



Studies on the effect on Concrete by Partial Replacement of Cement by Using Rice Husk Ash and Metakaolin

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Abstract—

The purpose of this study was to investigate the physico-mechanical properties of mortars by replacing normal portland concrete (OPC) with metakaolin (MK) and rice husk (RHA) in ternary cement. The investigation focused on the effects of this replacement on consistency, setting time, strength and compressive strength. In this review, a Vicat machine, a Le Chatelier machine, and a Tonic Methodology Compactor were used to assess cement strength, compressive strength of mixed mortars, and ultimate setting time. At different levels he evaluated 19 different ternary substance mortars including OPC, RHA and MK at 7, 14 and 28 days.

The results showed that the volumetric expansion of the ternary concrete paste gradually increased with increasing RHA content, while the MK content remained constant. Conversely, increasing MK content while keeping RHA constant slowed down the volumetric expansion. The weight variations in water grouping were 5% and 20% for MK and RHA, respectively, with the water requirement steadily increasing when 15% RHA (by weight) was used as MK. However, the increase and deceleration in speed were reasonable at both setting times when MK was increased from 5% to 20% (by weight), while RHA

remained constant.

In comparison to the control group, it was observed that maintaining a 15% RHA/MK ratio and increasing MK or RHA to 15% positively influenced the compressive strength of the ternary mix mortar. This improvement is attributed to regions of high silica/alumina resulting from MK incorporation, C/S fixation within the bulk structure, and autonomous pozzolanic reactivity of unburned carbon in RHA. The overall compressive strength of both the substance mixture and the benchmark group increased when the recovery time was increased from 7, 14 and 28 days. The higher strength, particularly at 28 days, was believed to result from a reduced pozzolanic response, leading to increased production of He-CSH and CAH through the association of remaining calcium hydroxide (CH) with available silica from MK and RHA. Among the tested mortars, the mixture containing 7.5% RHA and 7.5% MK exhibited the highest compressive strength of 28.21 MPa after 28 days.

Keywords—

Terms such as metakaolin, rice husk ash, consistency, setting time, similarity, and compressive strength are used.

Introduction

Studies on the effect of partial cement replacement in concrete through the use of rice husk and metakaolin have received much attention in recent years. These investigations aim to explore sustainable alternatives to traditional cement in concrete production, addressing both environmental concerns and improving the mechanical properties of concrete.

Cement, a crucial ingredient in concrete, is known to have a high carbon footprint due to its energy-intensive production process and significant CO₂ emissions. Researchers have turned their focus towards finding supplementary materials that can partially replace cement without compromising the overall performance of concrete structures. Two such materials that have been extensively studied are rice husk ash (RHA) and metakaolin.

Rice husk ash from rice processing are rich in silicic acid and have pozzolanic properties. With careful care, it is widely used as a cementitious material in material production. Metakaolin, on the other hand, is an exceptionally reactive pozzolan obtained by calcining kaolin dirt. This contributes to the development of additional calcium silicate hydrate (C-S-H) gels and increases the strength and strength of the cement.

Several studies have investigated the effects of replacing some of the cement with rice hull ash and metakaolin. As a result, various advantages were shown. First, the blending of these materials improves the workability of ready-mixed concrete, making it easier to handle and place. In turn, the compressive strength, flexural strength and durability of concrete are increased, resulting in a stronger and more durable structure.

Additional C-S-H gels are framed by pozzolanic reactions between RHA or metakaolin and calcium hydroxide (CH) released during concrete hydration. This gel acts as a filler and reduces the pore size, thus improving the microstructure of concrete. Consequently, it enhances the density, impermeability, and resistance to chemical attacks, such as chloride penetration and sulfate attack.

Furthermore, the use of rice husk ash and metakaolin in concrete offers environmental benefits. By partially replacing cement, these materials reduce the demand for clinker production, which is the most carbon-intensive stage of cement manufacturing. This reduction in carbon emissions contributes to sustainable construction practices and mitigates the environmental impact associated with concrete production.

