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Study of the correlation between the compressive strength of rice husk ash mortar

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ABSTRACT: Several studies in the scientific community have investigated the possibility of using rice husk ash in construction materials. Most of these studies looked at the possibility of using ground or unground rice husk ash. The aim of this work is to study the correlation between the compressive strength of ground rice husk ash mortar (GRHA) and the compressive strength of unground rice husk ash mortar (URHA), for the same cement replacement rates. To do this, we formulated cementitious mortars in which a mass fraction of cement is replaced by rice husk ash. The two types of mortar obtained are GRHA and URHA. The mass fractions of cement substitution by rice husk ash are: 0%, 2.5%, 5%, 7.5%, 10%, 12.5%. The different formulations obtained are Ref, GRHA2.5%, GRHA5%, GRHA7.5%, GRHA10%, GRHA12.5%, for ground rice husk ash and Ref, URHA2.5%, URHA5%, URHA7.5%, URHA10%, URHA12.5%, for unground rice husk ash. Density, porosity, and compression tests were carried out on the prepared specimens after 28 days of curing. The compressive strengths were analyzed in Excel Office to determine the correlation between the compressive strengths of GRHA mortars and URHA mortars. The results of this work show that, for low rates, an increase in the compressive strength of GRHA mortars is associated with an increase in that of URHA mortars. However, there is a weak link between the compressive strengths of the two materials for high levels of rice husk ash (RHA). The results of this work make it possible to estimate the compressive strength of URHA from that of GRHA.

Keywords: *Rice husk ash, Cement, Pozzolan, Rice husk ash mortar*

INTRODUCTION

The For several decades now, the whole world has been working to produce new materials (Givi et al., 2010). These new materials must be renewable and emit less greenhouse gas. A great deal of work is being done to make the most of plant biomass. The by-products of agriculture are renewable, making them a material that fits in very well with today's vision of sustainable development. fibers. In civil engineering, most construction materials are made from cement (Khoso et al., 2022). As cement of requiring non-renewable raw materials for its production, we need to consider reducing its use (Ghosal and Moulik, 2015). Several authors are aware of this and have therefore studied the possibility of partially replacing cement with a pozzolan derived from plant biomass (Washington et al., 2018; Bheel et al., 2019). Some authors have investigated the possibility of using sugarcane bagasse ash. However, other authors have studied ways of recovering RHA in cement (Datchossa et al., 2023; Ganta et al., 2022; Zaid et al., 2021; Thiedeitz et al., 2020; Jongpradist et al., 2018).

The work of (Bheel et al., 2019) qualifies RHA as highly pozzolanic. However, the quality of rice husk ash depends on the quality of the preparation conditions and its physical appearance. Other studies have shown that rice husk ash improves the mechanical properties of cementitious materials (Saand et al., 2019; Khoso et al., 2022; Datchossa et al., 2023). From all the reviews we have gone through, we are not aware of any work that establishes the correlation between the mechanical characteristics of cementitious mortars containing rice husk ash of different particle sizes.

This work aims to study the correlation between the compressive strength of ground rice husk ash mortar (GRHA) and the compressive strength of unground rice husk ash mortar (URHA) for the same cement replacement rates.

MATERIALS AND METHODS

Portland cement (PC) of quality CEM I 42.5R is used in the present research work. In this research, we used an unground rice husk ash obtained by controlled combustion and a ground rice husk ash obtained by grinding the former. To highlight the influence of grinding on the granulometry of the rice husk ash, an analysis of the ash was carried out using a scanning electron microscope, and a granulometric analysis of the ash and cement was carried out. The chemical composition of the rice husk ash was obtained by X-ray diffractometry. Scanning electron microscopy (SEM) images of the rice husk ash are shown at Figure 1.

