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Influence of fine recycled concrete aggregates on the properties of mortars

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HIGHLIGHTS

- Influences of saturation state of FRCA on the mortars' properties are studied.
- Mortars made with dried FRCA present larger slump and better mechanical properties.
- Compressive strength of mortars decreases quasi linearly with substitution rate.
- Fraction 0/0.63 mm of FRCA has a worse effect on mechanical properties of mortars.

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ABSTRACT

Fine recycled concrete aggregates (FRCA) also called recycled sand, having particle sizes smaller than 5 mm, are essentially composed of mortar and hardened cement paste. Therefore they induce a large water demand which makes them hard to recycle into mortar and concrete. In this paper, the properties of mortars containing FRCA have been studied, including fresh properties, mechanical properties and interfacial transition zone (ITZ) microstructure.

The influence of saturation state of FRCA (dried or saturated) on the properties of mortars of identical compositions has first been studied. The results showed that the slump of mortars containing dried FRCA is always larger than that of mortars containing saturated FRCA. Indeed, in the case of dried FRCA, the theoretical amount of absorbed water is added at the beginning of mixing leading to a temporary increase of the initial efficient W/C ratio and volume of paste, leading to a better workability before its absorption into FRCA. On the contrary, the absorbed water in saturated FRCA is not readily available and thus cannot contribute to increase the initial efficient W/C ratio. Moreover, the compressive strength of mortars containing dried FRCA is always larger than that of mortars made with saturated FRCA, which is attributed to a thinner interfacial transition zone improving its mechanical properties. The influence of the fraction of recycled sand and of the granular class of recycled sand on the mechanical properties of mortars has then been studied with saturated FRCA. The compressive strength of mortars decreases quasi linearly as the replacement percentage of recycled sand increases. Moreover, it is shown that the finer fraction of recycled sand (0/0.63 mm) has the worse effect on the mechanical properties of mortars.

1. Introduction

Very large quantities of construction and demolition wastes are produced every year, nevertheless only a small fraction of them is recycled in the manufacture of concrete and mortar. A larger part of these materials could be recycled into concrete to decrease the amounts of wastes which have to be disposed in landfill, and thus to preserve natural resources [1–6].

Old concrete is the most abundant material among various types of construction and demolition wastes. Recycled concrete aggregates (RCA) are composed of an intimate mix between aggregates and hardened cement paste [7–10]. The fine fraction of RCA (FRCA), essentially composed of mortar and hardened cement paste, possesses a large water demand which makes it harder to recycle into concrete and mortar compared to coarser RCA [11–15].

Lots of studies showed that the properties of concrete decreased as the replacement percentage of FRCA increased [16–18]. For a given replacement percentage, the saturation state of recycled

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aggregate also influences the properties of concrete [19–21]. Poon et al. [19] showed that oven dried coarse recycled concrete aggregates (CRCA) led to a higher initial slump and a quicker slump loss comparing with saturated surface dried CRCA. Moreover oven dried CRCA led to concrete that exhibited higher compressive strength than that with saturated surface dried CRCA. However, the influence of saturation state of recycled sand on the properties of mortars has not been systematically studied.

Like concrete, mortar manufactured with FRCA generally present a lower strength and as a consequence a lesser durability than similar mortar composed of natural sand [22–24]. Generally, compressive strength of mortar decreases as the content of FRCA increases. A few authors mentioned that the use of FRCA does not jeopardize the mechanical properties of mortar up to a replacement of 30% [25,26]. But for other authors the use of FRCA is not good for the properties of mortar due to the high water absorption and adherent cement paste content [27–30]. However, the influence of different granular classes of the recycled sand on the properties of mortars has not been systematically studied.

The objectives of this work were twofold: the influence of saturation state of recycled sand on the properties of mortars has been firstly explored; then the influence of either replacement percentage or replacement fraction of natural sand by recycled sand on the properties of mortars has been evaluated. The properties of mortars including fresh properties (slump), mechanical properties (compressive strength and flexural strength), and ITZ microstructure have been analyzed.

Table 1
Mineralogical composition of cement determined by XRD-Rietveld.

	C_3S	C_2S	C_3A	C_4AF	Anhydrite	Calcite	Periclase
CEM I 52.5 superblanc (%)	73.90	21.87	1.46	–	0.52	1.53	0.72

2. Materials and methods

2.1. Materials

Materials used in this study are as follows.

2.1.1. Cement

The cement used in mortars was a white Ordinary Portland Cement (CEM I 52.5 "superblanc") provided by Lafarge company whose mineralogical composition is shown in Table 1. White cement has been chosen in order to differentiate more easily the new cement paste from the FRCA.

