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Research on the Influencing Factors of the Strength Lightweight High Strength Foamed Cement

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Abstract: *In order to explore the factors affecting the strength of lightweight and high-strength foamed cement, ordinary Portland cement is used as the cementing material, and the target dry density is 400~410kg/m^3 by controlling the content of foaming agent and foam stabilizer. Lightweight high-strength foamed cement specimen with strength of 4.4MPa. Controlling a single variable, the compressive strength and microscopic morphology changes of foamed cement specimens with different self-made reinforcing agent content and fly ash content were studied. The research results show that when the fly ash content is 20%, the strength of the sample without reinforcing agent reaches the best 2.4MPa; when 2wt% of the reinforcing agent is added, the strength of the sample reaches the maximum compressive strength of 4.4MPa, an increase of 83 %. Scanning electron microscope microscopic morphological observation results show that after adding the reinforcing agent, the foamed cement cell is more uniform, the cell wall becomes denser, and the cell defects are reduced, which explains the macroscopic advantages of lightweight and high-strength foamed cement.*

Keywords: *foamed cement, portland cement, reinforcing agent, fly ash, compressive strength, microscopic morphology*

1. Introduction

Foamed cement is a new type of lightweight inorganic material for construction. Because of its good thermal insulation, sound insulation, fire and heat insulation properties, it has been widely used in building roofs, floors, walls and other thermal insulation projects [1]. Early foamed cement was produced with special cements such as sulfoaluminate cement [2], magnesium oxychloride cement [3-4], and ultra-fine Portland cement [5]. Now with the development of foaming technology and technology, the requirements for base cement are gradually reduced. Ordinary cement and various tailings materials are also used to prepare foamed cement [6-8], but there are higher standards for various performance requirements of foamed cement.

Wang Jun [9] et al. studied the effects of different modified reinforcement materials such as latex powder, polypropylene fiber, expanded vermiculite, etc. on the physical and mechanical properties of foamed cement; Guo Jialin [10] et al. Cao Jiahao [11] et al. The density and compressive strength properties of the material were studied, and the hydration products were microscopically characterized. In order to enhance the toughness and strength of foamed cement and improve its anti-cracking and freeze-thaw resistance properties, Qi Fei and Zhang Changsen [4], Sheng Hao [12], etc. and Zhou Xia [13] added different amounts of polypropylene fibers, respectively. Wood flour and glass fiber, explored the influence of the above additives on the mechanical properties and thermal conductivity of foamed cement; further, Zhu Ming [14] and others investigated the porosity and thermal conductivity of foamed concrete based on optical microscope and thermal conductivity tester performance relationship. Obviously, the internal void structure of foamed cement plays a key role in its excellent properties. Dai Yuchen et al. [15] studied the influence of different water-binder ratios on the average pore size, porosity and compressive strength of foamed cement with different density levels; and Dai Yonggang [16] et al. started with the research on the stability of foamed cement slurry and carried out a series of experimental studies on the rheological properties of foamed cement slurry with advanced rheometer. Both the pore structure and rheological properties of foamed cement are closely related to the foaming agent. Su Haiting [17] and others have carried out experimental studies on the foaming

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effect of different cement foaming agents and evaluated the foams made by different foaming agents, comprehensive performance of foam cement. High porosity also means that the contact area between foamed cement and water is increased, which puts forward higher requirements for the water resistance of the material. Wang Luming [18] et al. studied phosphoric acid, calcium stearate, and styrene-acrylic emulsion. The modified effect of the property agent on the foamed cement, in order to improve its water resistance. Velandia [19], Jin Yongfei [20], Zhang [21] and others optimized the combination of foamed cement, developed high-performance foamed cement curing filling materials, and analyzed the factors affecting their different properties.

In this paper, ordinary portland cement is used as the cementing material, and self-developed reinforcing agents and foam stabilizers are added. The scientific and chemical foaming process is used to prepare lightweight and high-strength foamed cement. The effect of the amount of fly ash and the amount of self-made reinforcing agent is explored, the impact of foamed cement compressive strength and micro-cell structure. Determine the optimal proportion of each component in order to improve reference and reference for related research.

2. Test overview

2.1 Experiment material

(1) Cement: Shanshui ordinary portland cement is used, the model is P.O42.5, and its main components are shown in Table 1.

