Available online at www.sciencedirect.com
SciVerse ScienceDirect
ELSEVIER
Procedia Engineering 45 (2012) 768 – 773
Procedia Engineering
www.elsevier.com/locate/procedia

2012 International Symposium on Safety Science and Technology

Experiment development of foam slurry materials

ZHANG Yinghua, YOU Lunan, HUANG Zhian*, GAO Yukun, YAN Jianhao

State Key Laboratory of High-Efficient Mining and Safety of Metal Mines, University of Science and Technology Beijing, Beijing 100083, China

Abstract

Based on the problems of goaf, such as serious air leakage, frequent spontaneous combustion, using foam cement material to reduce or even eliminate the spontaneous combustion of mined-out areas was put forward. Foam cement was made up with cement, blister, flash-setting agent and other materials, which breakthrough the limits of existing fire prevention foam material. Through a series of experiments, characters of foam stabilizing time, mobility density, strength and air leaking stoppage were tested under different proportions of blister and water. According to the experimental results, the fact was obtained that foam cement has minimal air-leakage rate and best effect of air leaking stoppage and the longest foam stabilizing time when the ratio between blister and water is 1:55. Cement samples with different content of flash-setting agent were compounded. By analyzing the cement condensation time under different content of flash-setting agent, it has been found that the content of flash-setting agent were best between 4.6% and 5.0%, which has the shorter condensation time and better condensation effect.

Keywords: foam cement; foaming agent; strength; fluidity

1. Introduction

In recent years, producing efficiency has increased greatly through the promotion and application of mechanized coal caving mining technology, bringing people huge economical and social benefits. However, this kind of coal mining technology has some weaknesses, such as high caving height and heavy air leakage, which increase the risk of spontaneous combustion of coal in goaf, making spontaneous combustion happen more frequently. So it has been one of the main factors restricting the mine development [1]. As a result, developing the preventing and controlling technology against mine fire and its secondary disaster is very meaningful for coal mine production safety [2].

At present, the mine fire extinguishing materials adopted in the domestic include not only traditional airtight materials, but also new materials, such as rockshow foam, polyurethane foam, amine salt gel, resin gel, FR-1 retardant foam and so forth, which have been successfully developed in the foreign countries. These materials can play roles of cooling, obstructing oxygen, blocking air leakage, having good effects on mine fire prevention [3–5]. However, they have many inadequacies, for example, polyurethane foam and amine salt gel can easily produce toxic and hazardous gases, which have bad influence on human being's health.

There are many kinds of plugging fire preventing foam materials, which have different performances. As one of them, foam cement has better application prospects [6–8], because it can be easily made (only through bringing a certain ratio of additives into slurry), cost lowly, and is still seldom adopted in mine. Compared with ordinary cement clay slurry, foam cement slurry has lower proportion. Its concretion body has lower density and lighter weight, especially reducing the amount of cement due to the generation of foam, and reducing the cost of grouting material significantly. Besides, the rate

* Corresponding author. Tel.: +86-13641010189; fax: +86-10-82385795.
E-mail address: huang_za@qq.com

1877-7058 © 2012 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2012.08.237

of water precipitation of foam cement slurry is very low, completely avoiding the phenomenon of water precipitation and stratification of ordinary cement slurry, improving the slurry's stability [9–10].

The best ratio of blowing agent and accelerating agent was determined by the experiments examining the various performance parameters of the cement samples, and the effect was verified by pouring the physical model with foam cement. Ultimately the foam cement formulation was determined to meet the underground actual need, which providing technical support for on-site wall closing process.

2. Method and materials in the experiment

2.1. Equipments and materials

This experiment makes foam agent foamed by using light foaming machine. Following equipments and materials are required: light foaming machine, plastic bucket, foaming agent, flash-setting agent, ordinary Portland cement, water, balance, measuring cylinder, and measuring glass, etc. Considering the stability of foaming agent and the thickness and viscosity of bubble well, we choose YX-M-8 type foaming agent [11]; In order to combine the effect and economical practicability, we would use the pc32.5 ordinary Portland cement; Based on the principles of producing quantities of smooth and uniform foam, small volume, light weight, simple operation and taking advantages of both import and domestic products, we choose YX-5 type foam machine which is developed by Beijing Zhongkeyaxin company. We use WPS-I as flash-setting agent according to the requirement of experiment.

2.2. Contents and methods of experiment

Our purpose is to figure out the different effects of foam materials on various foam agent proportions. To begin with, we make 5 samples of foam cement materials, which satisfy the relevant experiment rules [12–14] on cement. The volume proportion of foam agent in each foam cement sample is 1:45, 1:50, 1:55, 1:60 and 1:65. Then we process a series of experiment on characters of foam stabilizing time, mobility, density, strength and air leaking stoppage. Furthermore, we make 12 cement samples with different flash-setting agent proportion in order to measure its condensation time. At last, the best ratio was found by analyzing the experiment data.