2.1.2. Natural sand and FRCA

A calcareous natural sand was used for the manufacture of mortars. It was provided by the Holcim Company and was sourced from the quarry of Tournai. The water absorption of this sand was 1.05% according to the standard EN 1097-6 [31], and its density was 2.66 g/cm^3 measured by helium pycnometer (Micromeritics AccuPyc 1330).

The recycled sand used was provided by the Colas Company and has been produced in the recycling platform of Amiens (France). The density of this recycled sand was 2.54 g/cm^3 measured by helium pycnometer. It was divided into four granular fractions (0/0.63, 0.63/1.25, 1.25/2.5, 2.5/5 mm) that were remixed together with specific amounts to get a similar granular distribution than natural sand. The particle size distributions of natural and recycled sands (before and after recomposition) are shown Fig. 1. The water absorption of remixed recycled sand was determined according to the method developed by Zhao et al. [32]. The soluble fraction in salicylic acid (SFSA) of each granular fraction of recycled sand was first determined. SFSA is proportional to the cement paste content in RCA. The water absorption (WA) of the three coarser granular fractions was also measured by the method EN 1097-6. As the water absorption of the different granular fractions varies linearly with the cement paste content [32], the water absorption of fraction 0/0.63 mm can be extrapolated from the relationship between SFSA and water absorption values of the three coarser fractions (Table 2). Knowing the particle size distribution of remixed FRCA, the total water absorption coefficient of remixed FRCA (fraction 0/5 mm) was calculated as 7.54% (Table 2). Two saturation states of FRCA (Dried RCA and Saturated RCA) were used in this study. Dried RCA were obtained by heating the aggregates at 105 °C during 24 h. For the saturated RCA, the sample was presaturated 24 h before the fabrication of mortars.

2.1.3. Compositions of mortars

Three series of mortars were manufactured in the laboratory. Series I was used to study the influence of saturation state of FRCA on the properties of mortars.

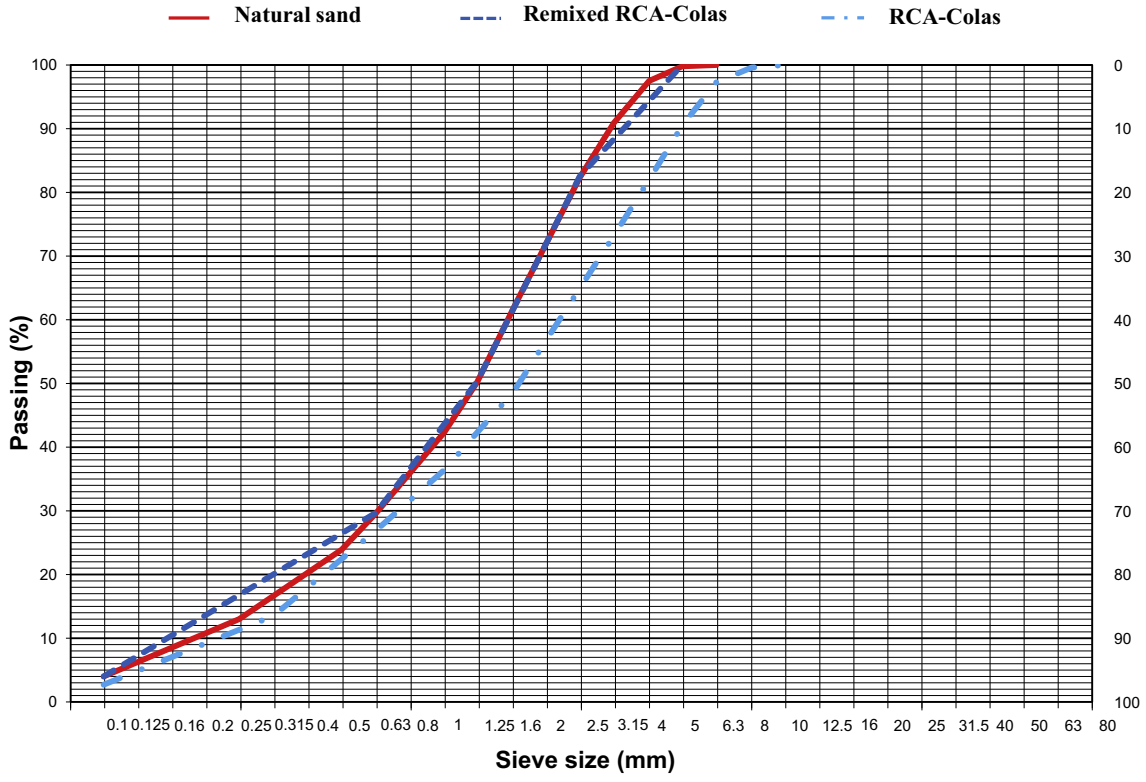

Fig. 1. Particle size distributions of natural and recycled sands used in mortars.