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A COMPREHENSIVE ASSESSMENT OF RICE HUSK ASH IN CONCRETE

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ABSTRACT

Rice husks, an abundant agricultural waste generated during the rice milling process, constitute approximately 25% of the weight of rice. When burned, the hard outer coating of rice grains yields rice husk ash (RHA), a fine powder largely made up of silica (SiO_2). Rice husk ash's remarkable pozzolanic activity, which allows it to mix with calcium hydroxide ($Ca(OH)_2$) during cement hydration to produce calcium silicate hydrate (CSH), an essential component of cement that improves concrete strength and durability, has strengthened its position as a valuable additive in concrete production. This study aims to examine the effects on concrete properties of using rice husk ash (RHA) in various grades of coarse aggregate as a partial replacement for ordinary Portland cement. Three different types of coarse aggregate with maximum sizes of 10, 15, and 20 mm and RHA ratios of 0.5%, 1%, 1.5%, 2%, 2.5%, and 3% were used to make concrete mixes for this investigation. To find out how varying replacement ratios and coarse aggregate size affected the concrete's compressive strength, a number of experiments were performed on the samples.According to the experimental results, the strength of the concrete decreases as the size of the coarse aggregate is reduced. The highest compressive strength was recorded at 2% RHA, where it reached 5.29 MPa, a 15% increase over the control 4.6 MPa for coarse aggregate size 20 mm at 90 days of age.

KEYWORDS: Rice husk, Rice husk ash (RHA), Compressive strength , Aggregate size, Corse Aggregate Size.

تقييم شامل لرماد قش الأرز في الخرسانة

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الملخص

قش الأرز، وهو نفاية زراعية وفيرة تنتج أثناء عملية طحن الأرز، يشكل حوالي ٢٥٪ من وزن الأرز. عند الاحتراق، ينتج عن القشرة الخارجية الصلبة لحبوب الأرز رماد قش الأرز (RHA)، وهو مسحوق ناعم يتكون في الغالب من السيليكا. (SiO2). النشاط البوزولاني الرائع لرماد قش الأرز، الذي يسمح له بالخلط مع هيدروكسيد الكالسيوم (Ca(OH)2) أثناء ترطيب الأسمنت لإنتاج هيدرات سيليكات الكالسيوم (CSH)، وهو مكون أساسي للأسمنت يحسن من قوة ومتانة الخرسانة، قد عزز من مكانته كإضافة قيمة في إنتاج الخرسانة. تهدف هذه الدراسة إلى فحص تأثيرات استخدام رماد قش الأرز (RHA) في درجات مختلفة من الركام الخشن كبديل جزئي للأسمنت البورتلاندي العادي على خصائص الخرسانة. تم استخدام ثلاثة أنواع مختلفة من الركام الخشن بأحجام قصوى تبلغ ١٠ و١٥ و٢٠ مم ونسب رماد الأرز (RHA) بنسبة ٠,٥٪ و١٪ و١,٥٪ و٢٪ و٢,٥٪ و٣٪ لصنع خلطات الخرسانة لهذا البحث. لإيجاد كيفية تأثير نسب الاستبدال المختلفة وحجم الركام الخشن على مقاومة ضغط الخرسانة، تم إجراء عدد من التجارب على العينات.وفقًا للنتائج التجريبية، تنخفض قوة الخرسانة

كلما تم تقليل حجم الركام الخشن. تم تسجيل أعلى مقاومة انضغاطية عند ٢٪ رماد قشر الأرز، حيث بلغت ٥,٢٩ ميغاباسكال، بزيادة قدرها ١٥٪ عن التحكم ٤,٦ ميغاباسكال لحجم الركام الخشن ٢٠ مم عند عمر ٩٠ يومًا.

الكلمات المفتاحية : قشر الأرز، رماد قشر الأرز (RHA)، قوة الضغط، حجم الركام، حجم الركام الكبير.

1. INTRODUCTION

Cement production emits significant CO_2 emissions, accounting for 7% of global emissions. Therefore, the investigation into concrete production began using green materials such as Portland limestone cement, large quantities of Class F fly ash, and cement kiln dust [1]. And also using rice straw and its husks, which is a more environmentally friendly alternative, economically feasible due to their low production costs [2]. Rice husk, a waste from rice milling, is abundant in all countries, with India producing 12 million tons annually. The global annual husk output is estimated at 80 million tons. Rice husk contains silica, which is 20-25wt% hydrated and amorphous. Thermal degradation and pyrolysis of rice husk, followed by combustion, produces highly porous and amorphous silica. Combusted at moderate temperatures, the white ash contains approximately 92-97% amorphous silica. Thermal treatment of rice husk to produce amorphous silica is an eco-friendly process, as it minimizes ash waste and offers a renewable source of silica [3].Raw rice husk (RRH) is made up of roughly 20% silica, 40% cellulose, and 30% mixed lignin [4].

