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Study on the Development and Change of Rock Fissure under Waterlogged Environment

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Abstract

The water-rock interaction has a great influence on the mechanical properties of rock and the degree of fracture development. The difference of acid-base of water in rock fracture will affect the degree of fracture development, the strength of water-rock chemical reaction and the weakening of rock mechanical properties. In this paper, thin stratified mudstone collected from the roof of a coal mine is taken as the research object. Dynamic soaking experiments were carried out with three kinds of solutions, pH=5, pH=7 and pH=9, and the change characteristics of mineral particles and the change of rock fissure development were observed under a 500-fold microscope, and the principle of water-rock chemical action and the cause of fissure change were analyzed. The following conclusions were obtained: (1) There are three kinds of changes: slow expansion, sudden increase, first expansion and then shrinkage of rock fissure in the immersed environment. (2) Different acid and alkaline aqueous solutions have a great difference in the degree of crack expansion and development, neutral > alkaline > acidic for rock crack expansion.

Keywords

Mudstone; Water-rock Action; Mineral Composition; Crack Propagation.

1. Introduction

Hydrochemical and physical effects will affect the structure of engineering surrounding rock, especially for the change of fracture mechanical properties, the influence of pH value of complex dissolved substances in groundwater is more significant. Water-rock interaction will change the development degree of fracture, rock porosity, permeability and permeability, brittleness and rigidity of rock mass, which will lead to major mine geological disasters caused by fracture. Water - rock action should be paid more attention to rock failure.

The mechanical properties of rock are greatly damaged by water-rock action, which mainly reflects the internal friction Angle, softening effect, peak stress and porosity. In the past two decades, scholars at home and abroad have made good progress on the water-rock interaction and the corrosion of water environment in rock fissure. In particular, the influence of aqueous solution at different pH values on the mechanical properties of rock has been extensively studied. Wang Wei[1]showed that ionic composition and pH value had a great influence on the mechanical properties of red sandstone, and the peak strength, residual strength and elastic modulus of rock after corrosion by various chemical solutions all decreased to varying degrees; Yang Jinbao[2] found that the rock fracture opening under alkaline solution penetration is smaller than that under acidic solution penetration; Wang Yanlei[3]found that the stronger the acid-base and the higher the concentration of the solution, the

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stronger the corrosion effect on the gray sandstone specimen and the more obvious the deterioration of the stress index; Luo Tao[4] studied the fracture and crack propagation process of sandstone soaked in chemical solution; Shang Delei[5] found that dissolution mainly occurs in acidic solutions, while precipitation crystallization mostly occurs in alkaline solutions, which has less effect on rock fracture shear strength than acidic solutions; Dong Xu[6] found that mudstone samples soaked in strong acid chemical solution were mainly damaged by tensile shear combination, while mudstone samples soaked in weak acid chemical solution were damaged by tensile cracking. Based on chemical damage variables; Yun Lin[7] obtained that the corrosion order of different chemical solutions on sandstone was HSO>NaOH> distilled water.

In this paper, the immersion experiment of thin layered mudstone samples with different pH values was carried out to observe the chemical effect of mineral particles under a microscope, analyze the type of water chemical action, and explore the mechanism of water-rock action.

2. Experiment Approach

2.1 Test Material

The thin stratified mudstone samples were taken from the direct roof of the thin stratified silty mudstone at the working face of a mine. They were grayish-black in color and brittle. There were obvious black brown interbedded joints, some clay minerals and calcareous minerals, and obvious horizontal cracks along the bedding direction appeared after immersion, and the bedding surface was smooth.

XRD analysis was carried out on the original rock sample and the interbedded material of the original rock sample. The text of the interbedded material was scraped from the interbedded material of several original rock samples. The chromatogram of the original rock sample was shown in Figure. 1, and the analysis of the interbedded material was shown in Figure. 2.

