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The Effects of Rice Husk Ash on Mechanical Properties of Mortar.

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Abstract: *This research analyzes the effects Rice Husk Ash (RHA) on the mechanical properties of mortar, specifically (flexural and compressive strength). Lately, there has been huge interest in the use of supplementary cementitious materials (SCMs) as a partial replacement for ordinary Portland cement (OPC) in mortar and concrete. The high carbon dioxide released into the environment during the production of (OPC) has caused a need to replace it. RHA is one of these (SCMs) being studied by many researchers. It is derived from burnt rice husks and can cause pollution when discarded in the environment and that is why it is so important to recycle it and make good use of it. RHA is a known admixture of mortar, working to increase the flexural modulus and the stiffness. The use of RHA with mortar improves workability and stability, reduces thermal cracking, heat revolution and plastic shrinkage. This increases strength development, impermeability and durability by strengthening transition zones.*

Keywords*: Mortar, Rice husk ash, Mechanical properties, Flexural strength, Compressive strength.*

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I. INTRODUCTION

Concrete and mortar are both used in building projects but there are some differences in their composition and therefore their strength which means they should not be interchanged and one should not be used as a substitute for the other. Basically concrete is stronger and more durable so it can be used for structural projects such as setting posts whereas mortar is used as a bonding agent for bricks, stones, etc.

Mortar is a mixture of water, cement and sand without coarse aggregates but it can be mixed with other admixtures in order to improve its mechanical properties.There are a lot of different types of mortar and admixtures such as; water reducing, retarding, accelerating, damp proofing, pozzolanic admixtures and many other admixtures. In this research, we look at a material that is considered be a waste material of rice. RHA which is obtained after burning rice husks (RH) is a pozzolanic material that has very little value commercially. Having pozzolanic properties means having little or no cementitious properties but can form compounds with these kinds of properties when mixed with water because of the high silica content present in these materials.

According to environmentalists, rice husks are known to cause pollution when carelessly disposed on land or in water. This had been a problem for many years until researches found out of its pozzolanic properties. Today there are a lot of studies about RHA properties and how it can be recycled and used positively to help reduce pollution. RHA is used for many other purposes including; as a filler additive that improves performance and improve surface faces while reducing cost. RHA also works as a suspension agent for porcelain glazes. Rice husk ash has an advantage because it has very little commercial value, meaning it is very cheap because it is considered to be waste but at the same time having very important properties required especially in the construction company. That is why it is important to experiment and check its effects on mechanical properties of mortar when it partially replaces cement.

Mechanical Properties

The compressive and flexural strength are the mechanical parameters of our mortars that have been evaluated.

1. **Compressive** strength is the major mechanical properties of mortar and all other mechanical properties are related to it. Earlier studies showed that mortar with no RHA has been reported to have higher compressive strength than those with RHA at replacement levels from 20 to 30 [6]. Mortar incorporating no SCM and those with silica fume (SF) as 10% replacement of OPC have reported a higher compressive strength compared to

those incorporating RHA at the same replacement level. However, Wada [1] reported a contradicting result indicating mortar/concrete incorporating RHA has a higher compressive strength compared to those without RHA. Higher compressive strength up to 91 days was also reported [2]. He also concluded that a 20% replacement level of OPC with RHA produced the highest compressive strength. Also supported that the maximum OPC replacement level with RHA as 20%, as there might be detrimental effects on the properties of mortar/concrete after this replacement level. Replacement level of OPC with RHA less than 5% have been found to be insufficient to improve the early age compressive strength of mortar).

2. **Flexural** strength which can also be referred to as modulus of rupture is the ability of a mortar/concrete to resist deformation as a result of bending. Flexural strength of mortar strength [4] reported an increase in flexural strength to 20% OPC replacement level with RHA. The compressive and flexural strength are the mechanical parameters of our mortars that have been evaluated. The flexural strength is carried out on the 4 × 4 × 16 cm3 mortars with a hydraulic press equipped with a 200 KN load cell at a controlled displacement rate of 0.5 mm/min. Equation (1) makes it possible to determine the limit stress in flexural strength:

σ=3FE2le2 (1)

F is the intensity of the force applied, E is the distance between the two specimen supports, l is the width of the specimens, e is its thickness and σ is the stress at break.