The chemical composition of rice husk varies between samples due to changes in paddy type, crop year, climate, and geographical factors [5].Rice husk ash (RHA), which is bio-organic silica (SiO2) with significant pozzolanic activity, is produced by burning rice husk at temperatures of 500, 600, and 700 degrees Celsius in a muffle furnace. The combustion process's temperature and duration are optimized. To ascertain the chemical makeup of rice husk and rice husk ash, X-ray fluorescence (XRF) examination is performed. To create silica, sodium hydroxide (NaOH) and hydrochloric acid (HCl) are applied to the resulting rice husk ash [6]. Un-leached, hydrochloric acid-leached, and sulfuric acid-leached rice husks were all burned for two hours at 500, 600, 700, 800, and 900 degrees Celsius in a muffle furnace. The average particle size was between 0.50 and 0.70 µm, and the results showed that all of the samples formed amorphous silica (SiO_2). Combustion at temperatures ranging from 500°C to 900°C has relatively little effect on the synthesis of silica, especially at temperatures higher than 600°C [7].

This RHA contains up to 90% non-crystalline or amorphous silica[8]. According to the classification and assessment of RHA and a comparison of the SiO_2 contents from the Charsada, Burner and KPK swat areas, the Charsada sample was determined to be the best. Three distinct techniques were used to incinerate rice husk to RHA in order to determine the maximum SiO_2; Method C, which involved a 24-hour combustion process in a control environment, produced the highest silica yield[9]. By burning rice husk in cylinders for 24 hours, an amount of 97.703% of SiO_2 is obtained.The RHA, when ignited by combustion in the cylinder for 24 hours, yields a maximum of 97.703% SiO_2[10].After chemical investigation, if the sum of iron oxide (Fe_2O_3), silicon oxide (SiO2), and aluminum oxide (Al_2O_3) exceeds 70%, the material is classified as pozzolanic [11].Partial replacement of Portland cement with RHA increases water demand, which can be mitigated with a super plasticizer. This impact is particularly noticeable in blends that contain finer cements[12].

RHA generated through controlled burning contains a large amount of silica (SiO_2), primarily in amorphous form [13]. The kind of silica found in RHA combines with the hydration result of cement, $Ca(OH)_2$, to produce another type of Calcium-Silicate-Hydrated (C-S-H) gel [14].

This C-S-H gel is primarily responsible for the hardness of concrete and mortar. The hydration of silica molecules in cement is the only source of $Ca(OH)_2$. Cement contains only tricalcium silicate (C_3S) and dicalcium silicate (C_2S). Ordinary Portland Cement (OPC) comprises a certain percentage of C_3S and C_2S, which results in a specific amount of CaOH. As a result, the secondary C-S-H gel is formed by the chemical reaction of a given amount of RHA with a certain amount of $Ca(OH)_2$.The pozzolanic response of rice husk ash primarily depend on the ash surface area, particle size, silica crystallization stage, and also the silica content in the rice husk ash [15].

using Portland cement combined with RHA to investigate how particle size ranges affect gap-graded concrete's compressive strength. The findings indicate that reduced porosity and better particle packing structure are the outcomes of using coarser cement. A superplasticizer can be used to offset the higher water consumption caused by partially substituting RHA for Portland cement. The impact of RHA blends with finer cements is more detrimental. Higher relative strength values are produced by the gap-graded binder, and the blending efficiency rises as the RHA percentage does. Strength gains more physical and chemical contributions as a result[16].

Under a controlled temperature, RH combustion yields amorphous silica content and particles with large surface areas [17]. A study on rice husk ash (RHA), rice straw ash (RSA), and wheat straw ash (WSA) found that up to 15% of OPC can be used as partial cement replacement (PCR) with good compressive strength, performance, and durability. This material can contribute to sustainable construction and improve the structural behavior of reinforced concrete beams under static loading conditions [18]. In another study, a study was conducted on the strength characteristics of high-strength rice-husk concrete.It was determined that a rise in the percentage of RHA substituted for cement in concrete results in a 27% slump and a 9% compaction factor reduction in workability [19]. And leads to an increase in water demand.RHA concrete improved replacement strength by 10% (an increase of 30.8% as compared to the standard mix). Using RHA with an average size of particles of 9.52 µm produces concrete with good strength [20]. According to the study, rice and wheat straw ash increased permeability and porosity in concrete mixtures somewhat, with 15% rice straw ash providing the best porosity[21].The study found that increasing the RHA percentage in concrete mixes with 10mm coarse aggregate increased its compressive strength from 15% to 31.5%. However, further increase decreased the strength, but still higher than the control specimen. The optimum strength was achieved with a 2.5% RHA percentage [22]. Rice husk ash-produced geopolymer concrete replaces traditional reinforced concrete. Tested under axial compressive loading, nine geopolymer virus cement columns showed acceptable performance, with expanded or welded virusment columns having higher failure loads [23]. Rice straw powder improves the fire resistance of UHPCC(Ultra-High-Performance-Concrete-Columns) [24].

