CHEMICAL ENGINEERING TRANSACTIONS
VOL. 62, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762090

Study on Building Energy - saving Performance of Diatomite Materials

Liang Dong

Northwest A&F University, Yangling 712100, China
dongliang@nwafu.edu.cn

In order to study the application of phase change materials in the field of building energy saving, diatomite / fatty acid shaped phase change materials were prepared by vacuum impregnation method using modified diatomite as carrier. The structural composition and thermal properties of the shaped phase change materials were analyzed. The phase change material is directly mixed into the cement mortar by stirring. The phase change mortar, phase change mortar test block and phase change mortar heat storage plate are made. Its structural properties, mechanical properties, thermal properties and energy-saving effect was detected and analyzed. The diatomite was modified by roasting, acid leaching, roasting/acid leaching. X-ray diffraction (XRD), scanning electron microscopy (SEM) and BET experiments were used to test the composition and structure of modified diatomite. The results show that the modified diatomite prepared by roasting / acid leaching method has better performance. It has the characteristics of uniform surface pore distribution, complete structure and moderate surface roughness. The stereotyped phase change material has good thermal stability at 105°C. The mass loss rate of the deformed phase change material is 41.65%. Therefore, the stereotyped phase change material can play a good role in the process of environmental temperature changes in the heat.

1. Introduction

With the development of society, people's demand for energy is increasing. The problem of energy shortage is getting more and more attention (Chen et al., 2015). Energy conservation and development and utilization of new energy is the trend. In the energy consumption, the proportion of building energy consumption is the largest (Edelman-Furstenberg, 2014). According to statistics, in 2009, about 40% of the energy consumption in the United States and Europe was in the construction industry. The total area of newly built houses exceeds that of all developed countries every year (He et al., 2015). With the rapid development of China's construction industry, the building energy consumption has also increased. According to the National Energy Department predicted that by 2050, China's building energy consumption accounts for about 40% of total energy consumption (Jeong et al., 2014). The huge demand of building energy consumption will undoubtedly pose a great threat to the country's energy supply and resources and environment. It can be seen that building energy conservation is an important link for China to achieve the goal of energy conservation and emission reduction and maintain sustainable development. The application of phase change energy storage materials and building materials can be traced back to 1980s. It first started in the United States. With the further study of the feasibility of phase change building materials, it is found that the phase change energy storage building materials have both the properties of ordinary building materials and phase change materials.
At present, phase change building materials can be seen everywhere in the western countries, and the application examples of phase change building materials are also common (Johra and Heiselberg, 2017). Its great potential value in the field of energy conservation is also waiting for further development and utilization. China started relatively late in the field of phase change building materials, and its foundation is relatively weak (Karaipekli and Sarı, 2016). However, after unremitting efforts by researchers, breakthroughs have been achieved, and the market has gradually emerged phase change building materials products. Building energy consumption includes building material manufacturing energy consumption, building construction energy consumption and operation energy consumption after completion of building (Khadiran et al., 2016). Energy

Please cite this article as: Liang Dong, 2017, Study on building energy - saving performance of diatomite materials, Chemical Engineering Transactions, 62, 535-540 DOI:10.3303/CET1762090

consumption mainly refers to heating, air conditioning, lighting and other energy consumption, which accounts for the main part of building energy consumption (Lorwanishpaisarn et al., 2017). Energy storage can be divided into three types: sensible heat storage, latent heat storage and chemical energy storage. Sensible heat storage and chemical energy storage show low energy conversion rate and large temperature change during energy transfer. Latent heat storage can achieve energy transfer and energy utilization at approximately constant temperature (Liu et al., 2017). Therefore, the latent heat storage can better realize the mutual conversion of energy relative to the other two energy storage methods (Kim et al., 2014). Phase Change Material (PCM) is a kind of material that utilizes its own phase change to achieve the absorption and release of heat. Because phase change process is only related to temperature, phase change material can be widely used in the field of energy transfer and temperature control. With the growing shortage of energy, people are looking for new ways to achieve energy conservation and recycling. The emergence of phase change material is undoubtedly brought new hope for energy saving (Kong et al., 2016).