Table1 Ordinary portland cement composition

Name	Ingredient	Abbreviation	Content/%
Tricalcium Silicate	$3CaO·SiO_2$	C_3S	44~62
Dicalcium Silicate	$2CaO·SiO_2$	C_2S	18～30
Tricalcium Aluminate	$3CaO·Al_2O_3$	C_3A	5~12
Tetracalcium Aluminate	$4CaO·Al_2O_3·Fe_2O_3$	C_4AF	10~20

(2) Fly ash: Qiangdong first grade fly ash, model qd-590, specification is 1000 mesh; its main components are shown in Table 2.

Table2 First grade fly ash composition

Ingredient	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
Range	34.3~65.8	14.6~40.1	1.5~6.2	0.4~16.8	0.2~3.7	0.0~6.0	0.1~4.2	0.0~2.1
Mean	50.8	28.1	6.2	3.7	1.2	0.8	1.2	0.6

(3) Foaming agent: industrial hydrogen peroxide, concentration 27.5%;

(4) Polypropylene (PP) short fiber: 12mm~15mm;

(5) Additives: foam stabilizer (homemade); enhancer (homemade).

2.2 Specimen preparation

Weigh the cement, fly ash, pp short fiber, foam stabilizer, and enhancer according to the proportions and add them to the measured hot water. Adjust the water temperature to control the slurry temperature to 40℃, stir for 3 minutes, and quickly add it to the weighing. Hydrogen peroxide solution, stir for 10s, stop stirring immediately, open the discharge valve to quickly pour the stirred slurry into the mold for foaming molding, place the mold at 20-23℃ for static molding, and demold after 12h. Put the sample in the standard curing box for 28 days.

2.3 Test method

Test the dry density of the test piece, by adjusting the amount of hydrogen peroxide added, to ensure that the dry density of all samples is controlled within 400kg/m^3~410kg/m^3, and the dry density is in accordance with GB/T11969-2008 "Test Method for Performance of Autoclaved Aerated Concrete Blocks" Requirements for testing. The obtained qualified specimens were tested for compressive strength, and the compressive strength was tested according to the test method in GB23451-2009 "Lightweight Partition Wall Strips for Construction".

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3. Analysis and discussion

3.1 The influence of fly ash content on the compressive strength of foamed cement

Using single-factor variable method, control the foam stabilizer content 0.1wt%, water-cement ratio 0.5, pp short fiber 0.5wt%, self-made reinforcing agent content 0%, and study the influence of fly ash content on the compressive strength of foamed cement the results are shown in Figure 1.

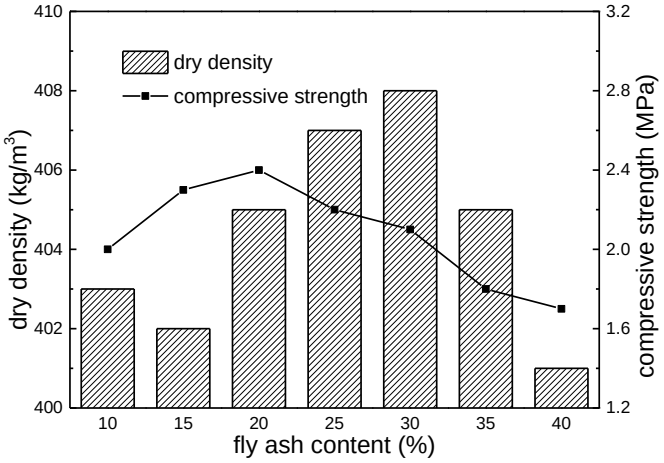

Figure. 1 The influence of fly ash content on the strength of foamed cement

It can be seen from Figure 1 that with the increase of fly ash content, the compressive strength first increases and then decreases. This is because when the fly ash content is low, the cement content is too high and the cement hydrates. Higher heat will produce micro-cracks, resulting in a loss of strength and relatively low strength [22]. Continue to increase the amount of fly ash, reduce the cement hydration heat in the early stage, reduce micro-cracks, and produce more hydration products. The strength of the samples with denser structure increased, and the strength reached the maximum when the blending amount reached 20%. When the blending amount of fly ash continued to increase, the strength of cement hydration products decreased and showed a decreasing trend. Therefore, the follow-up test fixed the cement content of 80%, fly ash content of 20%, foam stabilizer content of 0.1wt%, water-cement ratio of 0.5, pp short fiber 0.5wt%, to study the strengthening agent content of foamed cement compression resistance the impact of intensity.