In general, studies on the effects of using rice husk and metakaolin to partially replace concrete highlight how these admixtures can improve the presentation and supportability of cement. Continued investigation and use of these insights in the construction industry may

result in the creation of stronger and more environmentally friendly substantial designs.

Material used:

Rice Husk Ash: In an uncontrolled burning procedure, rice husk ash was burned in the air for around 72 hours. It was between 400 and 600 degrees Celsius. The ash that was gathered was screened through a BS standard sieve size of 75 microns, and it has a grey tint.



Figure 1- Rice Huck ash

Metakaolin: Metakaolin is created by calcining the sanitised kaolinite in a remote-controlled rotary kiln at temperatures typically between 650 and 700 degrees Celsius. Furthermore, HRM is warranted to hasten the hydration of ordinary Portland concrete (OPC) and the majority of its components within 24 hours.



Figure 2- Metakaolin

Cement: Ordinary Portland cement (OPC) of grade 43 was utilised; it complies with Indian standard organisation requirements in terms of composition and characteristics.

Aggregates: Only sand taken from a river is used in the research. To make sure that there were no harmful elements present in the sand, it was collected. The largest size of the granite employed in this study was 20 mm.

Methodology: -

To make a ternary mixture, I used RHA and MK in place of normal Portland concrete. Less than 40% of the weight of the employed ordinary Portland concrete was made up of the concrete substitute. As summarized, 19 different ternary concrete mixes were created using different ratios of normal Portland concrete, RHA, and MK.

The rice husks were gathered in Yelwa, in the Bauchi Region (city) of Nigeria. RHA was produced by ingestion of rice hulls heated for three hours at

temperatures of 600°C in a toner heater. The molecular size was then decreased to less than 65 m by ball milling the fragments. According to earlier studies, raw kaolin was taken from Alkalari town, where it was prepared for calcination and cooling at a temperature of 700°C for two hours in order to produce MK. X-ray diffractometers (XRD) and X-ray fluorescence (XRF) were used to distinguish between material and mineral fragments. The actual physical characteristics and component parts for OPC, RHA, and MK, the X-ray diffractometers (XRD) results for RHA and MK. By brain surface completion, the RHA brain surface is not completely fixed in 298 m²/kg and 323 m²/kg, respectively. The Vicat device was used to calculate the expected water for the standard consistency, the start and final gel times, and the firmness, while the Le Chatelier device was used to calculate the firmness. It was chosen. The pre-mixed concrete adhesive was combined with readily available commercial water. On samples of mortar that had been mixed with water, compression strength tests were run. Sand is the binding agent, component 1:1:2. A shaker was used to condense the mixture after it had been agitated for two minutes and poured into oiled 50mm cube molds. The mold surface was then polished, sealed with an impermeable coating to stop loss, and let too dry for 24 hours at room temperature. In order to test the solid molds at 7, 14, and 28 days, they were demolded after 24 hours and put in recovery tanks with pure water as needed. Using a Tonic Process Densifier, the samples were taken out of the recovery tank and evaluated for mortar compressive strength.