2. Properties and detection of modified diatomite

2.1 Experimental materials and instruments

The raw material used in this experiment is diatomite (filter aid). Sinopharm Chemical Reagent Co., ltd. $SiO_2 \geq$ 85%, burning loss≤2.0%, water soluble matter ≤ 0.2%, hydrochloric acid soluble matter≤3.0%, pH value (50 g / L, 25 °C) 5.5~9.0. The experimental apparatus is shown in Table 1.

Table 1: Experimental equipment for diatomite modification

Instrument name	Model	Manufacturer
Physical and chemical drying oven	LS-50	Shanghai Yuejin Medical Instrument Factory
Intelligent box type high temperature furnace	DC-B10/15	Beijing original technology Co., Ltd.
PH meter	PHS-25	Shanghai Hongyi instrument and Meter Co., Ltd.
Constant temperature water bath	HH-2	Guohua Electric Appliance Co., Ltd.
Electronic balance	MP5002	Shanghai Heng Ping Instrument Science Co., Ltd.
Ultrasonic oscillation	KQ-100DB	Kunshan Ultrasonic Instrument Co., Ltd.
Constant temperature heating magnetic stirrer	HJ-6	Guohua Electric Appliance Co., Ltd.
Recycling multi - function vacuum pump	SHZ-D	Bangxi Instrument Technology (Shanghai Co., Ltd.)

2.2 Diatomite modification method

Table 2: The conditions for the modification of diatomite by roasting

Roasting temperature	Roasting time	Number
300 °C	1h	Sample 1
	3h	Sample 2
	5h	Sample 3
500 °C	1h	Sample 4
	3h	Sample 5
	5h	Sample 6
700 °C	1h	Sample 7
	3h	Sample 8
	5h	Sample 9

The modification methods of diatomite can be divided into physical, chemical and physical chemical methods. At present, the commonly used methods are scrubbing method, pickling method, roasting method, dry gravity layer separation method and hot flotation mineral method. In China, the common method of study is scrubbing and pickling process and roasting method. The scrubbing method mainly uses the mechanical method to grind and grind diatomite as original material. After repeated scrubbing, clay impurities in diatomite can be removed better. The surface structure and adsorption properties of diatomite were greatly improved. By adding different concentration of sulfuric acid solution and heating it, the impurities such as mineral and sand in diatomite can be dissolved to form soluble inorganic salt. The modified diatomite with better properties can be obtained by washing, filtering and drying. This is the pickling method. The impurities in high fever can be obviously removed by roasting method. However, the firing temperature is generally not higher than 1000 °C. Otherwise, the transition of Si2O crystal form is likely to occur, and the microporous structure of diatomite is changed. Different methods have different ability to remove different impurities, so the application needs to be combined with the actual needs.

Roasting method: Each time the equivalent amount of diatomaceous earth filter aid was weighed in a crucible and the crucible was placed in a muffle furnace for firing. The calcination time and calcination temperature were controlled, and then calcined and cooled at room temperature to obtain modified diatomite samples. The conditions for the modification of diatomite by roasting are shown in Table 2.

2.3 Test technology of modified diatomite

SEM characterization of modified diatomite: Scanning electron microscope (SEM, EVO-18, German Carl Zeiss Company) was used to observe and analyze the apparent morphology of modified diatomite. The operation is performed according to the scanning electron microscope standard. The spectrum is analyzed and the output image is finally obtained.

XRD characterization of modified diatomite: The modified diatomaceous earth was qualitatively analyzed by X-ray diffractometer (XRD, X'PERT PRO MPD, Panalytical Analytical Instruments, Netherlands). Different scattering waves are produced by X ray irradiation with crystal materials, and then diffraction is produced by mutual interference. Different diffraction waves are reflected in the XRD spectrum, which is the peak and the peak area of different diffraction peaks, in order to determine the existence of elements.

The BET experiment of modified diatomite: The modified diatomaceous earth was tested using a BET tester (Autosorb IQ, USA). The specific surface area, pore size distribution and pore volume of modified diatomite were analyzed.