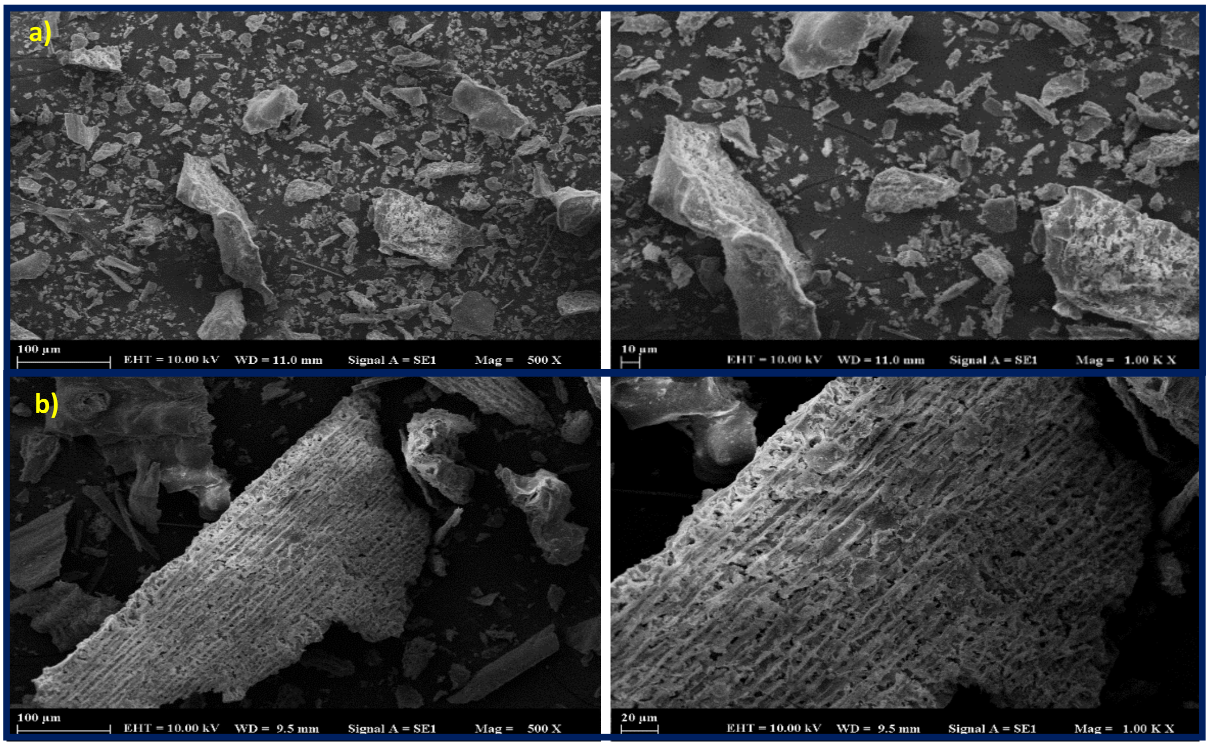

Figure 1: SEM appearance of ground rice husk ash a) and unground rice husk ash b)

It can be seen that unground rice husk ash is less compact than ground rice husk ash.

Materials used, curing conditions for rice husk ash mortars, compression test equipment.
Figure 2 shows from a) to f) the rice husk, the unground rice husk ash, the ground rice husk ash, the mortar curing conditions, the unground rice husk ash mortar, and the compression test equipment. The mortars were kept in a water bath for 28 days before being mechanically characterized.

Figure 2: Rice husk a), unground rice husk ash b), ground rice husk ash c), mortar curing conditions d), unground rice husk ash specimen e), compression test equipment f).

For our study we formulated rice husk ash mortars in which cement is partially replaced by rice husk ash. The replacement rates of cement by rice husk ash are 0%, 2.5%, 5%, 7.5%, 10%, 12.5%. The physical characteristics of the material were determined in accordance with ASTM C948-81. Specimens measuring 50x50x50mm3 are made and stored for 28 days before being used for compression testing.

RESULTS AND DISCUSSION

Chemical composition of rice husk ash

Table 1 shows the chemical composition of the rice husk ash used in this study. The sum Al_2O_3 + SiO_2 + Fe_2O_3= 88.32% is greater than 70%, so it can be said that this rice husk ash is pozzolanic in accordance with the standard ASTM C618. The table shows that quicklime accounts for more than 63% of the constituents of cement. This is normal, as quicklime is the target element in cement production; it is the very basis of cement. Once hydrated, quicklime becomes slaked lime, which can constitute a weak point in the cement matrix. We also note that rice husk ash is over 86% silica. This justifies the potential of rice husk ash to be pozzolanic. This is in fact the determining element of a pozzolan.

