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Research Article

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Study on the similar material characteristics for model test based on daye iron mine

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ABSTRACT

Based on the open pit to underground mining practice of Daye Iron Mine and the similar principles of model test, a new kind of similar material of underground caving mining model test which consists of iron ore powder, barite powder, quartz sand, unsaturated resin and gypsum is developed through a lot of material mechanics test. The physical and chemical characteristics of similar material from model test of Daye iron mine are studied. This similar material have been achieved national invention patent, patent number is 201210189082.X. The experimental results showed that 1. The physical and mechanical indexes of similar material vary in a large range and can meet the needs for underground caving mining model test. 2. The shape of the similar material particle is abnormal, the content of spherical particles and the pore connectivity are less. 3. Because 70% ingredients of the similar material are calcium oxide and iron oxide, so the chemical reactivity is low, physical and chemical properties is stable in the natural environment.

Keywords: similar material; physical and chemical properties; chemical composition; physical and mechanical properties

INTRODUCTION

With the ongoing exploitation of mineral resources, with the continuous exploitation of Daye Iron Mine for shallow resources, the slop caused by the beginning of mining is being high and steepen. It poses a serious threat to the safety and economic benefits of mining, so that the open pit to underground mining is the only way to solve this problem [1][2]. Necessarily involves many problems such as geotechnical strength failure, deformation instability and reinforcement, in the process of open pit to underground mining. About this complex issues, one hand to study with the help of theoretical and numerical analysis method; On the other hand to resolve by the geotechnical physical model testing means. The physical model is a reproduction of the real engineering entity, it can really reflect the basic physical and mechanical characteristics of the geotechnical medium, in the conditions of to meet a similar principle [3-5].

During the model test, the selection and proportioning of similar materials not only affect the physical and mechanical properties of the material, but also directly relate to the reliability of the model test results. As for the selection and proportioning of similar materials, there are already a lot of research work both at home and abroad [6-10]. There are widespread disadvantages with all kinds of similar geotechnical materials used at present, such as low specific weight, long drying time, narrow range of mechanical parameters and weak adaptability, meanwhile, domestic and foreign similar material researches mainly focus on physical and mechanical properties of materials, and the study of chemical composition and properties is less involved.

In view of this, this article is based on the act that Daye iron changes from open mining to underground mining. Under the basic principles of similarity theory, we have developed a new type of rock similar material, after many material mechanics parameters tests, and using the triaxial test, shearing test, compression test, fluorescence spectrum analysis and environmental scanning electron microscopy, to study physical and chemical properties of similar materials, so as to obtain the physical and mechanical properties and chemical characteristics, and to reveal the forming mechanism of material strength. So this study can provide scientific basis for the research of ultra-high steep slope changing from open pit mining to underground mining, and it lays a solid foundation for mutual influence mechanism model test of ultra-high steep slope and caving method underground mining.

EXPERIMENTAL SECTION

1 Project overview

Daye iron's east open pit is made up of three ore blocks, they named Elephant Trunk Hill, Lion Hill and Jian Shan from east to west(Fig.1), after decades of open-pit mining, the area forms large-scale ultra-high steep open pit slope which is up to $230 \sim 430$ m, with tilt angle from $38 \circ$ to $43 \circ$. The model test research is about ultra-high steep slope and caving method model test underground mining of Daye iron, its typical research section located in Lion Hill block, between $26 \sim 30 \#$ exploration line. The upper part of the section is diorite, the lower part marble, 200 meters from east to west, 800 meters from north to south, 500 meters in depth, the simulated underground non-pillar caving method mining depth is -168m[11].

2 Similar principles

The similar principles of model test is that the recurring physical phenomena on the model should be similar to the prototype, which call for the nature of material, shape and load of the model should to follow a certain similarity law[12]. According to elastic-plastic mechanics equation or dimensional analysis method, and the balance of model, geometry, physics and boundary condition equations, we deduced the basic similarity criteria of model and the prototype is:

 $C_{\sigma} \!\!=\!\! C_L C_{\gamma} \text{, } C_{\epsilon} \!\!=\!\! C_{\delta} C_L \text{, } C_{\sigma} \!\!=\!\! C_{\epsilon} C_E \text{, } C_{\epsilon} \!\!=\!\! 1$

In which, the similar constant C_{σ} , C_L , C_{γ} , C_{ϵ} , C_E , is respectively for stress, geometry, volume force, strain, displacement, and elastic modulus.