3. Methods

By using DSC, the phase transition temperature and latent heat of diatomite phase change materials were studied under controllable temperature. In the process of temperature change, the matrix material has no crystal form and phase change. The latent heat of the shaped phase change material is provided when the binary fatty acid mixture is solid-liquid phase transition. According to the phase transition latent heat of the binary fatty acid phase change material and the formula (1), the content of the binary fatty acid in the shaped phase change material can be calculated.

$$W_{SA} = \frac{\Delta H_{PCM}}{\Delta H_{SA}} \tag{1}$$

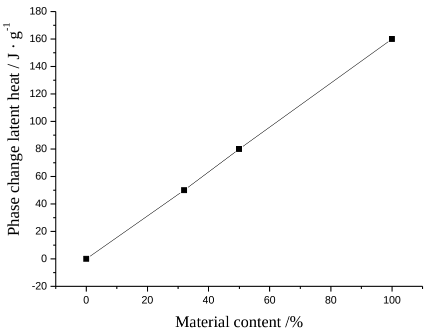
In the formula, ΔH_{PCM} is the actual measured value of the tangential phase change material, and the unit is J/g. ΔH_{SA} is the latent heat of melting of binary fatty acids in shaped phase change materials, and the unit is J/g. ΔW_{SA} is the mass fraction of binary fatty acids in the shaped phase change material.

Table 3: The phase transition temperature and phase change latent heat

Material	Phase change material content /%	Melting temperature/°C	Melting enthalpy (J/g)	Crystallization temperature/°C	Crystallization enthalpy (J/g)
CA-LA	100	19.80	156.17	18.72	156.12
Filtration method	42.55	17.68	66.65	16.63	68.61
Suction water washing method	32.05	17.55	50.05	16.56	51.20

The latent heat data of the binary fatty acid mixture in Table 3 are calculated. The mass fraction of CA-LA in the modified phase change material was 42.55% and 32.05% by direct filtration, filtration and washing. Since the fatty acid mixture is easily compatible with ethanol, it can be deduced that the mass fraction of the fatty acid mixture in the shaped phase change material obtained by the filtration and the alcohol washing method will be smaller. As can be seen from Table 3, although the two methods of preparation of the phase change material temperature has different degrees of decline, the fluctuation range is very small. It can be considered that the phase transition temperature of the shaped phase change material is almost the same as the phase transition temperature of the binary fatty acid. They all meet the comfort requirements of the building. The phase transition temperature and phase change latent heat of the shaped phase change material are shown in Table 3.

According to the change of the phase transition temperature of the shaped phase change material with the content of CA-LA of the fatty acid phase change material, the linear relationship between the two phases is shown in Figure 1.



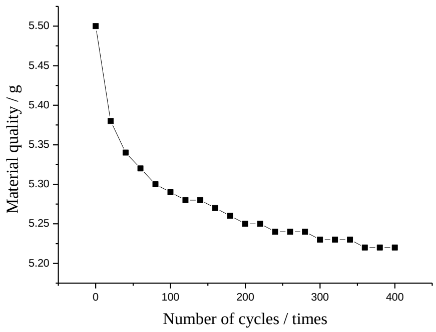


Figure 1: The relationship between the latent heat of phase transformation phase and the content of fatty acid phase change materials

Figure 2: The weight loss of thermal cycles of PCM by simple pumping way

As can be seen from Figure 1, the discrete points are basically in a straight line. The results show that the phase transition latent heat of the phase change material has a linear relationship with the mass fraction of the phase change material. The weight loss of thermal cycles of PCM by simple pumping way is shown in Figure 2.

As can be seen from Figure 2, the total mass loss of the shaped phase change material was 5.1%. The quality loss is mainly concentrated in the first 100 experiments. In the 100 to 400 experiments, the mass loss of the shaped phase change material was only 0.55%, which was less than 1%, as the number of cycles increased. It shows that the stability of the phase change material is good.

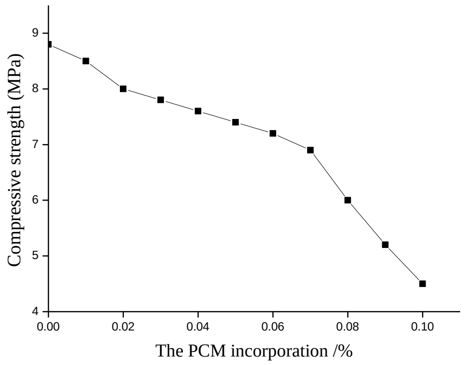
4. Results analysis

The crimp ratio is the ratio of compressive strength to flexural strength. It can be used to evaluate mortar crack resistance and flexibility. The lower the crimp ratio, the better the mortar flexibility. In order to ensure that the material has a certain resistance to bending and fracture capacity, cement mortar crimp ratio should be minimized. The compressive and flexural strength of the variable phase change material is shown in Table 4. The test time of cement mortar test block is 3 days.

