Test Study on the Expansional Properties of Regenerated Anhydrite Rock

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Abstract. Dihydrate gypsum was formed after the anhydrite was immersed in water, and the volume of rock increased significantly. In order to analyze the expansion properties of Ordovician anhydrite rock, anhydrite rock samples (regenerated anhydrite rock) were obtained by high temperature drying of anhydrite rock samples, and then the rock expansibility. Experiments show that: (1) Regenerated anhydrite rock exhibits four typical stages in both axial and radial expansion deformation: I linear rapid expansion stage, concave stage, II linear expansion stage and constant stage, in which II linear expansion stage is the main expansion stage, accounting for 50%-60% of the total expansion;(2) the axial expansion rate is 2.6% and radial expansion rate is 0.7%, and axial expansion deformation of rock is 2.6~3.2 times of radial expansion.

1. Introduction
As a widely used engineering building material, gypsum has good hydrophilicity and dehydration, and it has different shapes and strengths. It is widely used in cement retarders, building products and model making. Also because of this hydration property, gypsum rock has received much attention. Many domestic scholars have studied the mechanical properties of gypsum rock including compressive strength [1-5] and softening characteristics [6-8] in water environment. Studies have shown that gypsum rock has different degrees of strength reduction and softening affected by water, and the result is related to a variety of environmental factors. In addition to its compressive strength and softening characteristics in water environment, another property of the gypsum rock is closely watched: expansion characteristics. The expansion characteristics of gypsum rock is affected and controlled by the combination of calcium sulfate and water molecules. The anhydrite (i.e. anhydrous calcium sulfate) combines with two water molecules to form calcium sulfate dihydrate, and the volume can increase by 60% theoretically. It is often the object of research on the expansion mechanical properties of gypsum rock [9-13]. Due to different rock-bearing environment and existing strata, the anhydrite shows great differences in its expansional properties. The paper uses the Ordovician gypsum rock in Shanxi as the research object, and the rock expansion rate was tested according to the relevant experimental determination method. The characteristics of the axial expansion deformation curve and the microscopic change process of the rock were analyzed and discussed.
2. Introduction to the test process

2.1. Rock sample collection and test specimen production

The rock used in the experiment was taken from the marl stratum of the Upper Majiagou Formation of the Ordovician in the Dugongling Tunnel in Shanxi Province, China (see Figure 1). The test specimen was made by a combination of mechanical and manual ways. First, the rock core was got using the drill by drilling on the rock blocks. Then, it was cut and smoothed using the stone sawing machine and the stone grinder respectively, and the sample standard meets the requirements of < Method for Determination of Physical and Mechanical Properties of Coal and Rock >. According to the test items and related specifications, the test samples is with a diameter of 50mm and a height of 36mm.

![Figure 1. Rock specimen photo of Dugongling Tunnel.](image1)

The anhydrite will turn into dihydrate gypsum rock by absorbing water in the rock test specimen's collection, transportation and production process. To ensure that the anhydrite sample is without dihydrate gypsum, the sample is put into the 220°C drying oven to dehydrate and preserve heat for 48h so that the free water and the combined water in the rock sample are all dried and discharged. Anhydrite obtained in this way is different from the natural anhydrite protolith, so the anhydrite sample is referred to as regenerated anhydrite sample.

2.2. Rock expansion force test

The free expansion rate test uses the SC-55 type free expansion rate meter (see Figure 2) to test the expansion deformation of the sample. The instrument range is 5 mm and the precision is 0.001 mm. The test specimen has a diameter of 50 mm and a height of 36 mm.

![Figure 2. SC-55 type free expansion meter.](image2)

Test procedure: (1) Place the test specimen in a plastic bag in a plexiglass cup, dilute the test piece with distilled water, and inject water in time as the test specimen absorbing water; (2) fix four dial indicator on the column to test the radial deformation. Arrange the four fixed gauge holes on the wall of the glass in two straight lines; (3) the axial deformation is measured by the dial indicator on the top. There must be no resistance and deformation limits in the axial and radial direction during the test.

