ARTICLE

Preparation and Performance of Novel Functional Shield Residues-Based Unburned and Non-Autoclaved Ceramsite

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ABSTRACT

With the continuous expansion of city rail transit construction, the amount of shield residues was increased and caused serious threat to the city image and water quality. In this work, unburned and non-autoclaved ceramsite as well as colour ceramsite were prepared by using shield residues as raw material. The results showed that the water absorption rate of prepared ceramsite was about 30 % and better than that of commercially available sintering ceramsite. The methylene blue solution adsorption effect of prepared ceramsite was also better than sintering ceramsite. The cylinder pressure strength of the prepared ceramsite was about 1.5 MPa and bulk density of prepared ceramsite was about 0.827 g/cm^3. After soaking the prepared ceramsite was still not cracked, this was suitable for cultivation as bonsai. The unburned and non-autoclaved ceramsite can effectively solidify shield residue, which can avoid the pollution of water quality and also provide a new way for good use of shield residue for energy saving and environmental protection.

KEYWORDS

Shield residues, Unburned and non-autoclaved ceramsite, Adsorption, Cylinder pressure strength.

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INTRODUCTION

With the continuous expansion of city rail transit construction, the large amount of shield residues caused serious threat to the city such as occupying cultivated land, water pollution, blocking the river, the sand dust, *etc.*, developing resource utilization of shield residues in the generating process of rail traffic engineering construction is an important way to reduce the pressure of city environment and save resources. Tian and Li [1] used alkaline muck for padding sinkage in industrial area in Tang Shan. This method has significant economic benefits, but not overcome the environmental impact of waste muck.

In recent years, researchers did a lot of works about ceramsite production by using wastes. Hou and Wang [2] used sludge, slag and clay to prepare sintering ceramsite. Research showed the haydite has certain adsorption effect. Wang *et al.* [3] prepared water treatment ceramsite through high temperature roasting used the lead-zinc flotation tailings as raw material and showed that the removal rate of COD can reach 88.21 %. The sintering ceramsite exist defects such as large energy consumption and low yield. Zhang *et al.* [4] prepared sintering-inflating ceramsite used building muck. The ceramsite had some advantage such as lightweight, heat preservation and heat insulation effect. However, this way also exist disadvantage, such as large energy consumption and the utilization of solid waste was not high.

Unburned and non-autoclaved ceramsite is an artificial light weight aggregate which do not require high temperature roasting, using the activity of solid wastes as the main material. Then, adding some cementation material and other additives, after that, making the granulation into a ball, finally, using some means of curing to prepare it [5]. These materials have the unique property of acid and alkali resistance, durability and corrosion resistance which sintering ceramsite can not to achieve. Because of high density and strength can be adjusted by gelled material, activator and maintenance way to meet the design requirements [6-11]. Therefore, high strength ceramsite can be prepared used unburned ceramsite and roasting ceramsite is difficult to achieve. Ordinary ceramsite do not need high strength and small density [12], so that unburned ceramsite is most suitable for production of ordinary ceramsite. Gardening ceramsite must have rich in organic matter and the performance of high water absorption, but any organic matter in roasting ceramsite will burn out at high temperature, unburned ceramsite can avoid this kind of situation and the water adsorption rate of unburned ceramsite is higher than roasting ceramsite. In addition, the colour decorative ceramsite require colourful, which only the unburned ceramsite can achieve.

In this work, unburned and non-autoclaved ceramsite was successfully achieved. The cylinder pressure strength of the ceramsite is about 1.5 MPa. The bulk density is about 0.827 g/cm^3. The colourful ceramsite also was obtained. Compared with sintering ceramsite, absorption effect was studied.

EXPERIMENTAL

The ceramsites were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM) and flame atomic absorption spectrometer (WFX-1E2). XRD patterns were obtained with a diffractometer (Bruker D8Advance XRD, λ = 1.5418 Å, power = 3000 W) using CuK$_\alpha$ radiation. A SEM (JOEL, JSM-7500F) was used to observe the surface state and structure of the samples. Light weight bearing cylinder was used to measure the strength of the ceramsites. Air ion counter (AIC-2000) was used to show the ability of the ceramsites to release negative ions.

