Study on the Phase Change Cement Based Material

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***Abstract*—The hydrophilic of the phase change material (PCM) microcapsules was modified by surfactants (Sodium Dodecyl Sulfate, SDS). The microstructure of the cement paste with phase change microcapsules was observed by SEM. The result showed the modified PCM microcapsules affected the microstructure and the hydration heat. The cement strength declined after PCM microcapsules were added in the cement paste. With the increase of the content of the PCM microcapsules, the more the cement strength decreased. The modified PCM microcapsules make the mechanical properties of cement decreased less compared with the unmodified PCM microcapsules. The results showed that the phase change cement based material that we prepared have remarkable function of heat storage and decrease the peak temperature.**

***Index Terms*—microcapsule, phase change materials, cement paste**

I. Introduction

In recent years, the application of phase change materials in buildings is mainly in energy saving buildings [1]-[3], phase change materials are applied to make building envelope [4], [5], solar energy storage system [6], [7] and cool storage air-conditioning systems [8]-[10]. The usage of phase change wallboard can significantly reduce the indoor temperature and play an effect on energy efficiency.

Shi Xian [11] studied the influence of phase change wallboard on the indoor temperature and humidity. The results show that the phase change wallboard can adjust the indoor temperature and humidity. The combination style between the phase change material and the wall materials affects the indoor temperature and humidity regulating effect. Zhang Ni *et al*. [12] studied the thermal properties of the thermal storage cement board with composite phase change materials. Octadecane acted as the phase change material and expand graphite composite act as the support material. The results show that with the increase of the content of the composite phase change materialse, the density and compressive strength of the thermal storage cement board decreased, the thermal conductivity of the thermal storage cement board also decreases approximate linearly. Ding lifen *et al*. [13] use typical meteorological year hourly data to discuss the change of heating energy consumption of air conditioning of the buildings with external insulation or phase change materials in five thermal partition typical cities. The result shows that using phase change material in the interior wall can raise the comfort degree of the passive buildings in summer and reduce air conditioning energy consumption of active buildings. Hao xiancheng *et al*. [14] carried on the theoretical derivation to the thermal efficiency of phase change materials in building enclosure under the condition of stable heat source and the unsteady heat thermal source. Compared with the building enclosure without phase change materials under the same conditions, the building enclosure with phase change materials in can reduce the indoor peak temperature of about 4℃ and delay the peak temperature for about 2.65h when the outdoor temperature rise by 10℃.

Hydrophilic property is an important index of the phase change material. Good hydrophilic phase change material may be mixed with mortar and mud in any proportion to improve the use efficiency of energy. In addition, changing the hydrophilic properties of phase change material can also greatly increase the application range of the phase change microcapsules. Xing *et al*. [15] prepared silicone encapsulation paraffin PCM microcapsules. The results showed that the packaging of PCM can completely turn paraffin to hydrophilic-lipophilic from hydrophilic.

II. Experimental

A. Materials

The PCM microcapsules were supplied by Shanghai infinite new material technology Co., Ltd. The melting point is 38℃. The sodium dodecyl sulfate was purchased from Chengdu Kelong Chemical Reagent Factory. Cement was ordinary Portland cement (P.O 52.5) that was supplied by Nanjing Xiaoye Tian cement Co., Ltd. The size of the mould is 30×30×30mm.

B. Modified Phase Change Microcapsules

(1) 5g PCM microcapsules and 0.05g modifier (1% by weight of the PCM microcapsules) were weighed;

(2) The phase change heat storage material of the microcapsules and the weighed modifier were put into a

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good three-necked flask. 20ml of water was added into the flask. The mixture was put into a constant temperature water bath at 50℃and stirred at the rate of 850r/pm for 30min.

(3) 80ml of water was added into the mixture and stirred for 1h.

(4) The mixture was filtrated for three times and then dried and ground.

C. The Preparation of the Phase Change Cement based Material

The content of the PCM microcapsules in cement was 0wt%, 3wt%, 5wt%, 8wt%, 10wt%. The water cement ratio (W/C) is 0.4. The shaping steps are conducted as follows:

(1) 600g of cement and 0wt%, 3wt%, 5wt%, 8wt%, 10wt% of PCM microcapsules are put together and stirred for 3min until the mixture is uniform;

(2) Water (W/C = 0.4) was added into the mixing pot. The mixture was stirred for 3min.

(3) The slurry was poured into the mould with the size of 30 × 30 × 30mm. The mould was removed after 1 day and then the specimen was cured for 28days (20℃ ±2, 95RH%).

