

Proportion Test of Shale Similar Materials

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Abstract: Due to the unconventional reservoir core is difficult to obtain in great quantities, in order to do more groups of experiments for crack propagation law, need to be processed similar material specimen experiment. On the basis of theoretical analysis of the principle of the similar, from the aspects such as selection of similar material and ratio of gypsum can be determined through matching experiment of similar material, the proportion of soil, water, the influence of the strength of specimens. Through theoretical analysis to determine experimental specimen size is 70mm×70mm×70mm, with 24 groups of the comparison and analysis of experimental results, get water paste, clay for elastic modulus and compressive strength of the specimens, for shale similar material (bedrock, natural fracture, interface layer) production to provide the reference of the specimens.

Keywords: similar materials; shale; experiment; water paste ratio; clay.

SIMILARITY PRINCIPLE

Similarity theory is the study of two physical phenomena should satisfy the conditions of similarity, the similar phenomenon with the nature and how to put a phenomenon results are generalized to another phenomenon to method, is mainly composed of three theorems[1].

The first similarity theorem is proposed by Newton in 1686, which can be described as a physical phenomenon similar to each other, with the same values of the same, and the same number of similar values. Among them, the single value condition is the condition that determines the characteristic of a phenomenon and makes it separate from a group of phenomena. Under certain experimental conditions, only the results are the only one. In general, the single valued condition includes the geometric properties of the system, the physical parameters, the initial conditions and the boundary conditions of the system. The similarity criterion is a non-dimensional combination of physical quantities in similar systems. For all similar physical phenomena, similar numbers are the same. Similar to the numeral is similarity criterion.

Russian scholars understand Coleman and the American scholar put forward the second theorem, which describes the linear physical equations, can be transformed for similarity criterion equation. The result of model experiment can be processed by the data given in the form of a similar number, and the experimental results are generalized to other similar phenomena. Second similarity theorem can be described as: in a physical phenomenon, there are n physical quantities x_1, x_2, \dots, x_n , which contains k independent of the basic physical quantity, you can get the $(n-k)$ non dimensional value. The physical quantity of the phenomenon is $f(x_1, x_2, \dots, x_n) = 0$ and the similar formula is:

$$f(\pi_1, \pi_2, \dots, \pi_{n-k}) = 0:$$

Kilpich J and Gucher put forward the third theorem in 1930. The sufficient and necessary condition for the phenomenon is similar to the one in which the phenomenon is similar, and the values of the similar values derived from the single valued condition are equal

In the actual similarity simulation, it is almost impossible to make the prototype and the model fully meet the third theorem. The similarity simulation can only make a qualitative analysis to the research object, so the third similarity theorem is not used. It is also difficult to obtain the similarity criterion function of second similarity theorem, so the first similarity theorem is selected, and the physical properties, geometry, boundary and initial condition of the similar material can be similar to that of the original rock.

SIMILAR MATERIALS

Selection principle of similar materials

Choosing the proper test material is the key to the success of the experiment. Therefore, it is very important to choose the suitable test material. In general, the rock test materials should meet the following conditions[2-3]:

- (1) To meet the characteristics of prototype material requirements: similar material of main physical and mechanical properties should be similar to the material of the prototype, this experiment to simulate brittle strong rock, so should the selection of gypsum, lime and other materials with brittle characteristics, if to reduce the mechanical properties may be appropriate to add clay and other materials.
- (2) The composition of similar materials requirements: the similar materials should be composed of granular materials, cemented by the cementing agent and pressed into a certain size of the block, so as to ensure that the test piece with a dense structure and a larger internal friction angle.
- (3) The making process is simple: the selected material has good plasticity before solidification, convenient processing and repairing, proper solidification time, easy molding, and reducing the waiting time of model processing.
- (4) Nontoxic, non-polluting, low price

Similar materials should be selected for the human body non-toxic harmless materials, and no pollution to the environment, in order to reduce the experimental cost, try to choose low-cost materials.

According to the test requirements of production with bedding or natural cracks in the rock similar material, to make a similar choice of raw materials and the ratio is very important, have a direct impact on the accuracy and reliability of test results. Similar to the choice of materials and the protolithic material have some similarities, such as displacement similar, similar strain, geometric similarity, stress similar elastic modulus, Poisson's ratio of similar, more than a few similar conditions to similar materials selection and proportioning brought no small difficulty, similar simulation is difficult to meet the above requirements, to be successful in accurately obtain test results, we must take into account all aspects. To this end, the first ratio of similar materials real Check.