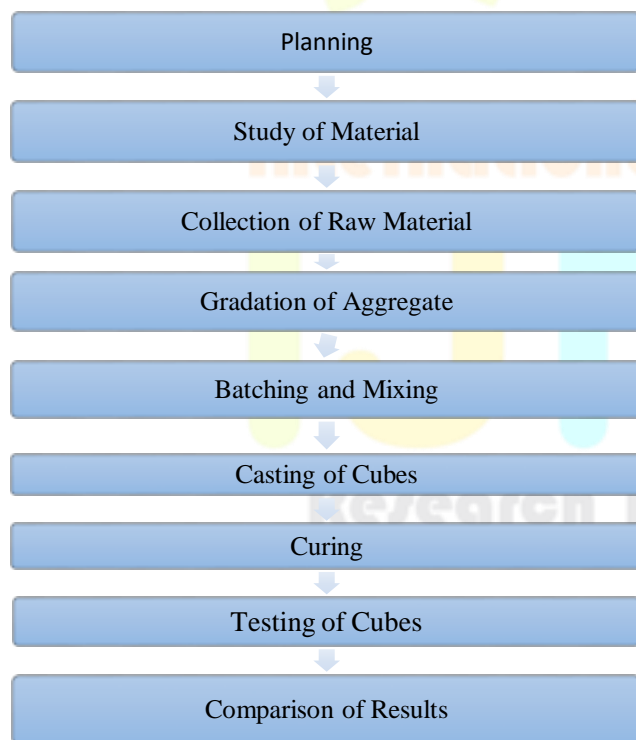


Figure 3- Flow Chart Showing Methodology

Table 1:– RHA, MK, and OPC chemical composition

No table of figures entries found.	% RHA	% MK	%OPC
Al ₂ O ₃	2.42	40.20	5.08
SiO ₂	81.28	53.15	20.25
MgO	1.09	0.14	3.80
SO ₃	0.23	0.01	2.61
CaO	0.75	0.57	62.35
K ₂ O	4.02	0.22	0.81
Na ₂ O	0.18	0.05	0.17
TiO ₂	-	2.79	0.28
C ₄ AF	-	-	10.49
C ₃ S	-	-	52.30
C ₂ S	-	-	17.56
Cr ₂ O ₃	-	-	0.84
LOI	1.25	1.25	3.36
inCl	-	0.00	0.05
Mn ₂ O ₃	0.23	-	0.16
P ₂ O ₅	5.73	-	0.12
C ₃ A	-	-	7.51

Physical properties of RHA and MK

RHA- RHA is a non-burning carbon paint with a greyish-dark tint. Nebulous silica is produced when the consumption temperature is between 550 and 800 °C, while glassy silica is produced at higher temperatures. With specific gravities ranging from 2.11 to 2.27 and a sizable apparent surface area, RHA is very light and permeable.

MK- Pozzolanic substance known as metakaolin (MK). It is created by heating kaolinitic clay to a temperature between 500 and 800 degrees Celsius. Strength variations for flexural strength are 25.7%, split tensile strength is 30.9%, and compressive strength is 33.5%.

Tests and Result: -**a) Preliminary tests for Materials****TABLE 2- Preliminary tests for Materials**

Sl. NO.	Properties of Materials	Standard Value	Experimental Value
1.	Cement Used	OPC-43 grade	OPC- 43 grade
2.	Cement's Specific Gravity	3.157	3.096
3.	The fine aggregate's specific gravity (Morum)	2.62	2.679
4.	Workability of concrete without adding RHA&MK	75 - 100 mm	79 mm
5.	Workability of concrete after adding RHA&MK	75 – 100 mm	89 mm
6.	Fine aggregate	Confirms zone- II	Fineness modulus value = 2.465 Confirms zone- II
7.	pH value of water	6.5 – 7.5	7.38
8.	Fineness of cement	0 – 10%	4.37%
9.	Standard Consistency value	32%	32%
10.	Initial & Final Setting time	30 min % 10 hours	35 min & 10 hours
11.	Soundness Teste (Expansion of Cement due to lime)	Less than 10%	8.65mm ≈ 9mm

b) Slump Test- To verify the material's functionality, the results of the newly put cement's downward test might be employed. Table 3 provides an explanation of the rutting test results. It is obvious that the blend's usefulness is significantly reduced when RHA and MK are employed in place of PPC. Due to their high fineness (formation of a certain surface area) and absorbency, RHA and MK cell particles in concrete require more water to obtain a specified consistency. Increasing displacement of espresso shell residue causes a net loss in strength because espresso shell residue can absorb water.

TABLE 3-SLUMP TEST RESULT

S.No.	% of replacement	Combination	Slump mm
1	0 %Control	100% cement0% RHA and MK	8.75
2	5 %	95% cement5% RHA and MK	8
3	10 %	90% cement10% RHA and MK	7.25
4	15 %	85% cement15% RHA and MK	6.75
5	20 %	80% cement20% RHA and MK	5.5

c) Compressive Strength- The compressive strength test is the most common test for bigger samples. The test is conducted in accordance with ASTM guidelines. His three runs for each case's findings are averaged. Table 4 lists the outcomes of the exploratory investigation. These findings demonstrate that a 5% change in concrete over time results in a loss of strength. It should be emphasised as well that 5% concrete replacement provides the best results when compared to 0% concrete replacement.

