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

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1. Introduction: Context and Challenges

Use of recycled concrete aggregates (RCA) in concrete

Use CD&W as sub-base and base material in road construction (“less noble”)

Meet Sustainable Development Goals: recovery targets to 70% of construction and demolition wastes (CD&W) by 2020 in European Union (Directive 2008/98/EC)

Reduced use of natural aggregates (preservation of natural resources)
1. Introduction: RCA

Two phases:
- Natural aggregates (NA)
- Hardened cement paste *(more porous* than NA)

Properties of RCA:
- Depend on: proportions and properties of these two phases
- Influenced by particle size, composition of original concrete, contaminants, crushing method…

Concrete made with RCA:
- Coarse RCA possesses satisfying properties for the reuse as concrete aggregates
- Fine RCA possesses a large water demand which makes it harder to recycle into concrete compared to coarser RCA
1. Introduction

**PREFER company:**
- Concrete slab
- Concrete block (6000m$^3$/month)
- Concrete block wastes (50m$^3$/month)

**Feasibility of using RCA obtained from old concrete block wastes in new concrete block**

Part of Project ConRePaD

BEWARE (BEcome a WALloon REsearcher) Fellowships Academia co-financed by the COFUND program of the European Union (FP7-Marie Curie Actions) and Walloon Government
2. Materials

RCA manufactured in laboratory
Old concrete block wastes (C8/10, from PREFER)

Crushing (jaw crusher in laboratory, opening ≈10mm)
Then dried in oven at 105°C

Separation of RCA by sieving (0/20mm)
Four granular classes:
0/2mm  2/6.3mm  6.3/14mm  14/20mm
3. Characterizations: RCA

Hardened cement paste content (CPC) of RCA
Principal soluble and insoluble phases in salicylic acid and methanol dissolution

(Zhao et al., 2013, Journal of Sustainable Cement-Based Materials, 2, 186-203)

- Natural aggregates
- Adherent hardened cement paste
- Cement paste
- Quartz, Dolomite, Calcite
  - Insoluble in salicylic acid
- \( \text{C}_2\text{S}, \text{C}_3\text{S}, \text{Ca(OH)}_2, \text{C-S-H}, \text{Ettringite} \)
  - Soluble in salicylic acid
- CEM I
  - C\(_4\)AF, AFm
- Calcite, Slag…
  - CEM II, III
3. Characterizations: RCA

Hardened cement paste content (CPC) of RCA
Salicylic acid and methanol dissolution
Water absorption (WA) (EN 1097-6)

(Zhao et al., 2017, European Journal of Environmental and Civil Engineering, 1-11)

CPC and WA of 0/2mm fraction larger than three coarse fractions
Recycled sand possesses higher CPC and WA than CRCA
### 3. Characterizations: Compositions

#### Compositions of concrete blocks (1 m³)

<table>
<thead>
<tr>
<th></th>
<th>B_RCA0</th>
<th>B_RCA30</th>
<th>B_RCA100</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA 2/7 (kg)</td>
<td>1080</td>
<td>754</td>
<td>0</td>
</tr>
<tr>
<td>RCA 2/6.3 (kg)</td>
<td>0</td>
<td>302</td>
<td>1008</td>
</tr>
<tr>
<td>NS 0/2 (kg)</td>
<td>825</td>
<td>825</td>
<td>825</td>
</tr>
<tr>
<td>Cement (kg)</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Efficient water (kg)</td>
<td>105</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Absorbed water (kg)</td>
<td>13.12</td>
<td>26.00</td>
<td>56.20</td>
</tr>
<tr>
<td>$W_{eff}/C$</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
</tbody>
</table>

- Different substitutions of NA 2/7 by the same volume RCA 2/6.3 (0, 30, 100%), same $W_{eff}/C$ ratio, cement CEM III/A 42.5
- Water absorption of all aggregates measured according to EN 1097-6
- All aggregates (air dried condition), pre-saturated in the mixer 5 min before the addition of cement by half of total water
3. Characterizations: Fresh properties of concrete

- Workability of three concretes is low (zero slump)

- The air content of concrete increases when the substitution of recycled aggregates increases
3. Characterizations: Fresh properties of concrete

- The fresh density of concrete slightly decreases when the substitution of RCA increases.
3. Characterizations:
Compressive strength of concrete

- Compressive strengths of concretes with RCA are slightly lower than those of concrete with natural aggregate.
- Compressive strength of concrete made with 100% RCA at 28 days decreases 14.4% comparing with the reference concrete (8 MPa), while Rc of B_RCA 30 decreases 7.2%.
- This behavior may be due to the poor properties of RCA (adherent cement paste leads to a higher porosity).
4. Conclusions et perspectives

Feasibility of using RCA obtained from old concrete block wastes in the new concrete blocks

⇒ Recycled sand possesses significantly higher cement paste content and higher water absorption than coarse RCA

⇒ Compressive strength of concrete blocks slightly decreases as the substitution of RCA increases; Rc of B_RCA100 could reach 8 MPa after 28 days without increasing the cement content of the concrete mix

⇒ Use of RCA obtained from old concrete block wastes can be envisaged depending on their class of exposure and the concrete grade requirement

⇒ Assessment of durability of new concrete blocks made with RCA (now)

⇒ Industrial application of new concrete block made with RCA will be realized in PREFER Company in September 2017
4. Conclusions et perspectives

Feasibility of using RCA obtained from old concrete block wastes in the new concrete blocks

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