3. Results and analysis

3.1. Determination of best blister-water ratio

When we use YX-M-8 type, we should dilute the blister 50-60 times with water and then add samples into foaming machine. The usage of foam is about 0.6 kg per cube concrete. The experiment makes contrast among foam cement samples which have blister-water ratio of 1:45, 1:50, 1:55, 1:60 and 1:65 and ordinary cement. The usages of these 6 samples are all 0.6 kg per cube concrete. Then we begin to analyse the mobility, density, strength and air leaking stoppage of each sample. These samples are marked by 1, 2, 3, 4, 5 and 6.

First, we test the foam stabilizing time and variation of cement brick density under different blister-water ratio, which were shown as Fig.1 and Fig.2.

From Fig.1 we can conclude that when the proportion of foaming agent and water is 1:55, the cement has longest stabilizing time as much as 23 hours. This ratio would be the best choice when we only care about stabilizing time.

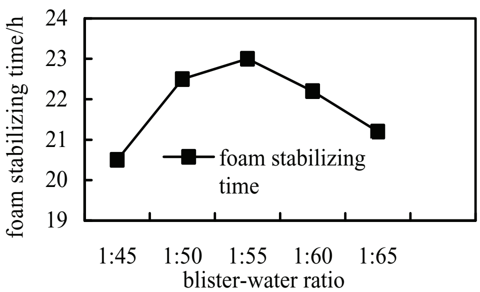


Fig. 1. Foam stabilizing time under different blister-water ratio.

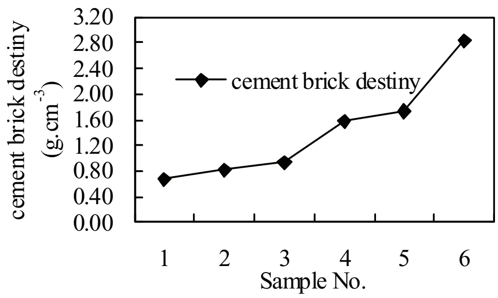


Fig. 2. Density of cement brick under different blister-water ratio.

For engineering construction, the density of foam cement should range from 0.3 g/cm3 to 1.5 g/cm3. The experiment data shows that sample No.1, sample No.2 and sample No.3 satisfy the requirement. It also indicates that the blister-water ration should not be less than 1:55 for the reason that the cement brick density of sample No.4 and sample No.5 is over large. The density of foam cement is smaller than the density of ordinary cement which ranges from 2.7 g/cm3 to 3.1 g/cm3.

Furthermore, we test the fluidity of cement slurry under different blister-water ratio. Fig.3 and Fig.4 indicate how the flow time and flow rate change under different foaming agent and water proportions.

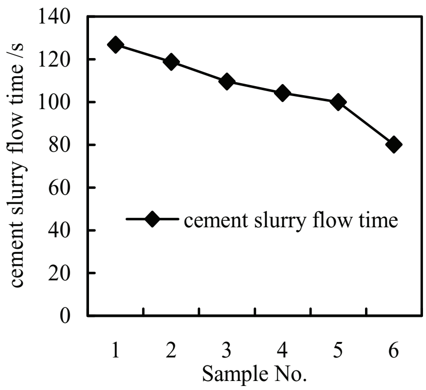


Fig. 3. Flow time of cement slurry under different blister-water ratio.

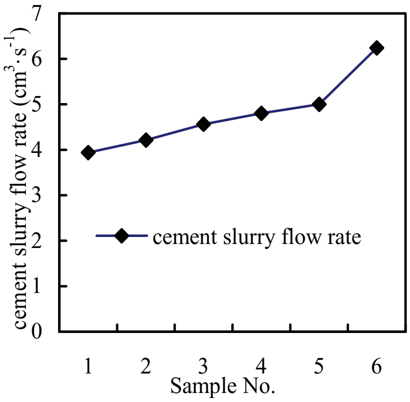


Fig. 4. Flow rate of cement slurry under different blister-water ratio.

From Fig.3 and Fig.4, we can see that the fluidity of foam cement slurry descends slightly when the blister-water ratio increases. The ordinary cement slurry which contains no foaming agent has the best fluidity.

What's more, we test the cement brick pressure resistance under different blister-water ratio. Fig.5 displays the results.

