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Properties of partition wall blocks prepared with high percentages of recycled clay brick after exposure to elevated temperatures

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HIGHLIGHTS

- High temperature properties of concrete blocks made with clay brick aggregate (CBA) were examined.
- At 300 °C, the nature of CBA origin made the concrete blocks stronger/more stiff.
- At 800 °C, a higher percentage of CBA used enabled a higher residual flexural strength.
- At 800 °C, CBA blocks retained about 48–91% of their original (20 °C) compressive strength.

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ABSTRACT

High temperature properties of partition wall concrete blocks prepared with recycled clay brick aggregate derived from construction and demolition (C&D) waste streams (e.g. collapsed masonry after an earthquake) were studied. For this purpose three series of concrete block mixes were designed using coarse and fine clay brick aggregate to replace recycled concrete aggregate and sand at percentages of 25%, 50% 75% and 100%. The residual density, mass loss, compressive and flexural strengths after exposure to elevated temperatures of 300 °C, 500 °C and 800 °C were determined. The results demonstrated that selection of an appropriate replacement for both coarse and fine clay brick aggregates can lead to better performance of the blocks at elevated temperatures. It is expected therefore that there will be significant advantages in terms of sustainability and fire safety by adopting this inherent fire-resistant material in concrete blocks especially for low rise residential developments.

1. Introduction

A huge quantity of construction and demolition (C&D) waste, which constitutes a major portion of the total solid waste stream, is generated every day [1]. The C&D waste includes, but is not limited to, demolished concrete, bricks, masonry, wood, steel, plaster, etc. According to a study by Xiao et al. [2] who reported that in the 2008 Sichuan earthquake about 382 million tonnes of construction waste derived mainly from collapsed buildings was generated. Most recently, a 6.6-magnitude earthquake hit Ya'an city, Sichuan Province on 2013 April 20, killing at least 192 people and injuring thousands [3]. It has been estimated that 90% of all houses in the Ya'an area collapsed due to this earthquake [3], resulting in huge quantities of waste. The nature of waste generated by earthquakes in China has created a great challenge in its disposal and its impact on the environment has also drawn considerable attention.

For the past few decades, systematic management systems and methods of recycling the C&D waste have been extensively discussed in the literature [4–7]. Among them, it is commonly accepted that recycling and reuse of C&D waste as an alternative aggregate in construction is one of the most economic and environmentally friendly ways of managing the waste. In addition to the environmental benefits in reducing the demand for land in which to dispose of the C&D waste, the recycled aggregates derived from the waste can also help to conserve natural materials.

A large number of studies has focused on reusing recycled concrete aggregate (RCA) to produce new concrete. The potential benefits and shortcomings of using RCA have been well researched [8–12]. Partial replacements of natural aggregates by RCA (30% or less) in concrete do not jeopardize the mechanical properties [9]. However, it is generally agreed that the compressive strength of

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concrete gradually decreases as the amount of RCA increases [10]. Furthermore, the high water absorption properties of recycled fine aggregate significantly affect durability by inducing excessive shrinkage problems in concrete [11,12]. The above mentioned drawbacks therefore restrict the use of recycled fine aggregate in concrete and limit the amount of RCA that can be used for structural concrete.

In comparison to wet-mixed conventional concrete, a number of studies [13–16] has demonstrated that it is feasible to incorporate up to 100% RCA as coarse and fine aggregates for the production of non-structural precast concrete blocks using a dry-mixed approach. This is probably due to the use of a combination of vibration and compaction forces in the dry-mixed production process that could improve the density (packing) and the quality of the concrete products produced.

A preliminary study was conducted to investigate the influence of the incorporation of crushed clay brick as a replacement for coarse RCA and natural sand on the properties of dry-mixed masonry partition wall blocks [16]. It was found that the hardened density and drying shrinkage of the blocks decreased with increase in the clay brick aggregate content. The overall results suggested that the replacement percentage of coarse aggregates by crushed clay brick should be controlled at less than 25%, while the replacement of natural sand by fine crushed clay brick should be within 50–75%.

As for building applications, masonry partition wall blocks prepared with recycled aggregates (RCA and clay brick aggregates) may be affected by fire. The aim of the present work is to study the properties of partition wall concrete blocks after being subjected to elevated temperatures of 300 °C, 500 °C and 800 °C. The residual high temperature properties (compressive and flexural strengths) and the total mass loss of concrete blocks prepared with coarse and fine crushed clay brick to replace recycled concrete aggregate and natural river sand at different (25%, 50%, 75% and 100%) ratios were examined.

