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PREPARATION AND PHSICAL PROPERTIES OF MUCK BASED CERAMICS FOR 700-900 DENSITY LEVELS

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ABSTRACT

To determine the optimum firing process, the influence of raw material, calcination temperature and mixing ratio on the packing density of muck based ceramics was studied. And then the apparent density, cylinder pressure, water absorption, loss and other physical properties were tested. The results show that: muck based ceramics for 700-900 density levels could be produced when the content of fly ash is 70%-83% and the content of fly ash is 17%-30%, the calcination temperature is 1170℃-1200℃, which is light brown with smooth surface and intact enamel layer, and the interior is loose and porous.

1. INTRODUCTION

As a kind of municipal solid waste, muck has reached 30%-40% of the total waste [1]. At present, the disposal of muck is only a simple landfill and discarded, which not only takes up a lot of land resources and pollutes the environment, but also is a waste of economy because of the transportation, the direct stacking of muck even exists a huge security risk [2]. The traditional way of muck treatment is no longer suitable for the development of the present city, to find the effective use of muck resources is the key to solve the problem of muck. At present, the study and application of muck at home and abroad are mainly used as filling materials of roadbed base [3-5]. Artificial ceramic has a small density, thermal insulation, high porosity, shock resistance, fire resistance, alkali-resistant aggregate reaction and other excellent performance, is widely produced and applied [6]. In particular, after the implementation of the "Circular Economy Promotion Law of the People's Republic of China" by the relevant departments on January 1, 2009, solid wastes (fly ash [7], coal gangue [8], red mud [9], sludge [10-11], seaside silt [12], etc.) as the main raw materials for the preparation of green ceramic research has made considerable progress.

In order to explore the application of muck in other areas, this paper studied the feasibility of preparing lightweight and high strength ceramic with muck as the main raw material, and provided alternative raw materials for the lightweight aggregate concrete.

2. Materials and methods

2.1 Raw material

Muck: accumulation field of Tianjin Metro Line 6, its chemical composition is shown in Table 1.Fly ash: a thermal power plant II fly ash of Tianjin, its chemical composition is shown in Table 1.Sludge: sewage sludge of a sewage treatment plant in Tianjin, its chemical composition is shown in Table 1.Straw: agricultural waste of a village in Tianjin, its chemical composition is shown in Table 1.

Tab.1 Chemical composition of raw materials

chemical composition	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	Carbon oxides	Loss
Muck	50.23	13.06	9.62	2.97	1.77	2.75	4.11	13.70	8.55
Fly ash	39.64	35.37	3.99	0.89	0.27	0.89	4.01	9.91	2.65
Sludge	7.81	7.05	21.51	1.82	0.28	0.53	4.57	45.35	38.50
Straw	4.38	0.10	0.39	0.36	0.68	1.18	0.08	90.79	----

As can be seen from Table **1**: the content of SiO_2 in muck is 50.23%, the lower content of Al_2O_3 is 13.06%, while the higher content of Fe_2O_3 is 4.11%, and the content of (CaO + MgO + Na_2O + K_2O) is 17.11%; the higher content of Al_2O_3 in fly ash is 35.37%, while the lower content of SiO_2 is 39.64%, and the content of Fe_2O_3 is 4.11%, and the content of (CaO + MgO + Na_2O + K_2O) is 6.04%; the highest content of organic C in sludge reaches 45.35%, and the content of (CaO + MgO + Na_2O + K_2O) is 24.14%, and the contents of Fe_2O_3、SiO_2 and Al_2O_3 are 4.57%、7.81% and 7.05%; the addition of straw as the additive shows that the content of organic C is more than 90%.

2.2 Test design

The content of muck in the test is more than 60% of the dry weight of the raw material ball, the chemical composition

of the material balls should be controlled within a reasonable range (Table **2**) [7-10]at the same time; it can be seen from Table 1 and Table **2** ,only the use of muck could not be fired to meet the requirements of the muck based ceramics. Therefore, in the preparation of lightweight high-strength muck based ceramics, in addition to the main raw material residue, but also adding a proper amount of fly ash, sludge and straw.

