Properties of concrete blocks made with recycled concrete aggregates: from block wastes to new blocks

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ABSTRACT

Large amounts of construction and demolition wastes (C&DW) especially concrete wastes are generated annually and will increase in the future. Until now, only a small fraction of concrete wastes is re-used as recycled concrete aggregates (RCA) in the manufacture of concrete. In this paper, the feasibility of using RCA obtained from old concrete block wastes in the production of new concrete blocks is studied. Concrete block wastes from Belgian Company PREFER were crushed in the laboratory by a jaw crusher and the different fractions of laboratory produced RCA were characterized by measuring the hardened cement paste content, the density, the porosity and the water absorption. Results clearly show that, the recycled sands possessed significantly higher cement paste content and higher water absorption than coarse RCA. Then, concrete blocks with different substitutions (0%, 30%, 100%) of natural aggregate by the same volume fraction of RCA were manufactured. The fresh properties (slump, density, air content), and mechanical properties (compressive strength) were studied. The compressive strength of concrete decreased as the substitution of RCA increased. Results show that the compressive strength of concrete made with 100% RCA could reach 8 MPa after 28 days. Therefore, the use of RCA obtained from old block wastes in the production of new blocks can be envisaged depending on their class of exposure and the grade requirement.

Keywords: recycled concrete aggregates, concrete blocks, water absorption, compressive strength.

1. INTRODUCTION

Large quantities of construction and demolition wastes are produced each year. So far, only a small fraction of these concrete wastes are reused as aggregate for concrete production (Topcu and Sengel, 2004). Recycled concrete aggregates are composed of a mix of natural aggregates and hardened adherent cement paste. The latter is usually much more porous than natural aggregates (Zhao et al., 2013) and leads to a large water demand which makes RCA harder to recycle into concrete (Courard et al., 2010). Properties of RCA such as water absorption, porosity can deeply influence the properties of fresh concrete as well as mechanical properties and durability of concrete made with RCA (Khatib, 2005).
In this study, concrete block wastes from Belgian Company PREFER were crushed in the laboratory by a jaw crusher and the different fractions of laboratory produced RCA were characterized. Then, concrete blocks with different substitutions (0%, 30%, 100%) of natural aggregate by the same volume fraction of RCA were manufactured. The fresh properties

(slump, density, air content) and mechanical properties of new concrete blocks were also studied.

2. MATERIALS AND EXPERIMENTAL PROGRAM

Concrete block wastes (C8/10) were collected from Prefer Company (Belgium) and then crushed in a laboratory jaw crusher retaining the same jaw opening for all products. After crushing, RCA_Blocks were separated into four granular fractions (0/2, 2/6.3, 6.3/14, 14/20 mm). RCA were characterized by measuring the hardened cement paste content, the density, the porosity and the water absorption. Only the fraction 2/6.3 mm was used for the manufacture of new concrete blocks.

New concrete blocks with different substitutions (0%, 30%, 100%) of natural aggregate by the same fraction of RCA (only fraction 2/6.3 mm) were manufactured. Table 1 shows the composition of new concrete blocks. CEM III/A 42.5 and water to cement ratio of 0.7 were used for the new concrete blocks. Natural calcareous aggregate (noted as NA 2/7) and natural river sand (noted as NS 0/2) were used for the manufacture of concretes. The water absorption of RCA 2/6.3 was 5.0% and its apparent particle density was 2.52 g/cm^3 according to the standard EN 1097-6 (while it was 0.68% and 2.7 g/cm^3 for natural aggregate). Natural aggregate and recycled aggregate were used in air dried condition. The absorbed water was adjusted according to the water content of the aggregates and their water absorption. A half of the total water was added to pre-saturate the aggregate in the mixer for 5 minutes before the addition of cement. The other half of the water was added after introduction of the cement.

Table 1. Compositions of concrete blocks (1 m^3)

	B_RCA0	B_RCA30	B_RCA100
NA 2/7 (kg)	1080	754	0
RCA 2/6.3 (kg)	0	302	1008
NS 0/2 (kg)	825	825	825
Cement (kg)	150	150	150
Efficient water (kg)	105	105	105
Absorbed water (kg)	13.12	26.00	56.20
E_{eff}/C	0.70	0.70	0.70

Cement paste content of RCA was measured by the salicylic acid dissolution (Zhao et al., 2013). Salicylic acid allows the dissolution of most phases contained in OPC cement paste (C_2S, C_3S, ettringite, portlandite and C-S-H for example) but not of the main phases contained in natural aggregates and especially limestone. The water absorption coefficient of three coarse fractions of RCA was determined according to EN 1097-6. The water absorption coefficient of the fraction 0/2 mm of RCA was determined on the basis of the relationship between water absorption and cement paste content (Zhao et al., 2017). After the mixing, the slump of fresh concrete was measured with the Abrams cone according to EN 12350-2. The air content of fresh concrete was measured according to EN 12350-7. The specimens were cast with the vibration table and stored in laboratory conditions. After 24h, they were demoulded and stored in climatic room (20±2°C and a relative humidity 95±5%). The compressive strength of concrete was measured according to EN 12390-3 on cubic samples (150mm x 150mm x 150mm), performed after 1 day, 7 days and 28 days of curing in climatic room.