4. EXPERIMENTAL PROGRAM

The present research focuses on evaluating the feasibility of employing rice husk as a cementation material by conducting several physical and chemical analyses and thus understanding the impact of RHA on the properties of (fresh and hardened). It has also been proposed to determine the optimal level of RHA substitution to reach the maximum compressive strength.

2.1 MATERIALS

2.1.1 CEMENT

The cement employed in this study is CEM I 42.5 N, which has the chemical and physical parameters listed in **Table 1.**

Table 1. physical properties of cement.

Property	Value	MAX
Fineness cm^2/gm	3330	≥60
Soundness (expansion) mm	0.5	≤10
Compressive strength 2D MPa	20.33	≥10
Compressive strength 28D MPa	46.82	≥42.5
Initial setting time (min)	175	≥60
Final setting time (min)	241	
Free lime%	65	

Table 2. The chemical characteristics of ordinary Portland cement

Chemical composition	OPC
SiO_2 (%)	20.38

Al_2O_3 (%)	4.77
Fe_2O_3 (%)	3.75
$SiO_2 + Al_2O_3 + Fe_2O_3$ (%)	93.5
SO_3 (%)	2.53
Mgo (%)	1.24
CaO (%)	62.44
Na_2O (%)	0.43
K_2O (%)	0.23
Loss on ignition (LOI)	3.43
C_3S%	52.07
C_2S%	19.14
C_3A%	6.29
C_4AF%	11.40

2.1.2 RICE HUSK ASH

Rice husk was gathered from farms in Kafr El-Sheikh Governorate, Egypt. The rice husk was first collected from the fields and then processed to remove any unwanted materials. The processed rice husk was then burned in a furnace at temperatures between 700 and 900 °C. The chemical structure of the RHA was established by X-ray fluorescence (XRF) analysis. Table 3 summarizes the findings. The physical properties of the RHA were determined using a variety of methods, including specific gravity and specific surface area. The results are shown in **Tables 4.** This was carried out according to the manual for laboratory tests of concrete materials.

Table 3. The chemical properties of RHA.

Chemical composition	Rice husk ash
SiO_2 (%)	92.0
Fe_2O_3 (%)	0.34
Al2O3 (%)	0.18
$SiO_2 + Al_2O_3 + Fe_2O_3$ (%)	92.52
MgO (%)	0.424
CaO (%)	0.91
SO3 (%)	0.12
K2O (%)	2.75
Na_2O (%)	0.62
Loss on ignition (LOI)	4.72

Table 4. specific gravity and fineness of used RHA.

RHA property	Value of property
Specific gravity	21.35 KN/m^3
Specific surface area (cm^2/g)	20560
Color	Dark gray

2.1.3 AGGREGATES

The type and grading of aggregates play a crucial role in modifying concrete properties. Therefore, understanding how aggregate type and grade affect the mechanical features of concrete has become increasingly important. Ordinary concrete (PC) was prepared using gravel aggregate (g) in three different grain sizes(N.M.S. 10mm, 15mm, and 20mm) in **Fig. 2.** to avoid difficulties during the manufacture, mixing, and pouring of concrete, as well as to prevent the segregation of heavy particles in fresh concrete, the aggregates were meticulously sifted, cleaned, and cleared of muck and silt. The sand was used as fine aggregate in **Table 5.** and **Fig. 3.** The fine aggregates had an absorption of 1.7 and a specific gravity of 2.6.

