Incorporation of electrodialytically treated MSWI fly ash in sintered clay brick

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The feasibility of incorporation of municipal solid waste incineration fly ash into clay bricks was studied. Yellow clay is commonly used in Denmark for production of building bricks. The fly ash-clay bricks with 5%, 10% and 20% ash substitution levels were handmade and fired at 1000 °C for 6 h. The fired fly ash bricks had higher porosity and lower compressive strength, compared to the 100% yellow clay brick, although washing-electrodialysis treatment improved the properties of the fired ash bricks. It may indicate MSWI fly ash could be fit for yellow clay replacement only at very low substitution ratio (< 5%). Otherwise, to make MSWI fly ash bricks with good quality and high ash substitution, other additives might be needed to balance the constituents in the raw material mixtures, such as CaO-SiO_2-Al_2O_3 system. Or the conditions for sintering need to be changed, such as increasing the sintering temperature.

Introduction

Fly ash generated from municipal solid waste incineration (MSWI) is a hazardous material. In Denmark, MSWI fly ash is currently exported to Norway for waste acid neutralization and to Germany for salt mines backfilling (Astrup, 2008). With regards to treatment of MSWI fly ash, there are techniques such as washing (Mangialardi, 2003), chemical stabilization (Youcai et al., 2002), thermal treatment (Park and Heo, 2002) as well as electrodialytic remediation (EDR) (Jensen et al., 2015). As for EDR, an electric DC field is applied to the ash-water suspension and, mobile heavy metals in the suspended MSWI fly ash electromigrate toward either the anode or cathode through ion exchange membranes, therefore achieving heavy metal extraction. Ferreira et al. (2008) combined washing pre-treatment with EDR, and observed that the combination of washing and EDR was successful in reducing the environmental risk of the MSWI fly ash, because the metals (Cd, Cu, Pb and Zn) were mainly found in the strongly bonded and residual phases after the treatment. Electrodialytically treated MSWI air pollution control residue has been investigated as a cement substitute in mortar (Kirkelund et al., 2014), and it shows that EDR could be a pre-treatment method prior to the ash reuse in mortar. Besides, MSWI fly ash showed potential of being a substitute of clay in brick production (Zhang, 2013), but the electrodialytically treated MSWI fly ash has not yet been studied in clay brick production. In this study fired clay bricks with different EDR-treated ash contents (5%, 10% and 20%) were made, characterized in terms of water absorption, density, open porosity, compressive strength and leaching of heavy metals, and compared with 100% clay brick and the brick made from raw MSWI fly ash at 20% substitution rate. The feasibility of incorporation of electrodialytically treated MSWI fly ash in production of sintered clay brick was investigated.

Methods

The materials used for brick production were yellow clay (relatively higher $CaCO_3$ content compared with iron), raw MSWI fly ash, and MSWI fly ash treated by EDR at room temperature. It is noteworthy that the raw MSWI fly ash was water washed at liquid-to-solid ratio of 15 prior to the EDR treatment. The bricks were handmade, and the overall process included mixing of raw materials (‘*C*’: 100wt.% clay; ‘*R20*’: 20wt.% raw ash and 80wt.% clay; EDR-treated ash (‘*T5*’: 5wt.%, ‘*T10*’: 10wt.% and ‘*T20*’: 20wt.%) and corresponding quantity of clay) with water (water content of green brick 23-26wt.%), moulding (5 cm × 5 cm × 5 cm), drying (first at 40 °C for 24 h and subsequently at 105 °C for 24 h), and firing (heating rate 10 °C/min; maintaining at 200 °C for 999 min to make sure water was removed from green brick; increasing to the maximum temperature 1000 °C and sintering for 6 h). After sintering, the bricks were allowed to cool down naturally in the furnace to room temperature. The fired bricks were characterized afterwards.

Findings and discussion

Such results as appearance, mass loss, shrinkage, bulk density, water absorption, apparent porosity and compressive strength are compared among the different ash substitutions. Manual preparation of the green bricks caused irregular surfaces, as appeared in the fired bricks. The fired bricks showed yellow-based colours, but were different in the shades of yellow. The shade became growingly lighter with increasing ash content, and the lightest was the brick with untreated ash (R20). It is also observed that only in the case of brick R20 the surface was fluffy, and particles peeled off from the surface, which was most likely ascribed to the presence of a great amount of soluble salts in the untreated MSWI fly ash.

The bulk density of the bricks (Fig. 1A) varied from 1.44 to 1.65 g/cm^3, which is lower than the bulk density of normal clay bricks (1.8-2.0 g/cm^3) (Lin, 2006). Water absorption (Fig. 1B) was between 24.5% and 33.7%. The high water absorption and low density is closely related to the porosity of the bricks. The apparent porosity (Fig. 1C) was higher than 40% for all the bricks. Incorporation of MSWI fly ash reduced the density of bricks and increased the water absorption and porosity when the bricks were sintered at 1000 °C, and all of these changes directly affected the engineering property of the bricks. Fig. 1E shows the compressive strength results. When applying handmaking process, only the clay bricks met the minimum compressive strength requirement for building bricks i.e. 10.3 MPa, and the fly ash bricks did not meet the specifications for building bricks in accordance with ASTM C62-13a, although the fly ash bricks showed total shrinkage no more than 8% during drying and firing, and weight loss less than 15% during firing (Fig. 1D).

The function of the washing-EDR treatment is worthy to be affirmed. Compared to the untreated fly ash, the treated ash did improve the compressive strength of the bricks having the same substitution rate. The leaching of heavy metals from the fired fly ash bricks will be discussed as well.

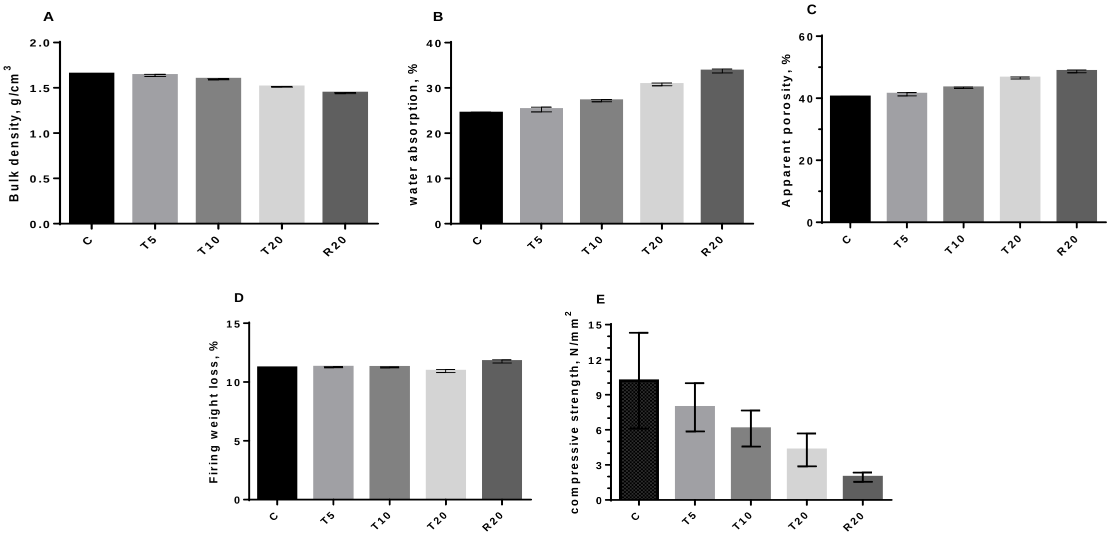

Figure 1: Properties of the fired bricks.

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