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# On Parameters Testing of an Innovative Mortar Made of Rice Husk to be Used for Housing Walls

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**Abstract**

During the design and construction of house walls, certain factors such as building materials and external climatic conditions, which are essentials and influence in human comfort, are generally ignored. The rice husk is one of the most common organic wastes generated around the word, and in Ecuador this is not an exception. The aim of this work is to study the feasibility of using a mortar which contains rice husk crushed (RHC). To show this feasibility, experiments have been conducted with mortar samples of different proportions of water, cement, sand, and crushed rice husk. The variables tested in this work include several parameters such as: analysis of flow, compressive strength, curing time, and adhesivity. As part of this project, this particular mortar is used during the construction of the housing walls in prototype houses located in one city of the Ecuadorian coastline.

Keywords: *Mortar, fluidity, compressive strength, curing time, adhesivity*.

## 1. Introduction

The raising of the world population and consequently their food consumption, result in the increment of organic and inorganic wastes. The overabundance of residual wastes causes a hard impact over the environment, and therefore can produce irreversible environmental issues to solve for the future generations. There are different initiatives to reduce the environmental impacts caused by the population´s consumption. For example, the waste recycling process to reuse this material during the manufacture of other products can be mentioned. Previous studies (Mahvi et al., 2004) mention the rice husk as one of the most common organic wastes generated around the world. Nowadays, it is found in large quantities in husking machines of rice; which is often burned, and in some occasions is thrown into rivers and estuaries, causing pollution and obstruction (Ganesan et al., 2008).

Finding a suitable utility of the rice husk in building construction will help not only to decrease the amount of this waste in the ambient, but it also improves the physical and thermal characteristics of the materials involved in the wall fabrication (Barzola et al., 2015).

The purpose of this work is to reduce the pollution generated for the husk rice wasted, using this organic waste during the manufacturing process of the housing wall mortar. According to its use, mortars in civil constructions can be classified in different ways according to its binding and use (Simba, 2007). In the present work, an innovative mortar for building applications that requires lower strengths like masonry and plastering is taken into account. Based on the mentioned characteristic, the weight ratio of the components is considered. However, the economic aspects of this alternative mortar with RHC was not considered during this study. It has been suggested as the next phase of this research.

The mortar must meet with certain characteristics; one of them is not displaying segregation in both fresh and hardened states; at inner and outer walls of a building. For this purpose, all mortar must follow technical


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processes and quality control in the laboratory, by reaching an optimal ratio among the constituent (Givi et al., 2010). The tests carried out over the mortars correspond to fluidity, compressive strength, curing time, and adhesion. Thus, the durability of mortar on the walls can be ensured, and it certainly will be complemented with the maintenance performed.

The rest of this paper is divided as follows: in Section 2, a detailed information about the materials and methods used to manufacture each sample is given. Section 3 is focused on the presentation of the results and discussions. Finally, the conclusions are given in Section 4.

## 2. Materials and methods

Along this section, information about the materials involved in the brick fabrication is given. The methodology followed and the composition for each sample mortar are presented.

### *2.1. Materials and mixture*

Mortars are the result of a mixture of different materials, which in this work were added in different proportions. Among the materials used during the manufacture of the mortars are cement, rice husk crushed and other aggregates. Amount specification and characteristics about all of these materials are given in the following sub-sections.

#### *2.1.1. Cement*

The main constitutive element of the mortar is the cement. Ordinary Portland Cement (OPC) obtained from Holcim Cement Manufacturing Company of Ecuador conforming to ASTM-C1157 standard was used.

#### *2.1.2. Rice husk crushed (RHC)*

The rice husk was obtained from rice mill. Then, this waste was ground using mill for 30 minutes. Table 1 shows sieve analysis of the RHC conforming to ASTM-C33 standard.