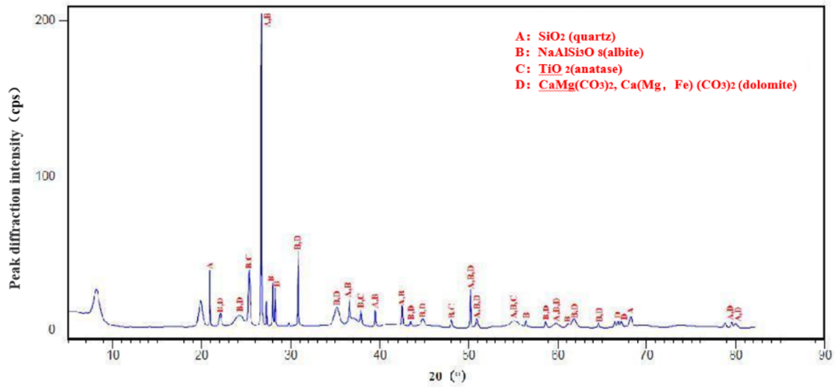

Figure 1. XRD analysis of the original rock sample

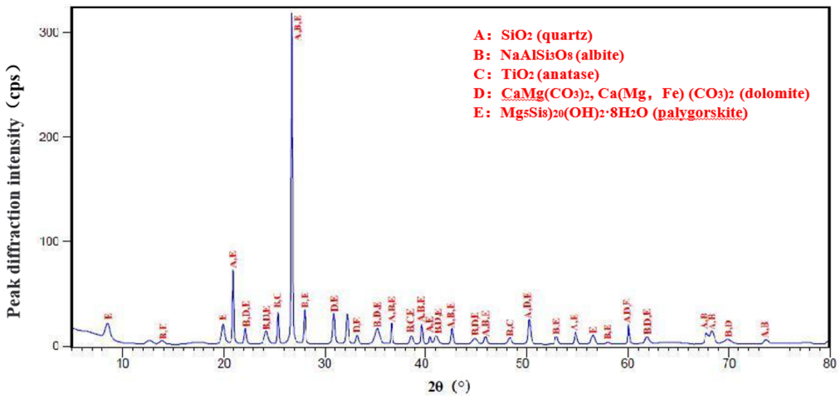

Figure 2. XRD pattern analysis of the interlayer material of the original rock sample

As shown in Figure. 1 and Figure. 2, In thin stratified mudstone, there are 45.50% alborite ($NaAlSi_3O_8$), 32.26% quartz (SiO_2), 10.27% dolomite ($CaMg(CO_3)_2$) and ferridolomite ($Ca(Mg,Fe)(CO_3)_2$), 6.00% illite ($K_{0.7}Al_2(Si,Al)_4O_{10}(OH)_2$), Anatase ($TiO_2$) 5.97%, quartz 64.00%, calc alborite 18.00%, Anatase 4.00%, dolomite 9.00%, palyhamite ($Mg_5Si_8O_{20}(OH)_2 \cdot 8H_2O$) 5.00% in interlayer material.

It can be seen that there are obvious differences between the original rock sample and the interlayer material. The clay minerals in the original rock sample are mainly illite, while the interlayer material is mainly perychite with stronger water absorption, and the content of quartz in the interlayer material is much higher than that in the original rock sample.

2.2 Experiment Design

1) The direct top rock of thin stratified mudstone was cut into 50×30mm standard specimens, from which 9 rock samples of similar size and relatively regular shape were selected for dynamic immersion test (Figure. 3), and the remaining rock samples were used as supplementary rock samples. Before the test, the standard specimen was put into the oven to dry its natural moisture, and its physical parameters were determined. Dilute sulfuric acid, distilled water and sodium hydroxide were selected to prepare soaking solution with pH=5, pH=7 and pH=9. 3×1000mL of each solution was prepared with a total of 9×1000mL.

Figure 3. Standard rock sample

2) Before immersion test, observe the front and back sides of each specimen under a digital microscope, and record the mesoscopic characteristics of the specimen in its natural state.

3) The 9 specimens were divided into 3 groups with 3 in each group. Specimens in group A were immersed in pH=5 solution, specimens in group B was immersed in pH=7 solution, specimens in group C were immersed in pH=9 solution, one specimen was placed in each cup of immersion solution, and the volume of each cup of immersion liquid was the same as the mass ratio of rock sample. During the immersion process, plastic wrap was affixed to the mouth of the beaker to prevent water evaporation.

4) Let it stand naturally, then pour out the soaking solution of all specimens every 24h, filter it through neutral filter paper and store it in a clean plastic water bottle, and pour the cuttings on the filter paper into the beaker again for the next day soaking test.