Specific test design is shown in the Table **3**, in which the **A** group and **a** group for the baseline group; in group **B**, 10% (10% of the dry mass of muck and fly ash) was mixed with the straw under the premise of ensuring the ratio of the muck and the fly ash in the raw material ball was the same as that in the **A** group; **B** group, **C** group and **D** group as the control group.

Tab.2 Range of chemical composition

chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO+ MgO	Na_2O+ K_2O
range	48～79	8～25	3～12	1～12	0.5～7.0

Tab.3 Design of experiment

number	mixing ratio（%）				temperature (℃)
	muck	sludge	fly ash	straw	calcination temperature
A-1	100	0	0	0	1150
A-2	90	0	10	0	1150
A-3	80	0	20	0	1150
A-4	70	0	30	0	1150
A-5	60	0	40	0	1150
a-1	0	100	0	0	1150
a-2	0	90	10	0	1150
a-3	0	80	20	0	1150
a-4	0	70	30	0	1150
a-5	0	60	40	0	1150
B-1	100	0	0	10	1150
B-2	90	0	10	10	1150
B-3	80	0	20	10	1150
B-4	70	0	30	10	1150
B-5	60	0	40	10	1150
C-1	90	0	10	0	1160
C-2	80	0	20	0	1170
C-3	70	0	30	0	1200
C-4	60	0	40	0	1230
D-1	83	0	17	0	1170
D-2	75	0	25	0	1190
D-3	70	0	30	0	1200

2.3 Test method

2.3.1 Preparation of muck based ceramics

First, the muck、 sludge and straw were grinded, screening followed by 100 mesh sieve and sealed preservation; followed by screening the raw materials by a certain proportion of the mixture evenly mixed with water mixing system in the slurry; then the mixed slurry was granulated into the ball with granulator, and the raw material balls were putted into the constant temperature blast drying oven for more than 4h; finally, the dried material balls were placed in a box resistance furnace and heated from room temperature to 400℃ at a heating rate of 8℃/min for 20 minute and then heated to 1150℃-1200℃ at a heating rate of 108℃/min, roasting 15minute, sintered ceramic placed in a fume hood naturally cooling to room temperature and sieving, that was lightweight muck based ceramics.
2.3.2 Physical properties of muck based ceramics

The packing density, apparent density, cylinder pressure, water absorption in 1h and loss of muck based ceramics were determined according to 《Lightweight Aggregate and Its Test Methods》(GB / T17431.2-2010).

3. Results

3.1 The effect of raw materials on packing density of muck based ceramics

The figure**1 (a)** shows that the curve **A** for the effect of the amount of fly ash on packing density of the muck-fly ash based ceramics; and curve **B** shows the effect of the amount of fly ash on packing density of the muck-fly ash-straw based ceramics, maintaining the same amount of muck and fly ash at the same time; the fig.**1 (b)** shows the influence of the sludge content on packing density of muck-sludge based ceramics.