3. RESULTS AND DISCUSSIONS

Figure 1 shows the cement paste content (CPC) and water absorption of RCA as a function of granular fraction. As can be seen, CPC of fraction 0/2 mm was larger compared with the three coarse fractions of RCA, while the values obtained for the three coarser fractions were similar. The fraction 0/2 mm of RCA revealed a larger value of water absorption in comparison with the three coarse fractions of RCA, while the values obtained were similar for the three coarser fractions. Recycled sands thus possessed higher cement paste contents than the coarse recycled aggregates, which may heavily penalize their use properties (such as water absorption, porosity) comparing with coarse recycled aggregates.

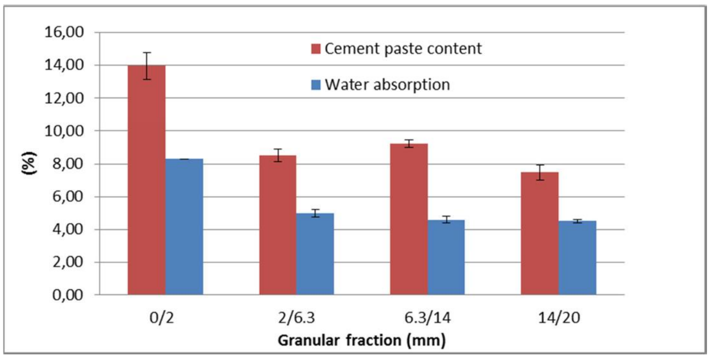

Figure 1. Cement paste content and water absorption of RCA as a function of granular fraction.

The workability of three concretes is low (the slumps were zero), which is conventionally observed in the industrial environment for the manufacture of blocks (using mechanical vibration for putting on a caisson). The air content of concrete increased (8% for concrete B_RCA0, 8.5% for concrete B_RCA30, and 10.5% for concrete B_RCA100) when the substitution of recycled aggregate increased. Increased air content is also known to occur in lightweight aggregate concrete, which shows some similarities with concrete made with recycled aggregate. Figure 2 shows the compressive strength of the various mixes at different ages. The compressive strengths of concretes with RCA were lower than those of concrete with natural aggregate. The compressive strength of concrete made with 100% RCA at 28 days deceased 14.4% comparing with the reference concrete, while the concrete made with 30% RCA at 28 days decreased 7.2%. These lower mechanical strengths are certainly caused by the poorer properties of RCA in comparison to natural aggregate used; the presence of adherent cement paste leading to higher porosity comparing with the natural aggregate. The compressive strength of concrete made with 100% RCA could reach 8 MPa after 28 days.

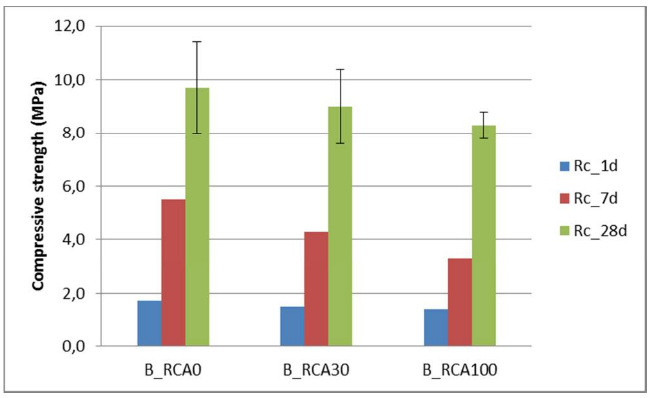

Figure 2. Compressive strength of new concrete blocks at different ages.

4. CONCLUSIONS

The feasibility of using RCA obtained from old concrete block wastes in the production of new concrete blocks is studied. Results clearly show that, the recycled sands possessed significantly higher cement paste content and higher water absorption than coarse RCA. The compressive strength of concrete blocks decreased as the substitution of RCA increased. The compressive strength of concrete made with 100% RCA could reach 8 MPa after 28 days without increasing the cement content of the concrete mix. Therefore, the use of RCA obtained from old block wastes in the production of new blocks can be envisaged depending on their class of exposure and the grade requirement.

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