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Co-sintering oyster shell with hazardous steel fly ash and harbor sediment into construction materials

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HIGHLIGHTS

- Proper amount of oyster shell could help sintering mixed wastes into LWAs.
- Cd, Se, Cr, Pb, As, Ag, Cu and Ba are much less leached from wastes after sintering.
- Over-addition of oyster shell in mixed wastes produces LWAs with higher density.

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ABSTRACT

Oyster shell is used to partially replace steel fly ash in the mixture of harbor sediment and steel fly ash for preparing lightweight aggregates, aiming to both prepare LWAs at temperatures lower than what usually employed and solve the disposal problem of oyster shell. The replacement percentages are 5%, 10%, and 15%. The mixtures are pressurized into pellets and sintered at 1050–1130 °C/1150 °C for 10 min. Heavy metal leaching from the sintered pellets is dramatically reduced as compared to raw materials. Leaching results of toxic metals, including Cd, Se, Cr, Pb, As, Ag, Cu, and Ba, well meet government's environmental legal limits. An increase in sintering temperature from 1000 °C to 1130 °C/1150 °C always reduces the leaching level. Sintered at ≥1050 °C, all pellet particle densities, except the one not containing oyster shell sintered at 1050 °C, meet the practical particle density requirement as lightweight aggregate, <1.6 g/cm^3, for construction sector. Oyster shell amendment generally results in lower particle density with the 5% amendment resulting in the least particle density. Over-replacement of steel fly ash with oyster shell leads to an increase in particle density due to partial melting. Moreover, 24-h water sorption rate of all lightweight aggregates also meets the requirement abided by practical construction sector, <18–20%.

1. Introduction

Lightweight aggregates (LWA) have wide application in various fields [1,2]. In civil engineering, they can be used in room partition, road pavement, parking lot surface, and others. In environmental engineering, bacteria in waste water treatment facility can be grown and fixed on their surface in a dispersive manner. In soil engineering and horticulture, due to the richness in pores they can be used for holding water [1,2]. LWAs with low density and water absorption rate, respectively, are desired to reduce construction objects' deadweight and to promote the workability of LWA-containing mortar [3]. The use of naturally occurring LWAs, such as volcanic ash and pumice stone, in construction sector can be dated back to Babylonian era, about five thousand years ago. Recently, man-made LWAs via high-temperature sintering have increasingly replaced natural LWAs [1,4]. To prepare LWAs from clay with sintering, Riley summarized proper clay compositions in ternary oxide groups, namely flux, SiO_2, and Al_2O_3, with their respective weight percentages being 3–12%, 48–70% and 8–25% [4,5]. The flux group is defined as the weight sum of iron oxides, alkali oxides, and alkali earth oxides [4]. To minimize the environmental impact of clay mining, various wastes have nowadays been studied in an attempt to prepare LWAs following Riley's ternary compositional criterion [1,5–15].

Abbreviations: EPA, Environmental Protection Administration; FAAS, flame atomic absorption spectrometer; IC, ion chromatographer; ICP/AES, inductively coupled plasma/atomic emission spectroscope; LOI, loss on ignition; LWA, lightweight aggregate; SEM, scanning electron microscope; TCLP, toxicity characteristic leaching procedure; XRD, X-ray diffraction.

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For ship navigation safety in harbors, some Taiwan's harbors are regularly dredged to keep navigation routes clear at certain minimum depth. Most of the dredged sediment is currently subjected to offshore dumping. In fact, the harbor sediment is fine in particle size and well suitable for recycling into construction materials through high-temperature sintering [10,12]. On the other hand, steel fly ashes have been blamed as a culprit for poisoning ducks and eggs with toxic and dioxins/furans, resulting from illegal dumping and stack emission nearby poultry farm. It has previously been shown that high-temperature sintering process can effectively de-toxify steel flay ash [12]. After sintering, organic contaminants including dioxins/furans present in raw materials were readily destroyed and toxic metals were stabilized to negligible leaching levels, thus well meeting official regulatory limits [12].