The appendix contains a list of compression strength verifications, including typical strengths. Because the structural elements were more fully hydrated, peak strength for all cements wasn't reached for all cements until he was 28 days old. Between days 7, 14 and 28, the development of peak strength was seen. With parts of different thicknesses, the compressive strength increased from 20 N/mm² to 29 N/mm² after 28 days. We find that the compressive strength of RHA and MK ages significantly more slowly than the reference combination as the replacement fractions of RHA and MK increase. The design is not minimalist, as opposed to huge samples lacking RHA and MK, leading to reduced strength. The substantially solid form's compressive strength test results reveal that when compressive strength rises, RHA and MK% drop.

TABLE4: CONCRETE CUBES'COMPRESSIVE STRENGTH WITH PERCENTAG REPLACEMENT

TABLE 4(i): The below table shows the partial replacement of cement 5% with 2.5% RHA + 2.5% MK, 10% with 5% RHA and 5% MK, 15% with 7.5% RHA + 7.5% MK and 20% with 10% RHA + 10% MK. The highest compressive strength of 19.60 N/mm² was obtained for the mix cement 15% with 7.5% RHA + 7.5% MK. This test result of compressive strength after 7 days are given below.

So. No.	Mix	Different Percentage (%) of replacement	Compressive Strength (in N/mm ²)	Average Compressive Strength (in N/mm ²)
1.	M25	0	16.20	16.30
			16.40	
			16.30	
2.	M25	5	16.80	16.80
			17.30	
			16.30	
3.	M25	10	17.40	17.10
			16.80	
			17.10	
4.	M25	15	18.90	19.60
			20.10	
			19.80	
5.	M25	20	19.60	19.13
			18.80	
			19.00	

TABLE 4(ii): The below table shows the partial replacement of cement 5% with 2.5% RHA + 2.5% MK, 10% with 5% RHA and 5% MK, 15% with 7.5% RHA + 7.5% MK and 20% with 10% RHA + 10% MK. The highest compressive strength of 22.40 N/mm² was obtained for the mix cement 15% with 7.5% RHA + 7.5% MK. This test result of compressive strength after 14 days are given below.

S.No.	Mix	Different Percentage (%) of replacement	Compressive Strength (in N/mm ²)	Average Compressive Strength (in N/mm ²)
1.	M25	0	22.00	22.3
			22.60	
			22.30	
2.	M25	5	20.80	20.53
			20.30	
			20.50	
3.	M25	10	21.60	21.30
			20.00	
			21.05	
4.	M25	15	21.70	22.40
			22.30	
			22.50	
5.	M25	20	21.50	20.93
			20.80	
			20.50	

TABLE 4(iii): The below table shows the partial replacement of cement 5% with 2.5% RHA + 2.5% MK, 10% with 5% RHA and 5% MK, 15% with 7.5% RHA + 7.5% MK and 20% with 10% RHA + 10% MK. The highest compressive strength of 19.60 N/mm² was obtained for the mix cement 15% with 7.5% RHA + 7.5% MK. This test result of compressive strength after 28 days are given below.

S. No.	Mix	Different Percentage (%) of replacement	Compressive Strength (in N/mm ²)	Average Compressive Strength (in N/mm ²)
1.	M25	0	24.60	25.13
			25.00	
			25.80	
2.	M25	5	27.80	26.71
			26.30	
			26.05	
3.	M25	10	25.70	26.58
			27.05	
			27.00	
4.	M25	15	27.90	28.21
			28.15	
			28.60	
5.	M25	20	27.90	27.75
			27.85	
			27.50	

d) Flexural Strength-The Flexural / Tensile strength of concrete is measured by its flexural strength. With a concrete load of 6 × 6 inches (150 x 150 mm), he at least has three times the depth span he measured.