D. Testing and Characterization

The micromorphology of the cement paste and the phase change cemented material were observed by a Sirion field emission scanning electron microscope (FEI Company). The acceleration voltage is 20KV. 30g PCM microcapsules, 120g water are added into 300g cement. Then the mixture was mixed uniformly. The contrast sample is the uniform mixture of 120g water and 300g cement. The two samples are put into an incubator immediately. The cement hydration process begins and the temperature changes of them are record with a multi-phase temperature recorder.

III. Results and Discussion

A. Morphology of the Phase Change Cement

Fig. 1 is the microstructure structure of the cement paste obtained by SEM. Fig. 1(a) is the cement paste without PCM microcapsules. Fig. 1(b) is the cement paste with 5% of unmodified PCM microcapsules. Fig.1(c) is the cement paste with 5% of modified microcapsules. As can be seen from Fig. 1, the microstructure of the cement paste was very compact. The interface between cement paste and the PCM microcapsules was good. Fig. 1 (b) and Fig. 1 (c) shows that the dense structure of the cement paste was decreased after PCM microcapsules were mixed into. Therefore, the compressive strength of the phase change cemented material was lower than that of the cement paste. The modified PCM microcapsules dispersed better than the unmodified PCM microcapsules in the cement paste. The reason is that the hydrophilicity of the unmodified PCM microcapsules is poor and inclined to agglomeration.

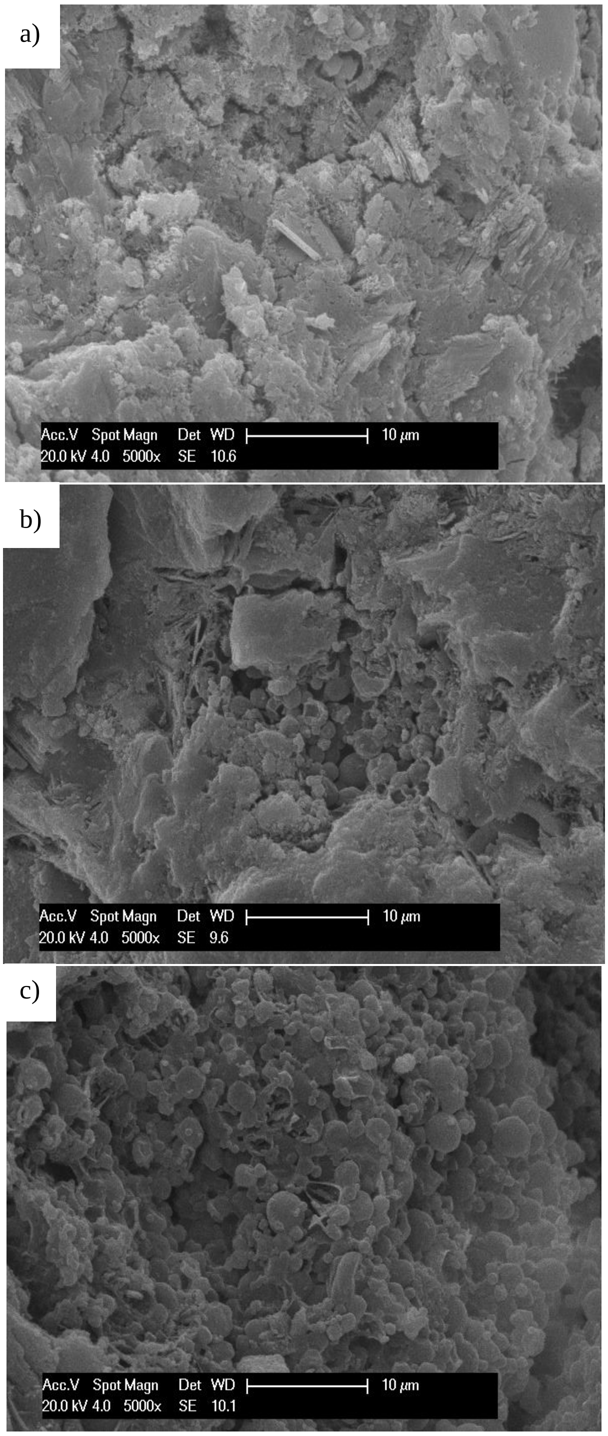

Figure 1. The SEM morphology of the cement paste (a) without PCM microcapsules; (b) with 5% of unmodified PCM microcapsules. (c) with 5% of modified PCM microcapsules

B. The Compressive Strength of the Phase Change Cement

Fig. 2 shows the compressive strength of the phase change cement based material at 7days and 28 days. Fig. 2 indicated that the compressive strength of the phase change cement based material dropped gradually with an increase of the content of the PCM microcapsules. The existence of the PCM microcapsules in the cement paste caused the emergence of the interface defects which leads to the drop of the compressive strength. The more the content of the PCM microcapsules, the more the compressive strength of the cement paste drops. So, the appropriate content should be considered when the phase change cement based material is applied to energy conservation.

