IOP Conf. Series: Earth and Environmental Science **128** (2018) 012074 doi:10.1088/1755-1315/128/1/012074

Study of Experiment on Rock-like Material Consist of fly-ash, Cement and Mortar

Qin Nan, Wang Hongwei，Wang Yongyan

College of Mechanical and Electronic Engineering，Qingdao University of Science and Technology，Qingdao 266061，China

Wang Hongwei: 17606399387@163.com

Abstract: Study the uniaxial compression test of rock-like material consist of coal ash, cement and mortar by changing the sand cement ratio, replace of fine coal, grain diameter, water-binder ratio and height-diameter ratio. We get the law of four factors above to rock-like material's uniaxial compression characteristics and the quantitative relation. The effect law can be sum up as below: sample's uniaxial compressive strength and elasticity modulus tend to decrease with the increase of sand cement ratio, replace of fine coal and water-binder ratio, and it satisfies with power function relation. With high ratio increases gradually, the uniaxial compressive strength and elastic modulus is lower, and presents the inverse function curve; Specimen tensile strength decreases gradually with the increase of fly ash. By contrast, uniaxial compression failure phenomenon is consistent with the real rock common failure pattern.

1. Introduction

Building materials is the most similar material with the real rock. It is an important method to simulate complicated engineering using geologic model which is made up of building materials [1-2]. The sort of similar material, the ratio of similar material's ingredient and the making method of experimental model have an essential influence to material's physical and mechanical property. Recently, many scientists have studied the real rock's similar material all over the world [3-11]. Compressive strength is an important index to measure rock's strength. The strength grade and character can be described with the results of compression test and the analysis of results have significant meaning to the evaluation of engineering robustness and stability. However, there are some elements determine rock's strength and the test results are variable, even those test specimen from the same rock still have significant differences. In this paper, we makes the test specimen with fly-ash, cement and mortar; we study the law of compressive strength by changing the sand cement ratio, replace of fine coal, water-binder ratio and height-diameter ratio; we study the change law of strength of extension by changing replace of fine coal.

2. Experimental Study

2.1 Main Experimental Tools and Equipment

Main experimental tools and equipment: electronic scales, cast iron dies, stainless steel basin, stainless steel sieve, beaker, stirring rod, vernier scale, TAW-200 electronic multi-functional material mechanics testing machine is shown in Fig.1.

Fig.1 TAW - 200 electronic multi-function material mechanics testing machine

2.2 Making Steps of Samples

Raw material preparation: First, dry sand to control the water content and grain diameter of sand; divide sand into six parts according to grain diameter, which are 20 meshes, 30 meshes, 40 meshes, 50 meshes, 60 meshes, 70 meshes. Second, weight the raw material according to the composition ratio of similar material and put them into stainless steel basin; stir the raw material with stirring rod uniformly. Then pour water into the stainless steel basin and stir them uniformly. Finally, compacted the raw material with cast iron dies. Demould after 12 hours' maintenance and write numbers and dates on the surface of samples. Store samples at cool and ventilate place makes them dry. Text samples after 7 days maintaining. Samples are shown in Fig.2.

Fig.2 Part of the sample in maintenance

3. Results of strength test and Analysis

3.1 Analysis of the influence of sand cement ratio to compressive strength

We made 8 kinds of specimens by changing sand cement ratio and performed uniaxial compression experiment. The component of samples shown as below. Proportion of sand cement ratio: 1/5、1/4、1/3、1/2、1/1、2/1、3/1、4/1; Proportion of replace of fine coal: 20%. Proportion of water-binder ratio: 0.4; Proportion of grain: diameter 40 meshes; Proportion of height-diameter ratio: 2. The changing curves of uniaxial compressive strength and elasticity modulus with sand cement ratio are shown in Fig.3. We can see from the changing curves that with the increase of sand cement ratio, uniaxial strength and elasticity modulus are decreased. The fitted equation of uniaxial compressive strength and sand cement ratio is shown below.

$$\sigma = 4470.098 - 4451.574x^{0.00167} \tag{1}$$

The fitted equation of elasticity modulus and sand cement ratio is shown below.

$$E = 2.23724x^{-0.3528} \tag{2}$$

In equation (1) and (2): σ means stress（MPa）; E means elasticity modulus（GPa）; x means sand cement ratio $(1/5 \le x \le 4)$.