Research centre tests are used to determine the flexural strength of metakaolin ferrocement. Both a metakaolin mortar and a reference mortar with grade 43 OPC and 5% to 20% metakaolin through concrete were prepared. Water relief was used for the tests for 7, 14, and 28 days. The results demonstrate that for up to 15% metakaolin replacement for all relieving ages and cross section layers, the flexural strength was higher than the control ferrocement. Nevertheless, in all lattice levels, over 20% of the alternatives were weaker than the control ferrocement.

Calculation

Flexural strength or modulus of rupture (f_b) is given by

$F_b = pl/bd^2$ (for > 20.0 cm for 15.0 cm samples or greater than 13.0 cm but > 11.0 cm for 10.0 cm samples.)

if

$F_b = 3pa/bd^2$ (<20> for 17.0, 15.0cm specimens or <13> for 11.0cm, 10.0cm specimens.)

where,

a = Distance between break line and nearby beam. Measured from the centerline of the tensile side of the sample.

b = sample width (cm)

d = depth of break (cm)

l = supported length (cm)

p = maximum load (kg)

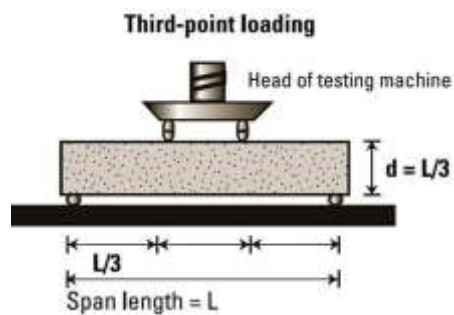


Figure 4- Flexural Strength

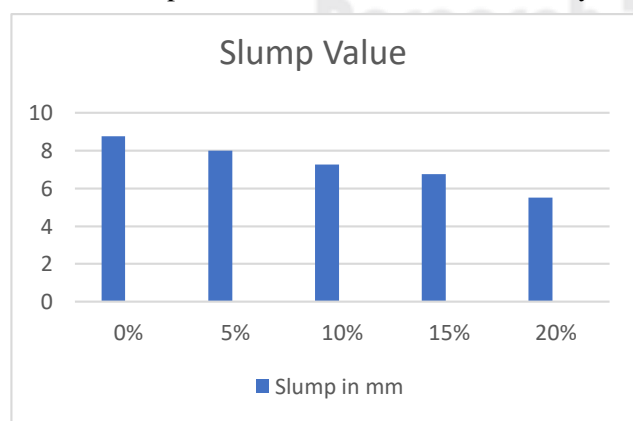
TABLE4: The below table shows the partial replacement of cement 5% with 2.5% RHA + 2.5% MK, 10% with 5% RHA and 5% MK, 15% with 7.5% RHA + 7.5% MK and 20% with 10% RHA + 10% MK. The highest Flexural / Tensile strength of 19.60 N/mm² was obtained for the mix cement 15% with 7.5% RHA + 7.5% MK. This test result of Flexural / Tensile strength after 7, 14 and 28 days are given below.

S.No.	Different Percentage (%) of replacement	Strength of Flexure (in N/mm ²) 7 days later	Strength of Flexure (in N/mm ²) 14 days later	Strength of Flexure (in N/mm ²) 28 days later
1.	0%	3.18	4.12	5.32
2.	5%	3.94	3.54	5.16
3.	10%	4.13	4.73	5.45
4.	15%	4.11	4.88	5.18
5.	20%	3.91	4.09	4.95

DISCUSSIONS AND RESULTS

Workability:- Workability is the ease with which the ready-mixed concrete can be mixed, poured and compacted without separating or excessive leakage. This is an important property that affects the handling, placement, and finishing of concrete during construction.