Fig. 2 showed that the decreasing degree of the cement paste with unmodified PCM microcapsules was larger than that of the cement paste with modified PCM microcapsules. When the content of the PCM microcapsules is 5%, the compressive strength of the cement paste with modified PCM microcapsules at 28 days was 35.6MPa, while the compressive strength of the cement past ewith unmodified PCM microcapsules was 31.8MPa. This was due to the difference of the hydrophilicity between the two kinds of phase change cement blocks. The good hydrophilicity is beneficial to form good dispersity and good interface between the cement paste and the PCM microcapsules.

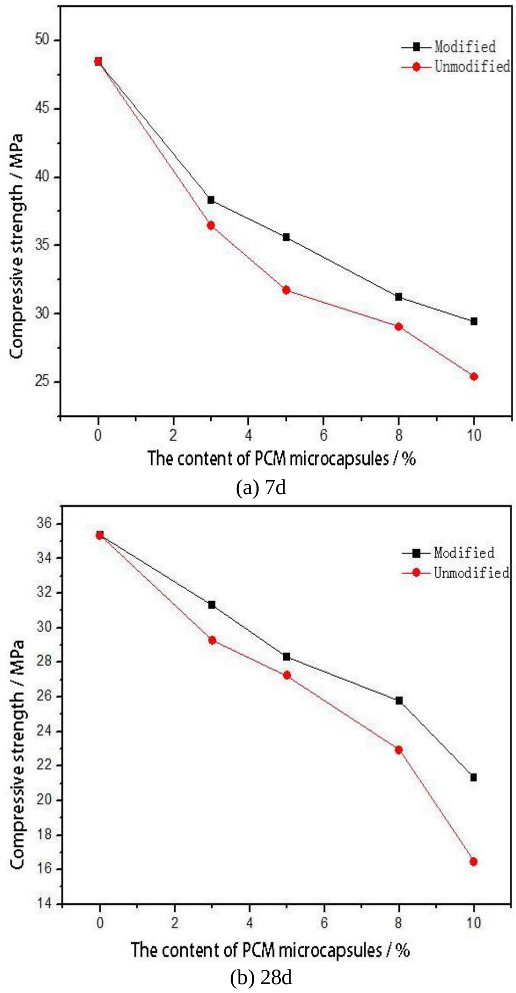

Figure 2. The strength of the phase change cement based material

C. The Cement Hydration Curve

Fig. 3 shows the hydration curve of the cement and the phase change cement. It can be observed that the hydration heat is released and the temperature began to rise from the beginning of the cement hardening for both the cement and the phase change cement. There is a temperature platform at around 28℃ in the hydration curve of the phase change cement, compared to the hydration curve of the cement. This proved the heat storage effect of the phase change cement. At around 28℃, the phase change occurred when the PCM microcapsules changed the form from the solid state to the liquid state. The latent heat make the form being changed and can not raise the temperature. The temperature rose from around 300min again.

In the elevated temperature phase, the temperature of the phase change cement is lower than that of the pure cement for about 5℃. The peak temperature of the phase change cement is lower than that of the pure cement for about 5℃. Moreover, the time arriving the peak temperature is delayed for about 60min for phase change cement. This is because some hydration heat was used to change the phase from solid to liquid. This result showed that the phase change cement based material that we prepared had remarkable function of heat storage and decrease the peak temperature. To some extent, this can solve the cracking phenomenon of massive concrete in the process of hydration.

