Use of concrete recycled aggregates as a raw material in lightweight mortar fabrication

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Abstract

Construction and Demolition Waste (CDW) raises an environmental problem due both to the lack of prevention in their production process and little use of recycled material. In order to improve this situation, over the last years the new legislation on the CDW has entered into force, fostering the recovery of waste at its end-of-life and incorporating a study on CDW management during the planning process and a plan on CDW management during the construction phase.

In the development of this research basic materials were used for the cement mortars elaboration in proportion 1:3 and 1:4: cement (CEM II/B-L 32.5 N and CEM IV/B (V) 32.5 N, aggregates (natural aggregates and concrete recycled aggregates) and water. In case of recycled mortars some additive was used.

The methodology of the research is divided in two parts: in the first part the most relevant properties of recycled aggregates such as bulk and dry density, absorption, fines content, fineness modulus and friability coefficient were analyzed. In the second part the following tests were carried out: flexural and compressive strength, bond strength, shrinkage, density and water vapour permeability of mortars elaborated with recycled aggregates with the objective to study their feasibility.

Because of lower density and higher absorption of recycled aggregates recycled mortars present generally poorer properties compared to traditional mortars.

On the other hand, lower density of recycled aggregates presents an advantage in the fabrication of lightweight mortars and thus mortars with lower coefficient of thermal conductivity, what means better thermal behaviour compared to mortars elaborated with natural aggregates. Regarding water vapour permeability, recycled mortars have higher permeability compared to traditional mortars, what enables evacuation of water vapour existing in the interior of a construction avoiding in such a way the condensation in the interior layers of the brick wall. According to the obtained results, recycled mortars develop poorer behaviour compared to traditional mortars. However, these mortars comply with the standards taken as a reference, and their density and water vapour permeability make more attractive the use of these materials in the construction sector.

Keywords: waste treatment, masonry mortar, recycled aggregate, Mechanical properties.

Introduction

One of the main objectives in today’s society is the conservation of environment and natural recourses. Current regulations foster the use of recycled aggregates reducing the generation of
waste without control and massive use of natural raw materials. In this sense, the incessant increase of Construction and Demolition Waste (CDW) generation creates a serious problem at the European level. CDW constitutes approximately 25%-30% of all the waste generated in the European Union [1], and although it is considered to be an inert waste, it produces a great visual impact in the landscape.

Presently in Spain the CDW is used mainly as packing for highways stretches and, to a lesser extent, in concrete fabrication. In Spain, the use of the coarse fraction of concrete recycled aggregate is regulated by the Structural Concrete Code [2], recommending substitution of up to 20%.

To increase recycling ratios, various scientific researches have studied the feasibility of incorporating fine fraction of recycled aggregates (RA) in masonry mortars production. Fernández et al. [3] studied the incorporation of recycled aggregates in masonry mortars using CEM II/B-L 32.5N. Obtained results show that replacement ratio of 50% can be achieved in mortar for indoor use.

Saiz [4] studied the possibility to fabricate recycled mortars using 100% of concrete, mixed and ceramic recycled aggregates. The results show that recycled mortars present technical, economic and environmental feasibility independently of the type of the used recycled aggregates, being concrete recycled aggregate one that gave better results.

Materials and Methods

The testing programme was developed using two types of binders: CEM II/B-L 32.5 N and CEM IV/B (V) 32.5 N. There were suggested two cement-to-aggregate by dry weight proportions were 1:3 and 1:4. Recycled aggregates coming from treatment plants were sieved in the laboratory, eliminating material retained on the 4 mm sieve and material passed through 0.063 mm sieve.

The following code was employed for the mixes identification:

M-Nº-Z

Where

M = RM= Recycled mortar, TM= Traditional mortar.
Nº = Recycled aggregate type (II = CEM II/B-L 32.5 N and IV= CEM IV/B (V) 32.5)
Z= c/a proportion (X= 1:3 and Y= 1:4)

Results and Discussion

Characterization of aggregates samples was based on the technical requirements regulated by the standard UNE-EN-13139: “Aggregates for mortar”. The results of physical characterization of recycled aggregates are shown in Table 1.

<table>
<thead>
<tr>
<th>Aggregates Characterization</th>
<th>Type</th>
<th>UNE-EN</th>
<th>UNE-EN</th>
<th>UNE-EN</th>
<th>UNE-EN</th>
<th>UNE-EN</th>
<th>UNE-EN</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>933-1</td>
<td>13139</td>
<td>83115</td>
<td>1097-3</td>
<td>1097-6</td>
<td>1097-6</td>
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<tr>
<td>Fine content (%)</td>
<td></td>
<td>2.55</td>
<td>4.22</td>
<td>22.60</td>
<td>1550</td>
<td>2400</td>
<td>0.98</td>
</tr>
<tr>
<td>Fin. modulus (%)</td>
<td></td>
<td>4.22</td>
<td>4.12</td>
<td>23.94</td>
<td>1550</td>
<td>2400</td>
<td>0.98</td>
</tr>
<tr>
<td>Friability (%)</td>
<td></td>
<td>22.60</td>
<td>4.22</td>
<td>23.94</td>
<td>1320</td>
<td>2110</td>
<td>6.05</td>
</tr>
<tr>
<td>Bulk. Dens. (kg/m3)</td>
<td></td>
<td>1550</td>
<td>22.60</td>
<td>1320</td>
<td>2400</td>
<td>2400</td>
<td>2400</td>
</tr>
<tr>
<td>Relat. Dens. (kg/m3)</td>
<td></td>
<td>2400</td>
<td>1550</td>
<td>2110</td>
<td>2400</td>
<td>2400</td>
<td>2400</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td></td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Table 1. Physical Characterization