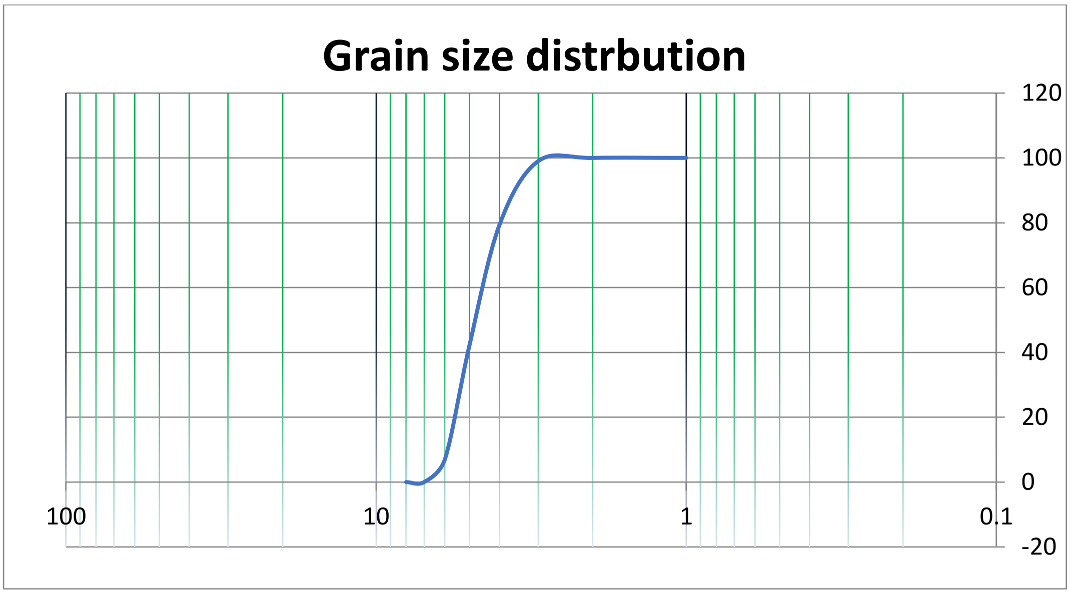


Fig. 1. Grain size distribution of fine aggregate.

Table 5. Grading of fine aggregate**.**

Sieve Number	Opening Size (mm)	Weight of aggregate retained in (gm)	Cumulative retained weight in (gm)	Cumulative retained weight (%)	Passing (%)
4	4.75	0	0	0	100
8	2.36	10	10	1	99
14	1.18	196.5	206.5	20.65	79.35
25	0.6	372	578.5	57.85	42.15
48	0.3	351.5	930	93	7
100	0.15	70	1000	100	0

Testing of Fine Aggregates: Weight of fine aggregate sample taken = 1000g.

Fig. 2. Illustrates three different aggregate gradations : (a)N.M.S 10 mm, (b)N.M.S 15 mm, and (c)N.M.S 20 mm.

Fig. 3. Illustrates the type of sand used in the Mixture.

2.1.4 WATER

For the mix design, tap water from Giza City's water supply network system was made available in the laboratory. It was free from organic materials and suspended solids, which may affect the properties of the bricks properties.All concrete mixtures had a 0.5 w/c ratio.

2.1.5 SUPERPLASTICIZER ADMIXTURE

Superplasticizers were employed to increase the fluidity and workability of the concrete during casting and curing, which were obtained from Sika and are known commercially as SIKAMENT N-N, as it is characterized by greatly improving workability as shown in **Fig. 4.** The dose that was used in the mixtures was `0.1% of the weight of the cement. Some of its characteristics are that the color is brown liquid and the density is equal to 1.185 kg/liter.

Fig. 4. illustrates the additive used in the mixtures**.**

2.2 CONCRETE MIXING

Mix the dry materials (cement, aggregate, rice husk ash) in the mixer for two minutes, then add water to the mixture. During mixing, plasticizers are gradually added to the mixture, and mixing is done for a minute until the mixture is homogeneous. It has been taken into account not to mix for more than five minutes as stated in the Egyptian code because there is no granular separation of the components.

2.3 MIX PROPORTIONS

Tests were carried out on different concrete specimens of rice husk ash to evaluate its quality. A variety of properties were measured, including compressive strength, the effect of aggregate size, the effect of rice husk ash content, the effect of density, and strength gain with age. The mixes were designed by volume. Two types of molds were used to prepare specimens for the proposed tests: Cube molds (15*15 cm and 10*10 cm).

All specimens were compacted by vibrator, finished, and stripped from their molds 24 hours after casting, and cured by submerging in water. Six concrete mixes with 1-3% RHA were tested to achieve high compressive strength with superplasticizers. Three 15*15*15 cm cubes from each mix were tested and compared to specimens with no RHA.

he Cube molds.

Table 6. shows the mix proportions for different RHA ratios.

	0 **kg / m³**	**1%** **kg / m³**	**1.5%** **kg / m³**	**2%** **kg / m³**	**2.5%** **kg / m³**	**3%** **kg / m³**
Cement	380	376.2	374.3	372.4	370.5	368.6
R H A	0	3.8	5.7	7.6	9.5	11.4
Water	190	190	190	190	190	190
Sand	680	680	680	680	680	680
gravel	1150	1150	1150	1150	1150	1150

Three groups of concrete mixes with different RHA ratios and coarse aggregate sizes NMS (10, 15, and 20) were tested to investigate the efficiency of RHA in improving the compressive strength of reinforced concrete.

5. RESULTS AND DESICCATIONS

3.1 COMPRESSIVE STRENGTH TEST.

Compressive strength is commonly regarded as one of the most essential qualities of concrete and a key indicator of overall quality control. The types and quality of materials, the mixture proportion, construction methods, curing conditions, and test methods all have an impact on concrete strength. From a microscopic standpoint, both the degree of hydration and porosity are significant. The larger the pores, the lesser the concrete's strength. Furthermore, as the binder/space ratio decreases (defined as the ratio of C-S-H gel content to the original volume of space), the strength increases. **Table 7.** makes this clear by displaying the correlation between the age at testing and the compressive strength of concrete at varied w/b ratios and with varying ground RHA contents.

e.

