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Cracking Control in *Mezzanine Floor Slabs* using Rice Husk Ash and Polypropylene Fibers

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Abstract. The continuous population increase in recent years requires a greater number of households to be built quickly, with good materials and produced under quality standards that guarantee their manufacturing process. The prefabricated concrete, produced and supplied by concrete plants, is poured into the different structural elements, the mezzanine slabs being the most careful surfaces in the appearance of fissures; because being horizontal and having larger dimensions, the dimensional changes in the concrete appear more frequently due to the rapid loss of water from the surface of the concrete before setting; which generates superior stresses to the resistant capacity of the concrete at early ages, which affect the durability and reduce the resistance of the structures, causing greater economic expenses in maintenance and repairs. In the present investigation, 5%, 10% and 15% of rice husk ash was used as a replacement for cement and 900g/m³ of polypropylene fiber; The results indicate that as the percentage of rice husk ash increases, there is a reduction in the slump and the crack fissures, and that the resistance to compression and flexion decreases, with respect to the concrete pattern.

1. Introduction

House constructions are constantly growing and the most used material that provides flexibility in its design is concrete [1], which after being placed on large surfaces, such as solid slabs, tends to crack due to plastic shrinkage [2]; the magnitude of the cracks depends on the ambient temperature, relative humidity and wind speed [3], producing in the structures the reduction of their serviceability and aesthetics [4]; The appearance of cracks in the concrete reduces its useful life and increases the permeability and the risk of penetration of environmental agents [5]. Rice husk residues are discarded in landfills and cause pollution [6], their ashes are used as partial cement replacement because they improve the quality and durability of concrete [7,8,9]; however, high amounts of replacement can negatively affect its resistance and permeability [10]. On the other hand, polypropylene fibers are used in the reduction of early cracking [5]; in the control of cracks, in the increase of durability and serviceability of the structure [12]. The particle size of rice husk ashes (RHA) is important because the smaller it is, the plastic shrinkage increases [13]; Compressive and flexural strengths are reduced by adding RHA, 10% being an optimal percentage [14,15]. On the other hand, synthetic fibers are used to prevent shrinkage cracking, polypropylene fibers stand out for their efficiency and can be applied in quantities by volume of 0.10% [16]. Fiber length is important in reducing shrinkage, with 19mm fibers better than 13mm fibers for volume replacements from 0.05% to 0.20% [17]. With regard to the compressive and flexural strengths, with the amount of 0.9% of total volume, resistances higher than conventional concrete are achieved [17]. The purpose of this work is to study the effect of RHA on the settlement, plastic shrinkage cracking, compressive strength and flexural strength in order to make a concrete to control the fissures of the mezzanine floor slabs.

2. Materials and Method

2.1 Materials

Andino Ordinary Portland Cement Type I was used; Natural fine aggregate from the “Trapiche” quarry; 1” natural coarse aggregate from the “Jicamarca” quarry; polypropylene (FPP) fibers of L = 12 mm, Ø = 0.012 mm, density 910 kg / m³ and tensile strength of 480 MPa; rice husk ash (RHA)



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obtained from uncontrolled combustion in the open air (temperature of 500 - 600 oC) from the city of Chiclayo and sieved by the mesh N 30 (600 μm). The water was drinkable.

2.2 Method

The mix design was made for a concrete $f'c = 210 \text{ Kg/cm}^2$ and according to [18]. Table 1 shows the designs of mixtures made for the mixing of standard concrete without inclusion of RHA or FPP. The elaborated mixtures are shown in Table 1 and in Table 2 the tests, standards, number of specimens and curing ages. The test specimens for the compressive strength test were cylindrical of 15 cm x 30 cm, for the flexural strength test with loads to the thirds of the light of 15 cm x 15 cm x 50 cm, which were demoulded at 24 hours and then rehearsed.