Table 1: Chemical composition of rice husk ash

Oxide composition (%)	Portland Cement	Rice Husk Ash
CaO	63.14	2.64
SiO_2	20.23	86.46
Al_2O_3	5.14	1.27
Fe_2O_3	3.87	0.59
MgO	1.25	0.47
Na_2O	0.26	0.06
K2O	0.83	1.37
SO_3	2.89	0.25
Loss on ignition	1.55	6.35
Others	0.84	0.54

Granulometry of rice husk ash

Figure 3 shows the particle size distribution of rice husk ash and cement. More than 30% of the particles are smaller than 20µm for ground rice husk ash. However, less than 5% of the particles are smaller than 20µm for unground rice husk ash. It should also be noted that cement contains more than 60% of particles smaller than 20µm. We would, therefore expect a more pronounced reactivity of the cementitious paste with ground rice husk ash

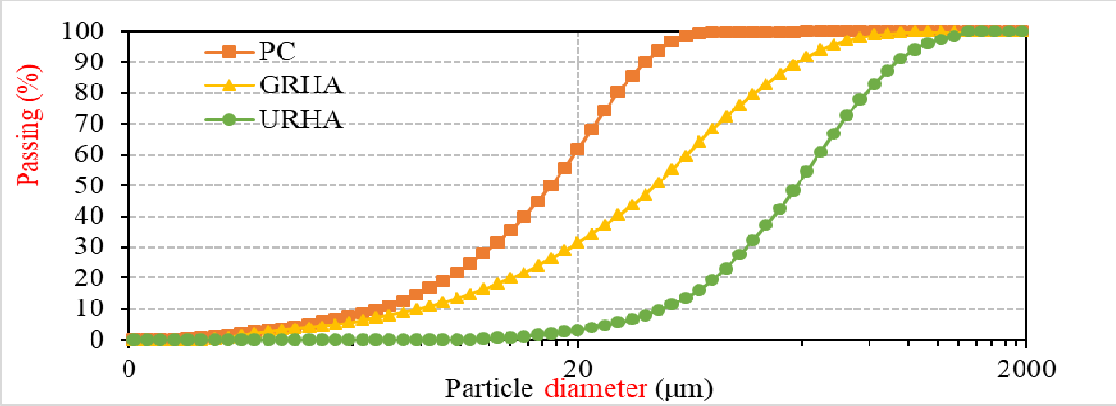

Figure 3 : Particle size distribution of rice husk ash and cement

Density of rice husk ash mortars

Figure 4 shows the evolution of the density of rice husk ash mortars. Overall, it can be observed an increasing density of the ground rice husk ash mortars with an increase in the rice husk ash rate up to a rate of 10%. After 10% the density of the rice husk ash mortars drops considerably. This could be explained by the fact that at low levels, all the rice husk ash reacts with the lime from the hydration of the cement, transforming it into silicates. This densifies the material. In the case of unground rice husk ash, there is an overall decrease in the material density with the increase of rice husk ash ratio. This could be explained by the intrinsic porosity of rice husk ash and the low reactivity of unground rice husk ash.