$CaCO_3$ addition is effective in bringing down sintering temperature of coal fly ash [16]. For the five flux components as defined by Riley in his ternary component diagram, CaO is of the lowest price; however, mining limestone is environment unfriendly and it is worthy to find Ca-containing wastes as limestone replacement. Oyster is an important aquaculture crop in Taiwan, and the resulting oyster shell waste is of great environmental concerns. Annual output of oyster shell in Taiwan is approximately twenty five thousand tons. Calcium carbonate represents approximately 95 wt% content of oyster shell. It decomposes at a notable rate when being heated to above 800 °C, generating CO_2 and CaO. Annual CaO production rate worldwide is approximately 300 million tons. It is mainly used in steelmaking process to chemically remove the impurities, mainly Si and Al oxides, as molten slag at elevated temperatures. However, the use of oyster shell to replace fractional $CaCO_3$ in steel and cement industries is limited because of the practical concerns that it might contains impurities, like Na, K, and Cl, that could be harmful to steel product due to corrosion.

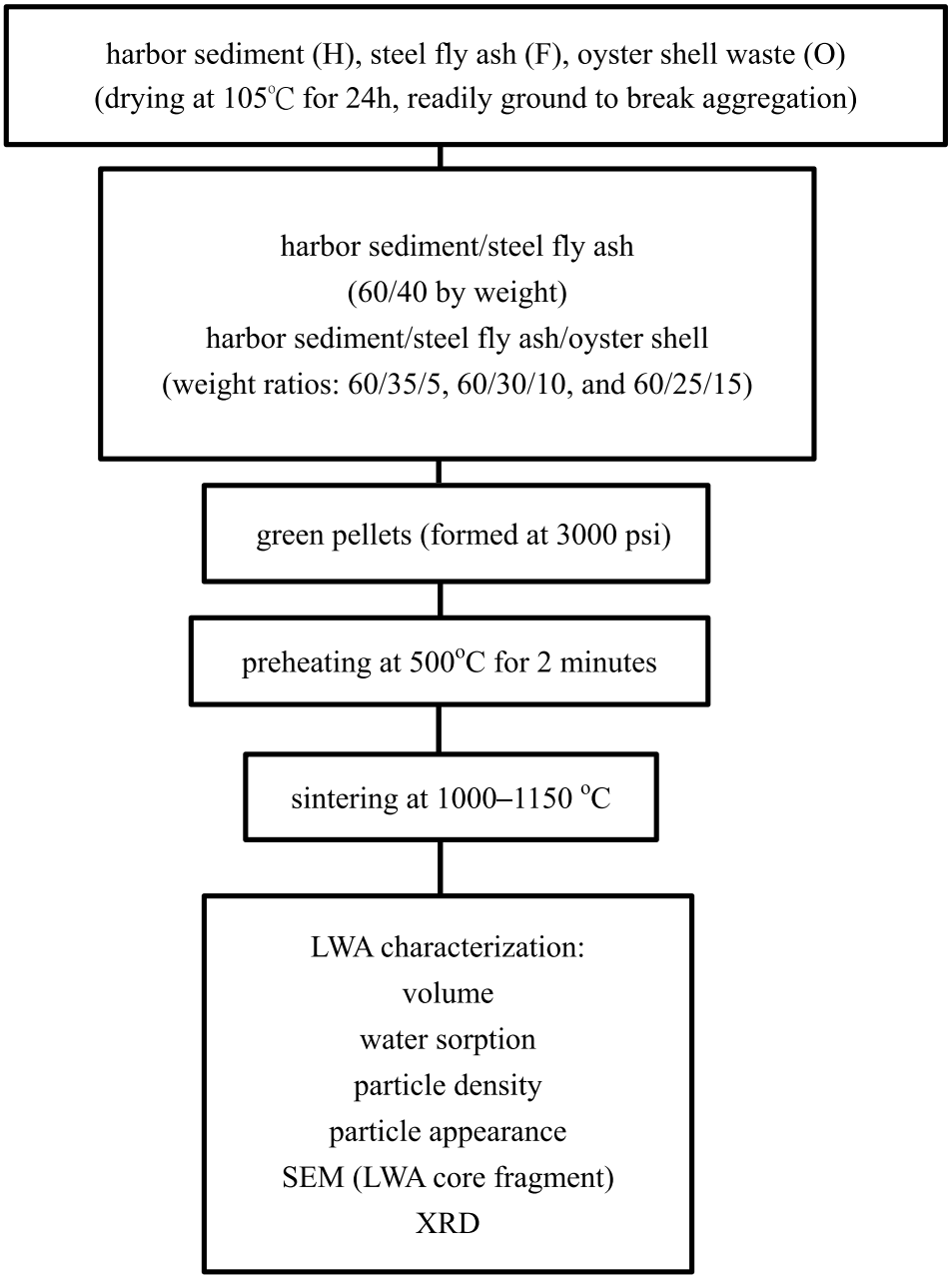

Fig. 1. Experimental flowchart.