Table 7. Shows the compressive strength for specimens with different NMS aggregate

MIX		RHA%	Group	At 90 days		At 120 days		At 300 days	
				Compressive strength KN/cm^2	Percentage	Compressive strength KN/cm^2	Percentage	Compressive strength KN/cm^2	Percentage
G1-Control-10NMS	MIX 1	0%	First	4.05	100%	4.70	100 %	5.31	100%
G1-1%RAH-10NMS	MIX 2	1%		4.10	101.23 %	4.84	102.98 %	5.38	101.31 %
G1-1.50%RAH-10NMS	MIX 3	1.5%		4.31	106.42 %	5.07	107.87 %	5.65	106.40 %
G1-2%RAH-10NMS	MIX 4	2%		4.55	112.25 %	5.12	108.94 %	6.02	113.37 %
G1-2.50%RAH-10NMS	MIX 5	2.5%		4.40	108.64 %	4.66	99.14 %	5.77	108.66 %
G1-3%RAH-10NMS	MIX 6	3%		4.29	105.92 %	4.62	98.29 %	4.41	84.67 %
G2-Control-15NMS	MIX 7	0 %	Second	4.53	100 %	4.72	100 %	5.94	100 %
G2-1%RAH-15NMS	MIX 8	1%		4.54	100.22 %	4.93	104.45 %	5.96	100.33 %
G2-1.50%RAH-15NMS	MIX 9	1.5%		4.58	101.10%	5.20	110.17%	6.01	101.18%

G2-2%RAH-15NMS	MIX 10	2%		5.20	114.79 %	5.45	115.47 %	6.63	111.62 %
G2-2.50%RAH-15NMS	MIX 11	2.5%		4.55	100.44 %	5.30	112.29 %	5.93	99.83 %
G2-3%RAH-15NMS	MIX 12	3%		4.52	99.78 %	4.40	101.06 %	5.14	86.53 %
G3-Control-20NMS	MIX 13	0 %	Third	4.60	100 %	4.80	100 %	6.03	100 %
G3-1%RAH-20NMS	MIX 14	1%		4.64	100.87 %	5.03	104.79 %	6.08	100.83 %
G3-1.50%RAH-20NMS	MIX 15	1.5%		4.65	101.08 %	5.38	112.08%	6.10	101.16%
G3-2%RAH-20NMS	MIX 16	2%		5.29	115 %	5.59	116.45 %	6.98	115.75 %
G3-2.50%RAH-20NMS	MIX 17	2.5%		5.02	109.13 %	5.48	114.16 %	6.58	108.66 %

3.1.1.THE EFFECT OF AGGREGATE SIZE ON COMPRESSIVE STRENGTH.

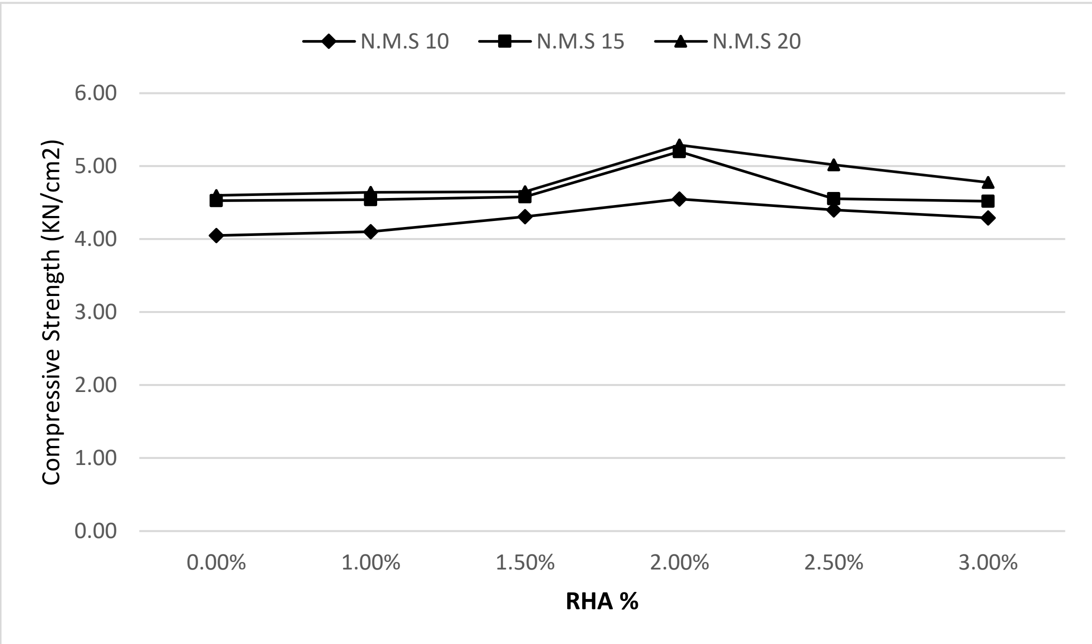


Fig. 7. The compressive strength at 90 days for specimens with different NMS aggregates.