In order to determine the compressive strength, the half-prism resulting from the flexural strength is subjected to a monotonously increasing load until breaking. Thus, the compressive strength is the ratio of the breaking load to the cross section of the specimen. The value of the resistance RC is obtained from Equation (2):

RC=PS (2)

With: S average value of the section in cm2 and P the load in KN. The flexural and compression strength tests are carried out in accordance with standard NF P 15-471. NFP15-471 . The images examination of mortars was performed with the Hitachi S2500 scanning electron microscopy (SEM).

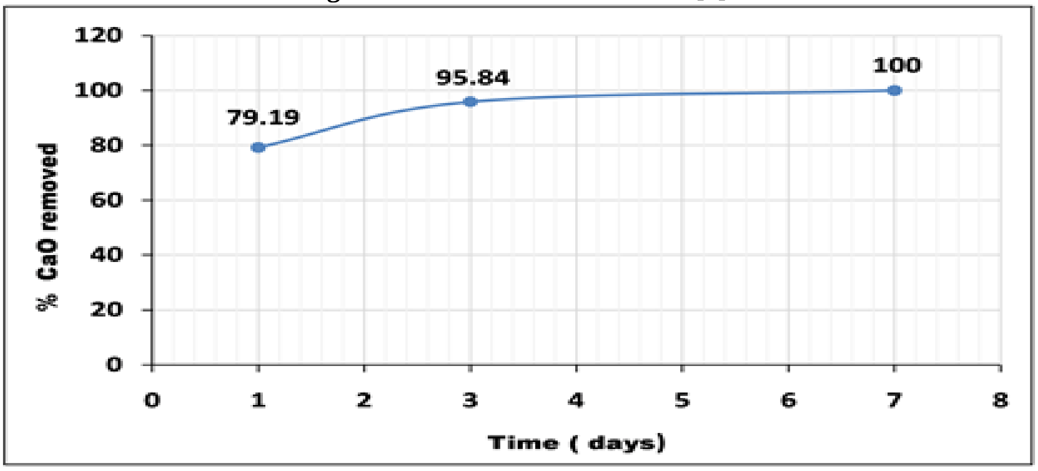
Water absorption and water permeability

The behavior of pore specimens is assessed by measuring sorptivity, water absorption and water permeability rate of unsaturated specimens by immersing in water with or without water head. observed that the sorptivity values decreased on increasing compressive strength and the blended concretes showed lower sorptivity values compared with reference OPC concrete at the similar strength values the authors used OPC as well as several binary and ternary blended mortars containing FA and MK with OPC at equivalent w/c ratios and compressive strengths. They reported that the addition of pozzolanic materials to OPC significantly reduced the sorptivity values of the mortar specimens. Sorptivity values of the FA binary blended cement mortar specimens were found to decrease with the addition of FA content up to 55%. On the other hand, sorptivity values of the MK binary blended cement mortars were found to decrease with the addition of MK content up to only 10%.

Saturated Lime Test

The results of the saturated lime test are shown in Figure 4. At a young age (1 and 3 days), the amount of lime fixed by the RHA is important, even approaching 95% on the third day. This indicates rapid kinetics. From only 7 days onwards, all the lime is fixed by the ash. The high pozzolanic reactivity of this material is mainly due to the combined effect of the high silica content and the fineness of the RHA. The pozzolanic reactivity is mainly controlled by the composition of active oxides of silica and [5]. However some authors suggest that the chemical composition does not really affect pozzolanic reactivity [6].

