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DETERMINATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF 1:4 MORTAR WITH ADDITION OF RICE HUSK AS A PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

Agricultural residues can be used as a resource for construction materials, one of these residues is rice husk which is generated in large quantities during rice processing. The aim of this article is to determine the physical and mechanical properties of a 1:4 dosage mortar with the addition of rice husks as a partial replacement of fine aggregate, seeking the possibility of innovating with the creation of a composite material with low environmental impact and optimal physical and mechanical performance characteristics. This research was carried out in five stages: Stage I, obtaining the materials for the mortar. Stage II, mix design. Stage III, tests to obtain the physical-mechanical properties of the mortar with a dosage of 1:4 with and without the addition of rice husks. Stage IV, selection of the specimens of the mortar for plastering with the addition of rice husks with the dosage that presented the best results in the physical-mechanical properties and the specimens without the addition of fibres. The selected materials were sand, cement type I "General use", water and rice husk as a reinforcing agent. The mix design allowed the production of mortar cubes and beams in 4 groups: 0%, 1%, 3% and 5% of rice husk, with respect to the sand content. The mortar with rice husks showed an increase in flexural strength compared to the mortar without rice husks between 5 and 19%. The inclusion of rice husks as a partial replacement of the fine aggregate in the 1:4 mortar is adequate and meets the requirements for this material.

INTRODUCTION

The unsustainability of the modern construction industry has generated a constant search for alternative building materials in order to reduce global carbon dioxide emissions (CO_2) and the consumption of raw materials (Silva et al., 2020), as it is responsible for 38% of the world's greenhouse gas emissions (UNEP, 2020). The construction industry is receiving more and more attention from the scientific community and the general public where the application of sustainable materials and processes together with the circular economy is being pursued with the use of different construction systems (Wang et al., 2022), such as fibreglass, glass fibre, glass fibre and glass fibre reinforced plastic such as fibreglass, steel, polypropylene or cellulose, are a proof of a market in development and innovation (Bustillo, 2008).

The construction boom has generated a massive rise in the production of concrete and mortar as they are the most widely used materials due to their high strength, durability and impermeability, which implies intensive use of raw material and energy, releasing high amounts of carbon dioxide into the atmosphere (Cheah & Ramli, 2011; Rashmi Nayak et al., 2022). However, there are additives derived from recycled or waste materials (agricultural and industrial waste) used in construction (Małek et al., 2021), which can reduce the environmental footprint on the planet because they generate lower carbon dioxide emissions, are low-cost and readily available (Rashmi Nayak et al., 2022).

River sand is one of the main raw materials used as filler to produce concrete and mortar, where the construction industry worldwide consumes around 40% of the sand, generating impacts such as deforestation, loss of biodiversity, soil erosion and air pollution (Selvaranjan et al., 2021). For this reason, alternatives must be sought for the conservation of natural resources and to reduce their extraction, which has intensified the search for materials that allow the use of traditional raw materials to be reduced.

Agricultural residues can be used as a resource for construction materials such as rice husk, coconut husk, bagasse or oyster shell, which are used to increase the strength in concrete where residues such as rice husk and starch improve the rheological properties and compressive strength (Thiedeitz et al., 2022). Rice husks are generated in large quantities during rice processing, and have been used as fuel in the rice milling process, biogas production and combustion; however, they are also dumped as waste in the process of rice milling, biogas production and combustion (Vishavkarma & Harish, 2022); however, it is also dumped in open areas generating a negative impact on the environment (Selvaranjan et al., 2021).

The purpose of this article is to determine the physical and mechanical properties of a 1:4 mortar with the addition of rice husks as a partial replacement of the fine aggregate, seeking the possibility of innovating with the creation of a composite material with low environmental impact and optimal physical and mechanical performance characteristics, to be used in the construction of dividing elements of any civil works project that may be developed in Colombia. The article is organised following the presentation of rice husk samples and the specimen fabrication stage, then the final results are shown.