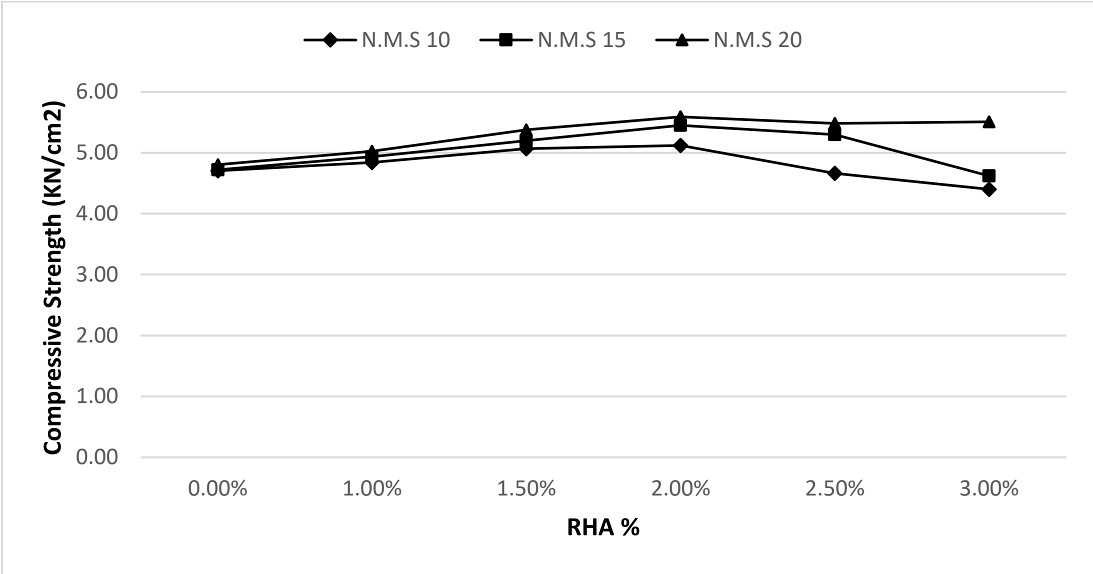


Fig. 8. The compressive strength at 120 days for specimens with different aggregates.

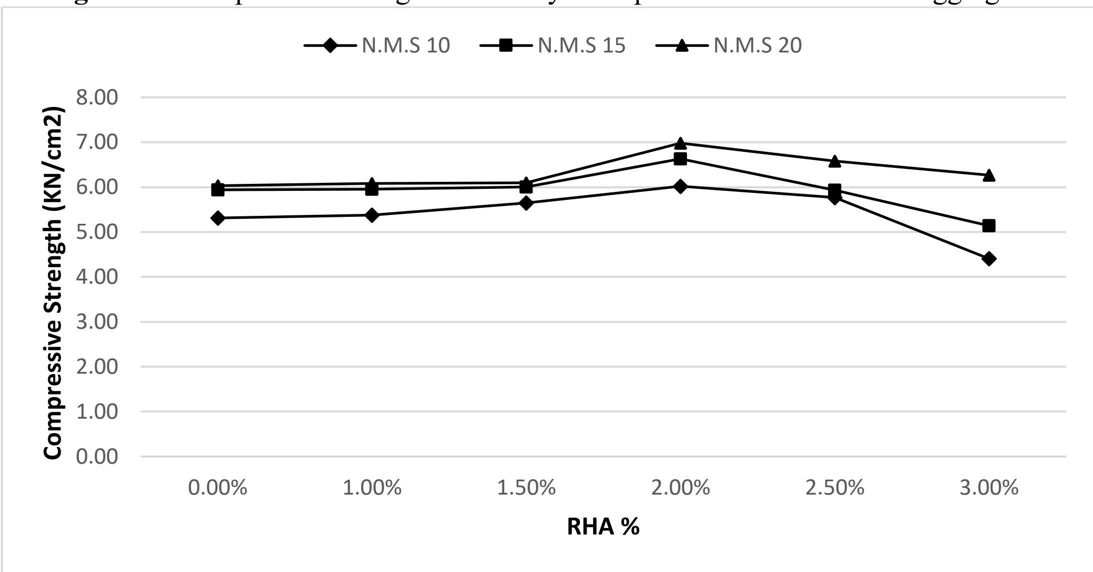


Fig. 9. The compressive strength at 300 days for specimens with different NMS aggregates.