Table 4: The compressive and flexural strength of the variable phase change material

The PCM incorporation	Compressive (MPa)	strengthFlexural strength (MPa)	Compression fold ratio
0%	8.67	1.83	4.74
1%	8.33	1.81	4.60
2%	8.05	1.78	4.52
3%	7.88	1.75	4.50
4%	7.66	1.74	4.41
5%	7.52	1.72	4.37
6%	7.33	1.69	4.34
7%	6.88	1.67	4.12
8%	6.01	1.54	3.91
9%	5.31	1.47	3.61
10%	4.52	1.40	3.23

The FSPCM content for the effect of compressive strength is shown in Figure 3. The FSPCM content for the effect of flexural strength is shown in Figure 4.



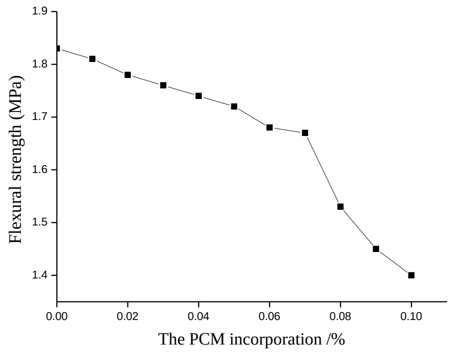


Figure 3: The FSPCM content for the effect of compressive strength

Figure 4: The FSPCM content for the effect of flexural strength

As can be seen from Figure 3 and Figure 4, the compressive strength and compressive strength of mortar show a decreasing trend with the incorporation of shaped phase change materials. One reason is that the stereotyped phase change material is loose. When the fixed phase change material is added, bubbles are introduced so that the internal porosity of the mortar increases. This will greatly affect the mechanical properties of the test block. Another reason is that the shaped phase change material has a certain water absorption capacity. After the test piece is formed, there will still be some moisture retained in the cement mortar inside, resulting in the test block is prone to fracture. Under the combined action of these two cases, the compressive and flexural properties of the test piece will gradually decrease with the increase of the amount of the mixed phase change material. It can also be seen from Figure 3 and Figure 4 that when the incorporation amount of the shaped phase change material is less than 7%, the compressive and flexural strength decreases. When the incorporation of the modified phase change material is more than 7%, the compressive and flexural strength of the modified phase change material is obvious. When the incorporation amount of the shaped phase change material reaches 10%, the mortar surface of the test piece can be clearly observed during the experiment. It can be seen that the incorporation of the shaped phase change material has seriously affected the stability of the cement mortar.

The crimp ratio is the ratio of compressive strength to flexural strength, which can be used to evaluate mortar cracking resistance and flexibility. When the crush is high, the brittleness of the mortar is large and the fragmentation is likely to occur. When the compressive strength is low, the strength of the mortar is weak, and it is easy to be destroyed. When the compression ratio is too high or too low, it is not conducive to the actual use of mortar. The FSPCM content for the effect of compression flexure ratio is shown in Figure 5.

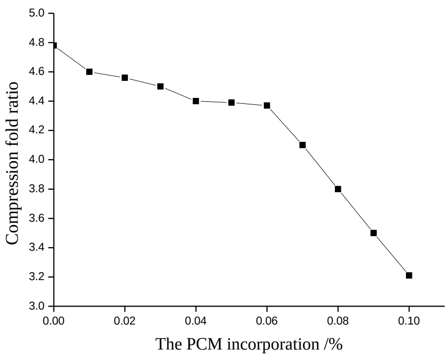


Figure 5: The FSPCM content for the effect of compression flexure ratio

As can be seen from Figure 5, the crimp ratio tends to decrease with the incorporation of the shaped phase change material as a whole. In the case of reduced compressive strength and bending strength, the compressive strength decreases more significantly. This phenomenon is particularly evident when the incorporation of the shaped phase change material is greater than 7%. According to the above analysis, when the amount of phase change material is 7%, the performance of the phase change mortar is better.

