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EFFECT OF BIOMASS ADDITION ON PREPARATION OF CERAMSITE MADE BY FLY ASH

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In this paper, effect of biomass addition on preparation of porous ceramite made by fly ash was studied. The results indicated that when the amount of biomass addition was increased from 15 % to 25 %, the porosity of ceramsite increased from 38,3 % to 46,7%, but excessive amount of biomass can affect other performances of ceramsite. Under this experimental conditions, the best experimental Scheme to preparation porous ceramsite is that the proportion of fly ash and clay is 5:5, calcination temperature 900 °C, mount of biomass addition 20 % and calcination time 40 min.

Key words: fly ash; porous ceramsite; biomass; porosity

INTRODUCTION

Fly ash is a solid powder residue after calcination of coal-fired boilers, about 75 percent of China's power plants rely on thermal power, in 2017, the production of fly ash will exceed 700 million tons. It is urgent to find efficient and feasible ways of comprehensive utilization [1-4]. The ceramsite made by fly ash has high strength, high refractoriness, low capacity, low thermal conduction and stable chemistry qualitatively, it can be used as lightweight aggregate to produce green and energy-efficient building materials. High quality porous ceramsite can improve the performance of subsequent building materials. The porosity of ceramsite directly influence it's performance.In this paper, the effect of adding biomass as pore former to produce the porous ceramsite will be discussed.

EXPERIMENT

During this experimental process, four parameters including the proportion of fly ash and clay, calcination temperature, calcination time and amount of biomass addition were choosen as investigated factors. The orthogonal experiment of tri-level L9(4^3) was designed. Table 1 shows the factors and levels of orthogonal experiment.

According to Table 1, nine orthogonal experiments were carried out, based on these above experiments, a blank experiment was proceed (the proportion of fly ash and clay is 5:5, calcination temperature 900 °C, calcination time 40 min and the mount of biomass addition 20 %).

Table 1 **Factors and levels of orthogonal experiment**

Factor	F:C	T_s / °C	T_c /min	Bb/%
Level1	4:6	800	40	15
Level2	5:5	900	60	20
Level3	6:4	1 000	80	25

F:C, Fly ash: Clay; T_s, Sinter temperature; T_c, Calcination time; B, Amount of biomass addition

RESULTS AND DISCUSSION

Results of orthogonal experiment

According to the orthogonal scheme of Table 2, nine experiments were carried out. And the water absorption rate, porosity and compressive strength of ceramsite were measured. Specific methods were expressed as following.

(1) Porosity (P)

Porosity refers to the percentage of the total volume of pores in the ceramsite. Porosity was calculated using the following equation:

$$P = \frac{m_3 - m_1}{m_3 - m_2} \times 100\ \% \qquad (1)$$

Where P is porosity of ceramsite made by fly ash, m_1 is the quality of ceramsite, m_2 is the quality of ceramsite in water after vacuum absorption, m_3 is the quality of ceramsite in air after vacuum absorption.

(2) Water absorption rate (W)

The water absorption rate of ceramsite made by fly ash refers to the ratio of the quality of the water absorbed by the drying ceramsite in 1 hour and the dry ceramsite. Water absorption rate was calculated using the following equation:

$$W = \frac{M_{wet} - M_{dry}}{M_{dry}} \times 100\ \% \qquad (2)$$

Where W is water absorption rate of ceramsite in one hours, M_{dry} is the quality of ceramsite, M_{wet} is the quality of ceramsite after water absorption in one hour.

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The compressive strength was determined by the compressive strength tester, and the results of relevant performance tests are shown in Table 2.

Table 2 shows the porosity of ceramsite was between 37,61 % and 50,83 %, the water absorption rate was between 15,26 % and 33,93% and the compressive strength was between 8 MPa and 24 MPa. the performance indexes of ceramsite are quite different under different conditions. Good ceramsite should have higher porosity and compressive strength, at the same time, the water absorption rate was relatively low. Therefore, it was necessary to make further analysis of different factors, and the influence of different factors on the performance of ceramsite must be explored.

