Use of recovered resources in construction industry: cellulose fibres from urban wastewater

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Objectives

CIRCULAR ECONOMY

• Cellulose
• Biopolymers

RECOVERY OF MATERIALS AND BIOBASED PRODUCTS

SMART-Plant

NEW TECHNOLOGIES FOR IMPLANTS

Zero Energy Plant
Cellulose

- Natural Polymer: linear units of glucose joined by β-1,4-glycosidic linkages
- Completely insoluble in water and with a considerable mechanical strength.
- Low cost, widely available, sustainable, widely use as reinforced and insulated material

Suitable in building construction
Cellulose in Wastewater Treatment

Major constituent of wastewater collected into the sieves

Hydrolysis process makes difficult its degradation during the conventional biological treatment

Secondary Raw Material

Hydrolysis process makes difficult its degradation during the conventional biological treatment.

<table>
<thead>
<tr>
<th>Region</th>
<th>Per capita annual consumption of toilet tissue (<a href="http://www.worldwatch.org/node/5142">http://www.worldwatch.org/node/5142</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>23.0 kg</td>
</tr>
<tr>
<td>Western Europe</td>
<td>13.8 kg</td>
</tr>
<tr>
<td>Latin America</td>
<td>4.2 kg</td>
</tr>
<tr>
<td>Asia</td>
<td>1.8 kg</td>
</tr>
<tr>
<td>Africa</td>
<td>0.4 kg</td>
</tr>
</tbody>
</table>

Quantity of cellulose that could be recovered (www.Smart-plant.eu)
Building sector consumes 40% of the global energy and it is important to reduce the amount of non-renewable raw materials, replacing them partially with waste products.
Aim

- Characterization of Recovered Cellulosic fibres (CREC)

- Investigate the influence of the addition of different amounts (0%, 5%, 10%, 15% and 20% by volume) of fibres on the properties of mortars for indoor non-structural plasters and finishes. Each mix has been tested on:
  - Workability
  - Microstructure
  - Mechanical properties (UNI EN1015-11:2007)
  - Moisture Buffering Value (the NORDTEST method)
Mix design

- Water/binder ratio equal to 0.63 by weight
- Aggregate/binder ratio equal to 3 by weight
- Fibres added in ssd conditions
- Each specimen has a different amount of fibres added by volume and they have been compared to a Reference with the 0% vol of fibres.
- **Same workability** for each sample in according to **UNI EN 1015-3:2007**

<table>
<thead>
<tr>
<th>Density</th>
<th>g/cm³</th>
<th>Water</th>
<th>NHL5</th>
<th>CA400</th>
<th>CREC</th>
<th>Slump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>g</td>
<td>294</td>
<td>467</td>
<td>1401</td>
<td>0</td>
<td>118 cm</td>
</tr>
<tr>
<td>CREC 5%</td>
<td>g</td>
<td>280</td>
<td>445</td>
<td>1335</td>
<td>22</td>
<td>117 cm</td>
</tr>
<tr>
<td>CREC 10%</td>
<td>g</td>
<td>267</td>
<td>424</td>
<td>1274</td>
<td>42</td>
<td>115 cm</td>
</tr>
<tr>
<td>CREC 15%</td>
<td>g</td>
<td>256</td>
<td>406</td>
<td>1218</td>
<td>60</td>
<td>111 cm</td>
</tr>
<tr>
<td>CREC 20%</td>
<td>g</td>
<td>245</td>
<td>389</td>
<td>1168</td>
<td>77</td>
<td>109 cm</td>
</tr>
</tbody>
</table>
Microstructure

- Scanning Electron Microscope (SEM)
Interfacial Transition Zone (ITZ) between binder paste and a recovered cellulose fiber
Mercury Intrusion Porosimetry (MIP)

% Cellulose

% Pores

Total accessible porosity (%)

Relative volume [mm$^3$/g]

Pore diameter [µm]

- REF
- CREC 5%
- CREC 10%
- CREC 15%
- CREC 20%

- RIF
- CREC 5%
- CREC 10%
- CREC 15%
- CREC 20%
Density

% Cellulose

Density

Density (g/dm³)

Cellulose (vol%)
Mechanical Properties

- % Cellulose
- R_max Flexural Strength
- R_max Compression Strength

Graphs showing mechanical properties vs. cellulose content.
Moisture Buffering Value (MBV)

*Specimens are cyclically exposed to different RHs for fixed periods: UR 75% in NaCl and UR 33% in MgCl₂*
Conclusions

Recovered cellulose coming from advanced dynamic sieving of urban wastewater was characterized and added in hydraulic lime based mortars at the amount of 5%, 10%, 15% and 20% by mix volume.

The valorisation of this secondary product from urban wastewater can improve the final performances of mortars, in terms of:

- increased lightness
- flexural strength
- moisture buffering capacity in indoor application, together with a viable technological solution for waste management by using a circular approach
Thank you for your attention

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