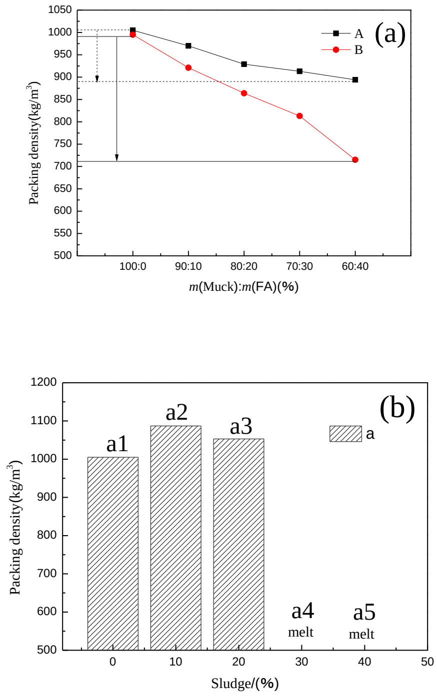

Fig.1 The effect of raw materials on packing density of muck based ceramics

The curve A shows that the packing density of muck based ceramics has a decreasing trend with the increase of the amount of fly ash; when the content of fly ash is 40%, the muck based ceramics can reach 900 density level, this phenomenon may be due to the addition of fly ash to increase the skeleton of ceramic components, along with the extension of the calcination time, the external skeleton component gradually presents the viscosity and the internal expansion of the gas effectively wrapped; when the internal gas is larger than the external skeleton binding force, the ceramic volume gradually expands, and the packing density of muck based ceramics decreases. Therefore, the incorporation of a certain percentage of fly ash in the muck can be prepared to meet the requirements of muck based ceramics.

The curve B shows that the packing density of muck based ceramics prepared by the composite straw decreases with the increase of fly ash content, but the experimental results show that the fired ceramic grain shrinkage ratio is large and the grain size should not be controlled. This phenomenon may be due to the production of straw under low temperature conditions more, ceramic surface has not been able to produce sufficient liquid viscosity, the gas cannot be fully wrapped, resulting in most of the gas from the ceramic due to escape under low temperature, this is also the important reason caused by the curve B in the mixed with straw after the decline in the packing density of muck based ceramics is larger than the A curve, so that it is not recommended mixed with straw.

The figure 1(b) shows that when the sludge content is less than 20%, the density levels of ceramic which are produced is higher than 1000; when the sludge content is more than 20%, muck based ceramics may be melted, this phenomenon may be due to the incorporation of sludge to increase the flux of ceramic components, making the muck based ceramics is too sensitive to temperature, the sintering interval becomes narrow, it is not recommended to add sludge.

3.2 The effect of calcination temperature on packing density of muck based ceramics

Figure **2** shows the effect of calcination temperature on packing density of muck based ceramics, the curve **C** shows the effect on packing density of muck based ceramics with the ratio of raw materials in the calcination temperature of 1150 ℃, the curve **D** shows the effect on packing density of muck based ceramics with the ratio of raw materials in the optimum calcination temperature.

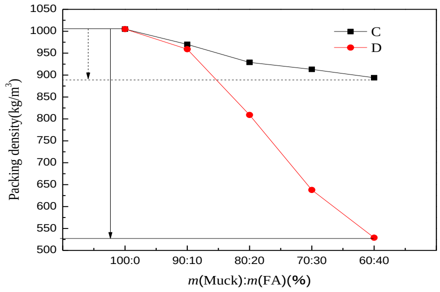

Fig.2 The effect of calcination temperature on packing density of muck based ceramics

It can be seen from the figure **2**, the packing density of muck based ceramics in the same proportion of curve **D** is significantly lower than that of the curve C. In the curve **C**, the calcination temperature is 1150 ℃, the packing density of muck based ceramics has a tendency to decrease with the increase of the amount of fly ash; when the content of fly ash is less than 40%, the packing density of muck based ceramics is more than 900kg/m^3; While the content of fly ash is 40%, the packing density of muck based ceramics is 894kg/m^3. In the curve **D**, the optimum firing temperature was selected and the other sintering conditions remained unchanged, the packing density of muck based ceramics in the same proportion of the curve **D** is significantly lower than that of the curve **C**. When m(muck):m(fly ash)=60:40,the packing density of muck based ceramics is 529 kg/m^3, which is 600 density level. This phenomenon may be due to the ceramic gas production components gradually release sufficient expansion of gas with the increasing of calcination temperature and time, the outer skeleton component gradually show viscosity and the internal expansion of gas is effective packaged at the same time, when the internal gas is greater than the external framework of the binding force, the volume of muck based ceramics is gradually expanded, resulting in a decline in packing density of muck based ceramics.

