CARBON DIOXIDE UPTAKE BY RECYCLED-AGGREGATE NO-FINES CONCRETE

by

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The building construction sector uses much energy and emits large quantities of carbon dioxide to the atmosphere.

Energy is used for extracting, transporting, processing and assembling materials, and CO$_2$ is emitted by fossil fuel combustion, land-use practices and industrial processes reactions, such as chemical reactions in the production of cement.
If the whole life cycle of cement-based products is considered, there is a **positive CO$_2$ emission** from **calcinations reaction** during cement manufacture but also a **negative CO$_2$ emission** due to **carbonation reaction** during the building lifecycle.

More than 50% of the CO$_2$ emitted during cement production originates from the calcination of limestone. This CO$_2$ can be reabsorbed in a process called carbonation.
In order to accelerate the process of CO$_2$ uptake, low-strength porous concrete can be advantageous with respect to high-strength concrete, at least when structural requirements are not so important.

For this reason, **no-fine concrete** has been proposed with the aim of enhancing CO$_2$ uptake. As its name implies, no-fines concrete does not contain fine aggregates (sand).
A possible application of no-fine concrete can be ACoustic BarriERs to be placed along highways and street-traffic roads. In fact, traffic noise has become a serious environmental problem.

By using no-fine concretes the development of porous concrete having water and air permeability, good sound absorption ability etc. can be achieved, by artificially forming continuous porosity.
CASTING OF ANCONA WALL
CURING OF ANCONA WALL

open air

surface finishing
EXPERIMENTAL PART: MATERIALS AND CONCRETE MIXTURE PROPORTIONS
GRAIN SIZE DISTRIBUTION CURVES OF THE AGGREGATE FRACTIONS

- ○ Gravel
- ■ Fine recycled fraction
- ▲ Coarse recycled fraction
- ○ Fine gravel
## MAIN PHYSICAL PROPERTIES OF THE AGGREGATE FRACTIONS

<table>
<thead>
<tr>
<th></th>
<th>Fine gravel (6-12 mm)</th>
<th>Gravel (11-22 mm)</th>
<th>Fine recycled fraction (6-12 mm)</th>
<th>Coarse recycled fraction (11-22 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative specific gravity</td>
<td>2.58</td>
<td>2.60</td>
<td>2.47</td>
<td>2.48</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>2.9</td>
<td>2.5</td>
<td>9.0</td>
<td>8.7</td>
</tr>
</tbody>
</table>
## MIXTURE PROPORTIONS

<table>
<thead>
<tr>
<th></th>
<th>NATf&amp;c</th>
<th>NATf</th>
<th>RECf</th>
<th>RECf&amp;c</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/C</td>
<td>14</td>
<td>4.5</td>
<td>4.5</td>
<td>14</td>
</tr>
<tr>
<td>W/C</td>
<td>0.25</td>
<td>0.35</td>
<td>0.35</td>
<td>0.25</td>
</tr>
<tr>
<td>Water</td>
<td>40</td>
<td>120</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td>Cement</td>
<td>160</td>
<td>350</td>
<td>350</td>
<td>160</td>
</tr>
<tr>
<td>Fine recycled fraction (6-12 mm)</td>
<td>/</td>
<td>/</td>
<td>1600</td>
<td>1086</td>
</tr>
<tr>
<td>Coarse recycled fraction (11-22 mm)</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>1090</td>
</tr>
<tr>
<td>Fine gravel (6-12 mm)</td>
<td>1134</td>
<td>1670</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Gravel (11-22 mm)</td>
<td>1143</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>
EXPERIMENTAL PART: TESTING OF CONCRETE
Compressive strength (MPa) vs. Curing time

- NATf&c
- NATf
- RECf
- RECf&c

**3 days**
- NATf&c: 2
- NATf: 6
- RECf: 2
- RECf&c: 2

**28 days**
- NATf&c: 12
- NATf: 12
- RECf: 12
- RECf&c: 12
Carbon dioxide uptake was evaluated:

- on concrete core test specimens exposed to either atmosphere or accelerated conditions in a climatic chamber
- on concrete cores extracted from the Ancona-wall subjected to the natural climatic conditions of the wall site
Resistance to the penetration of carbonation was measured on cubes exposed to an environment with 21±1°C, 60±10% R.H., and a constant flux of 1% CO₂ according to UNI EN 13295 (2005)
100-mm cubic concrete specimens were split in two parts and carbonation depth was measured by the phenolphthalein test, according to prEN 14629 (2003).
Cores extracted from Ancona-wall (200-mm long, equal to the wall thickness)

After extraction they were divided into four portions (about 50-mm long):
Each portion of core was ground and the resulting powder was analysed by means of thermogravimetric (TG) and differential thermal analysis (DTA) in order to quantitatively evaluate the content of \( \text{CaCO}_3 \).
Content of CaCO$_3$ (in %) of the cores extracted from the no-fine concrete wall, after one month after casting, depending on the portion of the core.

<table>
<thead>
<tr>
<th>Core portion</th>
<th>NATf&amp;c</th>
<th>NATf</th>
<th>RECf</th>
<th>RECf&amp;c</th>
</tr>
</thead>
<tbody>
<tr>
<td>External ‘A’ (0-5 mm depth)</td>
<td>86.4</td>
<td>74.1</td>
<td>68.2</td>
<td>74.9</td>
</tr>
<tr>
<td>Internal ‘B’ (5-10 mm depth)</td>
<td>83.5</td>
<td>76.4</td>
<td>58.4</td>
<td>74.5</td>
</tr>
<tr>
<td>Internal ‘C’ (10-15 mm depth)</td>
<td>86.1</td>
<td>72.5</td>
<td>62.9</td>
<td>75.2</td>
</tr>
<tr>
<td>External ‘D’ (15-20 mm depth)</td>
<td>83.7</td>
<td>72.9</td>
<td>65.6</td>
<td>75.4</td>
</tr>
</tbody>
</table>
In terms of mechanical strength the best results for the production of no-fine concretes can be obtained by only using as inert fraction the fine recycled-concrete aggregate.

In terms of CO\textsubscript{2} uptake, all the tested no-fine concrete mixtures performed very well due to the high rate of continuous porosity of such kind of concrete; in particular, preliminary results obtained in field showed that the evolution of carbonation reaction seems faster for the mixture prepared with the only fine recycled-concrete aggregate, but this result needs further confirm. Future development of this experimental work is to monitor the evolution in time of CO\textsubscript{2} uptake in field, in order to estimate the time necessary for the carbonation reaction depletion and, consequently, the wall service life before its recycling.
Thank-you for your kind attention