3 Manufacture of similar materials

According to the model test similar principles and engineering practice of Daye Iron Mine, and after more than 300 mechanical parameters tests of material specimens in more than ten months, a new type of rock similar material in ultra-high steep slope mining and sublevel caving underground mining has been developed. It is a kind of composite material which made up of barite powder, iron ore powder, quartz sand, gypsum, unsaturated resin, glycerol and water in accordance with the provisions ratio through mixing and compacting, in which iron essence pink, barite powder, quartz sand are used as aggregate, unsaturated resin as bonding materials, gypsum as regulating material. Ore-bearing rock similar material and its preparation method have been achieved national invention patent, patent number is 201210189082.X.

This similar material has the following characteristics:

(1)To effectively simulate gravity stress field of wall rock, the barite powder and iron ore powder, and the low density quartz sand and plaster are used. So that the severe distribution range of similar materials is large, this can effectively simulate the gravity stress field of rock ore body at different depth.

(2)The molded test block material is easy to cut and bond, so it's easy to splice into different shapes and sizes as an overall model.

(3)The selected material has high practicalities, such as stable property, simple fabrication process, short maintenance cycle, wide range of sources, being inexpensive and without toxic side effects.

4 Testing instruments

The physical and chemical properties of the material, include the physical and mechanical properties, chemical composition and chemical properties. The physical and chemical properties of the material are not only related to material type, properties and ratio, at the same time, it also depends on the production and curing methods of the material specimens. In the test, we firstly mix the materials in evenly proportion, and then compact after pouring them into a standard mold, after stripping, dry the materials in an incubator for 7 days, and carry on research with the physical and chemical properties.



Fig.1 Aerial view of daye iron mine



Fig.2 Triaxial shearing test of similar material



Fig.3 Compressive tests of similar material



Fig.4 shearing tests of similar material

Mechanical testing includes parameters of material density, compressive strength, modulus of elasticity, cohesion and shear strength. We use YAW-300D type automatic compression testing machine to test material compressive strength, ZJY- type strain direct shear apparatus to test material cohesion and internal friction angle, SJ-1A type triaxial shear apparatus to test material elastic modulus, Figures 2-4 are some photos of the physical and mechanical tests.



Fig.5 Influence of Iron ore powder contents on mechanical properties of similar material



Fig.6 Influence of unsaturated resin contents on mechanical properties of similar material



Fig.7 Influence of quartz sand contents on mechanical properties of similar material

The materials chemical property test is performed in China University of Geosciences state key laboratory of geological processes and mineral resources, using Shimadzu scanning X-ray fluorescence spectrometer XRF-1800 to analyze chemical composition of similar materials[13-14], scan speed 1000 $^{\circ}$ / min and scan angle range from 0 $^{\circ}$ to 118 $^{\circ}$. Using environmental scanning electron microscope Quanta 200 of Philip Company to analyze its morphology[15-16], with resolution of 3.5nm, 20-300000 magnification times.

RESULTS AND DISCUSSION

1 Material mechanical properties

Figure 5- figure 7 are the influence of different components of similar material mechanical properties. Figure 5 shows that the greater the percentage of Iron powder, the greater the elastic modulus and compressive strength and density of similar material. The figure 6 shows that to adjust the percentage content of unsaturated resin can adjust material compressive strength, elastic modulus and cohesion. The larger the percentage content of cementing agent, the greater the compressive strength, elastic modulus and cohesion of similar materials. The figure 7 shows that quartz sand percentage content has influence on the compressive strength, elastic modulus and internal friction Angle. The greater the percentage of Quartz sand, the greater the internal friction angle in the material, the greater the narrowing trend of compressive strength and elastic modulus presents. At the same time, Figure 6-figure 8 shows a wide distribution range of physical and mechanical properties of the similar material, enough to meet the need of ultra-high and steep slope caving underground model test.

