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Properties of self-compacting concrete on fresh and hardened with residue of masonry and recycled concrete

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HIGHLIGHTS

- The residue of masonry is used in self-compacting concrete mixtures as an addition.
- The fresh properties of self-compacting concrete with recycled aggregate and residue of masonry were investigated.
- The use of recycled coarse aggregate in the production of self-compacting concrete is feasible.
- The incorporation of recycled aggregate cause a decrease in the mechanical properties (compressive strength and splitting tensile strength) of self-compacting concretes.

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ABSTRACT

The present paper discuss the results of an experimental study about self-compacting concretes (SCC) made with recycled coarse aggregates and a mineral admixture obtained from a residue of masonry (RM). It was evaluated the effects of the use of the recycled aggregate on the properties of SCC. Five types of SCC mixes were tried, where the virgin coarse aggregate was substituted by the recycled aggregate between 0 and 100% by volume. The blended cement (Portland cement + admixture) remained constant at 480 kg/m^3 and included 20% by weight of RM. The rheological properties of the fresh SCC were determined by means of slump and flow tests, V-funnel, and L-box tests. It showed appropriate workability and resistance to segregation, passing ability, and filling capacity. The mechanical properties were reduced with the incorporation of the recycled coarse aggregate due to the poor adhesion between the old mortar and aggregate; however, the results fall within admissible characteristics to be used in several constructive elements for its acceptable mechanical properties.

1. Introduction

The use of self-compacting concrete (SCC) has been extended around the world from its early development in the eighties, due the benefits of production and the final product high performance [1–4]; the main rheological advantage of SCC is that being a fluid concrete can be placed and compacted without any vibration into the formwork of highly reinforced structures. This characteristic allows to have many benefits as reduction in construction time, maximize the freedom of design work as well as improvement in product quality and working environment. Also, this type of concrete brings a positive impact on the environment because it allows the use of additions or fillers from industrial or construction and demolition waste [5,6].

The main requirements in fresh status of SCC are filling ability, passing ability and very high segregation resistance. The first two properties can be obtained by using a high-range water reducer admixture (HRWR). To secure stability/cohesion of the mix, a large quantity of powder materials (active addition or filler) and/or viscosity-modifying admixture (VMA) is required [7]. One purpose of the addition of powder in self-compacting concrete is to densify the interface created between the aggregate and the Portland cement paste. In order to ensure sustainable production a waste material is added to SCC, that could be proceed from residues of mining, industry and agroindustry. This fact does that this kind of self-compacting concrete could be classified in the category of "green concrete" [8]. The negative environmental impact generated by the concrete derives from CO_2 emissions and other gases as a result of the decarbonation of limestone and consumption of

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electricity and fuel during the process of production of the Portland cement [8]. The emissions of CO_2 in the production of the components of concrete mixtures of medium strength using Portland cement as the only binder fluctuate between 0.29 and 0.32 t CO_2/m^3 [9]. Other way to reduce CO_2 emissions is the use of additions from industrial sub-products and recycled materials [10,11]; one of them is the utilization of construction and demolition wastes (C&D).

The incorporation of masonry wastes [4] and rubbles, resulting from construction activities or demolition of concrete buildings, as coarse aggregate in the preparation of concrete is an alternative for the production of self-compacting concrete [12–14]. Therefore, the recycling of C&D is important, because it minimizes the consumption of mineral resources, which require considerable energy in their extraction and grinding processes. The harnessing of C&D, results in a reduction of fuel consumption, indeed the demolished concrete is an eco-friendly alternative source of aggregates for production of concrete [15]. The objective of this research was the analysis of the properties in fresh and hardened states as the compressive strength and splitting tensile strength, and permeability properties at curing ages of 3, 7, 28 and 60 days for the different mixtures incorporating 20% of residue of grinding masonry (RM) as partial replacement of cement, and different percentages, from 0% to 100%, of recycled coarse aggregate instead of natural aggregate, the recycled aggregate was obtained from crushed construction and demolition wastes (C&D) that proceeded from some constructive elements with more than 40 years of being built in Universidad del Valle (Cali-Colombia).

Table 1
XRF analysis and loss on ignition of cement.

Oxide/element	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	K_2O	Na_2O	L.I
% mass	19.13	4.42	4.32	57.7	2.32	0.28	0.16	9.78

2. Experimental framework

2.1. Materials

2.1.1. Cement

A commercial type I Portland cement, complying with the requirements of specification ASTM C150, was used. This cement contains a limestone addition done by manufactory, this is the reason why a high loss on ignition is exhibited. Analysis of the chemical composition of this cement was performed by X-ray fluorescence (XRF); the result are shown in Table 1. The particle size distribution (PSDs) measured by laser distribution method are provided in Fig. 1. It was obtained in the PSD a mean particle size D (4.3) of 20.67 μm, which is identified that 10% of the sample has a particle size less than 1.96 μm, the 50% less than 15.82 μm and (D90) 90% less than 46.82 μm.

2.1.2. Residue of masonry (RM)

The powder of RM was obtained from a wall of red clay bricks cemented with Portland cement mortar, this wall was demolished in a building of the Universidad del Valle (Fig. 2). These demolition waste were subjected to a milling process to obtain a mean particle size D (4.3) of 26.6 μm determined by laser diffraction granulometry, this mean particle size was similar to the cement used. Its chemical composition and other main characteristics are presented in Tables 2 and 3.

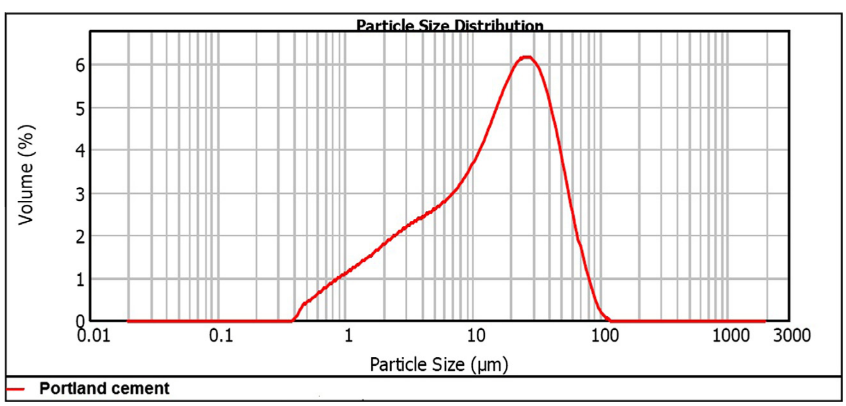

Fig. 1. Particle size distribution of Portland cement.

Fig. 2. Residue of masonry (RM).