3. Experimental Results and Analysis

3.1 Macro-observation of Sample Surface after Immersion

The size difference is great, there are flake fragments, the fragmentation surface is sharp, the section is smooth; After neutral dynamic soaking, the disintegration degree of the sample is low, and the sample rock mass is relatively complete, but there is still partial disintegration. After alkaline dynamic soaking, the sample disintegrated seriously, but the degree of disintegrating was smaller than that after acidic soaking. The size of all disintegrated rock blocks varied greatly, and there were flake wedge-shaped fragments.

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Table 1. Macro-picture of specimens after immersion

	A	B	C
1			
2			
3			

To sum up, compared with acidic and alkaline dynamic soaking samples, the damage degree of neutral dynamic soaking samples is smaller. Acidic dynamic soaking samples are more broken. Compared with alkaline samples, the size of broken blocks is more uneven and small fragments appear. The degree of breakage of samples after alkaline soaking is between neutral and alkaline. The size of the broken block is more uniform. It is obvious that the water-rock chemical reaction occurred between acidic and basic samples. Chemical reactions break the rock even more.

3.2 Changes of Microscopic Cracks after Different Acid and Alkaline Soaking Experiments

The rock fissure of thin stratified mudstone was emphatically observed, and the fissure observation was carried out for 0-8 days, and recorded under a 500-times microscope. Three fractures with typical changes were selected for description, and the length and opening of the fissure were measured.

As shown in Figure. 4, fissure 2-1-2 has a fissure of 2.02mm×0.03mm in mudstone before initial soaking. On the first day of soaking in acid solution, the fissure suddenly increases into a fissure of 2.22mm×0.21mm; on the second day and the fourth day, the fissure decreases slightly into a fissure of 2.72mm×0.20mm; and on the fourth day, the fissure changes little.

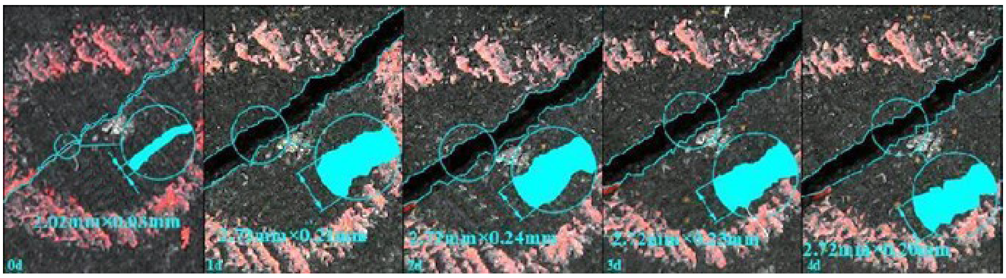

Figure 4. Crack 2-1-2

As shown in Fig. 5, when crack 3-2-2 was not soaked, there was a slender and discontinuous crack of 2.62mm×0.03. After the first day of alkaline solution soaking, the crack gradually developed into a continuous crack of 2.80mm×0.03mm, and no obvious change occurred after the second day.

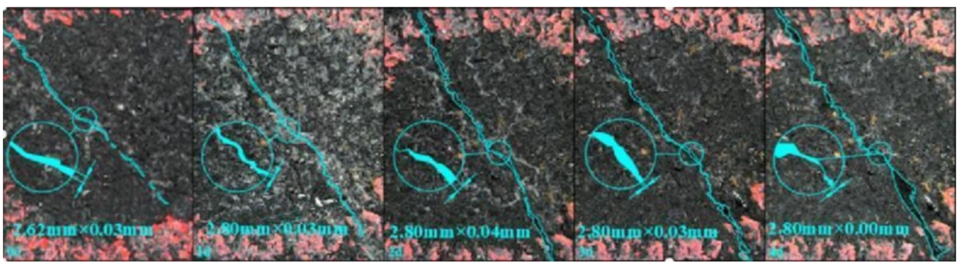

Figure 5. Crack 3-2-2

As shown in Fig. 6, a crack of 1.08mm×0.02mm appeared when crack 3-2-3 was not soaked, which expanded into a crack of 1.19mm×0.07mm after soaking in alkaline solution for one day. After the third day, the crack gradually expanded into a crack of 1.19mm×0.17mm. No significant changes subsequently occurred.