As it is observed in Table 1, the characteristics that mainly differentiate recycled aggregates from natural aggregates are their lower density and higher absorption. Higher absorption
provokes higher water demand in mortars fabricated with recycled aggregates and thus these mortars have higher water-to-cement proportion what limits their mechanical properties. Regarding the results of the X-ray diffraction test, main crystalline phases obtained are quartz and calcite. Observed phases, with the exception of quartz, do not show a high crystalline state presenting low intensities. Other observed phases are sanidine, phlogopite, albite and gypsum.

The results of the characterization of recycled mortars are shown in Table 2.

<table>
<thead>
<tr>
<th>Test</th>
<th>RM-II-X</th>
<th>RM-II-Y</th>
<th>TM-II-X</th>
<th>TM-II-Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability time (min)</td>
<td>89/92</td>
<td>83/90</td>
<td>118/122</td>
<td>121/126</td>
</tr>
<tr>
<td>Dry density (kg/m³)</td>
<td>1830/1810</td>
<td>1780/1780</td>
<td>2060/2030</td>
<td>1980/1970</td>
</tr>
<tr>
<td>Real density (kg/m³)</td>
<td>2390/2150</td>
<td>2280/2130</td>
<td>2320/2300</td>
<td>2270/2270</td>
</tr>
<tr>
<td>Shore hardness (ud)</td>
<td>73/73</td>
<td>72/70</td>
<td>80/78</td>
<td>78/77</td>
</tr>
<tr>
<td>Flexural strength (Mpa)</td>
<td>4.74/5.02</td>
<td>3.12/3.42</td>
<td>5.12/5.75</td>
<td>3.87/4.36</td>
</tr>
<tr>
<td>Compress. strength (Mpa)</td>
<td>17.41/19.21</td>
<td>9.82/11.92</td>
<td>21.94/23.10</td>
<td>14.75/17.02</td>
</tr>
<tr>
<td>Bond strength (N/mm²)</td>
<td>0.41/0.42</td>
<td>0.37/0.39</td>
<td>0.51/0.50</td>
<td>0.49/0.49</td>
</tr>
<tr>
<td>Shrinkage (mm/m)</td>
<td>0.082/0.083</td>
<td>0.090/0.089</td>
<td>0.023/0.025</td>
<td>0.031/0.034</td>
</tr>
<tr>
<td>Water vapour,permeability (kg/msPa)</td>
<td>-5.65x10⁻¹²</td>
<td>-6.34x10⁻¹²</td>
<td>-2.40x10⁻¹²</td>
<td>-3.09x10⁻¹²</td>
</tr>
</tbody>
</table>

Note: 1% of additive over the weight of cement.
Note: same water amount for all types of cement.

Table 2. Recycled mortar characterization

The time in minutes obtained with CEM II is shorter than that obtained in the mortars elaborated with CEM IV. It happens due to the presence of fly ash in high proportion in this type of cement, leading to the improvement in the workability of mortar.

The decrease in the compressive strength is more important in the mixes made with CEM II compared with mixes made with CEM IV. In case of CEM II the decrease of strength was 20.65% for the dosage 1:3 and 33.42% for the dosage 1:4. In either case, all the mixes comply with the limit of 7.5 N/mm² established by the reference standard (UNE-EN 998-1).

Surface hardness of recycled mortars are slightly lower than that of mortars made with natural aggregates. In terms of the type of the used cement, there were observed no differences in hardness.

Both bulk density in hardened state and real density of mortar depend on the density of the materials it is fabricated with, on the particle size distribution and on the water-to-cement proportion.

Generally, bulk density and real density in hardened state are lower in recycled mortars compared with mortars elaborated with natural aggregates.

The results of the bond strength test show poorer behaviour of recycled mortars compared with the reference mortars. However obtained results are higher than the limit of 0.30 N/mm² established by the standard UNE-EN-998-1 for this type of mortars.

Recycled mortars present higher shrinkage than mortars fabricated with natural aggregates. This is produced mainly by the higher absorption of recycled aggregates. Water vapour permeability values for the mixes containing recycled aggregates are higher with respect to the mixes made with natural aggregates. This characteristics enable the evacuation of water
vapour existing in the interior of the construction avoiding in such a way the condensation in the interior layers of the enclosure wall.

**Conclusion**

The experimental research leads to the following conclusions:

Recycled aggregates have lower density and higher absorption compared with natural aggregates due to the amount of adhered mortar in this type of aggregates.

Real density of recycled mortars is lower than that of mortars elaborated with natural aggregates due to the lower density of recycles aggregates. This causes a slight decrease of the building permanent loads.

Generally, recycled mortars have poorer mechanical behaviour than traditional mortars. Shrinkage is one of the properties that is affected more significantly. However, recycled mortars comply with all the requirements of the standards taken as a reference.

As a final conclusion, it can be stated that masonry mortars elaborated with CEM IV and 1:3 and 1:4 compounds proportions can incorporate 100% of three types of RA complying with the requirements established by the Spanish standards.

**References**