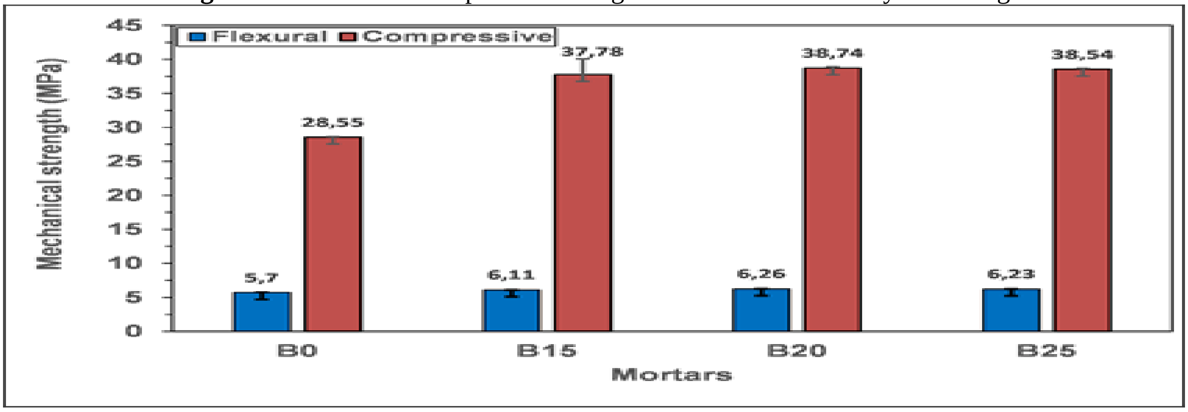
Figure 1: Saturated lime test results [2].



Evolution of the Mechanical Strength of Mortars

In order to monitor the development of the mechanical behavior of the mortars, the flexural and compressive strength of the mortars (Figure 2) was determined 28 days after their formulation. The analysis of the Figure shows that the reference mortar B0 that does not contain RHA has a low mechanical strength compared to the mortars modified with the RHA. Thus the addition of the RHA contributes to the mechanical strength increase. In addition, the mechanical strength of mortars increases with the rate of RHA up to 20% substitution. With 25% substitution the resistance drops very slightly. The optimal substitution percentage for a better resistance is therefore 20%.

Figure 2 Flexural and compressive strength of mortars after 28 days of curing



Curing The mortar cubes were kept inside the humid chamber for 24 hours. The cubes (92.5g) were submerged in the curing chamber for 3, 7, 14 and 28 days. The cubes were then crushed on their respective days and the compressive strength determined. [7]

The main and the most important mineral content of Portland cement are the calcium silicates, C3S and C2S. These silicates hydrate as follows:

2C3S + 6H → C3S2H3 + 3CH
2CS + 4H → C3+S2 + H3+CH
2C3S+2C2S+10H → 2C3S2H3+4CH
In the presence of RHA that contains 68% SiO2, the SiO2 will combine with the released Ca(OH)2.
SiO2+ 3CH → C3S2H3

This means that the Ca(OH)2 is being depleted from the system. It is very essential that the hydrated cement should have a pH of 13±1 otherwise the hydrated silicates and aluminates will be destabilized thereby causing the weakening of the cement structure which explains the reduction of the compressive strength with the increase in concentration of RHA When water is added to cement, the hydration starts topically. In the presence of RHA there is competition for the added water between the SiO2 and other cement material. Since the SiO2 is finer it absorbs the water first before the commencement of the hydration of the other cement materials. This, therefore, explains the retardation effect of the RHA on the setting time [8] The results of the compressive strength tests are shown in Table 2. The compressive strength tests carried out on six mortar cubes showed that the strength of the blocks for all mixtures increases with age at curing and decreases as the RHA content increases. The best compressive strength result was obtained with the percentages of cement replaced by 10% rice husk ash (RHA) and it decreased appreciably as the percentage of RHA increased. However the strength showed impressive increase with ageing. The highest compressive strength encountered in the 28 days; [9]

Table 2: The Compressive Strength Tests Parameter. [3]

Table 2: The Compressive Strength Tests Parameter

Amount of Cement (%)	Amount of RHA(%)	Design Strength (N/mm^2)				
		1 Day	3 Days	7 Days	14 Days	28 Days
100	0	16.00	25.70	28.00	32..30	41.00
90	10	12.60	14.20	22..10	28.50	36.30
80	20	6.70	10.40	18.6 0	24.30	30.20
70	30	4.20	8.60	16.3 0	22.40	24.00
60	40	2.00	6.20	14.4 0	18.20	20.30
50	50	0.90	4.10	9.20	11.50	14.00