Table 2 **Result of orthogonal experiment**

Sample	F:C	T_s /° C	T_c / min	B/%	Porosity /%	Water absorption /%	Compressive strength / MPa
1	4:6	800	40	15	15,26	37,61	24
2	4:6	900	60	20	18,72	39,68	15
3	4:6	1 000	80	25	24,97	44,63	11
4	5:5	800	60	25	30,27	44,64	8
5	5:5	900	80	15	19,93	37,99	18
6	5:5	1 000	40	20	22,83	40,22	10
7	6:4	800	80	20	21,83	38,02	11
8	6:4	900	40	25	33,93	50,83	9
9	6:4	1 000	60	15	22,58	39,51	23

Effect of different factors on properties of ceramsite

Porosity

According to the experimental results of Table 2, the range analysis of orthogonal experiments was conducted to explore the influence of various factors on porosity, and the results were shown in Table 3.

Table 3 **Effect of different factors on porosity**

Factor	F:C	T_s / °C	T_c / min	B / %
Level 1	40,64	40,08	42,88	38,37
Level 2	40,95	42,83	41,28	39,31
Level 3	42,79	41,45	40,28	46,7
Range	2,15	2,75	2,67	8,33

Table 3 shows that during the preparation process of ceramsite, the porosity of ceramsite would be increased with increasing of the proportion of fly ash in the raw material. The increase of calcination time would decrease the porosity, and with the increase of calcination temperature, the porosity of ceramsite would be increased at first and then decreased. However, the addition of biomass is the most important factor, followed by the proportion of fly ash and clay, calcination temperature and calcination time. but the differences between these three factors were small.

Water absorption rate

According to the experimental results in Table 2, the range analysis was carried out, and the effect of various factors on the water absorption rate of ceramsite was analyzed. The results were shown in Table 4.

Table 4 **Effect of different factors on water absorption rate**

Factor	F:C	T_s / °C	T_c / min	B / %
Level 1	19,65	22,45	24,02	19,27
Level 2	24,34	24,21	23,86	21,13
Level 3	26,13	23,46	22,24	29,47
Range	6,48	1,76	1,78	10,47

Table 4 shows the proportion of clay and biomass addition in the samples have great influence on water absorption rate. With the increase of the proportion of clay and biomass addition, a melting phenomenon will be happened during the preparation process of ceramsite ,pore will be melting or blocking, pore number of inner surface will be increased, surface density can be declined, so that water absorption rate of ceramsite increases. But the most important factor is the amount of biomass addition. And the trend of water absorption rate was similar to that of porosity.

Compressive strength

Good compressive strength not only ensure that ceramsite had good physical properties, but also can guarantee its own storage and transportation. According to the experimental results in Table 5 and the range analysis method of orthogonal experiment, the influence of different factors on the compressive strength of ceramsite was shown in Table 5.

Table 5 **Effect of different factors on compressive strength**

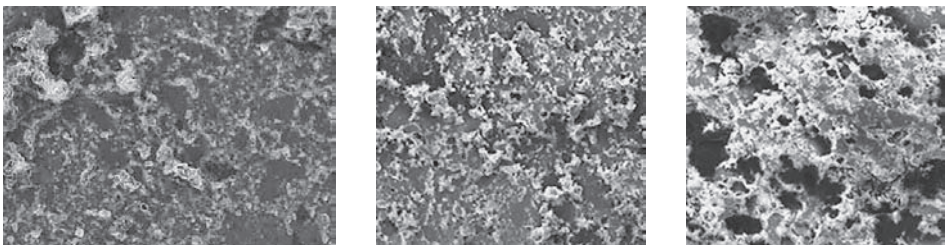
Factor	F:C	T_s / °C	T_c / min	B / %
Level 1	16,67	14,33	14,33	21,67
Level 2	12	14	15,33	12
Level 3	14,33	14,67	13,33	10
Range	4,67	0,67	2,00	11,67

It can be seen from Table 5, with the gradual increase of biomass addition in the sample, the porosity will increase at the same time, and the structure and density also suffered damage, the strength after reaction will be decreased significantly. The influence degree of the sample strength after reaction was amount of biomass addition, proportion of fly ash and clay, calcination time and calcination temperature respectively.

In summary, the main factors affecting the performance of ceramsite were amount of biomass addition, the next are proportion of fly ash and clay, calcination time and calcination temperature.

