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Effect of the constituents (asphalt, clay materials, floating particles and fines) of construction and demolition waste on the properties of recycled concretes

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HIGHLIGHTS

- The effect of the constituents of mixed recycled aggregate was studied.
- The workability of recycled concretes is similar to reference concrete (RC).
- The recycled concretes have lesser mechanical behaviour and higher sorptivity than RC.
- The organic constituents have more influence than the inorganic fraction on properties concretes.
- The recycled aggregate can be used by manufacturer concretes housing and other applications.

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ABSTRACT

The present study explores the viability of reusing mixed recycled aggregate from construction and demolition waste as a partial (25 and 50 wt%) replacement for natural coarse aggregate in the manufacture of concretes with a compressive strength of 30 MPa. It further analyses the effect of some of the constituents (asphalt, clay-based materials, floating particles and fines) of these recycled aggregates on the properties of recycled concretes. Despite the high asphalt and floating particle content of the recycled aggregate used, came from waste management plant at Glasgow, it was found to have no adverse effect on the workability of the new concretes. Hardened concrete density and compressive strength were observed to decline with increasing replacement ratios, at a variable rate depending on the components of the recycled aggregate mix and the thickness of their ITZs (the thicker the weaker). While concrete with 25% recycled aggregate exhibited lower sorptivity than the reference concrete, absorption was higher when the replacement ratio was 50%. The findings showed that this type of recycled aggregate can be used in concrete manufactured for housing applications and confirmed the importance of good construction and demolition waste management to deliver high quality recycled aggregate.

1. Introduction

Concrete is the construction industry's most popular material because of its mechanical properties, durability, cost effectiveness and availability. Concrete output in the European Union (EU-27) is estimated to be on the order of $1350 \cdot 10^9$ t/year [1].

Such a sizeable volume entails the consumption of vast amounts of natural resources (aggregate) that could be replaced by recycled materials such as aggregates from construction and demolition waste (C&DW). Approximately $3 \cdot 10^{12}$ tonnes of (coarse and fine) aggregate are produced yearly in the EU-27 [2].

Scotland's 9 million tonnes of C&DW account for over 44% of the country's total annual waste. At this time, 75% of Scots C&DW is reused. That value is higher than the European average (43%) but lower than found in countries (>80%) such as Netherlands, Denmark, Estonia and Germany [1]. Valorisation lowers the percentage of waste deposited in landfills, yields by-products that can be used as prime materials in construction, and furthers sustainable development by reducing CO_2 emissions and the exploitation of natural resources [3].

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C&DW is treated at specific plants (Fig. 1) where, after an initial inspection, it is subjected to a series of operations (initial screening, crushing, magnetic separation, manual separation of impurities, mechanical grinder, etc.) that may vary depending on the initial composition of the waste and the end product requirements.

Depending on its constituents, recycled aggregate (the end product) is divided in British standard BS 8500-2 [4] into two classes: recycled concrete aggregate (RCA), containing essentially crushed concrete ($\geqslant$95%), and mixed recycled aggregate (RA), comprising stone-based materials (such as concrete, bricks, roof tiles or asphalt), as well as organic (including wood, plastic and cardboard) and inorganic (metal and gypsum plaster) matter.

The volume of RCA generated yearly in Europe is smaller than the amount of RA [5]; in Spain, for instance, an estimated 67% of the total recycled aggregate is RA [6].

Recycled concrete aggregate has been the focus of countless research studies [7–10]. As a rule, the use of this material as a partial (<50%) replacement for natural coarse aggregate has been reported to induce minor variations in the physical and mechanical properties of the resulting concretes, due to its intrinsic properties (sorptivity, density, shape and texture).

The application of mixed recycled aggregate (RA) from C&DW to manufacture concrete has been the object of much less research [6,10–13], because of the complexity deriving from the variability of the material involved. Depending on the sources of the waste and the recycling technology, the resulting RA may contain impurities (such as wood, plastic, clay-based materials or asphalt) whose presence affects fresh and hardened concrete performance adversely. Previous research has shown that RA-containing concrete has lower density and poorer physical (workability) and mechanical properties than conventional concrete. The decline in concrete compressive strength usually intensifies with increasing RA replacement ratios, with slides as steep as 30% in concrete made with 100% of RA.

A few researchers have nonetheless studied the effect of recycled aggregate components (such as clay-based materials, asphalt and floating particles) on the end product [14–16]. These authors analysed the impact of the presence of aluminium, plastic and different percentages of clay-based materials on the physical and mechanical properties and durability of the new concretes, respectively.

The present study explored the effect of the main constituents (asphalt, clay-based materials, floating particles and fines) of recycled aggregate on the properties of 30 MPa recycled concretes. The RA used in this study was provided by a construction and demolition waste management plant in Glasgow, Scotland. The study aimed to use that aggregate (with or without floating particles, asphalt, brick and fines) to replace 25% or 50% of the natural coarse aggregate in concrete apt for housing applications. The research focused on the effects of the RA replacement ratios and the removal of impurities on the resulting concrete density, workability, sorptivity and compressive strength and the microstructure of the coarse aggregates/paste ITZs.

2. Materials and experiments

2.1. Materials

* The natural coarse and fine aggregate (Fig. 2) used was crushed siliceous rock. The morphology of the coarse fraction (gravel) was irregular and rough, with sharp edges and a maximum size of 20 mm, while the fines (sand) comprised particles of under 4 mm. Its chemical composition (Table 1) consisted primarily of silica and aluminium oxides (67 wt%), with smaller proportions of other oxides (Fe_2O_3, Na_2O, CaO) and a number of trace elements. While quartz prevailed in its mineralogy, feldspars and phyllosilicates were also present.
* The recycled aggregate (RA) used was a typical product from a C&DW management and processing plant in Glasgow, Scotland (Fig. 1). With a maximum particle size of 20 mm, it exhibited compositional heterogeneity and a morphology that varied depending on the source material (see Figs. 3 and 5). The material selected was analysed to determine its physical, chemical and mechanical composition.

Fig. 1. Recycling process of CDW.