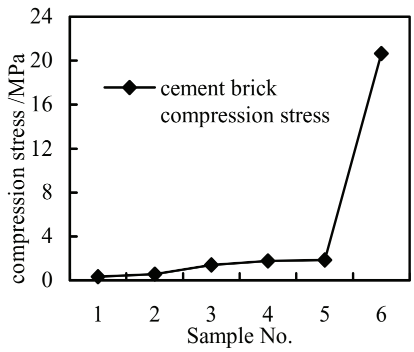


Fig. 5. Compression stress of cement brick under different blister-water ratio.

The strength of foam cements concrete ranges from 0.6 MPa to 2.5 MPa. According to Fig.5, sample No.1 and sample No.2 do not satisfy the requirements so that the blister-water ratio should be no less than 1:55. It also indicates that the pressure resistance of foam cement is much less than that of ordinary cement. Purely considering pressure resistance, the foam cement brick strength of sample No.3, sample No.4 and sample No.5 locate between 1 MPa to 2.5 MPa, which satisfies the requirements of underground foam cement wall construction.

At last, we examine the air leaking stoppage of each sample. Equipments such as DF-4 type ventilating fan (Power: 370W, Ventilation volume: 660 m^3/h), TESTO-425 type measuring wind velocity, goaf model and air blower are used in the test (Figs 6–8).

There are 5 observation points in the goaf model: intake airflow roadway point, 3 working face isometric measure points and return airway point. These points are marked by 1, 2, 3, 4 and 5, which as shown in Fig.9.

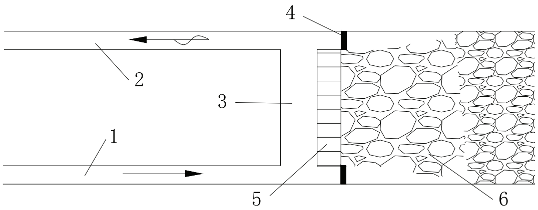
According to the air leaking laws, the void between upper and down corner angle support and tunnel wall is the major passage of air leaking towards goaf. Therefore, building a closed wall in those two parts is the first step. Due to the limits of ventilation volume in the lab, we construct one airtight wall on each side. The position of construction was shown in Fig.10.

Fig. 6. DF-4 type ventilating fan.

Fig. 7. TESTO-425 type wind velocity measuring.

Fig. 8. Goaf model.

Fig. 9. Model of site location map.



1—intake airflow roadway; 2—air-return roadway; 3—working face; 4—airtight wall; 5—fully mechanized support; 6—goaf

Fig. 10. Diagrammatic sketch of airtight wall constructing for air leakage stoppage.

Figs 11–17 show the examining results of each sample.

From Figs 11–16, we can see that after pouring samples, the air quantity in measure point No.2, No.3 and No.4 increase obviously, which indicates pouring a airtight wall has great effect on air leaking stoppage. By taking vertical analysis, we can conclude when the blister-water ratio is 1:55, the effect of air leaking stoppage is the best. Fig.17 shows the same results.

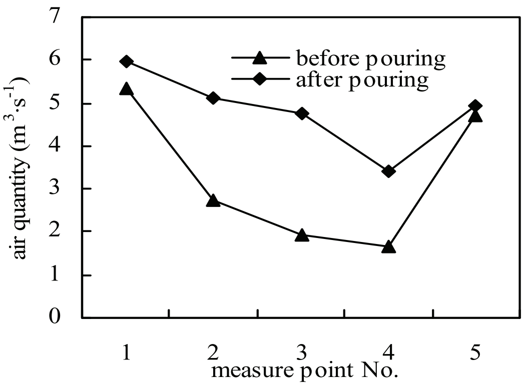


Fig. 11. Air quantity variations before and after pouring the sample No.1

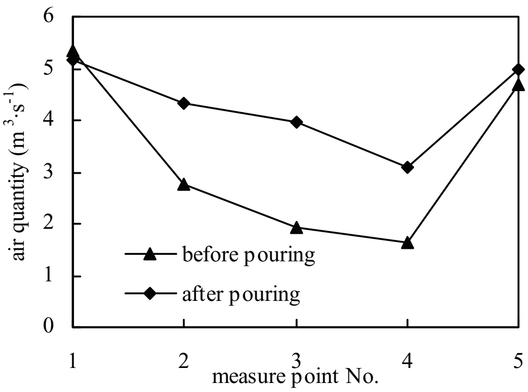


Fig. 12. Air quantity variations before and after pouring the sample No.2.