3.2 The influence of the amount of reinforcing agent on the compressive strength of foamed cement

The single-factor variable method was used to control the foam stabilizer content to 0.1wt%, the water-cement ratio 0.5, pp short fiber 0.5wt%, and the 0.5% content gradient to study the influence of the self-made reinforcing agent content on the compressive strength of the foamed cement, as shown in Figure 2.

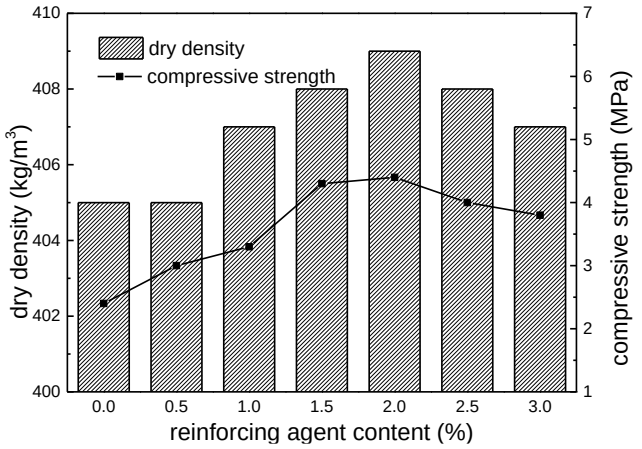

Figure.2 The influence of the amount of reinforcing agent on the strength of foamed cement

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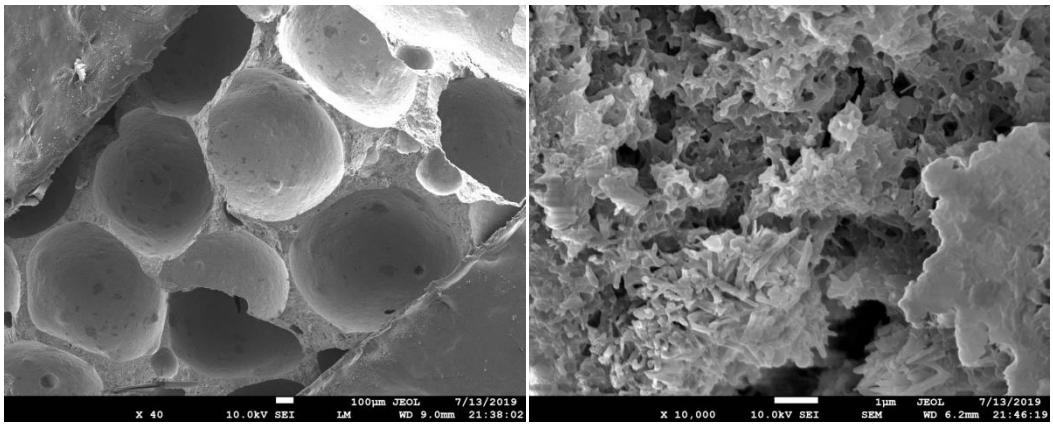
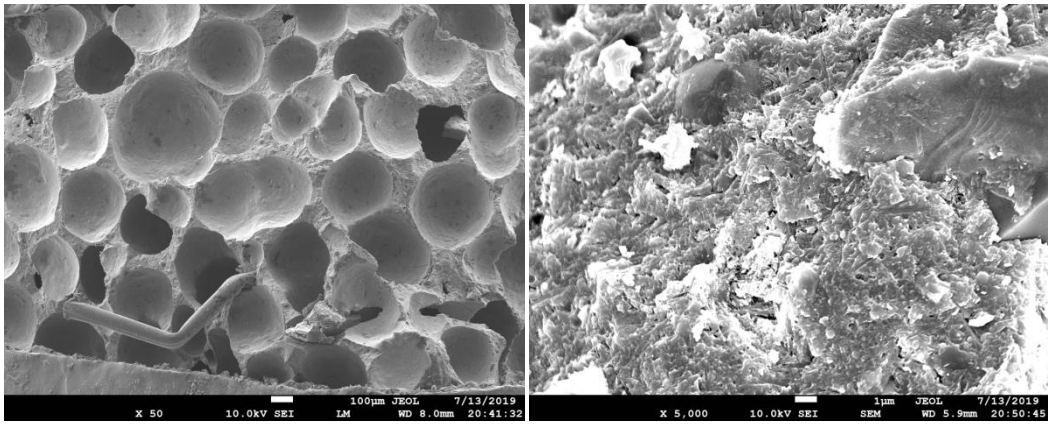
Figure 2 shows the effect of the amount of enhancer on the strength of foamed cement. It can be seen from the figure that the addition of enhancers has a significant effect on the strength of the sample, and with the increase of the amount of addition, the compressive strength shows a trend of first increasing and then decreasing, when the amount of addition is 2%, the strength reaches the highest, the highest increase can reach 112.5%. This is because the addition of the reinforcing agent affects the hydration of the cement, which can make the crystal arrangement become regular and dense, and part of the nanopowder in the reinforcing agent will be filled into the pores of the gel, thereby making the foam wall more dense, showing higher strength. When the addition amount exceeds a certain value, the strength will decrease when the addition amount exceeds a certain value. This is because the excessive amount of enhancer will affect the foaming of the system and make the foamed cement cell structure uneven, thus affecting the sample the compressive strength.