3. Analysis of test results

A group of 3 rock samples were tested in the rock expansion rate test. The curve of the relationship between the expansion deformation and time of each sample is shown in Figure 3 and Figure 4.
According to the curves of test data of Figure 3 and Figure 4, it can be known that:

1. Type I linear rapid expansion phase (OA phase in Figure 5 and Figure 6). In the initial stage, the free expansion deformation increased rapidly, showing the characteristics of fast growth and short duration. At this stage, both the axial and radial deformation of the test specimen increased linearly and rapidly, and the angle with the horizontal axis was greater than 80°; the duration time of the three test specimens was less than 40 mins.

2. The concave phase (AB phase in Figure 5 and Figure 6). At this stage, the deformation-immersion time curve is in a concave shape, showing a characteristic of slowing deformation and short duration. For example, in the A1 sample, the duration of this phase is about 336 mins, and the radial deformation increased by $181.3 \times 10^{-3}$ mm, accounting for 50.4% of the total deformation; the axial deformation increased by $592 \times 10^{-3}$ mm, accounting for 62.4% of the total deformation.

3. Type II linear expansion phase (BC phase in Figure 5 and Figure 6). At this stage, the deformation-time curve is in a linear uniform increasing shape, showing a large deformation and a long duration. For example, in the A1 sample, the radial deformation lasted about 106 mins in this phase, increased by $27.2 \times 10^{-3}$ mm and accounted for 7.6% of the total deformation; the axial deformation lasted about 90 mins in this phase, increased by $51 \times 10^{-3}$ mm and accounted for 5.4% of the total deformation.

4. Constant phase (CD phase in Figure 5 and Figure 6). At this stage, the deformation amount growth rate becomes slower, and the deformation amount tends to be constant. The sample expansion deformation is released.
(2) By comparing the radial and axial expansion deformation values of the regenerated anhydrite sample (Figure 7), it is known that the sample takes mainly the axial free expansion deformation, and expansion deformation of the axial direction is 2.6-3.2 times of the radial direction.

![Figure 7. Deformation comparison of axial and radial.](image)

(3) From the deformation test values of the three test specimens, the maximum amount of free expansion deformation took place on the A1 test specimen, and the maximum values were: $360 \times 10^{-3}$ mm for radial deformation, $948 \times 10^{-3}$ mm for axial deformation; The deformation rate was 0.7% in the radial direction and 2.6% in the axial direction.

(4) The whole expansion deformation of the test specimens after immersion is basically completed within 1500 mins. At this time, the deformation rate is less than $0.09 \times 10^{-3}$ mm/min.

Comprehensively analyzing the changing characteristics of these four stages, the physicochemical process of rock immersion expansion is derived as follows:

① In the initial stage of rock immersion, the surface of the rock sample first contacts the water. Under the affection of water, the surface layer of the sample rapidly expands and deforms in both the radial and axial direction, and the expansion deformation of this part is subject to no or little constraints (OA phase in Figure 8 and Figure 9).

② As time increases, water enters the interior of the rock along the pores of the sample. Due to the existence of the pore space, the rock particles around the pore expand and deform first towards the unconstrained pore space, resulting in the slower expansion and deformation of the sample macroscopically. (AB phase in Figure 8 and Figure 9).

③ After the rock pores are completely filled by the expansion deformation, the water can only penetrate along the microvoids of the rock particles, and the infiltration rate of the water and the expansion distribution of the sample tend to be uniform. At the same time, the expansion deformation of the sample can only be in the radial and axial direction. Macroscopically, the axial and radial expansion deformation increased steadily at a certain rate (BC phase in Figure 8 and Figure 9).