**Tab. 1: Sieve analysis of the RHC used in the samples**

| Sieve size | Cumulative Gram Retained | Cumulative % Retained | % Passing | ASTM – C33 |
|---|---|---|---|---|
| 3/8” | | | | 100 |
| No. 4 | | | | 95-100 |
| No. 8 | 0.4 | 0.03 | 99.97 | 80-100 |
| No. 16 | | | | 50-85 |
| No. 30 | 179.7 | 64.36 | 35.64 | 25-60 |
| No. 50 | 119.6 | 73.94 | 26.06 | 10-30 |
| No. 100 | 122.9 | 83.79 | 16.21 | 2-10 |
| PAN | 202.3 | 100 | 0 | 0 |

#### *2.1.3. Aggregates*

Graded river sand passing through 0.425 mm sieve with a fineness modulus of 2.01, and specific gravity of 2.58 was used as fine aggregate.

#### *2.1.4. Mixture proportioning*

A total of four series of mixtures were prepared in the laboratory trials. MSC0 series mixture which has traditional proportions of cement, sand and water were prepared as control specimens. MCA1, MCA2, MCA3 and MCA4 series mixture were prepared with different proportions of RHC and water.

Table 2 presents the amount and proportions used for the different samples. The amount of water is not affected because the container of the mixer is aluminum, and there is no absorption issue. (Mas i Barberà, 2006).

**Tab. 2: Amount of the different elements in the sample mortars and water/cement ratio**

| Mortar | Cement (g) | Sand (g) | Rice Husk (g) | Water (g) | Water / cement |
|---|---|---|---|---|---|
| MCA1 | 233 | 700 | 23.3 | 200 | 0.86 |
| MCA2 | 233 | 700 | 23.3 | 215 | 0.92 |
| MCA3 | 233 | 700 | 46.6 | 220 | 0.94 |
| MCA4 | 233 | 700 | 46.6 | 250 | 1.07 |

According to the information presented in Table 2, it is important to mention that each sample mortar has the same amount of cement and sand. The variable that has been subjected to change is the corresponding to the rice husk and water. The samples were prepared with two different amounts of rice husk, and four different quantities of water. The last column of Table 2 presents the ratio between the water and cement for each sample analyzed.

### *2.2. Preparation of test specimens*

MCA1, MCA2, MCA3 and MCA4 series mixture were prepared by mixing the fine aggregate and powder materials (cement and RHC) in a laboratory mortar mixer. They were mixed in dry condition for 3 min followed by another 4 min after adding the water. The powder material in MSC0 series mixtures was only cement.

### *2.3. Mortar flow*

Fluidity is the physical property of a material that shows the ability to flow. Considering that each sample is built from materials in different proportions, different values of fluidity are expected. Mortar flow is most sensitive to water content and air content. Once prepared, mortar samples were placed immediately at the flow table test in order to observe its workability. The test was done in accordance with the ASTM C 1437, the Standard Test Method for Flow of Hydraulic-Cement Mortar.

### *2.3. Compressive strength*

Mortar strength is very important because it reflects the mortar's ability to carry intended loads. In our case, the adhesion force between the masonry and mortar in the wall. For all samples, cube specimens of size 50 X 50 X 50 mm were used for the compressive strength test of mortar. They were tested at the age of 7, 14 and 28 days. The test was done in accordance with the ASTM C 109, the Standard Test Method for Compressive Strength of Hydraulic-Cement Mortar.

### *2.4. Curing time*

Another important property to analyze during the mortar fabrication is the hardening time, water retention and curing start. The mortar samples should be cured with the normal OPC hardening. The test was done in accordance with the ASTM C 191, the Standard Test Method for Time of Setting of Hydraulic-Cement by Vicat Needle.

### *2.5. Adherence*

Adherence is a property that must maintain both fresh and hardened mortar. The test was done in accordance with the ASTM C 780, the Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.

Additionally, sclerometer method is applied in housing prototypes built in order to test this mortar. This instrument measures compression strength in Q units, which can be converted in MPa units through of a curve supplied by the manufacturer. For each point to evaluate, ten measurements were made. Then, the median Q values are determined. These measurements are carried out in each both outer and inner walls, during the September 14, 2014; September 28, 2014 and May 23, 2015.