Preparation of unburned and non-autoclaved ceramsite: First, the dry shield residues which has been grinded was sieved by molecular sieve, the pore size was 0.6 mm, Then, different amount of cement, agglomerate and curing agent were added into above shield residues according to different ratio. After that, they were evenly stirred. In the next moment, different amount of sodium silicate and sodium sulfate were added into 18 mL deionized water and they were stirred at 30-40 °C on magnetic stirrer until sodium silicate and sodium sulfate were completely dissolved. The next step was that the residues which have been evenly stirred were added into above mixed solution and they were stirred again until clay was completely wet. Last, spherical ceramsite was obtained, stand for 30 min, water were added for curing. Fig. 1 was the flow chart of the preparation of unburned non-autoclaved ceramsite. Table-1 was the optimum mixture ratio of the unburned and non-autoclaved ceramsite by observing cracking desquamate phenomenon of the ceramsite. Take prepared ceramsite into a certain amount of iron oxide red and iron oxide green respectively, after shake constantly, colour ceramsite (Fig. 2) was prepared.

Ceramsite adsorption experiments: A certain quantity of sintering ceramsite and unburned and non-autoclaved ceramsite were took into two small beaker respectively, ceramsites were soak into water for 5 min. Then, ceramsites were took out

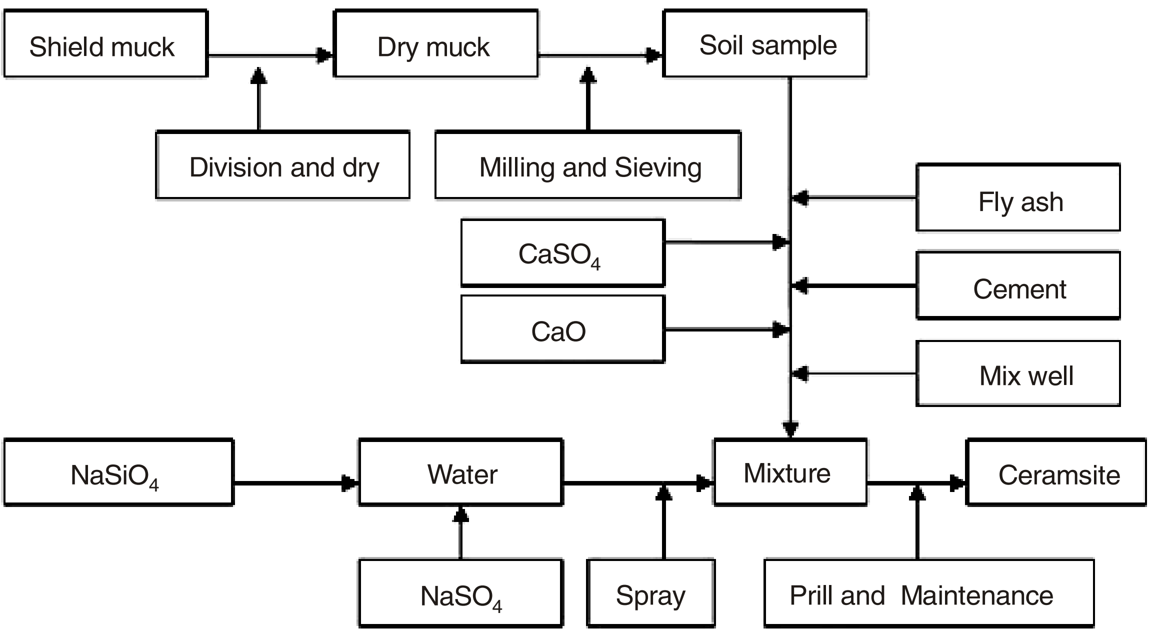

Fig. 1. Flow chart of the preparation of unburnt non-autoclaved ceramsite

TABLE-1
OPTIMUM MIXTURE RATIO

Composition	Content (%)	Composition	Content (%)
Shield residues	70-80	Fly ash	6
Cement	6-13	Tourmaline	6-13
Calcium oxide	2-7	Sodium silicate	2-7
Calcium sulphate	4-9	Sodium sulfate	4-9

Fig. 2. Colour of the unburned and non-autoclaved ceramsite

and water on the surface was rubbed away. Next, ceramsites were put respectively into the methylene blue solution; 3 mL sample solution was extracted used syringe every 30 min. Finally, spectrophotometer was used to measure the concentration of methylene blue solution and the data was recorded.