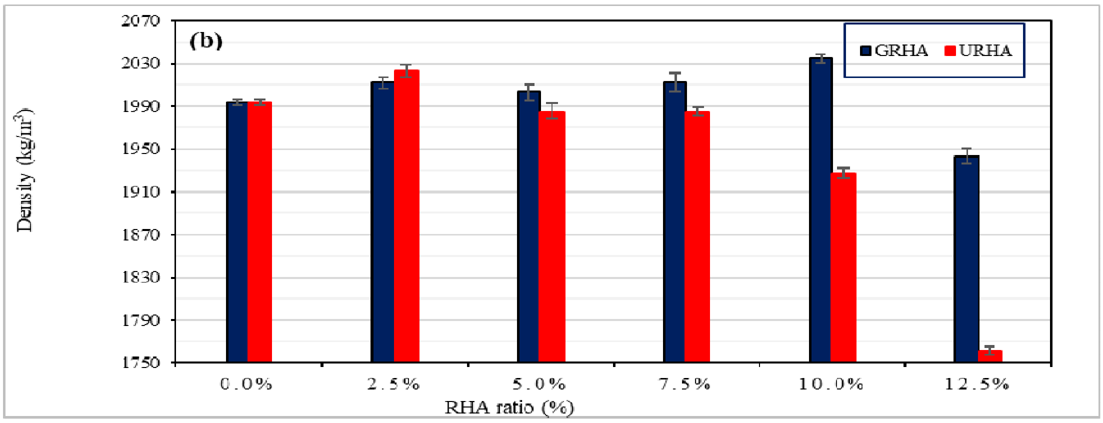

Figure 4: Density of rice husk ash mortars

Porosity of rice husk ash mortars

Figure 5 shows the porosity evolution in rice husk ash mortars with the rate of rice husk ash. This figure shows that the curve representing ground rice husk ash has two phases. The first phase shows a decreasing part of the curve, while the second corresponds to the increasing part of the curve. The first phase explains that all the rice husk ash is transformed into a silicate that closes the voids (Dao et al., 2018), while the second phase indicates that some of the rice husk ash is not transformed and forms pores (Olutoge & Adesina, 2019). The curve representing the unground rice husk ash shows overall growth. This means that the porosity in the material increases as the rice husk ash content increases (Acodji et al., 2020). The rice husk ash intrinsic porosity explains this increase in the mortar's porosity (Datchossa et al., 2023). However, the fact that 2.5% of unground rice husk ash replacing cement leads to a lower porosity in comparison with the reference indicates a reactivity of this rice husk ash while highlighting the lower reactivity of this ash compared with ground one.

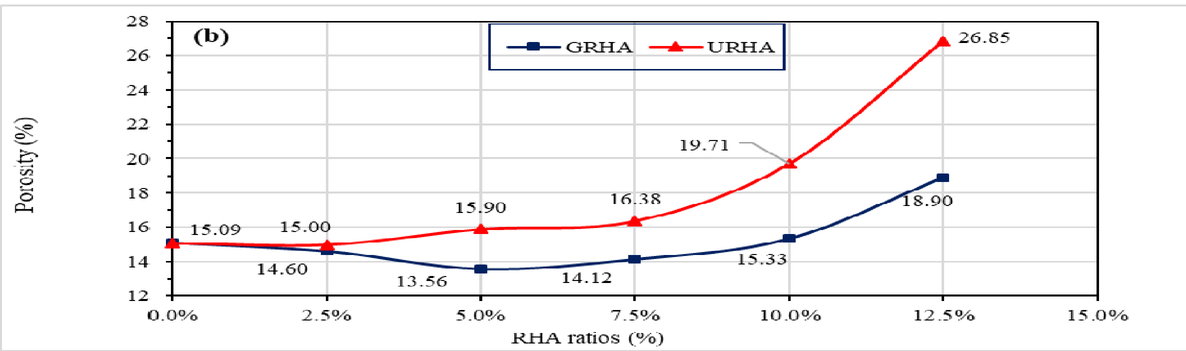

Figure 5: Porosity of rice husk ash mortars

Compressive strength of rice husk ash mortar

Figure 6 shows the evolution of the compressive strength of rice husk ash mortars. This figure shows an increase in compressive strength with the level of rice husk ash up to 10% cement replacement by ground rice husk ash. After 10%, there is a sharp drop in compressive strength. Before the 10% replacement of cement by ground rice husk ash, almost all the ground rice husk ash introduced into the cementitious paste reacted with the lime to transform it into solid elements that are silicates (Dao et al., 2018). As we saw above, the material becomes denser than the reference, resulting in higher compressive strength. Regarding the use of unground rice husk ash, we observe a decrease in compressive strength with increasing rice husk ash rate. However, we observed a greater compressive strength than the reference with the 2.5% replacement rate cement replacement rate by unground rice husk ash. This means unground rice husk ash is reactive but less reactive than ground rice husk ash (Datchossa et al., 2023).