## 3. Analysis and discussion of results

### *3.1. Fluidity*

Figure 1 shows the percentages of fluidity obtained during the measurements to the samples, i.e., MCA1, MCA2, MCA3 and MCA4, each one presenting different fluidity. The results are contrasted with a traditional pattern named MSC0, which does not contain crushed rice husk. Among the four samples of mortar with crushed rice husk, results show that the MCA3 sample has better fluidity. This is as expected, because of the higher amount of water. This reduces the resistance to compression.

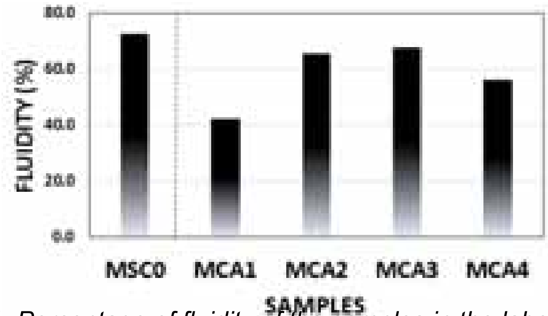


*Fig. 1: Percentage of fluidity of the samples in the laboratory*

### 3.2. Compressive strength

Figure 2 shows compression-resistance ratio. It is noticed that when W/C ratio increases, compressive strength decreases. Laboratory tests were performed on the day 7, 14 and 28. MCA1 shows a better performance in compressive strength, and therefore this sample was selected for being used in the construction of the walls in the prototypes.

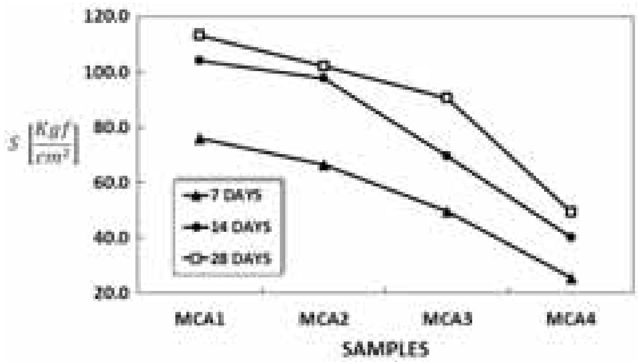


*Fig. 2: Behavior of the compressive strength of the samples according ASTM C 109*

Figure 3 presents a contrast between traditional mortar MSC0 and MCA1 selected. The traditional mortar always has a higher strength compared to mortar MCA1. In addition, on average MCA1 has a lower resistance compared to traditional mortar, since crushed rice husk also absorbs water; however, as discussed later, it has good adhesion.

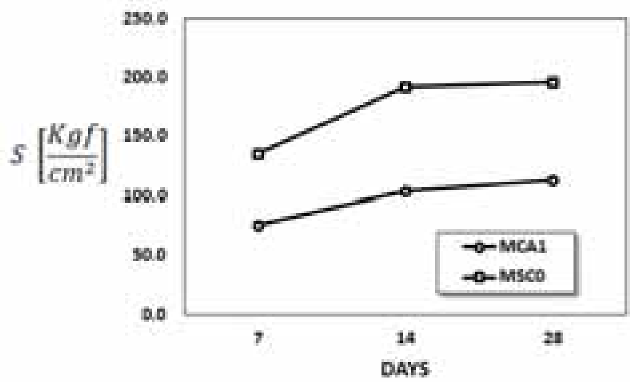


*Fig. 3. Comparison of the Compressive Strength between the traditional mortar and mortar MCA1 selected.*

### *3.3. Curing time*

Figure 4 shows the Vicat needle experimental penetration behavior applied to the sample MCA1, the data were obtained every 15 minutes, according with the ASTM C 191, the Standard Test Method for Time of Setting of Hydraulic-Cement by Vicat Needle. The result presents a very good approximation between the experimental and the corrected (theoretical) curve. When 25 mm height is reached, the hardening of cement in the mortar is achieved, which corresponds to about 4 hours (243.3 minutes) of curing time. This was a reference value to consider for the curing stage of the mortars during their utilization in housing prototypes.