Table 1. Mix design for concrete $f'c = 210 \text{ Kg/cm}^2$

Mix	OPC (Kg/m^3)	FA (Kg/m^3)	CA (Kg/m^3)	Water (L/m^3)	RHA (Kg/m^3)	FPP (Kg/m^3)
Pattern	366	844	944	224	0	0
RHA-5_FPP	347.7	844	944	224	18.3	0.9
RHA-10_FPP	329.4	844	944	224	36.6	0.9
RHA-15_FPP	311.1	844	944	224	54.9	0.9

Table 2. Tests Performed

Concrete Tests	Methods	N° Specimens	Cure Age (days)
Slump	[19]	8	---
Plastic shrinkage cracking	[20]	2	1
Compressive strength	[21]	9	7, 14 y 28
Flexural strength	[22]	9	7, 14 y 28

3 Results and Analysis

3.1 Slump

Table 3 shows the effect of the percentage of RHA and fixed amount of FPP in the slump. It can be seen that as the percentage of RHA replacement increases, the slump decreases, by 0.50", 0.75" and 1" in relation to the pattern mixture. [23], for a ratio of $w/c = 0.60$, the slump decrease values of 0.4" and 0.7" are obtained for 10% and 15% with respect to traditional concrete. Similarly [24], for the same w/c ratio and a replacement of 10% of RHA, the slump decreases by 0.50". These trends are similar to those of the study. [25] explains that this behavior is due to the fact that RHAs have a high specific surface that attracts more water molecules, requiring increasing the water in the mixture to maintain an optimum level of workability.

3.2 Plastic Shrinkage

Table 3 shows the effect of the percentages of RHA and fixed amount of FPP on plastic shrinkage. It is observed that the crack reduction ratio (CRR) increases with the percentage of RHA, reaching the values of 26.67%, 40% and 78.32% for mixtures RHA-5_FPP, RHA-10_FPP and RHA-15_FPP with respect to the pattern sample. [26] perform concrete mixtures with 1% FPP in total volume, finding that after 24 hours the mixtures with FPP increase the CRR by 65% compared to traditional concrete. [27] performs concrete mixtures with $a/c = 0.50$ and cement replacements of 15% and 25% of fly ash with 0.05% of basalt fibers in total volume, obtaining that after 24 hours the CRR increases 50% in average. These trends are similar to those of the present study. According to [28], this behavior can be

attributed to the lower cement content compared to control mix, as well as to the pore size and grain size refinement processes which strengthen the mechanical interlocking in the transition zone.

3.3 Compressive Strength

Figure 2 shows the effect of cure time on compressive strength for different percentages of RHA and a fixed amount of FPP. It can be seen that as the curing time increases, the resistance increases for all the mixtures, the pattern mixture being the one that obtains the greatest resistance; reaching for the 28 days the value of 251.33 Kg / cm² which represents 9.32%, 18.12% and 28.53% more than the RHA-5_FPP, RHA-10_FPP and RHA-15_FPP mixtures. Similar results after 28 days of curing. [29], that partially replacing the cement with 5%, 10% and 15% of RHA obtains lower resistance values with respect to traditional concrete being these of the order of 25.13%, 30.57% and 31.05%. In the same way, [30] demonstrates for replacements of 10%, 20% and 30% the resistance with RHA, at the age of 28 days, is lower than traditional concrete in 8.88%, 9.96% and 27.20%. These trends are similar to those of the study. [23,30] indicates that this behavior is due to the increase in RHA content, the volume of capillary pores increases and Ca (OH)₂ accumulates in the interface, resulting in a less compact structure that causes the resistance to be less; that is, by adding RHA to the concrete, the porosity increases and the density decreases causing a lower resistance to compression.