The decreasing tendency of uniaxial compressive strength and elasticity modulus with sand cement ratio are obvious and the fluctuation range of curves are largely, which means the adhesion stress between binding material and framework material has significant influence to similar material's mechanical property. With the increase of sand cement ratio, the cement and fly-ash in the similar material are decreased, which means the contact area between binding material and framework material are decreased. The adhesion stress between binding material and framework material are decreased, the uniaxial compressive strength is decreased as well.

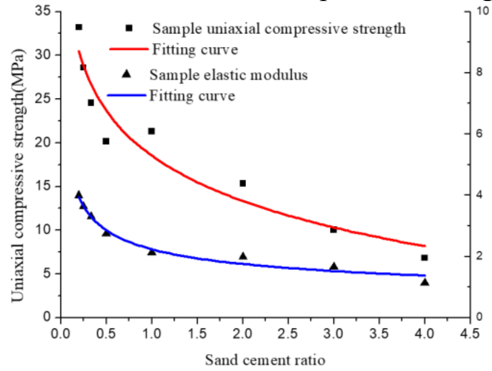

Fig.3 The influence of sand binder ratio on the mechanical properties of test specimen

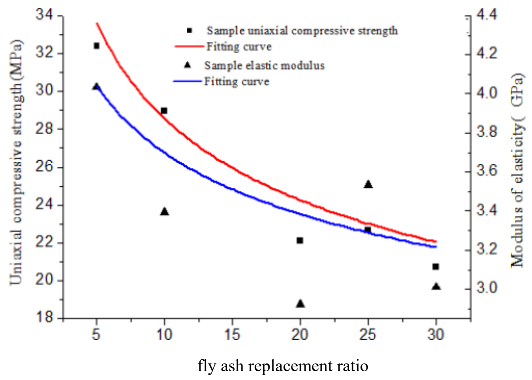

Fig.4 The influence of fly ash replacement ratio on the mechanical properties of test specimen

3.2 Analysis of Replace of Fine Coal to Uniaxial Compressive Strength

We made 6 kinds of specimens by changing replace of fine coal and performed uniaxial compression experiment. The component of samples shown as below. Proportion of sand cement ratio: 1/1; Proportion of replace of fine coal: 5%、10%、15%、20%、25%、30%. Proportion of water-binder ratio: 0.4; Proportion of grain: diameter 40 meshes; Proportion of height-diameter ratio: 2. The changing curves of uniaxial compressive strength and elasticity modulus with replace of fine coal are shown in Fig.4. The fitted equation of uniaxial compressive strength and replace of fine coal is shown below.

$$\sigma = 49.09372\, x^{-0.23548} \quad (3)$$

The fitted equation of elasticity modulus and replace of fine coal is shown below.

$$E = 4.96438\, x^{-0.12794} \quad (4)$$

In equation (3) and (4): σ means stress（MPa）; E means elasticity modulus（GPa）; x means replace of fine coal $(5 \le x \le 30)\,\%$.

According to the results are show in Fig.4, we can draw a conclusion that with the increase of replace of fine coal, the uniaxial compressive strength and elasticity modulus are decreased as well. The decrease tendency of uniaxial compressive strength is obvious when replace of fine coal at the range of 5%-20%. The decrease tendency of uniaxial compressive strength is smoothly when replace of fine coal overpass 20%.

3.3 Analysis of Water-Binder Ratio to Uniaxial Compressive Strength

We made 6 kinds of specimens by changing water-binder ratio and performed uniaxial compression experiment. The component of samples shown as below. Proportion of sand cement ratio: 1/1; Proportion of replace of fine coal: 20%. Proportion of water-binder ratio: 0.35、0.4、0.45、0.5、0.55、0.6; Proportion of grain: diameter 40 meshes; Proportion of height-diameter ratio: 2.The changing curves of similar material's uniaxial compressive strength and elasticity modulus with water-binder ratio are shown in Fig.5.

The fitted equation of uniaxial compressive strength and water-binder ratio is shown below.

$$\sigma = 7.41102\, x^{-1.29495} \quad (5)$$

The fitted equation of elasticity modulus and water-binder ratio is shown below.

$$E = 1.80074\, x^{-0.70787} \quad (6)$$

In equation (5) and (6): σ means stress（MPa）; E means elasticity modulus（GPa）; x means water-binder ratio $(0.35 \le x \le 0.6)$.

In this experiment, only the water-binder ratio is changeable. According to the results are show in Fig. 5, the uniaxial compressive strength is decreased when water-binder ratio is increased. When water-binder ratio increase from 0.35 to 0.6, the uniaxial compressive strength is decrease from 29.868 MPa to 13.203 MPa and the elasticity modulus is decrease from 4.149 MPa to 2.496 MPa. It means water-binder ratio has a significant influence to uniaxial compressive strength and elasticity modulus.