According to the results shown in **Fig. 7,8,9.** compressive strength improves with increasing maximum aggregate size, with samples 1, 7, and 13 having higher strength with coarse aggregate. Mix 13 had a compressive strength of 4.60 kN/cm2 for 20 mm NMS, Mixture 7 had 4.53 kN/cm2 for 15 mm NMS, and Mixture 1 had a value of 4.05 kN/cm^2 for 10 mm NMS.

The compressive strength of samples with 1% rice husk ash increases with coarse aggregate size. Mix 14 has a compressive strength of 4.64 kN/cm² for 20 mm of coarse aggregate. The compressive strength of mix 8 was 4.54 kN/cm² for the NMS system at 15 mm. It involves out that the resistance decreased by 2.20 %. The compressive strength for NMS 10 mm (mixture 2) was 4.10 kN/cm². With a decrease by 13.17% compared to the control mix.

The compressive strength of samples containing 1.5% RHA increases with the increase in coarse aggregate. The compressive strength of mix 15 for NMS 20 mm is 4.65 kN/cm², while the strength of mix

9 is 4.58 kN/cm², and the strength of mix 3 is 4.31 kN/cm², with a reduction rate of 1.53% and 7.88% in compressive strength respectively compared to mix 15.

Samples containing 2% RHA showed compressive strengths increasing with coarse aggregate increase, with mix 16 compressive strength for NMS 20 mm being 5.29kN/cm², while mix 10 and 4 compressive strength for NMS 15and 10 mm were 5.02 and 4.55 kN/cm2, respectively.

Samples with 2.5% RHA had higher compressive strengths with the size of the coarse aggregate increases. For example, mix 11's strength for NMS 15 mm was 4.55kN/cm², resulting in a 9.96% decrease in strength, but mix 17's compressive strength for NMS 20 mm was 5.02kN/cm². Mix 5's strength for NMS 10 mm was 4.40kN/cm², which led to an 11.55% decrease in strength.

Finally, the samples with 3% RHA indicated increasing compressive strengths as coarse aggregates increased. For example, mix 18's compressive strength for 20 mm NMS was 4.78 kN/cm2, while mixtures 10 and 4's compressive strengths for 15 and 10 mm NMS were 5.75 and 4.29 kN/cm², respectively. In comparison to mixture 18, the strength decrease by 5.75 and 11.42%.

3.1.2 RICE HUSK ASH RATIO'S IMPACT ON COMPRESSIVE STRENGTH

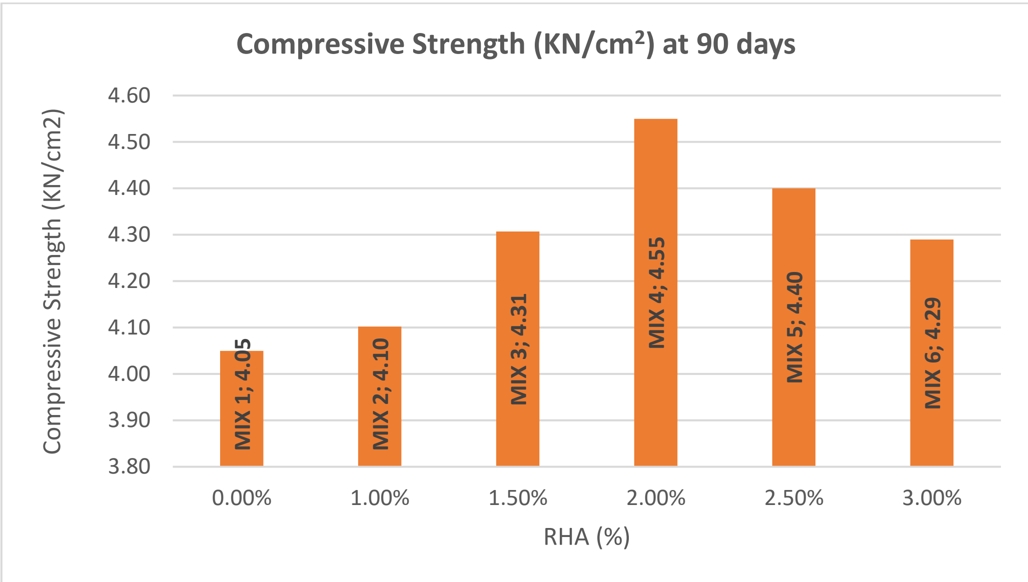


Fig. 10: Effect of RHA on the concrete compressive strength related to the control specimen.

According to the test results, the specimens containing RHA had a higher compressive strength than the control specimen, as shown in **Fig. 10.** It was observed that the concrete's compressive strength increased to 12.25% when the RHA was raised to 2%. However, the concrete's compressive strength is still higher than that of the control specimen, it diminishes as the RHA increases. For this concrete mix, a RHA ratio of 2% produced the best compressive strength.

