Fig. 5, we can concluded the following results:

(1) Seepage instability occurs in the specimens cemented by clay, rock debris or gypsum after a period of time. Before seepage instability, the permeability gradually increases. However, the permeability of the specimen cemented by cement gradually decreases and tends to be stable after a short increase.
(2) The water-resisting ability of the specimen cemented by cement is the highest, which is mainly due to the fact that the cementing performance of the cement is the strongest, and the overall structure of the specimen is stable. Under the drive of the water flow, the fine particles are not washed away but precipitated at the bottom of the specimen. As a result, the local porosity of the specimen decreases, and the water flow channels become narrow, thereby leading to the decrease of the permeability. Additionally, the volume expansion of the mudstone particles also can cause the decrease of the permeability. On the contrary, the cementing performance of clay, rock debris and gypsum is weak. Under the action of the water flow, the particle loss occurs, and then the porosity of the specimens increases. Thus, the water flow channels become wide, and the permeability gradually increases. As a result, the overall structures of the specimens are damaged, leading to seepage instability.

### 3.2. Impact of aggregate type on water-resisting ability

The permeability–time curves of the specimens with different aggregate types are shown in Fig. 6. From Fig. 6, we can conclude the following results:

(1) Seepage instability occurs in all three specimens, and the times attaining to reach seepage instability have little difference. This suggests that the aggregate type has little effect on water-resisting ability.
(2) The permeability of specimens with mudstone particles is the smallest. It is mainly due to that the secondary breakage of the mudstone particles is most serious in the process of fabricating the specimens. As a result, the fine particles

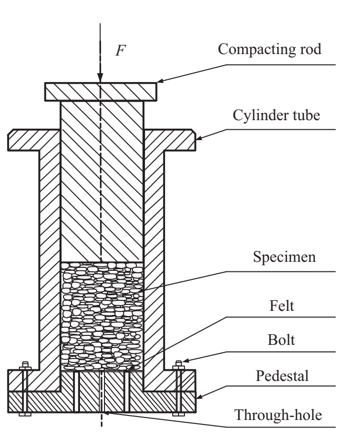


**Fig. 1.** Compacting device for seepage specimens.