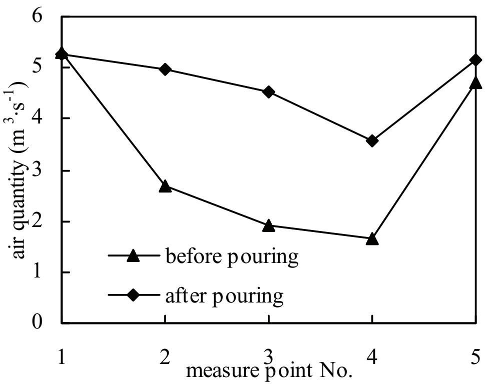


Fig. 13. Air quantity variations before and after pouring the sample No.3.

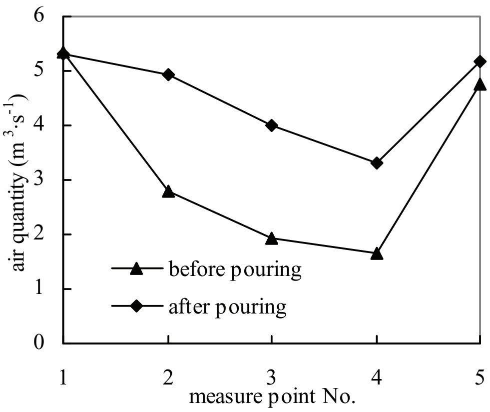


Fig. 14. Air quantity variations before and after pouring the sample No.4.

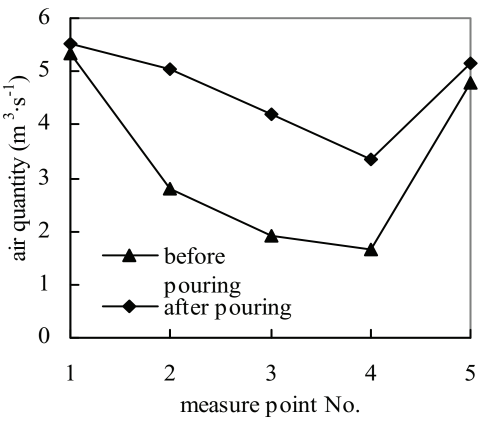


Fig. 15. Air quantity changes before and after pouring the Sample No.5.

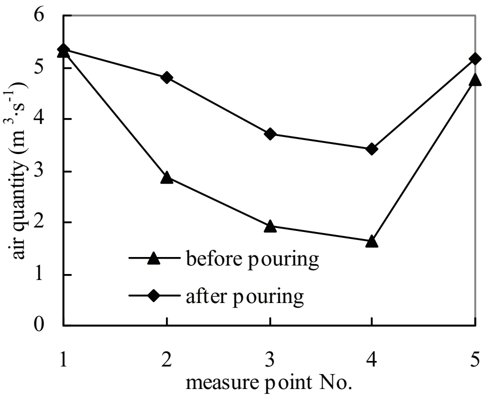


Fig. 16. Air quantity changes before and after pouring the sample No.6.

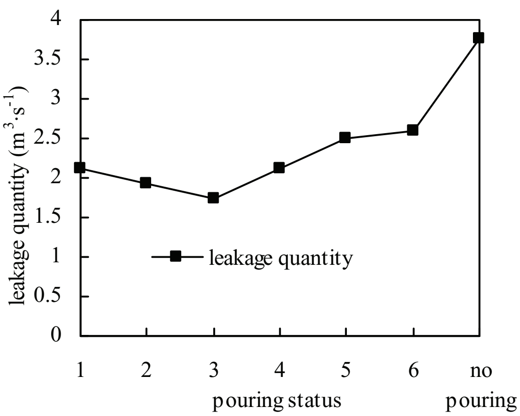


Fig. 17. Air leakage quantity comparison after pouring samples.

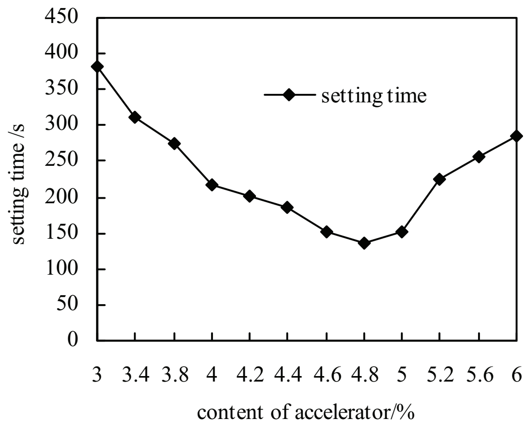


Fig. 18. Effect of accelerator dosage on cement setting time.