MATERIALS AND METHODS

Collection of rice husk samples

The rice husk samples were collected in the department of Norte de Santander, where there are about 18,000 hectares dedicated to rice cultivation, whose annual production exceeds 200,000 tonnes, which represents more than 20,000 tonnes of rice husks, which are totally discarded and therefore become a source of contamination in the processing centres of this product. There are currently 10 rice processing companies in the department: Ecofermil S.A.S., Grupo Villamizar Flórez S.A.S., Agrorugeles S.A.S., Malvilla S.A.S., Madoplast S.A.S., Fe y Futuro S.A.S., Agroinversiones Loma Verde S.A.S., Arrocera Guarín S.A.S., and Preago S.A.S. (Albarracín et al., 2019).

Test tubes

Specimens were made to obtain the physical-mechanical properties of the material, which were tested according to ASTM C-109 (NTC 220), ASTM C-438 (NTC 120), ASTM E-114 (NTC 4325), and ASTM E-1348 standards, where a minimum number of 18 specimens for each percentage of rice husk added to the mortar (between beams and mortar cubes) was established for the research. The total number of specimens tested was 66. Table 1 shows the specimens used in each test.

Table 1. Number of specimens of render or mortar for each test

Essay	**Number of specimens**
Compressive strength	24
Bending strength	24
Ultrasound	12
SEM	6
Total test tubes	**66**

Number of trials determined by investigator's judgement based on similar research.

Test-tube manufacturing stages

The first stage consisted of obtaining the necessary materials for the development of the mortar, which were sand, cement type I "General Use", water and rice husk as a reinforcing agent. Grain size tests were carried out to comply with ASTM C-144 Standard specification for aggregates for masonry mortar and NTC-2240 Aggregates for backfill mortar used in masonry. In the second stage, the mix design was determined, where test specimens (cubes and beams) were made for 4 groups, one group without rice husk addition, and the other 3 with a different percentage of rice husk. The percentages used were 1, 3, and 5% with respect to the sand content. The cubes had the corresponding dimensions established in ASTM C-109 and NTC-220, and the beams had the dimensions indicated in ASTM C-348 and NTC-120.

In the third stage, tests were carried out to obtain the physical-mechanical properties of the mortar with a 1:4 dosage with and without the addition of rice husks, according to ASTM C-109 and NTC-220 for the compressive strength test, ASTM C-348 and NTC-120 for the flexural strength test, and ASTM E-114 and NTC 4325 for the ultrasonic test. At this stage, the respective categorisation of the mortar for rendering was carried out according to NTC-3329 Specification of mortar for masonry units. In the fourth stage, the specimens of the mortar for rendering with the addition of rice husk were selected with the dosage that presented the best results in the physical-mechanical properties and the specimens without the addition of fibres. A total of 6 specimens were tested under the Scanning Electron Microscope (SEM).

RESULTS

The sand was subjected to a granulometry test before the preparation of the specimens, where it was verified that it complied with the requirements established in NTC-2240 Aggregates for backfill mortar used in masonry, as shown in Figure 1. The format of the test results and the evidence of their performance is shown in Appendix A. This test was carried out at the Soils and Pavements laboratory of the Universidad Francisco de Paula Santander Ocaña.