The setting time

Table 3 shows the initial and final setting times of the entire cubes were considered using cement and different percentages of rice husk (RHA). The initial and final setting times increases with increase in rice husk ash content. [3]

Table 3: Initial and Final Setting Times of Cement Pastes [3]

Table 3: Initial and Final Setting Times of Cement Pastes

Cement (%)	RHA (%)	Initial Setting Time (Mins)	Final Setting Time (Mins)
100	0	122	183
90	10	136	227
80	20	154	255
70	30	165	275
60	40	213	350
50	50	281	402

The following conclusions were drawn:

i. The chemical analysis done on rice husk ash indicated high amount of silica for rice husk ash (68.12%) which is a very good value for workability.

ii. The increase in setting time of paste having rice husk ash showed low level of hydration for rice husk ash concrete which result from reaction between cement and water, which liberate calcium hydroxide (Ca(OH)2).

iii. Rice husk ash which contains high amount of silica, as in cement, is important as a minor cement substitute, if there is addition of other raw materials containing slightly higher calcium oxide and alumina.

Applications: The main reason and importance of this research is to confirm that rice husks can be recycled and be used for other industrial purposes to help reduce such kinds of pollution. The applications of RHA include its use as a pozzolan in the construction industry, it can be used as an insulator, additive, abrasive agent, oil adsorbent, sweeping component, in waterproofing chemicals and as a suspension agent for porcelain enamels. In the construction industry, RHA can be used as a partial replacement for cement and to make high-performance concrete.

The use of RHA is less-expensive because it reduces the cement requirement, thereby decreases the overall production cost of concrete. Reduction in cement requirement leads to less environmental pollution by cement factories and provides economic and environmental benefits, along with providing a utilitarian way of disposing this agricultural waste product which has little alternative use.

Advantages:

1. RHA helps in cutting down the environmental pollution.
2. RHA improves the compressive and flexural strength of mortar and concrete.
3. The high silica content makes it a good supplementary cementitious material.
4. The density of concrete containing rice husk ash is similar to the normal weight concrete; hence, it can also be used for the general-purpose application too.
5. The impervious microstructure of rice husk ash concrete provides better resistance to the sulphate attack,

chloride ingress, carbonation etc.
6. RHA increases the durability of mortar and concrete.

Therefore, the significance of this research is to help reduce environmental pollution by testing RHA and putting it to better use by checking the effects it has on mechanical properties of mortar.

2.2 Main problems to be solved

Environmental consciousness is growing rapidly in the society and the pollution and health hazards associated with the cement industries are coming under intense examination from environmentalists. The use of RHA in the construction industry as pozzolanic material would bring about a marked reduction of CO2 emission associated with the manufacturing of cement. It would not only decrease the level of pollution in the atmosphere but will also eradicate a major land pollutant as RHA is dumped as waste in rivers. Therefore, using it in concrete as a partial replacement of cement will make a waste material into one of value.

Materials

In order to carry out the experiment, the following materials were required;
1. Water: the water used throughout the experiment was from the laboratory's tap water.
2. Cement: Ordinary Portland cement was used.
3. Rice husk ash with a high percentage of (SiO2).
4. Coarse sand with a sieve size of 2.36mm.
5. Fiber.

Figure 2.1 below shows the quantities of materials used for each specimen. Seven groups of samples namely; M-R0, M-R5, M-R10, M-W45, M-W55, M-F05 and M-F10 were casted. Each sample group had three specimens to be tested and later get the average value.

Figure 2.1: mixtures used for compressive strength test

Group	Cement (g)	RHA (g)	Water (g)	Sand (g)	Fiber (g)	
M-R0	450	0	225	1350	0	
M-R5	427.5	22.5	225	1350	0	
M-R10	405	45	225	1350	0	
M-W45	427.5	22.5	202.5	1350	0	
M-W55	427.5	22.5	247.5	1350	0	
M-F05	427.5	22.5	225	1350	6.5	
M-F10	427.5	22.5	225	1350	13	

2.3.4.1 Flexural strength test

Flexural test and compressive strength test was first carried out on the specimens, each group of samples had 3 specimens meaning 3 specimens from the same group; having the same raw materials and mix ratio were tested and the average value was collected. Specimens at ages; 7 days and 28 days of curing are analyzed. Flexural strength is calculated according to figure 3.1 shown below.