2. Experimental details

2.1. Materials

The cementitious material used in this work was an ASTM type 1 ordinary Portland cement (OPC) with a density of 3160 kg/m^3. The recycled concrete aggregate (RCA) used was obtained from a recycling facility located in Hong Kong. At the facility, crushed concrete rubble (from demolition projects) was crushed and processed to produce coarse recycled aggregate with particle sizes between 5 and 10 mm. Crushed clay brick originally from red bricks were produced by crushing and sieving them into two different particle sizes: 5–10 mm (coarse brick aggregate CBA) and <5 mm (fine brick aggregate FBA). River sand with a maximum size of 2.36 mm was used as the fine natural aggregate. All the aggregates used in this study were in air-dried condition. The physical properties of all coarse and fine aggregates were tested according to BS 882 (1992) and ASTM C128 and the results are presented in Table 1. The photographs and grading curves of these aggregates are shown in Figs. 1 and 2.

2.2. Partition wall block mix proportions

A total of three series of partition wall block mixtures were designed (see Table 2) and fabricated in the laboratory using a dry-mixed method described in our previous studies [16,17]. The block specimens produced aimed to meet the requirements stipulated by the BS 6073 (1981) specification for partition wall blocks. All the mixtures were proportioned with a fixed total aggregate/cement ratio of 11.5, and 65% of the total aggregate was fine aggregate (<5 mm). In each of the mix series, five different mix proportions were prepared.

Table 1
Properties of recycled coarse and fine aggregates.

Properties	Coarse aggregate		Fine aggregate	
	5–10 mm		<5 mm	<2.36 mm
	RCA	CBA	FBA	Sand
Density-SSD[a] (kg/m^3)	2366	2036	1839	2620
Density-oven-dry (kg/m^3)	2186	1764	1358	–
Water absorption (%)	8.22	15.43	35.56	0.88

[a] SSD – Saturated Surface Dry.

Fig. 1. Photographs of recycled and natural aggregates used in this study.

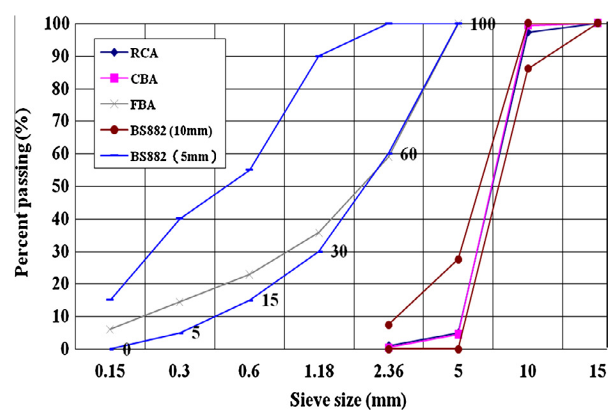

Fig. 2. Grading curves of recycled coarse and fine aggregates.

In Series 1 and 2, the influence of using crushed clay brick for sand replacement (fine aggregate) at 25%, 50%, 75% and 100% was examined. The coarse aggregates with RCA/CBA ratios of 3 and 1 were fixed in Series 1 and 2 respectively. For Series 3, the effect of using crushed clay brick as coarse aggregate was investigated with RCA being replaced by CBA at 25%, 50%, 75% and 100% by weight, while a fixed sand/FBA ratio of 1 was used (in fine aggregate). The details of the mix proportions are shown in Table 2.

Each concrete block was fabricated by applying a compaction stress of 25 N/mm^2 on the materials in steel moulds with internal dimensions of 200 × 100 × 60 mm. The fabricated block specimens were then covered with a plastic sheet and left at room temperature of 23 ± 3 °C and 75 ± 5% relative humidity (RH). After 1 day, they were demoulded and further cured (covered by a hemp bag to maintain a RH of over 90%) at room temperature of 23 ± 3 °C for at least 28 days before testing.

2.3. Heating temperature and testing

The specimens were heated to 300 °C, 500 °C and 800 °C separately. The heating rate was set at 2.5 °C per minute until the target temperature was reached and the respective maximum temperature was maintained for 4 h to ensure uniform temperature distribution throughout the specimens. The specimens were allowed to cool naturally to room temperature prior to testing.