The reason why water-binder ratio has a significant influence to uniaxial compressive strength and elasticity modulus is when the water-binder ratio is increasing, the free water in samples is increased at the same time. Extra water occupied more space in the specimens, but after specimens' natural withering, the space occupied by extra water turn into micro-fissuring. The more micro-fissuring the specimens have, the worse of specimens' compaction. Which means with the increase of water-binder ratio, the micro-fissuring is increasing too, whereas the uniaxial compressive strength and elasticity modulus are decreasing.

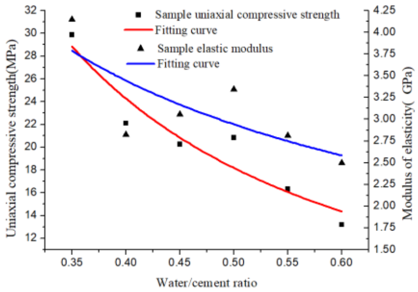

Fig.5 The influence of water-binder ratio on the mechanical properties of test specimen

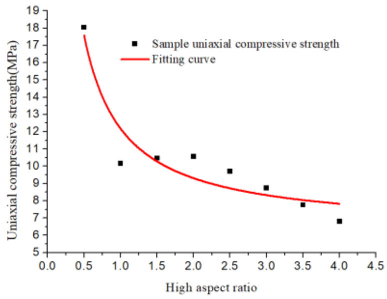

Fig.6 The influence of aspect ratio on the uniaxial compressive strength of test specimen

3.4 Analysis of Height-Diameter Ratio to Uniaxial Compressive Strength

We made 8 kinds of specimens by changing height-diameter ratio and performed uniaxial compression experiment. The component of samples shown as below. Proportion of sand cement ratio: 1/1; Proportion of replace of fine coal: 20%. Proportion of water-binder ratio: 0.4; Proportion of grain: diameter 40 meshes; Proportion of height-diameter ratio: 0.5、1、1.5、2、2.5、3、3.5、4.The changing curves of similar material's uniaxial compressive strength and elasticity modulus with height-diameter ratio are shown in Fig.6.

The fitted equation of uniaxial compressive strength and height-diameter ratio is shown below.

$$\sigma = 6.3 + \frac{3.13787}{x + 0.04348} \tag{7}$$

In equation (7): σ means stress（MPa）7; x means height-diameter ratio $(0.5 \le x \le 4)$.

The curves in Fig.6 can be divided into three processes: the first process is height-diameter ratio range from 0.5 to 2, the uniaxial compressive strength is rapid decrease with the increase of height-diameter ratio in this process. The second process is height-diameter ratio range from 2 to 3, the uniaxial compressive strength is decrease with the increase of height-diameter ratio in this process, but the tendency of uniaxial compressive strength's decrease is smooth. The second process is height-diameter ratio range from 3 to 4, with the increase of height-diameter ratio, the uniaxial compressive strength is decreased at beginning and then tends to the stable trend. On the whole, the uniaxial compressive strength decreases with the increase of the height-diameter ratio and it's going to be stable at the end. The reasons are shown as follows: with the increase of height-diameter ratio, the size of samples is bigger and the quantity of fissuring is more. Which means the probability of destruction is increased and the stability of the sample is gradually reduced, then the intensity of the sample gradually decreases.

Fig.7 The failure form of different aspect ratio specimen

We can see from Fig.7, with the increase of height-diameter ratio, the failure position also gradually increasing. The two left samples' bottom in Fig.7 were not destroyed, which means with the increase of height-dimeter ratio, samples' stability are decreased. The common failure forms of rock specimen under uniaxial compression show inFig.8. The common failure forms of the Soft rock similar material specimen show in Fig.9.