Proportioning experimental raw materials

Through previous studies, the failure experiment, which the material model is the gypsum, the gypsum's failure characteristics is basically similar as that of the deep rock mass. The process of their failure characteristics are the elastic stage, the elastic and plastic stage, finally reached the stage of brittle failure. Therefore, the performance of the deep rock mass is the most suitable for the use of gypsum(Du Qing plaster similar material)[4].

A. Gypsum

Gypsum is the main component of calcium sulfate as the main component of the gas hard cement material; it also is the most widely used similar and cementing material. The similar material, whose main cementing material is gypsum, has the characteristic of solidification fast, to achieve a stable state of a short time, etc. It's usually used to simulate the prototype material with brittle failure characteristic.

The main performance indexes of gypsum are setting time, fineness and strength. The concrete parameters vary with the grade of gypsum. In China, at present, gypsum is roughly divided into three grades.

Table 1: Physical and mechanical properties of gypsum

Grade	Fineness%	Setting time/min		2h strength/MPa	
		The initial setting	The final setting	Bending strength	Compression
3.0	≤10	≥3.0	≤30	≥3.0	≥6.0
2.0				≥20	≥4.0
1.6				≥1.6	≥3.0

B. Clay

Clay, whose plasticity of aluminosilicate particles is very small, is an important mineral material. And it has the characteristics of good plasticity, mixed with an appropriate amount of water can form mud, deformation and cloth crack under the action of external force, after the external force is dispersed, the original shape can be kept unchanged.

C. Water

The preparations of the vast majority of similar materials need to be mixed with water. There are three main functions of water in the configuration of similar materials. First, when the cementing material set and hardens, it needs water(hydration). Second, when making similar materials and making models, in order to meet the process requirements,

water must be used. Third, the amount of water can affect the strength of the specimen.

D. Retarder

When making the similar material specimen take gypsum as cementing material, due to the setting time of gypsum is very short, general which come to initial setting state with a few minutes, the processing of specimen shape and flatness cannot be completed in such a short space of time, so we must add some retarder to prolong the setting time. The common retarder include borax, sodium hydrogen phosphate, and so on, one of the most convenient and frequent is borax.

EXPERIMENTAL RESULTS AND ANALYSIS OF SIMILAR MATERIAL MIXTURE

To test the effect of gypsum, soil, and water for specimen strength, we designed two types of similar material mixture test, and made 24 test pieces is about 70mm×70mm×70mm.



Fig-1: Standard test specimen



Fig-2: Experimental facility

Table2: Effect of water-gypsum ratio

test piece	water-gypsum ratio	Compressive strength/MPa	elasticity modulus /MPa	Poisson's ratio
A1	0.888 : 1.5	2.065	882	0.21
A2	0.988 : 1.4	1.851	781	0.23
A3	1.058 : 1.33	1.67	662	0.26

By changing the water-gypsum ratio, we can see that elasticity modulus of test piece and compressive strength are gradually reduced with the decrease of the content of gypsum and the increased ratio of water. As the water yield increase in the hydration process of gypsum, free water were increased, the extra water are gradual volatilized during the hardening of gypsum, leaving many small hole in the test piece, which will lower density of gypsum specimen, and also reduces the compressive strength and elasticity modulus of gypsum.

The effect of clay

Table 3: Effect of clay

sample	Water plaster and soil mass ratio	Compressive strength /MPa	Elastic Modulus /MPa	Poisson's ratio
B1	0.888:0.75:0.75	0.445	170	0.35
B2	0.888:1.0:0.5	0.837	207	0.32
B3	0.888:1.125:0.375	1.326	458	0.29

The plasticity of Clay is strong, but brittleness of pure gypsum is strong, therefore adding the clay to the ratio of material can reduce the strength of the specimen, it can be used to simulate the rock which the brittle is weak and the mixed materials in the natural fracture.

It can be seen from the experiment, under the condition of invariable in water, with the increase of proportion of clay, elastic modulus and compressive strength of the specimens will reduce gradually.

CONCLUSION

- (1) The influence law of different content gypsum, water and clay on the mechanical properties of the specimens can be obtained through the matching experiment.
- (2) With the decrease of the content of gypsum, as the water yield increase in the hydration process of gypsum, free water were increased, the extra water are gradual volatilized during the hardening of gypsum, leaving many small hole in the test piece, which will lower density of gypsum specimen, and also reduces the compressive strength and elasticity modulus of gypsum.
- (3) On the condition of invariable in water, with the increase of proportion of clay, elastic modulus and compressive strength of the specimens will reduce gradually.

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