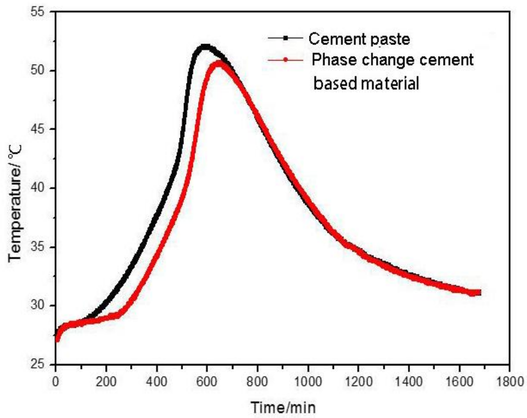

Figure 3. The cement hydration curve of the cement and the phase change cement

IV. Conclusions

The hydrophilic of the phase-change microcapsules was modified by SDS. Then the modified PCM microcapsules were mixed into cement to prepare the phase change cement based materials. Some conclusions were drawn as follows:

(1) The incorporation of microcapsules had a negative impact on the strength of the cement based materials. The compressive strength of the phase change cement based material dropped gradually with an increase of the content of the PCM microcapsules. The decreasing degree of the cement paste with unmodified PCM microcapsules was larger than that of the cement paste with modified PCM microcapsules.

(2) The peak temperature of the phase change cement is lower than that of the cement for about 5℃. Moreover, the time arriving the peak temperature is delayed for about 60min for phase change cement. The phase change cement based material that we prepared in this paper had remarkable function of heat storage and decrease the peak temperature.

REFERENCES

[1] S. H. Lee, S. J. Yoon, Y. G. Kim, Y. C. Choi, J. H. Kim, and J. G. Lee, “Development of building materials by using micro-encapsulated phase change material,” *Korean Journal of Chemical Engineering*, vol. 24, no. 2, pp. 332–335, 2007.

[2] D. Rozanna, A. Salmiah, T. G. Chuah, R. Medyan, S. C. Thomas, and M. Saari, “A study on thermal characteristics of phase change material (PCM) in gypsum board for building application,” *Journal of Oil Palm Research*, vol. 17. pp. 41–46, 2005.

[3] F. Kuznik and J. Virgone, “Experimental assessment of a phase change material for wall building use,” *Applied Energy*, vol. 86, pp. 2038–2046, 2009.

[4] B. Boh and B. Sumiga, “Microencapsulation technology and its applications in building construction materials,” *RMZ—Materials and Geoenvironment*, vol. 55, no. 3, pp. 329–344, 2008.

[5] Y. F. Tan, “The application study of new phase change energy storage wall,” *New Building Materials*, vol. 2, pp. 3-5, 2003.

[6] V. Tyagi, K. A. Pandey, R. Kothari, *et al*., “Thermodynamics and performance evaluation of encapsulated PCM-based energy storage systems for heating application in building,” *Journal of Thermal Analysis and Calorimetry*, vol. 115, no. 1, pp. 915-924, 2014.

[7] D. Jain and P. Tewari, “Performance of indirect through pass natural convective solar crop dryer with phase change thermal energy storage,” *Renewable Energy*, vol. 80, pp. 244-250, 2015.

[8] P. Chandrasekaran, M. Cheralathan, V. Kumaresan, *et al*. “Enhanced heat transfer characteristics of water based copper oxide nanofluid PCM (Phase Change Material) in a spherical capsule during solidification for energy efficient cool thermal storage system,” *Energy*, vol. 72, pp. 636-642, 2014.

[9] D. Zhao and G. Tan, “Experimental evaluation of a prototype thermoelectric system integrated with PCM (phase change material) for space cooling,” *Energy*, vol. 68, pp. 658-666, 2014.

[10] A. D. Gracia, L. Navarro, A. Castell, *et al*., “Thermal analysis of a ventilated facade with PCM for cooling applications,” *Applied Thermal Engineering*, vol. 84, pp. 331-338, 2015.

[11] X. Shi and H. Z. Cui, “Different influences of PCMs in various positions of wallboards on indoor temperatures and humidity,” *Building Energy Efficiency*, vol. 40, no. 262, pp. 34-36, 2012.

[12] N. Zhang, X. M. Fang, and Z. G. Zhang, “Study on the thermal properties of cement boards based on composite phase change material,” *New Chemical Materials*, vol. 40, no. 3, pp. 41-42, 2012.

[13] L. F. Ding and H. Ye, “Comparative analysis of the effects of PCMs and insulation materials on energy saving buildings located in five typical cities,” *Acta Energiae Solaris Sinica*, vol. 32, no. 4, pp. 508-510, 2011.

[14] X. C. Hao and C. Xian, “Effect analysis and application oil phase change material in building envelope,” *Energy Conservation Technology*, vol. 25, no. 142, pp. 137-138, 2007.

[15] X. Liu, H. Y. Liu, and S. J. Wang, “Encapsulation and thermal performance of paraffinshape-stabilized phase change materials,” *Fine Chemicals*, vol. 23, no. 1, pp. 8-11, 2006.

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