MECHANICAL STRENGTH OF LIME-RICE HUSK ASH MORTARS: A PRELIMINARY STUDY

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Abstract. Rice is produced in many countries in the world, and this product permits to feed a lot of people, most of them in undeveloped countries. Approximately one tone of rice produces 200 Kg of rice husk, and when this rice husk is burnt 20% of rice husk ash (RHA) is obtained. A very important part of rice husk is abandoned in the field producing environmental problems. RHA can be obtained by controlled combustion, when this fact occurs, a good quality RHA is produced. This RHA can be used as a pozzolanic material in mixtures with lime or Portland cement, producing good mechanical properties and durability. In this work a preliminary results about the influence of RHA/lime ratio on workability and mortars strength was studied. The results showed that mortars workability improves when RHA/lime ratio do. Compressive strength (Cs) of mortars with different RHA/lime ratios was studied, in this sense, for 28 days curing time at 20°C an increase of Cs when RHA/lime ratio do is observed. However for 90 and 180 days curing time a maximum or Cs for RHA/lime equal to 2 is obtained. The lowest and highest Cs values obtained were 6 and 18 MPa respectively, when 20°C curing temperature was used. When curing temperature increases until 65°C similar tendency of Cs respecting RHA/lime ratio was observed. A preliminary study of binders for using in mortars tiles reveals that at least low quantities of Portland cement must be included in binder composition in order to obtain short term strengths that make easy tile demoulding process.

Introduction

There is a high percentage of "informal construction", i.e., the construction that is not governed by any rules and which is dominated by self-construction [1]. This kind of construction tries to use the same constructive materials as those used by high economic income people, which are expensive and inaccessible for poor people. This is due to the little confidence on innovative materials and the limited knowledge about them. Innovative materials are those that improve properties on the traditional ones, with researching and development [2]. Portland cement is a very good material, that today is irreplaceable for some uses that requires high strength, however Portland cement is employed in some cases in low strengths uses, most of this cases occurs in developing countries, in this situations Portland cement could be replaced by lime-pozzolan mixture [3]

The use of pozzolans as alternatives form the commonly used Portland cement have been introduced in the last few decades either for cost reduction, performance, durability or environmental reasons. According to Malhotra and Metha [4] pozzolans are defined as siliceous or siliceous and aluminoous materials which in themselves possess little or no cementing property but will in a finely dispersed form in the presence of water chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Already in the antiques volcanic soils were used to produce hydraulic mortar. These days, fly ash and agricultural waste are commonly used pozzolans.
Of the plant residues the ash of rice husks contains the highest proportion of silica. Rice plants ingest orthosilicic acid from ground water, where upon it is polymerized to form amorphous silica in the husks. [5]. Rice husk is a by-product in the process of obtaining rice grain. It contains nearly 20% amorphous silica form. Under controlled combustion conditions amorphous silica with high reactivity is produced [6]. It has been demonstrated that RHA can be added to concrete mixtures and substitute partially Portland cement, that is more expensive and to make a significant contribution towards the provision of low cost building materials. RHA is not just a cheap alternative, however as it has been used to improve the durability of concrete [7] and to produce high-performance cement [8,9].

Lime mortars and lime plus pozzolan mortars are construction materials that have been widely used all through antiquity; but they lost importance with the rising of Portland cement. However there is an attempt to retrieve their use mostly in low-cost construction and restoration works. Among the main characteristics these building materials may offer are: low mechanical strength, easy workability, high enough deformability, high permeability to liquid and vapor water and low resistance to frost [10].

**Experimental Work**

**Materials.** A commercial lime LC90 was supplied by CALCASA. It contains an 85% of Ca(OH)$_2$. The average size of the particle diameter is 48μm and in Fig 1a the grading curve is presented. Rice husk ash (RHA) was provided by Maicerías Españolas DACSA S.A. Before being used it was milled for 20 minutes in a Gabrielli-2 mill with 18mm diameter-alumina balls, to increase its reactivity, obtaining particles with a mean diameter of 10μm, and in Fig 1b the grading curve is shown. Chemical composition of DACSA rice husk ash is shown in table 1. In the Fig 2 optical microscope micrograph is shown. For the manufacture of tile, a Portland cement I 52.5R was used. The chemical composition is shown in Table 1.

![Fig. 1 a) Grading curve of lime LC90](image1)

![Fig. 1 b) Grading curve of ground RHA](image2)

<table>
<thead>
<tr>
<th>Samples</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>Fe$_2$O$_3$</th>
<th>CaO</th>
<th>MgO</th>
<th>SO$_3$</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
<th>Cl$^-$</th>
<th><em>L.I.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>RHA</td>
<td>91.8</td>
<td>0.27</td>
<td>0.23</td>
<td>1.96</td>
<td>0.54</td>
<td>0.28</td>
<td>0.72</td>
<td>-</td>
<td>0.34</td>
<td>8.92</td>
<td></td>
</tr>
<tr>
<td>CEM I</td>
<td>19.90</td>
<td>5.38</td>
<td>3.62</td>
<td>63.69</td>
<td>2.14</td>
<td>3.66</td>
<td>1.27</td>
<td>-</td>
<td>-</td>
<td>2.02</td>
<td></td>
</tr>
</tbody>
</table>

* L.I.: Loss on Ignition
**Apparatus and procedures.** To prepare 40mmx40mmx160mm specimens, according to the UNE-EN 196-1:1996 Standard, an Ibertest mixer and compactor was used. To test the workability of fresh mortar according to the UNE-EN 1015 Standard, a manually standardized shaking table was used. The specimens were immersed in water and stored in a moisture chamber under constant humidity and temperature (approx 20º C and 98% of relative humidity). These specimens were compressive strength tested after 28, 90 and 180 days curing time according to the UNE-EN 1015 Standard, with a universal computer-controlled INSTRON-3382 testing machine. The load was applied at a rate of 1mm/min.