RESULTS AND DISCUSSION

Flame atomic absorption spectrophotometer was used to determine the content of heavy metal ions in aqueous solution of shield residues. Table-2 was metal elements content in the residue in the samples. According to the state soil environment quality standard (GB15618-2008), Table-2 showed that the heavy metal did not exceed bid in the shield residues and it was safe to use in real life. SEM was used to study the residue in the surface topography. Fig. 3 showed that cementing among particles on the residue surface was inadequate and the porosity was larger.

Fig. 4 showed that ceramsite did not produce dust in dry state. After bubble water test, ceramsite did not collapse or produce mud. Compared to the SEM of shield residues, Fig. 5 showed that prepared ceramsite had internal formed network structure which made the soil solidified and pore are abundant.

TABLE-2
METAL ELEMENTS CONTENT IN THE RESIDUE IN THE SAMPLES

Element	Content (mg/kg)	Element	Content (mg/kg)
Ba	451.8	Cu	35.7
Ni	19.0	Zn	55.7
V	52.5	Pb	33.6
Cr	56.3	Rb	83.9
Mn	724.8	Sr	133.1
Co	10.3	Zr	313.6

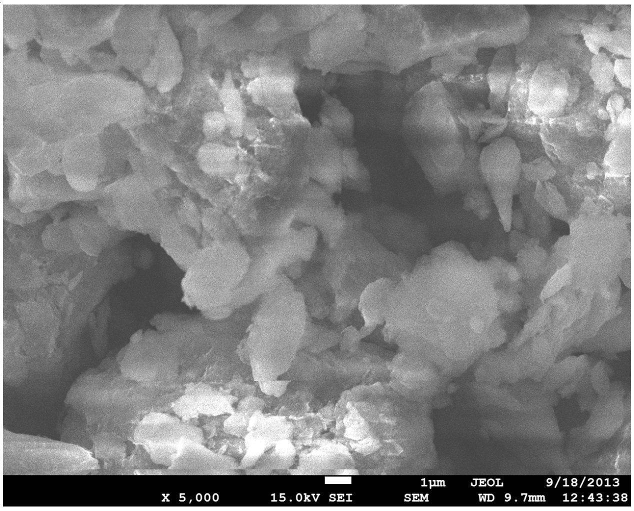

Fig. 3. SEM of shield residues

Fig. 4. Bubble water experiment and the appearance of unburned and non-autoclaved ceramsite

Fig. 6 was the XRD of the samples, it showed that the characteristic peak of quartz appeared in 2θ° equals 21.984°, 28.438° and 36.701° and 42.152° and 42.508° and 55.242° and 60.302° and 68.674°, the characteristic peak of montmorillonite appeared in the d (crystalline interplanar spacing) value of 1.0 nm and 0.358 nm and 1.8 nm, according to PDF CARDS, the samples were mainly composed of minerals such as quartz and montmorillonite.

Fig. 7 showed that sintering ceramsite and unburned and non-autoclaved ceramsite both had adsorption capacity, but unburned and non-autoclaved ceramsite ceramsite was about