Optimization experiment and results

According to the above experimental results and analysis, an optimization experiment to prepare porous ceram-



(a) biomass 0 (b) biomass 15 % (c) biomass 25 %

Figure 1 Comparison of micro morphology of porous ceramsite

site made by fly ash is that the proportion of fly ash and clay is 5:5, calcination temperature 900 °C, calcination time 40 min and the mount of biomass addition 20 %.

The related performance of the reaction product were measured, the results were shown in Table 6.

Table 6 **Result of optimization experiment**

Porosity / %	Water absorption rate/ %	Compressive strength/ MPa
42,75	20,07	18

Table 6 shows that comprehensive performance of porous ceramsite of optimization experiment is more better, porosity can reach 42,75 %, water absorption rate 20,07 %, and compressive strength 18 MPa.

Comparison of microstructure and structure

According to the above experimental results, representative samples were selected, and the prepared ceramsites were milled. The scanning electron microscope was used to observe the microstructure, and the results were shown in Figure 1.

Figure 1 shows that in the process of preparation of ceramsite, the volatilization, combustion and reaction of biomass make the voids of reaction materials increased gradually, and the compactness of surface structure decreases correspondingly. With the increase of biomass, the pore volume and diameter of ceramsite expand correspondingly, but the distribution of voids was still uniform. As can be seen from Table 5, when the amount of sawdust added change from 15 % to 25 %, the porosity of ceramsite increased from 38,37 % to 46,7 %. However, when the biomass pore-forming agent was excessive, the pore would be larger directly, which would not only affect the porosity and water absorption, but also influence the compressive strength of the ceramsite. Therefore, the amount of pore-forming agent should be controlled within the appropriate range.

The samples obtained from the reaction and the blank experimental samples without biomass were analyzed by X-Ray diffraction (XRD), and the phase structure changes of ceramsite under different conditions were analyzed. The results were shown in Figure 2. It can be seen that under high temperature, the pore-forming agent can be discharged from the reaction block because of evaporation, reaction and decomposition process after the reaction of ceramsite. After the reaction,

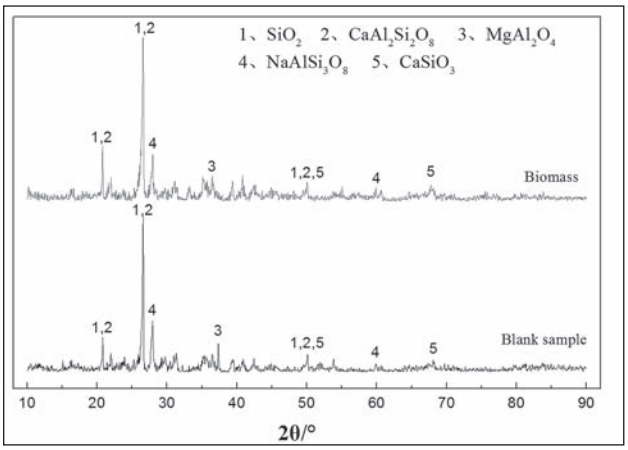


Figure 2 Phase structure changes of porous ceramsite

the porosity and other properties of ceramsite were improved, and the phase structure of the product was basically consistent with that of the blank group. The main phase structure was SiO_2 (Quartz), and a certain amount of $CaAl_2Si_2O_8$ (Anorthite), $MgAl_2O_4$ (Spinel), $NaAlSi_3O_8$ (Soda feldspar), $CaSiO_3$(Wollastonite) were contained.

CONCLUSIONS

The most important factor affecting the comprehensive performance of porous ceramsite made by fly ash is the mount of biomass addition, the next are the proportion of fly ash and clay, calcination time, calcination temperature.

When the amount of biomass addition was increased from 15 % to 25 %, the porosity of ceramsite increased from increased from 38,37 % to 46,7%. But too much addition can affect the other properties, biomass addition should be added in appropriate amount.

Under this experimental conditions, the best experimental Scheme to preparation porous ceramsite is that the proportion of fly ash and clay is 6:4, calcination temperature 900 °C, mount of biomass addition 15 % and calcination time 60 min.

Acknowledgements

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Note: The responsible translator for language English is doctor W.L. Zhan - Univerisity of Science and Technology Liaoning, China.