3.2. Determination of flash-setting agent content

Cement flash-setting agent is a powerful setting accelerator, which makes water in the slurry dissipation drastically thus accelerates the setting of foam cement. Most of the main component parts of flash-setting agent are sodium aluminates, sodium carbonates and sodium silicates [15–16], etc. In theory, the best proportion of all kinds of flash-setting ranges from 3% to 6% (mass ratios). In our experiment, we use WPS-I type flash-setting agent (best proportion ranges from 4% to 8%).

From Fig.18 we know there is not a liner relationship between setting time and accelerator dosage. When the proportion locates between 3.0% and 4.8%, the setting time of cement slurry descends fast. But when the proportion of flash-setting agent locates between 4.8% and 6.0%, the setting time gradual rises replace descends.

In general, the less setting time, the better the flash-setting agent is. Combining the practical construction situation, the best option of flash-setting dosage should range from 4.6% to 5.0%.

4. Conclusions

(1) As a new kind of fire prevention material, foam cement has extensive application prospects in the coal mine. It is lighter than ordinary cement, strong enough to meet corresponding engineering needs, and its air leakage blocking effect is very good.

(2) According to the analysis of experimental results, we can know that, when the proportion of blowing agent and water is 1:55, the amount of air leakage of the foam cement is the least, and foam stabilize for the longest time. So we can conclude that the best proportion of blowing agent and water is 1:55.

(3) Through producing cement samples of different amounts of accelerating agent and analyzing their condensing time, we can draw conclusion that when the content of accelerating agent is 4.6%–5.0%, the time for cement to condense is short, and the condensing effect is the best. So we think the best content of accelerating agent is 4.6%–5.0%.

(4) Foam cement fire prevention material is pollution-free, non-toxic, ensuring the underground a good working environment. It has wide source of raw materials, and its price is inexpensive. Compared with other materials, it has better economic value.

References

[1] Qin, B.T., Wang, D.M., Bi, Q., et al., 2006. Three-phase foam for preventing spontaneous combustion of coal in goaf, Journal of China University of Mining & Technology 35, pp. 162–163. (in Chinese)
[2] Liang, Y.T., Luo, H.Z., 2008. Current situation and development trend for coal mine fire prevention & extinguishing techniques in China, Journal of China Coal Society33, p. 126. (in Chinese)
[3] Chu, F J., Zhang, K., Sun, T.X., 2004. Application of new-type foam fire-fighting material in No.1 coal mine in Xinji coal mine, Safety in Coal Mines 35, pp. 20–21. (in Chinese)
[4] Chen, W.B., Zhang, J.S., Wu, Y.G, et al., 1996. Rapid sealing in preventing leakage recovery in coal mine production application, Safety in Coal Mines 4, pp. 22–23. (in Chinese)
[5] Shi, H., Yuan, X.Y., Zhang, Y.W., 2010. FR-1 foam inhibition material development and application in fire prevention and extinguishing in coal mine. Coal Mine Modernization 1, pp. 59–60. (in Chinese)
[6] Ji, Y.S., 2002. A new type of light magnesium cement foamed material, Material Letters56, pp. 353–356.
[7] Li, F., Hu, L.N., 2008. Development of foam cement materials, Concrete 5, pp. 80–82. (in Chinese)
[8] Zhang, Y.F., 2010. Study on new material of foam cement, Technology Trend 9, p. 112. (in Chinese)
[9] Cao, M.L., Lv X.J., 2007. The status and development of foaming agent and foamed concrete (Part Ⅰ). Research & Application of Building Materials, 4, pp. 7−8. (in Chinese)
[10] Hu, H.X., Luo,W., Tang, L.Z,, et al, 2011.The application research of light weight foam cement in the grouting materials, Journal of Central South University of Forestry & Technology 31, p. 83. (in Chinese)
[11] Wang, Q.J., Tan, X.J., 2011. Properties and application of some foaming agents, Leather Science and Engineering 1, pp. 14–16. (in Chinese)
[12] Shen, C.L., 2007. Polymer modified cement mortars foe waterproof, Chemical Industry Press, Beijing. (in Chinese)
[13] National Development and Reform Commission of the People's Republic of China. JC/T984—2005 Polymer modified cement mortars foe waterproof. Beijing: China Building Industry Press. (in Chinese)
[14] Zhong, S.Y., Yuan, H., 2003. Polymer application in the concrete, Chemical Industry Press, Beijing. (in Chinese)
[15] Xi, Y.Z., 2007. Quick-setting cement paste: Cause of flash set and mechanism discussion, China Cement 1, pp. 52–55. (in Chinese)
[16] Yue, T., Dou, G.L., 2011. The effect of additives and active mineral admixtures on the performance of fly ash aerated concrete, Zhejiang Construction, 1, pp. 67–71. (in Chinese)