④ After most of the interior of the rock sample is soaked by water, the overall expansion deformation of the sample is basically completed. Only in the denser "boulder" or a small part of the rock particles away from the boundary of the specimen, the expansion deformation is not yet completed, still continuing. Macroscopically, the amount of expansion deformation of the specimen tends to be stable (CD phase in Figure 8 and Figure 9).
4. Discussion
In this paper, the anhydrite sample (regenerated gypsum rock sample) was obtained by high-temperature dehydration of gypsum rock specimens. Based on the rock test standard, the expansion mechanical properties of gypsum rock were tested. The characteristics of the sample acquisition route made it different from the anhydrite protolith expansion mechanics test, mainly in the following ways:

The microstructure of the rock specimen itself is different. By high temperature, the regenerated anhydrite specimens are removed of the two water molecules combined with the calcium sulfate molecules, so that the space occupied by the combined water inside the rock sample is vacated. Whether this part of space is in the anhydrite protolith (assuming the protolith’ s initial state to be anhydrite) or in the previous conversion process from anhydrite to dihydrate gypsum is unknown. If it derives from the former, the microscopic difference between the regenerated anhydrite and the anhydrite protolith is small, while if it is from the latter, the difference is greater.

5. Conclusion
(1) The rock deformation curve of regenerated anhydrite rock can be divided into four stages: the type I linear rapid expansion stage, the concave type stage, the type II linear expansion stage and the steady stage.

(2) The rock specimen expands mainly in axial expansion, and the axial expansion deformation is 2.6-3.2 times that in the radial direction; the maximum expansion deformation rate is 0.7% in the radial direction and 2.6% in the axial direction.

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References
[1] Gao H., Liang W., Yang X. (2011) Experimental study on mechanical property of gypsum rock soaked in hot saturated brine. Chinese Journal of Rock Mechanics and Engineering, 30: 935–943.
[2] Zhu Y., Wu Y., Yu H. (2013) Strength behavior of tunnel’s gypsiferous surrounding rock. Journal of Yangtze River Scientific Research Institute, 30: 53–58.
[3] Huang Y., Pan Y., Tang S. (2008) A study on triaxial compression mechanical tests of anhydrite. China Non-Metallic Minerals Industry Herald, 6: 34–36.
[4] Yu L., Zhang W., Fan M. (2012) Study of gypsum rock triaxial compression experiment and characteristic of high temperature phase transition. Rock and Soil Mechanics, 33: 3318–3322.
[5] Song F., Zhao F., Lu Q. (2007) Experimental study on strength propriety of gypsum breccias. Highway, 2: 177–180.
[6] Ren S., Deng G., Wu J. (2017) Immersion tests on gypsum rocks using fresh water. Rock and Soil Mechanics, 38: 943–950.
[7] Ren S., Li Z., Deng G. (2018) Softening characteristic of gypsum rock under the action of multi-factors. Rock and Soil Mechanics, 39: 789–798.
[8] Zhou Y., Chen C., Liu X. (2017) Experimental study on mechanical properties of water-softering gypsum rock in Jingmen. Rock and Soil Mechanics, 38: 2847–2855.
[9] Liu Y., Yu H., Wang C. (2011) Research on mechanism of damage of anhydrock in dolomite layer to tunnel structure. Rock and Soil Mechanics, 32: 2704–2709.
[10] Jiang S., Wang S., Wu Y. (2017) Experimental study on expansion characteristics of gypsum. Subgrade Engineering, 3: 147–150.
[11] Ren S., Ouyang X., Jiang D. (2018) The swelling properties of anhydrite and its humidity-stress-field swelling constitutive model. Journal of Chongqing University (Natural Science Edition), 4: 71–79.
[12] Raugh F., Thuro K. (2007) Investigations on the swelling behavior of pure anhydrites. In: 1st Canada-US Rock Mech. Sympos., Vancouver, 741–748.
[13] Molina M. (2010) The anhydrite surface: cause of problems in tunnel constructions. In: ISRM International Symposium- EUROCK. Lausanne.: 343–346.