Microconcrete (mortar) tiles were prepared using a TEVI machine designed by Centro de Estudios de Construcción y Arquitectura Tropical that belongs to Instituto Superior Politécnico José Antonio Echevarría in La Habana, Cuba. This machine consists on a shaking table which can be connected to a car battery or other electricity production system. This fact permits to produce tiles in isolated areas out of the cities. In Fig. 3a and b a photograph of TEVI machine and tile microconcrete respectively is presented.

**Mixture dosage.** Lime-RHA mortars were prepared according to the UNE-EN 1015 Standard, with an aggregate/binder ratio of 3, RHA/lime ratios between 1 and 3 and 0.8 water/binder ratio. In microconcrete tiles 20% of binder was Portland cement and 80% a mixture lime-RHA.

**Results and discussion.**

**Influence of RHA/lime ratios on workability of fresh mortar.** Fig. 4 shows the workability of mortar for a constant water/binder ratio of 0.8, and for different RHA/lime ratios between 1 and 3. In general, workability increases when pozzolan in the mix do. In the most unfavourable case...
(RHA/lime ratio equal to 1), the mixture presents enough workability to be well compacted in the mortars mould.

Fig. 4. Influence of RHA/lime ratio on mortar workability

**Influence of RHA/lime ratios on compressive strength.** Two different curing temperatures were used: 20º C and 65º C. For 20ºC curing temperature, in general an increase of compressive strength (Cs) with curing time is observed however for 3 RHA/lime ratio, no significant difference between 90 and 180 days curing time is observed. (see Fig. 5) This fact is probably due to a lime deficit in the mixture that stops pozzolanic reaction. The best results were obtained for RHA/lime ratio equal to 2; however in all ratios studied good Cs was obtained this fact would permit to employ this kind of mortars in different uses that don’t require high strengths.

Fig. 6 represents results obtained curing the samples at 65º C. These results had similar trends as those cured at 20º C (see Fig. 5), so the same conclusions obtained above are valid for this case. As seen in figure 6, results obtained at 3 days of curing at 65º C, are very similar to the results obtained at 28 days of curing at 20º C.

Fig. 5. Compressive Strength (Cs) versus RHA/lime ratio for 28, 90 and 180 days curing times. 20ºC curing temperature.
Preliminary study of the RHA-lime mortars in tile preparation. Mortars using 2 and 3 RHA/lime ratio were prepared, this mortars were used for preparing tiles using the technology described in apparatus and procedures. Mortar tile and mould were maintained for 24 hours in moisture chamber at 20°C, but in both cases (2 and 3 RHA/lime ratios) tiles don’t resist demoulding process and break because of low mortar strength. In order to avoid this fact, a new binder was design including a low Portland cement content. The new binder composition was: 20% of Portland cement and 80% RHA-lime mixture. The RHA/lime binder ratio employed was 3, instead of 2 that produced a little more mortar strength (see Fig. 5). The reason of this decision is because we consider that in developing countries scene the economic aspects are decisive, and the cost of lime is higher than RHA. In this kind of mortars that include Portland cement an increase of workability was observed, for this reason water/binder ratio was reduced from 0.8 used in RHA-lime binders to 0.65 and no significant mortars workability reduction was produced.

Three different tests were done to the tiles cured at 20°C for 28 days: permeability, impact resistance and bending load. The first two were positive, but bending load obtained was 576 N, lower than 800 N demanded by UNE EN 490:2005. For this reason in future experiences the increase of Portland cement in binder design should be considered.

Conclusions.

Workability of mortars increases when the amount of RHA does. In all cases studied, mortars presented enough workability to be well compacted in the mortars mould.

In general an increase of compressive strength with curing time occurs however for 3 RHA/lime ratio, no significant difference between 90 and 180 days curing time is observed. This fact is probably due to a lime deficit in the mixture that stops pozzolanic reaction. The best results were obtained for RHA/lime ratio equal to 2; however in all ratios studied good Cs was obtained this fact would permit to employ this kind of mortars in different uses that don’t require high strengths.

Fig. 6. Compressive Strength (Cs ) versus RHA/lime ratio for 1,3 and 7 days curing times. 65°C curing temperature
A preliminary study of binders for using in mortars tiles reveals that at least low quantities of Portland cement must be included in binder composition in order to obtain short term strengths that make easy tile demoulding process.

In general it can be concluded that RHA-lime mixtures show good results. They could be a technological viable low-cost alternative for basic mortars, to be used mainly in developing countries. The use of RHA studied in this report would reduce the production of clinker, which contributes to the greenhouse effect. This also supposes an environmentally friendly waste management; because RHA used is an agricultural waste material and has a lower economical and environmental cost than Portland cement.

The use of these mortars would be limited to situations that do not require high mechanical strength at short curing times. The experiences should be complemented with durability studies, which should confirm the good behaviour of this kind of binders.

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