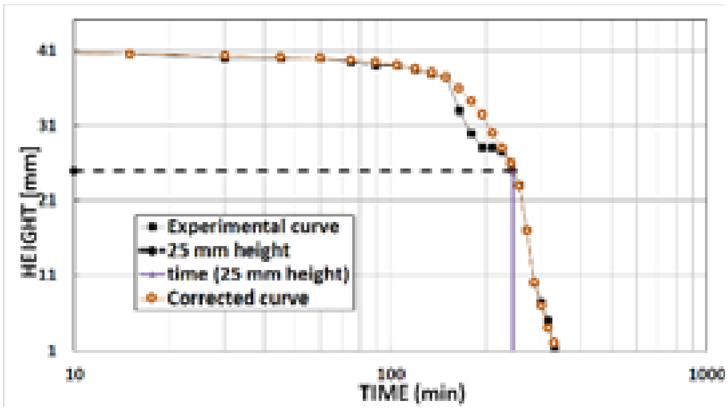


*Fig. 4: Penetration curves Vicat needle applied to mortar MCA1*

### *3.4. Adherence*

Figure 5 depicts prototypes plastered with MSC0 and MCA1 mortars, the results showed good adhesion (Barzola et al., 2015). All the prototypes have the same dimensions (2.8 m by side) and characteristics. In order to improve the thermal isolation between the inner and outer ambient of the prototypes, windows and doors were treated. Special isolation treatment on the roof was applied.

*Fig. 5: From left to right: Prototypes plastered A (MSC0), B (MCA1) and C (MCA1) in Atahualpa parishes.*

Figures 6 - 8 show the sclerometer measurements which corroborated the resistance and adhesion of the mortars in each wall. For each point to evaluate ten measurements with the sclerometer were performed, and with these values the median was determined. This instrument measures compression strength in Q units, which can be converted in MPa units by using a curve supplied by the manufacturer. This process is carried out in each outer and inner wall of each module. The dates considered for analysis of the evolution of resistance were 14, 28 September 2014 and 23 May 2015.

Radar charts summarize the results of the medians of the data obtained from the external walls. These walls were labeled counter-clockwise, starting with the front wall, E1; right side, E2; posterior and left side are labeled as E3 and E4, respectively. Each colored line depicts the measurements of a particular date according to the legend box. It can be noted that the resistance at these test points has been increasing chronologically.

The results of applying sclerometer method evidences that the best compressive strength a short term is obtained with MSC0 mortar in Prototype A. However, the MCA1 mortar used to build the prototype C showed better median values compared with Prototype B. Note that Prototype C was built with brick block, unlike Prototype A and B with concrete block.