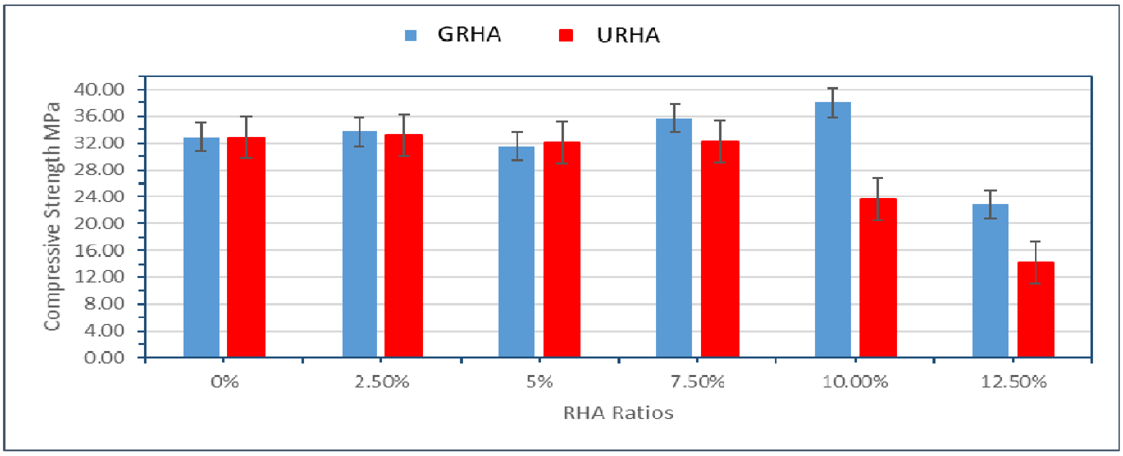

Figure 6: Compressive strength of rice husk ash mortar

Correlation between the compressive strength of ground rice husk ash mortars and unground rice husk ash mortars.

Figure 7 shows the progression of the compressive strength of unground rice husk ash mortars as a function of the compressive strength of ground rice husk ash mortars. The trend curve shows that as the compressive strength of the ground rice husk ash mortar increases, the compressive strength of the unground rice husk ash mortar increases. However, we note a correlation coefficient $r^2 = 0.42$; this means that the link is weak between the compressive strength of unground rice husk ash mortars and the compressive strength of ground rice husk ash mortars. This weak relationship is explained by the fact that ground rice husk ash and unground rice husk ash behave differently in the cementitious paste. Because of its greater porosity, unground rice husk ash absorbs water and greatly increases long-term mechanical strength (Akturk et al., 2022). In contrast, ground rice husk ash develops mechanical strength more quickly at a young age (Bheel et al., 2019).

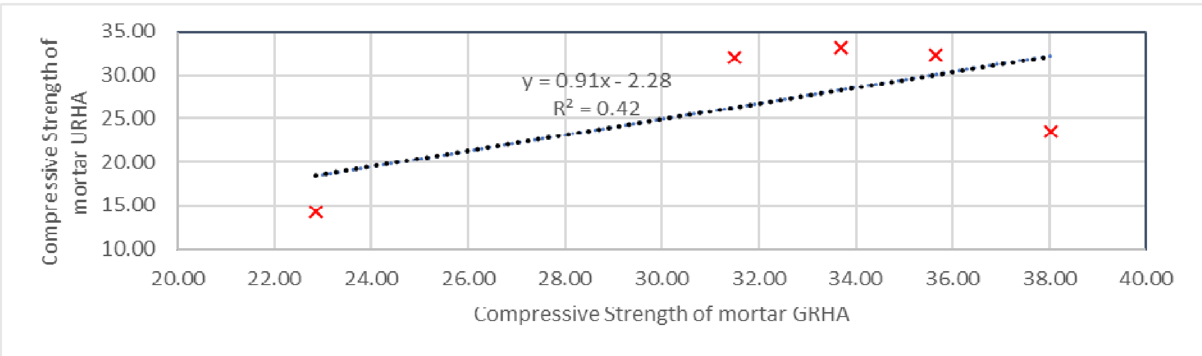

Figure 7: Correlation between the compressive strength of ground rice husk ash mortars and unground rice husk ash mortars

CONCLUSION

The present study investigates the correlation between the compressive strength of rice husk ash mortars. From this study, we realized that the material's porosity increases with the rice husk ash level. Ground rice husk ash induces fewer pores in the mortar than unground rice husk ash. In addition, unground rice husk ash results in lighter mortars compared with ground rice husk ash. Maximum compressive strength is obtained with 10% ground rice husk ash. The correlation between the compressive strength of unground rice husk ash and the compressive strength of ground rice husk ash is very weak.

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Ethical clearance number
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Competing interests
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Authors contributions
The authors of this research participated on an equitable basis.

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