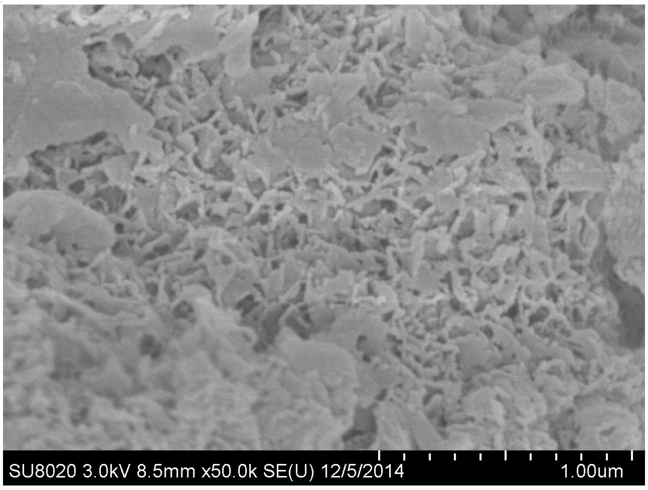

Fig. 5. SEM of unburned and non-autoclaved ceramsite

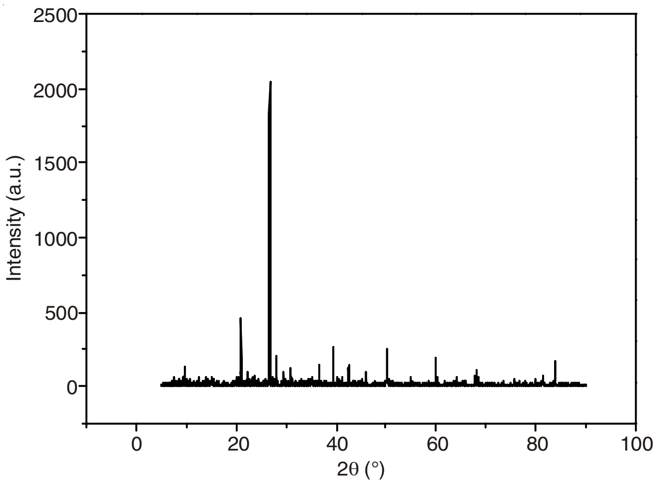

Fig. 6. XRD of the samples

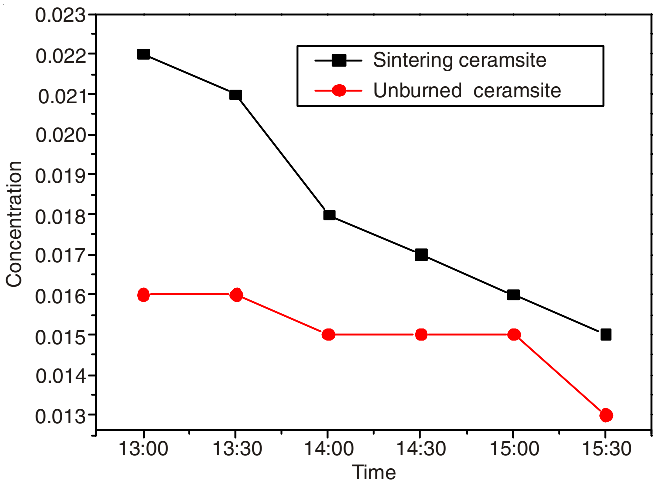

Fig. 7. Trend of methylene blue solution concentration change over time

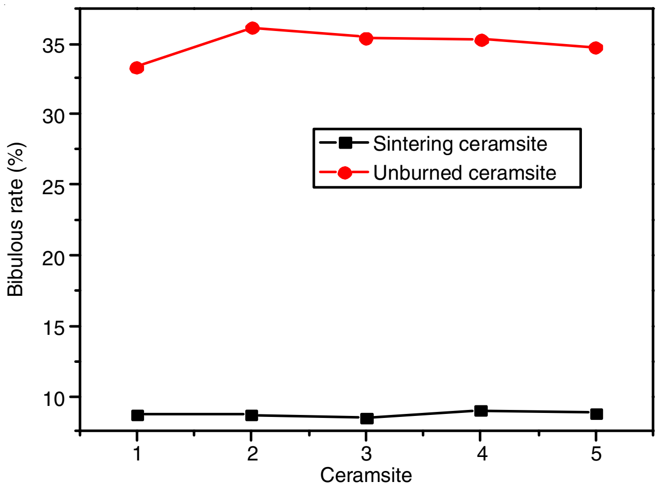

Fig. 8. Bibulous rate of sintering ceramsite and unburned ceramsite

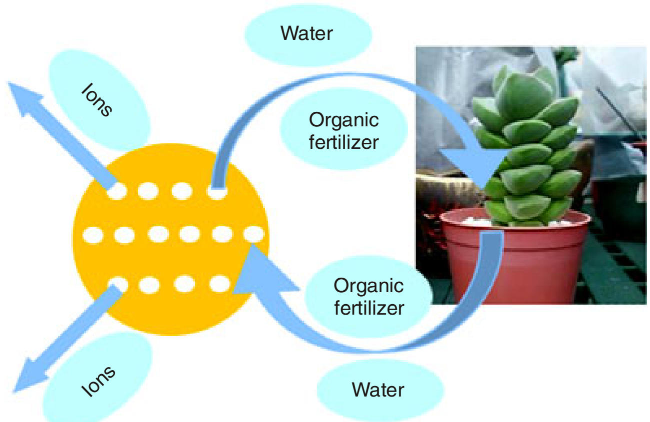

Fig. 9. Pictorial representation of ceramsite as flower cultivation substrate

30 % and better than that of commercially available sintering ceramsite. This may be caused by much porosity which was prepared by water evaporation. Higher water impoundment of unburned ceramsite can keep flower pot adobe moist all the time and released water when no watering which was conducive to the growth of flowers and trees. Thus it provided possibility for application in gardening ceramsite (Fig. 9).