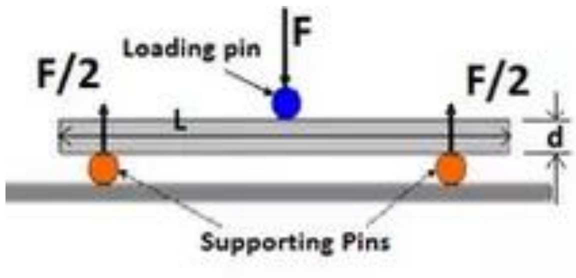


Figure 3.1: Flexural strength test

$$\sigma_f = \frac{3FL}{2bd^2}$$

Where:
F= force applied
b= width of specimen = 40mm
L= effective length = 100mm
d= thickness of specimen = 40mm

Table 3.1 flexural strength test results at 7 days

Group	Failure load (KN)			Average(KN)	Flexural strength(Mpa)
M-R0	1.21	1.15	1.32	1.22	2.86
M-R5	1.33	1.29	1.35	1.32	3.09
M-R10	1.02	1.04	1.01	1.02	2.39
M-W45	1.50	1.39	1.67	1.52	3.56
M-W55	1.44	1.23	1.61	1.43	3.35
M-F05	1.89	1.64	1.73	1.75	4.10
M-F10	1.53	1.69	1.67	1.63	3.82

Table 3.2 flexural strength test results at 28 days

Group	Failure load (KN)			Average(KN)	Flexural strength(Mpa)
M-R0	2.61	2.85	2.74	2.73	6.40
M-R5	2.00	2.02	2.14	2.05	4.80
M-R10	1.89	1.28	1.36	1.15	2.70
M-W45	1.36	1.05	1.22	1.21	2.84
M-W55	1.86	1.68	1.82	1.79	4.20
M-F05	2.40	3.16	2.45	2.67	6.26
M-F10	3.52	3.24	3.59	3.45	8.09

3.2 Compressive strength data analysis
The data analyzed is that of the specimens at ages; 7 days and 28 days of curing. Compressive strength is calculated according to the figure below.

Compressive strength formula is shown below:

$$\sigma = \frac{F}{A}$$

Where:
F = the force in Newton (N)
A= is the area of the specimen in mm2

Table 3.3: Compressive strength test results at 7 days

Group	Failure load (KN)						Average (KN)	Compressive strength (Mpa)
M-R0	11.75	13.89	14.14	12.62	15.31	13.66	13.56	8.48
M-R5	5.90	5.59	5.16	5.93	6.10	5.77	5.74	3.59
M-R10	3.71	2.61	3.34	3.62	3.21	2.88	3.23	2.02
M-W45	2.37	2.59	2.69	2.59	2.64	3.01	2.65	1.66
M-W55	10.08	11.93	13.55	13.31	11.86	10.35	11.85	7.41
M-F05	15.26	17.04	17.91	16.88	16.46	15.53	16.51	10.32
M-F10	9.35	11.24	11.46	10.84	11.02	10.24	10.69	6.68

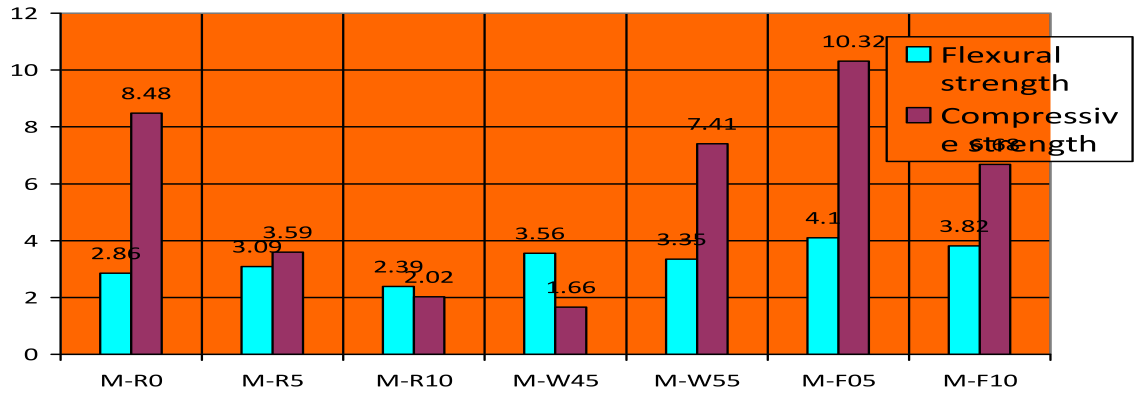
Table 3.4: Compressive strength test results at 28 days