5. Conclusions

In order to study the field of building energy efficiency, stereotyped phase change materials were prepared. The diatomite / fatty acid shaped phase change materials were prepared by vacuum impregnation method with modified diatomite as carrier. The prepared fatty acid / diatomaceous earth shaped phase change material is directly mixed into the cement mortar by stirring. Phase change control mortar, phase change mortar test block and phase change mortar heat storage plate are made, and its performance is tested. In order to further understand the energy saving effect of phase change mortar, the experimental box was prepared by pouring pouring method. The phase change mortar is smeared on its inner surface. The temperature control effect of the phase change experimental box is simulated under the condition of environmental temperature change. The diatomite was used as the matrix material of the shaped phase change material. The diatomite was modified by roasting, acid leaching, roasting and acid leaching. Through the analysis of XRD, SEM and BET of the modified diatomite, it is found that the modified diatomite prepared by roasting / acid leaching method has good structural characteristics. It has the characteristics of maximum specific surface area, high porosity, complete structure and moderate surface roughness.

Reference

Chen Z., Su D., Qin M., Fang, G., 2015, Preparation and characteristics of composite phase change material (CPCM) with SiO 2 and diatomite as endothermal-hydroscopic material, Energy and Buildings, 86, 1-6. DOI: 10.1016/j.enbuild.2014.10.013

Edelman-Furstenberg Y., 2014, Distribution and paleoecology of molluscan skeletal remains along an upwelling tract: Benguela system, Namibian shelf. Marine Geology, 353, 153-162, DOI: 10.1016/j.margeo.2014.04.011

He, H., Zhao P., Yue Q., Gao B., Yue D., Li Q., 2015, A novel polynary fatty acid/sludge ceramsite composite phase change materials and its applications in building energy conservation, Renewable Energy, 76, 45-52, DOI: 10.1016/j.renene.2014.11.001

Jeong S. G., Lee J. H., Seo J., Kim S., 2014, Thermal performance evaluation of Bio-based shape stabilized PCM with boron nitride for energy saving, International Journal of Heat and Mass Transfer, 71, 245-250, DOI: 10.1016/j.ijheatmasstransfer.2013.12.017

Johra H., Heiselberg P., 2017, Influence of internal thermal mass on the indoor thermal dynamics and integration of phase change materials in furniture for building energy storage: A review, Renewable and Sustainable Energy Reviews, 69, 19-32, DOI: 10.1016/j.rser.2016.11.145

Karaipekli, A., Sarı, A., 2016, Development and thermal performance of pumice/organic PCM/gypsum composite plasters for thermal energy storage in buildings, Solar Energy Materials and Solar Cells, 149, 19-28, DOI: 10.1016/j.solmat.2015.12.034

Khadiran T., Hussein M. Z., Zainal Z., Rusli R., 2016, Advanced energy storage materials for building applications and their thermal performance characterization: A review, Renewable and Sustainable Energy Reviews, 57, 916-928, DOI: 10.1016/j.rser.2015.12.081

Kim S., Paek S., Jeong S. G., Lee J. H., Kim S., 2014, Thermal performance enhancement of mortar mixed with octadecane/xGnP SSPCM to save building energy consumption, Solar Energy Materials and Solar Cells, 122, 257-263, DOI: 10.1016/j.solmat.2013.12.015

Kong X., Zhong Y., Rong X., Min C., Qi C., 2016, Building energy storage panel based on paraffin/expanded perlite: preparation and thermal performance study, Materials, 9(2), 70. doi:10.3390/ma9020070

Liu Z., Hu D., Lv H., Zhang Y., Wu F., Shen D., Fu P., 2017, Mixed mill-heating fabrication and thermal energy storage of diatomite/paraffin phase change composite incorporated gypsum-based materials, Applied Thermal Engineering, 118, 703-713, DOI: 10.1016/j.applthermaleng.2017.02.057

Lorwanishpaisarn N., Kasemsiri P., Posi P., Chindaprasirt P., 2017, Characterization of paraffin/ultrasonic-treated diatomite for use as phase change material in thermal energy storage of buildings, Journal of Thermal Analysis and Calorimetry, 128(3), 1293-1303, DOI: 10.1007/s10973-016-6024-3