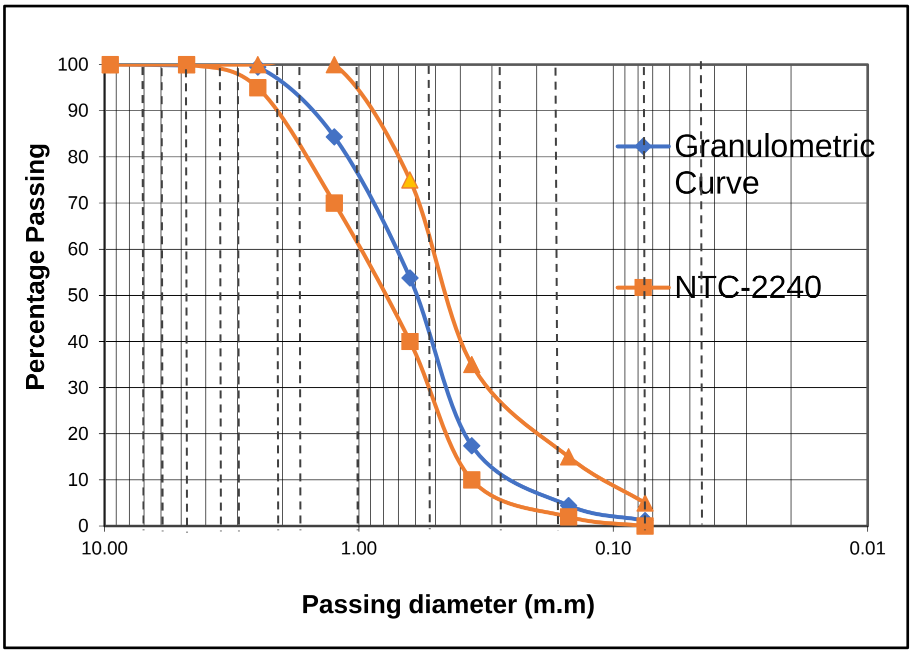

Figure 1. *Granulometry of the sand used.*

The results of compressive strength obtained in the 7 and 28 days cubes are shown in (figure 2), where it is clearly observed that the strength at 28 days is higher than at 7 days, which shows a normal behaviour in this type of materials.

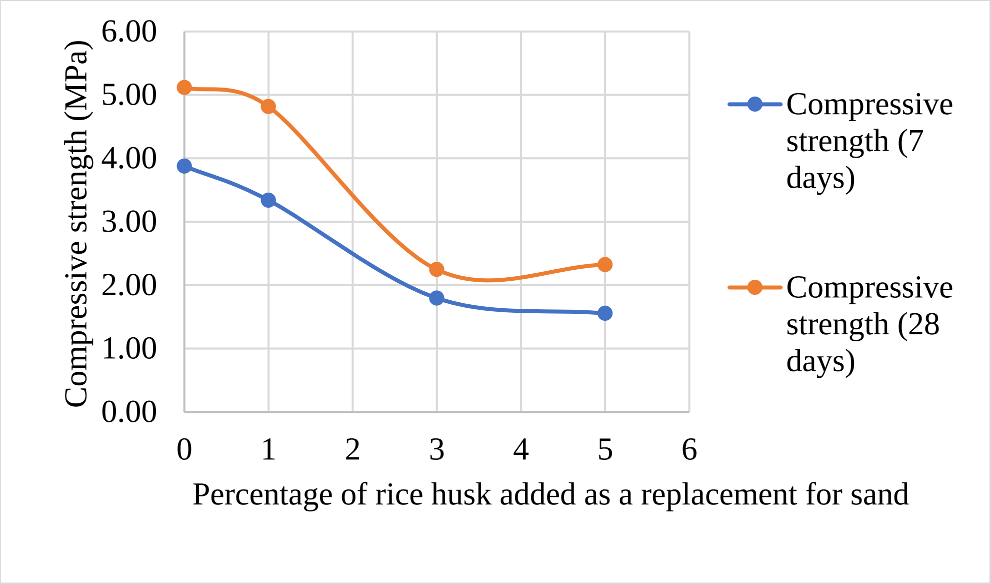

Figure 2. *Comparison graph of mortar compressive strength at 7 and 28 days.*

According to NTC 3329 Concrete mortar specifications for masonry units, mortars can be classified according to their compressive strength as shown in Table 2. Based on this classification the mortar studied, and specifically the one with the inclusion of 1% rice husk, can be classified as Type O, and therefore meets the minimum requirement to be used for masonry units.