Group	Failure load (KN)						Average (KN)	Compressive strength (Mpa)
M-R0	36.78	39.43	31.81	32.98	37.40	36.42	35.80	22.38
M-R5	32.57	27.18	25.54	26.48	26.72	28.31	27.80	17.38
M-R10	13.46	17.45	18.35	15.75	16.13	17.73	16.48	10.3
M-W45	15.23	13.25	13.67	15.90	14.25	13.44	14.29	8.93
M-R55	26.99	27.88	28.68	25.73	26.36	29.53	27.53	17.21
M-F05	26.27	28.51	28.16	27.36	28.48	26.47	27.54	17.21
M-F10	48.84	41.39	50.13	47.65	48.43	44.24	46.78	29.24

3.3.1 Mechanical strength at 7 days

The chart below shows the results of the mechanical test conducted after 7 days of curing. Strength measured in (Mpa).

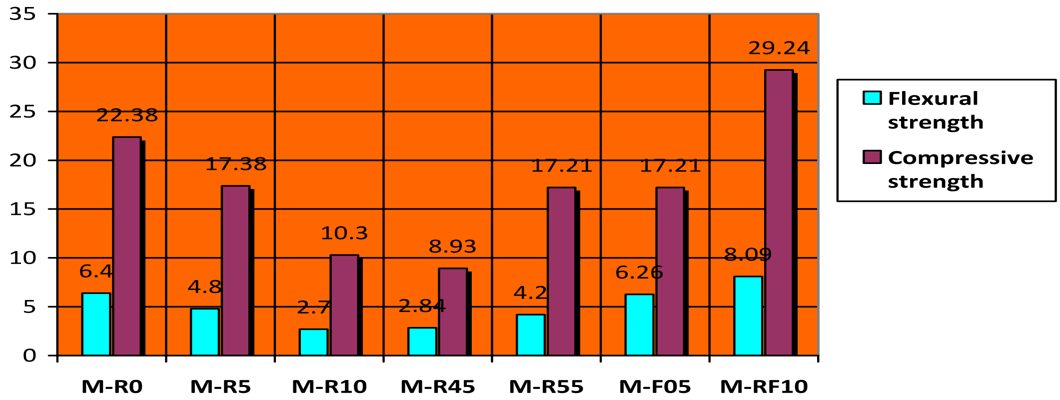
Chart 1.1: Strength in (Mpa) at 7 days



Mechanical strength at 28 days

The chart below shows the results of the mechanical test conducted after 28 days of curing. The strength was measured in (Mpa)

Chart 1.2: Strength in (Mpa) at 28 days



II. CONCLUSION

Accessing from the results of the experiments and past reviews, the following conclusions are made.

1. Compressive strength of mortars containing rice husk ash (RHA) depends on the water-cement ratio as shown in sample M-W55 which had similar strength to that of M-F05 but also only slightly weaker than M-R0. This shows the strength had not adversely been affected.
2. RHA can partially replace ordinary Portland cement only in specific amounts and it acts as a high water

absorbing material.

3. RHA proved to have pozzolanic properties which give it potential for use in structural construction.
4. Only sample M-F10 had a greater compressive strength than M-R0 which had 100% cement and no RHA present. M-F10 had a partial cement of 5% and also 13grams of fiber which is known to increase strength.
5. Rice husk ash which contains high amount of silica.

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