3.4 Flexural Strength

Figure 3 shows the effect of curing time on flexural strength for different percentages of RHA and a fixed amount of FPP. It is seen that as the curing time increases, the resistance increases for all the mixtures, the pattern mixture being the one that obtains the greatest resistance; reaching for the 28 days the value of 27.40 Kg / cm² that represents 17.01%, 18.14% and 28.47% more than the RHA-5_FPP, RHA-10_FPP and RHA-15_FPP mixtures. These results are consistent with [23], which with 10% and 15% RHA for ages 7, 14 and 28 days finds that the flexural strength decreases with respect to the standard concrete by 1.85%, 2.96%, 16.57% and 2.78%, 3.94%, 27.68% for replacements of 10% and 15% respectively. In turn, [31] investigates the addition of RHA in flexural strength using 3 calcination methods (outdoors, in stoves and in ovens) for 5%, 10% and 15% replacement at 28, 90 and 150 days; obtaining that the resistance at 28 days for the 3 calcination methods with replacements of 5%, 10% and 15% RHA, is lower with respect to the control sample in average values of 35%, 48% and 52% . These trends are similar to those of the present study. [32,33] indicate that this behavior is due to the low pozzolanic activity of the RHA.

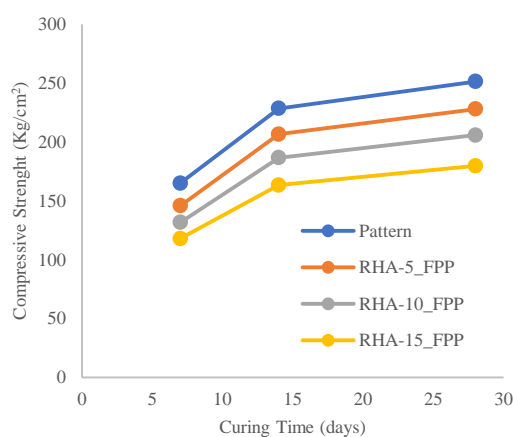


Figure 1. Effect of cure time on compressive strength

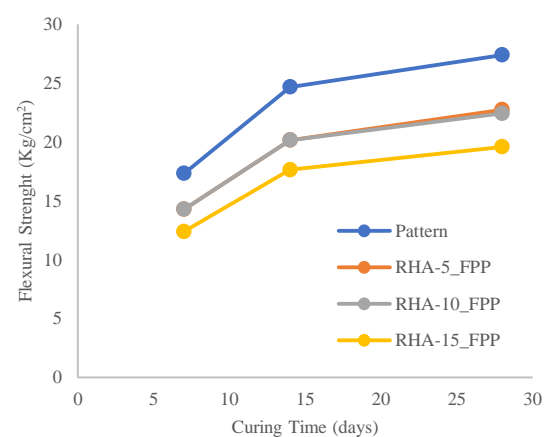


Figure 2. Effect of cure time on flexural strength

4. Conclusions

- The partial replacement of cement by 10% of RHA and 900 g/m³ of FPP demonstrates that plastic shrinkage cracks decrease in size and width, preventing the entry of external agents that can damage the durability of the structure.
- The workability of the mixture decreases with the additions of RHA and FPP, because the hydrophilic nature of the RHA stimulate the absorption of water from the mixture, and the FPP produce higher friction in the mixture.
- Compressive strength and flexural strength decrease, with RHA particles favorable for fissure reduction and FPP reinforce concrete elements.
- Plastic shrinkage cracking decreases, indicating that the combined incorporation of RHA and FPP helps in reducing the crack fissures.

Table 3. Effect of the percentage of RHA and FPP on slump and CRR

Code	Slump (in.)	# Cracks	Crack Width (mm)		Average Crack Width (mm)	CRR (%)
			Mín.	Max.		
Pattern	1,5"	10	0,1	0,6	0,375	---
RHA-5_FPP	1"	10	0,05	0,5	0,275	26,67
RHA-10_FPP	0,8"	10	0,05	0,3	0,225	40,00
RHA-15_FPP	0,5"	10	0,05	0,1	0,0813	78,32

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