Table 1. Compressive strength of mortar at 28 days

Type	**Compressive strength at 28 days (MPa)**
M	17.20
S	12.40
N	5.20
O	2.40

Figure 3 shows a comparison between the flexural strengths obtained at 7 and 28 days, where several aspects are observed in the results obtained, such as the highest flexural strength is obtained in the mortar with the addition of 1% rice husk, which is even higher than that of the mortar without the addition of husk, both at 7 and 28 days.

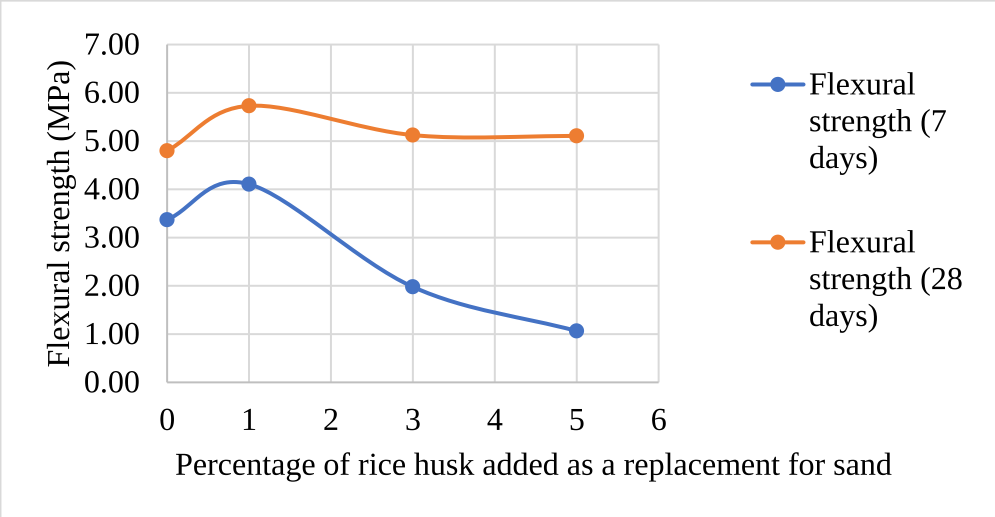

Figure 3. Graph of comparison of mortar flexural strength at 7 and 28 days .

The results obtained in the Ultrasonic Pulse Velocity test show a clear proportionality with the increase of the percentage of rice husk. These values indicate that the higher the amount of rice husk in the mortar, the higher the porosity or air content present in the mortar, which is related to the decrease in weight of the specimens tested. Figure 4 shows the graphical comparison between the results obtained at 7 and 28 days.