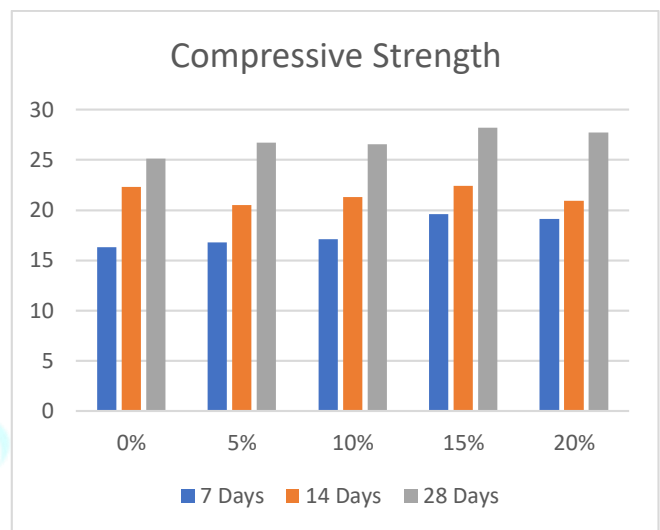
The slump test is a widely used method for measuring the workability of concrete. Fill a standard metal cone with ready-mix concrete, compact and remove. It measures depressions and settlements observed in concrete and provides information on workability.



Graph 1:- Slump value (in %) when replacing cement

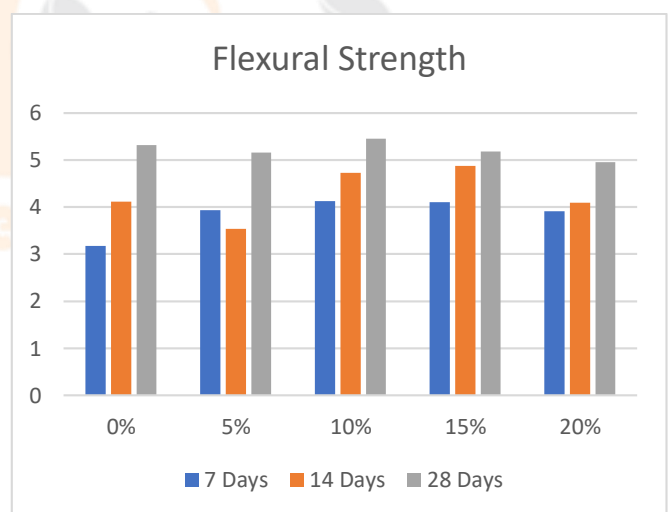
with RHA and metakaolin

Compressive Strength Test:- The compressive strength of the concrete reached different levels after 7, 14 and 28 days. This is shown in the graphic below. The samples were cast and tested according to IS:516-1959.



Graph 2:- Compressive strength is improved by replacing some of the cement with RHA and metakaolin.

Flexural strength Test:- The tensile strength of concrete with a curing time of 28 days for different proportions is given below. The samples were cast and tested according to IS: 516-1959.



Graph 3 :- Flexural strength when part of the cement is replaced by RHA and MK.

Conclusion: -

In this study, the effects of partial replacement by RHA and MK on essential properties were investigated. The research found that using RHA and MK together outperforms the compression and elasticity of cement. In addition, the blend of RHA and MK provides significant strength, which has been confirmed by less weight reduction in corrosion and sulphate attack tests. We tested concrete in which rice hull ash and MK replaced part of the cement and fine aggregates, which improved strength and mechanical properties and

reduced construction costs.

- In this we find the rice husk ash 7.5% and MK 7.5% provided compressive strength of 28.21N/mm².
- The use of MK and RHA also reduces the problem of waste disposal, as MK and RHA pollute the climate and cause harmful critters, making safe disposal a major challenge.
- Involving Mk and RHA as halfway substitutes for concrete, a reduction in the plastic thickness of the blend was noticed.
- In terms of life properties, MK and RHA were found to have lower water absorption and porosity as the exchange rate increased.
- This can result in lower concrete utilization and carbon emissions, as well as reduced agricultural and modern industrial waste consumption.

Future scope: Future work Future work could focus on optimizing the RHA and MK content to achieve maximum concrete strength and durability. In addition, further studies could investigate the effects of RHA and MK on other properties of concrete such as workability, setting time and shrinkage.

In addition, the effects of RHA and MK on the long-term performance of concrete under different environmental conditions are investigated. Freeze-thaw cycles and chloride exposure. Finally, you can also consider using RHA and MK in other building materials such as mortar and plaster.

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