2 Surface morphology

Rock similar material is a mixture of particles, which not only contains 800 mesh barite powder of fine particles, but also coal-like iron powder that shows black gray after dried and has a wide distribution, as well as quartz sand coarse particles of 100 mesh. Its morphology depends on the composition of the various particles and its syntagmatic relation.



Fig.8 Particle size distribution of similar material



с

Fig.9 SEM patterns of similar material (a. magnified 150 times, b. magnified 500 times, c. magnified 5000 times)

As can be seen from Figure 8, similar material particle size varies from 5 to100 microns, wherein the iron powder particles size is from $50 \sim 105 \mu m$, barite powder particles $10 \sim 30 \mu m$, plaster particles $90 \sim 150 \mu m$. As can be seen from Figure 9, the similar material contains many particles with different structures and morphologies. Because of the uneven size of raw materials and limited by block production process, the material forms a certain number of irregular shaped, loose and porous structure, in which pores connection is not unobstructed, the overall granularity is coarser, particles shape irregularly and not rounded, there is a different degree of cementation, that's the strength mechanism of the similar material from model test.

3 The chemical composition

Based on EDS spectrum analysis for open pit to underground mining similar materials, the obtained its chemical composition is shown in figure 10, the similar material mainly containing C, O, Si, S, Ca, Ba, Fe and other elements. According to the chemical composition of the material, XRD measurement conditions of the various elements in similar materials are as shown in Table 1.



Fig.10 EDS spectrum of similar material

Chemical composition of similar materials obtained by XRD semi-quantitative analysis is shown in Table 2. Calcium oxide and calcium sulfate can react with water at normal temperature, and forms hydrates, enhancing the strength of similar material. The higher content of calcium oxide and calcium sulfate, the stronger the chemical activity of similar material. The table 2 shows that the rock similar material see ferric oxide and calcium oxide as main ingredients, of which the iron oxide content more than 50%. Therefore, the chemical activity is low, and chemical change is not easy to take place in similar material of natural environment to change its physical and mechanical properties.

Channel	Radiation			Separation		Gonio			
	TG	KV	mA	Slit	Crystal	Angle	Time	Speed	Step
Si	Rh	40	70	Std	PET	46-72	45	8	0.1
Al	Rh	40	70	Std	PET	52-58	45	8	0.1
Mg	Rh	40	70	Std	TAP	90-96	45	8	0.1
Fe	Rh	40	70	Std	TAP	90-118	60	8	0.1
Ca	Rh	40	70	Std	LIF	108-114	200	8	0.1
S	Rh	40	70	Std	LIF	46-72	120	8	0.1
Ba	Rh	40	70	Std	Ge	52-58	120	8	0.1
0	Rh	40	70	Std	Ge	60-92	200	8	0.1

Table 1 Measurement conditions of XRD

Table 2 Chemical compositions of similar materials wt%

ingredient	BaO	CaO	SiO ₂	SO ₃	Al ₂ O ₃	MgO	other
content	7.87	23.41	1.35	13.43	0.75	0.58	1.39

CONCLUSION

According to development and research of physicochemical properties of open pit to underground mining similar materials, we have the following conclusions:

1) The rock similar material has many advantages, such as: stable and simple fabrication process, short maintenance cycle, and wide variety of sources, inexpensive and non-toxic side effects.

2) The greater the percentage of Iron powder, the greater the elastic modulus and compressive strength and density of similar material. The larger the percentage content of cementing agent, the greater the compressive strength, elastic modulus and cohesion of similar materials. The greater the percentage of Quartz sand, the greater the internal friction angle in the material, the greater the narrowing trend of compressive strength and elastic modulus presents.

3) Similar material particle size varies from 5 to 100 microns, and it has irregular shape, little round particles, the overall granularity is coarser, unobstructed pores connection and a different degree of cementation.

4) The rock similar material sees ferric oxide and calcium oxide as main ingredients, and their content is more than 70%. Therefore, the chemical activity is low, and chemical changes in similar material of natural environment are not easy to take place to change its physical and mechanical properties.

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