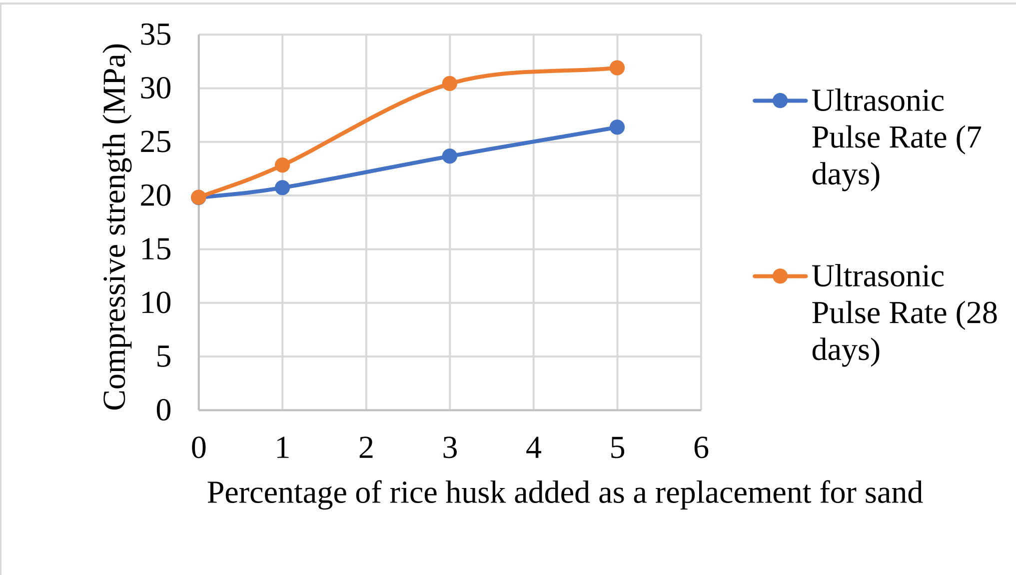

Figure 4. Graph of the comparison of the Ultrasonic Pulse Velocity of the mortar at 7 and 28 days.

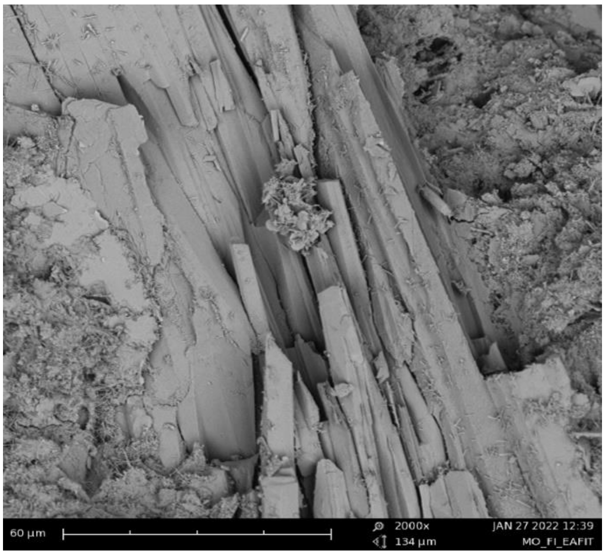

Figure 5. Microscopic composition of the mortar without the addition of rice husks.

The Scanning Electron Microscopy (SEM) test showed the distribution of the particles that make up the mortar with and without the addition of rice husks. Figure 5 shows the microscopic aspect of the mortar without rice husk addition, and figure 6 shows the microscopic aspect of the mortar with 1% rice husk addition.

Figure 6. Microscopic composition of the mortar with the addition of 1% rice husk.

Figure 6, shows, in contrast to the previous figure, the presence of voids within the mortar, which explains why the mortar with 1% has a higher Ultrasonic Pulse Velocity than the mortar without the scale, as well as being slightly less resistant to compression. The complete photographic record of this test is shown in Appendix F.

CONCLUSION

The characterisation of the materials used for the manufacture of the mortar determined that they complied with the specifications required by NTC 2240 Aggregates for filler mortar used in masonry. The mix design allowed the production of the mortar cubes and beams in 4 groups: 0%, 1%, 3% and 5% rice husk, with respect to the sand content. The physical-mechanical properties of the mortar allowed to determine that all percentages of rice husk decrease the compressive strength, however, the mortar with 1% rice husk reaches up to 95% of the strength of the mortar without additions, which also allows to classify it as Type O mortar, according to NTC 3329, which indicates its application for masonry units.

The mortar with rice husk showed an increase in flexural strength compared to the mortar without rice husk, for all percentages: 1%, 3% and 5%, this increase ranges between 5 and 19%, which indicates that rice husk can be an important element in mortars that are subjected to constant bending stresses, such as pavements, pavements, floors, among others. The results of the Ultrasonic Pulse Velocity indicate that the higher the rice husk content, the higher the value of this property, which in turn demonstrates the increase in porosity present in the mortar. The microscopic images obtained from the SEM test show that the addition of 1% rice husk produces the appearance of pores within the particles that make up the mortar, while the mortar without rice husk shows noticeable cement clusters.

The inclusion of rice husks as a partial replacement of the fine aggregate in the 1:4 mortar is adequate, and that the use of 1% rice husks guarantees the achievement of physical-mechanical properties that meet the requirements demanded of this material.

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