3.3 The effect of mixing ratio on packing density of muck based ceramics

The figure **3** shows that the effect of mixing ratio on packing density of muck based ceramics in the optimum calcination temperature; the packing density of muck based ceramics has a decreasing trend with the increase of the amount of fly ash.

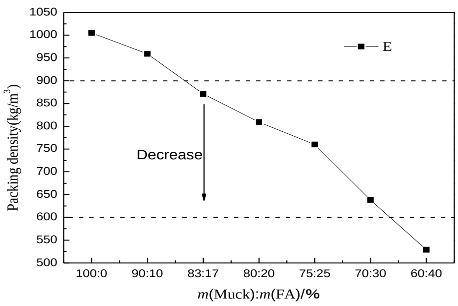

Fig.3 The effect of mixing ratio on packing density of muck based ceramics

When m(muck):m(fly ash)= 90:10, the packing density of muck based ceramics is 959kg/m^3; When m(muck):m(fly ash)= 80:20, the packing density of muck based ceramics is 819kg/m^3; When m(muck):m(fly ash)= 70:30, the packing density of muck based ceramics is 638kg/m^3; it can be seen that the packing density of muck based ceramics has a decreasing trend with the increase of the amount of fly ash, it is deduced that the ratio of m(slag): m(fly ash) is between 90:10-70:30, the muck based ceramics with the density of 700-900 maybe prepared; and when the content of fly ash is higher than 30%, the sludge bulk density is less than 700 kg/m^3, to adjust to the optimize ratio, when m(muck):m(fly ash)= 83:17, the packing density of muck based ceramics is 871kg/m^3, when m(muck):m(fly ash)= 75:25, the packing density of muck based ceramics. Therefore, when the content of fly ash in the ball is 70%-83%, and the content of fly ash is 17%-30%, the muck based ceramics with the density of 700-900 can be prepared.

3.4 Physical properties of muck based ceramics

The optimum firing process is determined by studying the influence of raw materials, calcination temperature and mixing ratio on the packing density of muck based ceramics. As shown in the fig 4, the results show that the optimum size of muck based ceramics is 15-25mm and the density levels are 700、800 and 900.

The physical properties of prepared muck based ceramics which are in accordance with the claim in 《Lightweight Aggregates and Their Test Methods》(GB/T17431.1-2010) are shown in the table 4.

Fig.4-1

Fig.4-2

Fig.4-3

Fig.4 Muck based ceramics

(The density level of muck based ceramics in fig.**4-1** is 700、The density level of muck based ceramics in fig.**4-2** is 800、The density level of muck based ceramics in fig.**4-3** is 900)

Tab.4 Physical properties of muck based ceramics

***m*(muck):*m*(fly ash)**	**Packing density kg/m³**	**Density level**	**Water absorption /%**	**Cylinder pressure / MPa**	**Loss /%**
83:17	871	900	1.7	6.5	1.53
75:25	760	800	1.7	4.6	1.14
70:30	638	700	2.0	4.3	1.61

4. Conclusions and prospects

The muck based ceramics for 700-900 density levels which are light brown with smooth surface and intact enamel layer, and the interior is loose and porous could be produced when the content of fly ash is 70%-83% and the content of fly ash is 17%-30%, the calcination temperature is 1170℃-1200℃; and the physical properties of prepared muck based ceramics are in accordance with the claim in 《Lightweight Aggregates and Their Test Methods》(GB / T17431.1-2010).

It is technically feasible to produce light weight and high strength ceramic by using muck and waste fly ash, the popularization and application of this technique is beneficial to turning waste into treasure and protecting the environment, and promoting the sustainable development of economy. At the same time, a new way of preparation of lightweight and high-strength ceramic is explored, which decreases the consumption of natural mineral resources such as clay and has good economic, social and environmental benefits.

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