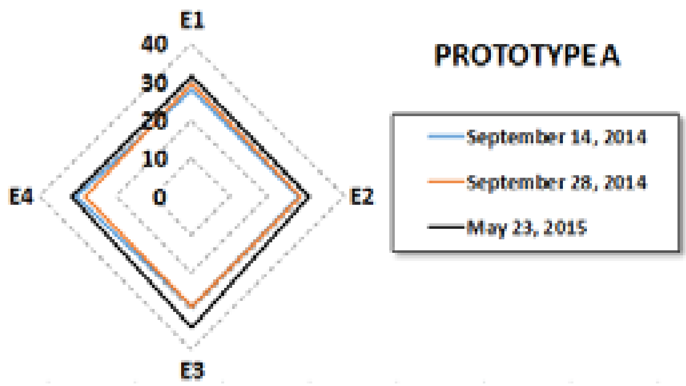


*Fig. 6: Resistance performance at external walls prototype A*

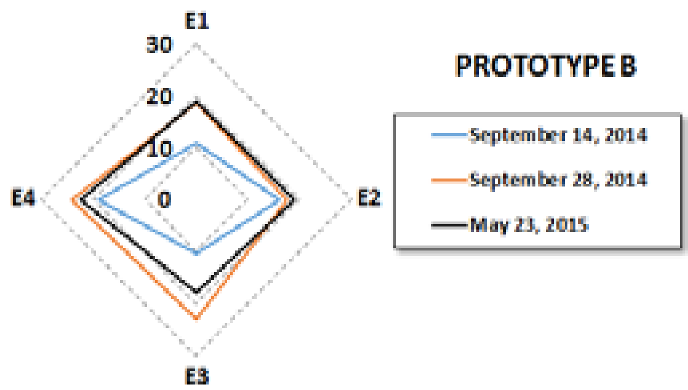


*Fig. 7: Resistance performance at external walls prototype B*

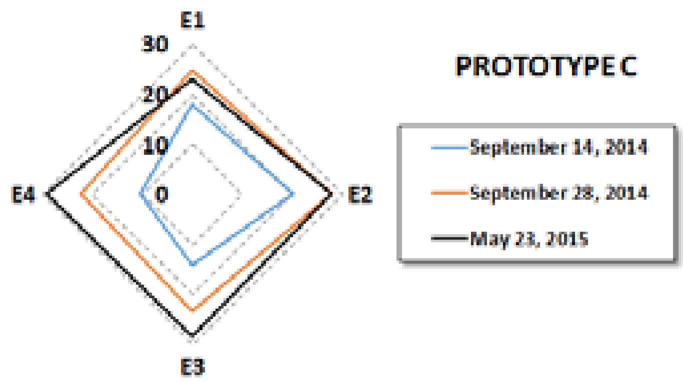


*Fig. 8: Resistance performance at external walls prototype C*

## 4. Conclusions

An innovative mortar, which contains RHC was tested. Although MCA1 mortar has lower compression strength compared to the traditional mortar, its feasibility for masonry and plastering due to both fluidity and adhesion performances is demonstrated.

In (Barzola et al., 2015), field test results of the MCA1 are shown. Two different geographical locations of the Ecuadorian coast were considered for this study, which have different weather conditions. The field test results show a thermal behavior similar to the expected if traditional mortar with OPC is used.

Finally, this study suggests that the mortar made of RHC represents a viable alternative to being used in wall constructions. At the same time using this type of mortar, the environmental impact of the overproduction of organic wastes is reduced.

## 5. References

Barzola, J., Cabrera, F., & Espinoza, M. (2015). Test Results of a Mortar Made of Crushed Rice Husk Used for Housing Walls. In proc. 13th LACCEI Annual International Conference (pp. 29–30). Santo Domingo, Dominican Republic.

Ganesan, K., Rajagopal, K., & Thangavel, K. (2008). Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete. Construction and Building Materials, 22(8), 1675–1683.

Givi, A. N., Rashid, S. A., Aziz, F. N. A., & Salleh, M. A. M. (2010). Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete. Construction and Building Materials, 24(11), 2145–2150.

Mahvi, A.H., Maleki, A., Eslami, A., 2004. Potential of Rice Husk and Rice Husk Ash for Phenol Removal in Aqueous Systems. Am. J. Applied Sci. 1, 321-326

Mas i Barberà, X. (2006). Study and characterization of composite mortars for use in sealed interventions, replacements and retort of stone sculptural-ornamental elements (In Spanish). Universitat Politècnica de València. Spain. Retrieved from https://riunet.upv.es/bitstream/handle/10251/1941/tesisUPV2517.pdf

Simba, E. (2007). The waterproofing in new and existing buildings (In Spanish). Escuela Potècnica Nacional. Ecuador. Retrieved from http://bibdigital.epn.edu.ec/bitstream/15000/1982/1/CD-0562.pdf