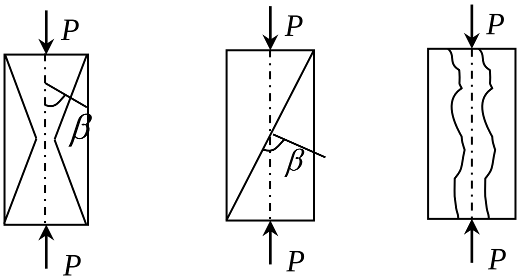

Fig.8 The common failure forms of rock specimen under uniaxial compression

Fig.9 The common failure forms of the Soft rock similar material specimen

3.5 Analysis of Replace of Fine Coal to Tensile Strength

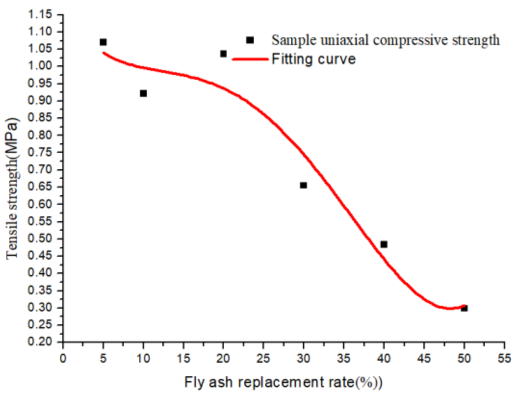

Fig.10 The influence of fly ash replacement the ratio tensile strength of test specimen

We made 6 kinds of specimens by changing replace of fine coal and performed tensile experiment. The component of samples shown as below. Proportion of sand cement ratio: 1/1; Proportion of replace of fine coal: 5%、10%、20%、30%、40%、50%. Proportion of water-binder ratio: 0.4; Proportion of grain: diameter 40 meshes; Proportion of height-diameter ratio: 2. The changing curves of similar material's tensile strength with replace of fine coal are shown in Fig 10. We can see from fig.10 that with the increase of replace of fine coal, the similar material's tensile strength is decreased and the tendency of tensile strength is obvious. The similar material's tensile strength collapsed from 1.070 MPa to 0.299 MPa. That is to say, the cementation and structure of similar material have changed greatly due to using replace of fine coal as cement, which enlarged the range of simulation of real rock mechanics performance.

4. Conclusion

Our study is focused on the uniaxial compression experiment of rock-like material. The effect law of each factors to similar material's uniaxial compression characteristics and their over-fitting relation can be got by changing the sand cement ratio, replace of fine coal, water-binder ratio and height-diameter ratio. The effect law can be concluded as follows: Samples' uniaxial compressive strength and elasticity modulus are decreased with the increase of sand cement ratio, replace of fine coal and water-binder ratio, and the tendency of decreasing is obvious. With the increase of height-diameter ratio, samples' uniaxial compressive strength and elasticity modulus are decreased and the tendency is inversely proportional relationship. With the increase of replace of fine coal, samples' tensile strength is gradually decreased.

REFERENCES

[1] XU Zhiying. Rock Mechanic. Beijing: China Water&Power Press. 2007.
[2] CHEN Anmin, GU Jincai, SHEN Jun, el,al. Application study on the geomechanical model experiment techniques [J]. Chinese Journal of Rock Mechanics and Engineering, 2004, 23(22):3785-3789.
[3] WANG Hanpeng, LI Shucai, ZHANG Qiangyong, et,al. Development of a new geomechanical similar material[J]. Chinese Journal of Rock Mechanics and Engineering,2006,25(9):1842-1847.
[4] WANG Yongyan, LI Jianguang. Experimental study of using asphalt and marine sand as soft rock equivalent materials.Journal of Experimental Mechanics,2013,28(2)：242-246.
[5] ZHANG Ning, LI Shucai, LI Mingtian, et,al. Development of a new rock similar material. Journal of Shandong University(Engineering Science),2009,39(4):149-154.
[6] ZUO Baocheng, CHEN Congxin, LIU Caihua. Research on similar material experiment [J]. Rock and Soil Mechanics,2004,25(11):1805-1808.
[7] HAN Boli, CHEN Xialing, SONG Yile. Research on similar material of rock mass[J]. Journal of Wuhan University of Hydraulic and Electric Engineering, 1997,30(2):6-9.
[8] MA Fangping, LI Zhongkui, LUO Guangfu. NIOS model material and its use in geo-mechanical similarity model test [J]. Journal of Hydroelectric Engineering,2001,23(1):48-51..
[9] ZHANG Qiangyong, LI Shucai, GUO Xiaohong, et,al. Research and development of new typed cementitious geotechnical similar material for iron crystal sand and its application[J]. Rock and Soil Mechanics,2008,29(8):2126-2130.
[10] ZHANG Qiangyong, LIU Dejun, JIA Chao,et,al. Development of geomechanical model similitude material for salt rock oil-gas storage medium[J]. Rock and Soil Mechanics,2009,30(2):3581-3586.
[11] LI Yuan. Theoretical and experimental study of the rheological properties of soft rocks in asphalt mixture [D]. Qing Dao： Qingdao University of Science and Technology, 2013.