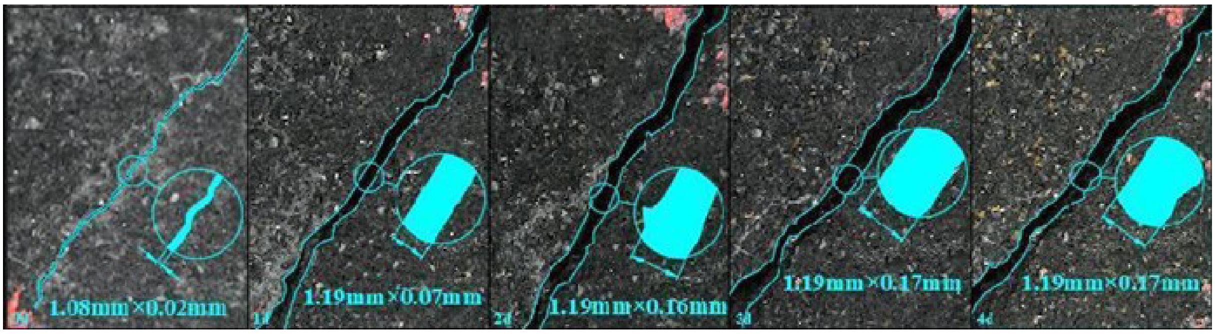

Figure 6. Crack 3-2-3

3.3 Crack Change Data Analysis

Through the observation of microscopic cracks, we summarized three typical crack change forms: crack surge, crack slow expansion, crack first expansion and then contraction. Table 2 lists six typical curves. Group A is the fracture growth group, corresponding to fracture 1-3-1 and fracture 2-1-4 in A1 and A2, respectively. Group B is the slow expansion group, corresponding cracks B1 and B2 are cracks 3-2-3 and 1-1-3, respectively. Group C is the group of fissure expansion followed by contraction. Corresponding fissure C1 and C2 are fissure 1-2-3 and 1-1-2, respectively. As shown in Fig. 7, crack expansion in Group A increases rapidly, which is obvious in the figure, and the slope is extremely high. The crack in group B increases slowly, the slope is lower than that in group A, and the change is gentle. Group C cracks increased slowly and then decreased slowly.

Table 2. Variation table of crack width

time / fissure	0d	1d	2d	3d	4d	5d	6d	7d	8d
A1	0.02	0.64	0.48	0.48	0.48	0.48	0.48	0.48	0.48
A2	0.00	0.00	0.42	0.49	0.49	0.49	0.49	0.49	0.49
B1	0.02	0.07	0.16	0.17	0.17	0.17	0.17	0.17	0.17
B2	0.17	0.17	0.17	0.24	0.25	0.25	0.23	0.27	0.23
C1	0.06	0.06	0.06	0.06	0.21	0.21	0.04	0.04	0.04
C2	0.00	0.05	0.09	0.09	0.09	0.13	0.10	0.10	0.10

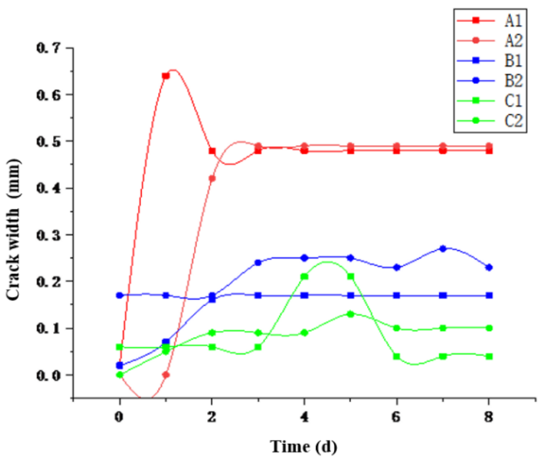

Figure 7. Variation of crack width

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4. Conclusion

After chemical soaking experiments of different acid and alkaline solutions were carried out on the thin layered mudstone collected from the roof of coal seam, the following conclusions were drawn after exploration and analysis of its water-rock action.

(1) There are three kinds of changes: slow expansion, sudden increase, first expansion and then shrinkage of rock fissure in the immersed environment. Different types of rock fissure change have different effects on rock stability. The experimental surge phenomenon has a good effect on the stability of real rock strata. The reason for the surge phenomenon is that large clay minerals expand and squeeze the surrounding rock mass. Other kinds of rock fissure change have destructive effect on the stability of rock mass.

(2) Different acid and alkaline aqueous solutions have a great difference in the degree of crack expansion and development, neutral > alkaline > acidic for rock crack expansion.

Acknowledgments

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