3.3 The effect of reinforcing agent on the cell structure of foamed cement

In order to study the changes in the cell structure, scanning electron microscopy (SEM) observation and analysis were carried out on the foamed cement samples without and without reinforcing agents, the results are shown in Figure 3.



a.SEM images of foamed cement samples at different magnifications without reinforcement



b.SEM images of foamed cement samples mixed with 2wt% reinforcing agent under different magnifications

Figure. 3 SEM image of foamed cement

Figure 3(a) is the SEM image of the foamed cement without reinforcement, and Figure 3(b) is the SEM image of the foamed cement with 2wt% reinforcement. It can be seen from the figure that the foamed cement foam without reinforcement there are more wall defects and more pores in the bubble wall, and the crystal arrangement structure is looser. After adding the reinforcing agent, the cells are more uniform, the cell wall structure is more compact, and the crystal arrangement is more regular. This is because the addition of the enhancer will affect the hydration of cement. During the hydration stage, crystals will preferentially gather on the surface of the enhancer, and the enhancer will act as a "nucleation" [23-24], thereby making cement hydration relatively orderly, so that the structure becomes orderly and dense, thereby increasing the macroscopically the compressive strength of the foamed

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cement.

4 .Conclusion

In order to explore the influence of fly ash content and self-made reinforcing agent content on the compressive strength and micro-cell structure of foamed cement, this paper uses ordinary portland cement as the cementing material, adding self-developed reinforcing agents and foam stabilizers , Prepared lightweight and high-strength foamed cement, and obtained the following conclusions:

1) For the samples without adding reinforcing agent, with the increase of fly ash content, the compressive strength of foamed cement firstly increases and then decreases. When the content of fly ash is 20%, test the dry density of the sample is 405kg/m^3, and the compressive strength is 2.4MPa.

2) The addition of enhancers can significantly enhance the compressive strength of foamed cement, and with the increase in the amount of enhancers, the compressive strength will first increase and then decrease, when the addition is 2wt% at this time, the compressive strength reached the maximum at 4.4MPa, which was 83% higher than that of foamed cement without reinforcement.

3) Scanning electron microscopy results show that the foamed cement foam wall becomes denser, the crystal arrangement is more regular, the foam cells are more uniform and the foam wall defects are reduced after adding the reinforcing agent, thereby enhancing the macroscopic performance of the foamed cement.