Fig. 10 showed that the strength increased with curing time. This is caused by hydration reaction of fly ash and cement at room temperature is a quite long, the strength of gelled material increased with curing time. Fig. 11 showed that the strength increased with curing temperature. The higher temperature promoted the hydrolysis which in alkaline of vitreous in fly ash, so that to release active substances, especially the bead body, its surface with a layer of dense oxide film which is difficult to be destroyed at room temperature. The cylinder pressure strength of the ceramsite is above 1.5 MPa at the optimum mixture ratio. These performance can completely satisfy the requirements in volume weight of gardening ceramsite [12] and decorative ceramsite. In addition, changing the way of curing, formula ratio to improve the strength, it will be reported in subsequent papers. Different quality of ceramsite and air ion counter was used to show the ability of the ceramsites to release negative ions. Table-3 showed that the ceramsites have a higher release of negative ions and more ceramsites more ions, the person feels more comfortable.

Conclusion

Unburned and non-autoclaved ceramsite was successfully achieved by using shield residues. The ceramsite has adsorption effect and the effect was obvious; the ceramsite had good hydroscopicity. The water absorption rate was around 30 %, about 10 % higher than that of commercially available sintering

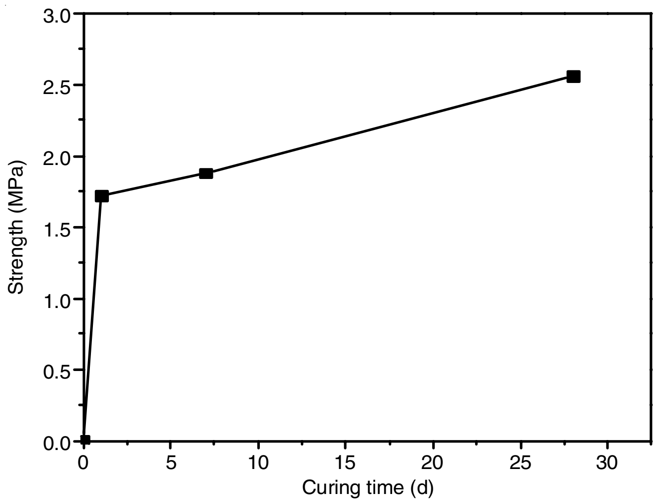

Fig. 10. Relationship of curing time and strength (temperature = 20 °C)

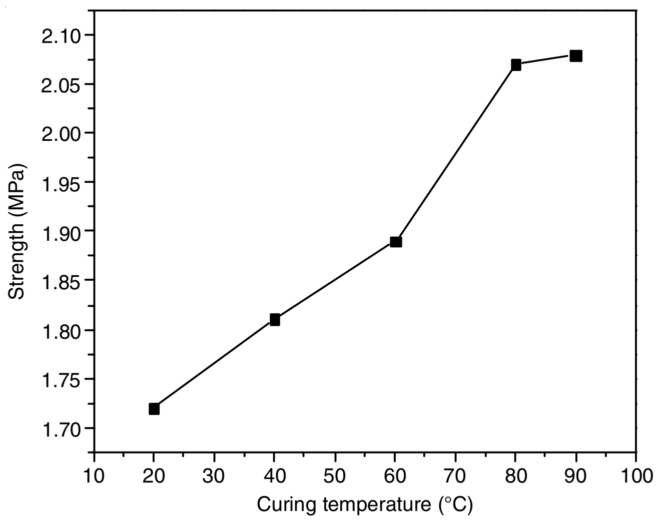

Fig. 11. Relationship of curing temperature and strength (curing time = 1 d)

TABLE-3
ABILITY TO RELEASE NEGATIVE IONS

Quality of ceramsite (g)	Number of negative ions (1000 ions/cm^3)	
	Static range	Static maximum
10	10.9	9.2-10.4
20	13.4	9.9-12.2
30	18.7	13.3-17.6
40	20.1	17.8-19.3

ceramsite. The cylinder compressive strength of unburned and non-autoclaved ceramsite was higher than 1.5 MPa. This study showed that shield residues-based unburned and non-autoclaved ceramsite was not only disposed Shield residues in safety and environmental way, but also provided possibility for application in gardening ceramsite and decorative ceramsite.

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