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References

[1] Zhu Qingwei, Wu Fade, Zhao Jinping. Research status and progress of exterior wall insulation materials[J]. New Building Materials, 2012 (6): 12-16.
[2] Li Qiuyi, Zhang Xiuqin, Han Shuai, et al. Performance test study on foaming system of desulfurized petroleum coke-sulfoaluminate cement[J]. Concrete and Cement Products, 2015(07): 87-90.
[3] Xu Huijun, Wang Qian, Li Sen, et al. Study on the water resistance of magnesium oxychloride cement by the ratio and additives[J]. Journal of Shandong University of Technology, 2016, 30(05), 49-51.
[4] Qi Fei, Zhang Changsen. The influence of additives on the properties of magnesium oxychloride foamed cement[J]. Building Energy Efficiency, 2017, 45(01): 69-71.
[5] Liu Chengjian, Zhang Zhenqiu, Ge Zhongxi. Application of ultra-light composite cement foam insulation board in external wall insulation[J]. Concrete, 2016(10): 127-130.
[6] Zhang Xin, Ye Jianfeng, Zhou Haibing, et al. Experimental research on new external wall thermal insulation materials[J]. Bulletin of the Chinese Ceramic Society, 2013, 32(05): 982-986.
[7] Hu Guisheng, Zhang Chao, Qian Chenyang, et al. Overview of the latest research progress on the comprehensive utilization of molybdenum tailings resources[J]. Materials Review, 2019, 33(S2): 233-238.
[8] Wang Zhiyu, Li Chun, Duan Yumin, et al. The influence of graphene oxide on the structure and properties of foamed cement[J]. Nonmetallic Minerals, 2020, 43(03): 26-29.
[9] Wang Jun, Fan Chen. Preparation of foamed cement and its physical and mechanical properties [J]. New Building Materials, 2019, 46(05): 152-155.
[10] Guo Jialin, Wang Zhiyu, Liu Mingbao. Study on the mechanical properties of aluminum powder reinforced molybdenum tailing foamed cement[J]. Comprehensive Utilization of Mineral Resources, 2020(04): 167-171.
[11] Cao Jiahao, Li Yajing, Liu Hongli, et al. Microstructure and properties of SiO2 aerogel/foamed cement-based composites[J]. Bulletin of the Chinese Ceramic Society, 2020, 39(04): 1064-1070.
[12] Sheng Hao, Jiang Qiufang, Nie Yujing, et al. The influence of wood flour content on the properties of foamed magnesium oxychloride cement[J]. New Building Materials, 2020, 47(03): 125-128+153.
[13] Zhou Xia. The effect of glass fiber on the performance of sulfoaluminate cement-based foamed insulation board[J]. New Building Materials, 2019, 46(02): 102-104+117.

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[14] Zhu Ming, Wang Fanggang, Zhang Xulong, et al. Research on the relationship between the pore structure and thermal conductivity of foamed concrete[J]. Journal of Wuhan University of Technology, 2013, 35(03): 20-25.

[15] Dai Yuchen, Gao Peiwei, Lin Hui, et al. Study on the influence of foam concrete pore structure on compressive strength[J]. New Building Materials, 2018, 45(03): 130-133.

[16] Dai Yonggang, Ma Menglan, Zhang Guotao. Research on the Rheological Properties of Foamed Cement Slurry[J]. Journal of Hubei Institute of Technology, 2020, 36(04): 44-46+50.

[17] Su Haiting, Wu Qize, Ma Qian, et al. Foaming effect evaluation of four cement foaming agents[J]. Journal of Shandong Agricultural University (Natural Science Edition), 2020, 51(03): 559-561.

[18] Wang Luming, Feng Koubao, Chen Xuefei. Research on the water resistance and mechanism of composite modified magnesium oxychloride cement foamed concrete[J]. Functional Materials, 2015, 46(12): 12009-12014.

[19] VELANDIA DF, LYNSDALE CJ, PROVIS JL, et al. Effect of mix design inputs, curing and compressive strength on the durability of Na2SO4-activated high volume fly ash concretes[J]. Cement and Concrete Composites, 2018, 91: 11-20.

[20] Jin Yongfei, Li Chuansheng, Cheng Ming. Research and application of foamed cement solidified filling materials[J]. Coal Mine Safety, 2020, 51(06): 37-42.

[21] Duo Zhang, Weifeng Wang, Jun Deng, et al. Experimental study and application of LASC foamed concrete to create airtight walls in coal mines[J]. Advances in Materials Science and Engineering, 2020, 2020.

[22] Jin Yongfei, Yan Li, Zhang Dian, et al. Optimization of filling materials for fire fighting foamed cement curing in mines