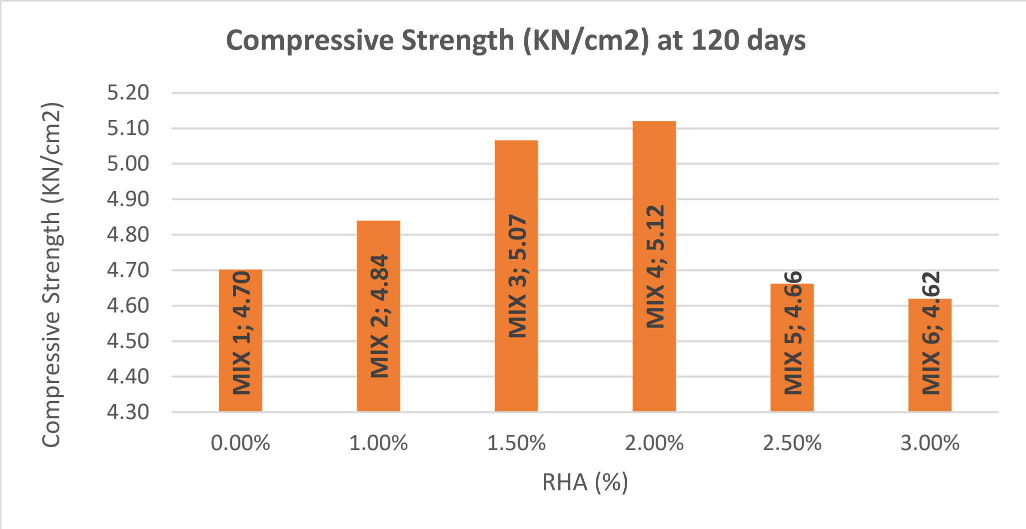


Fig. 11: Effect of RHA on the concrete compressive strength related to the control specimen.

According to the test results, the specimens with RHA had a greater compressive strength than the control specimen at age 120 in **Fig. 11.** It was observed that the concrete's compressive strength increased to 8.94% when the RHA was raised to 2%. Although the concrete's compressive strength is still higher than that of the control specimen, it decreases as the RHA increases. For this concrete mix, a RHA proportion of 2% produced the best compressive strength .

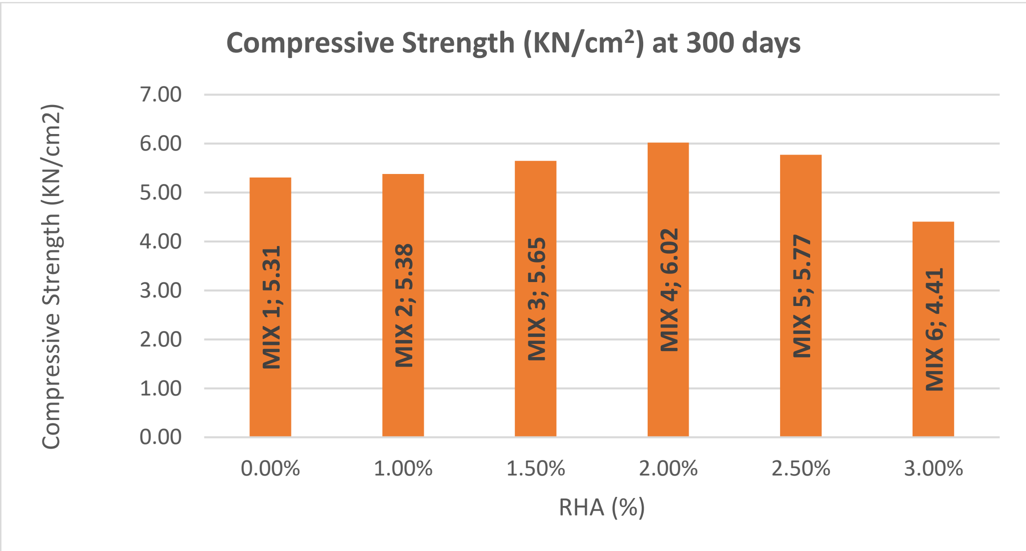


Fig. 12. Effect of RHA on the concrete compressive strength related to the control specimen.

According to the test results, the specimens with RHA had a greater compressive strength than the control specimen at age 300 in **Fig. 12.** It was observed that the concrete's compressive strength increased to 13.37% when the RHA was raised to 2%. Although the concrete's compressive strength is still higher than that of the control specimen, it decreases as the RHA increases. For this concrete mix, a RHA proportion of 2% produced the best compressive strength.

3.1.1 The impact of density on compressive strength;

Fig. 13. shows the effect of RHA% on the density of concrete mixtures. According to the analysis, increasing the RHA percentage to 2% increases density from 2497.7 to 2568.8 kg/m3 by 2.8% over the

control, however increasing it to 3% reduces density to 2499.26 kg/m3. The highest density was achieved with 2% RHA as a substitute material.

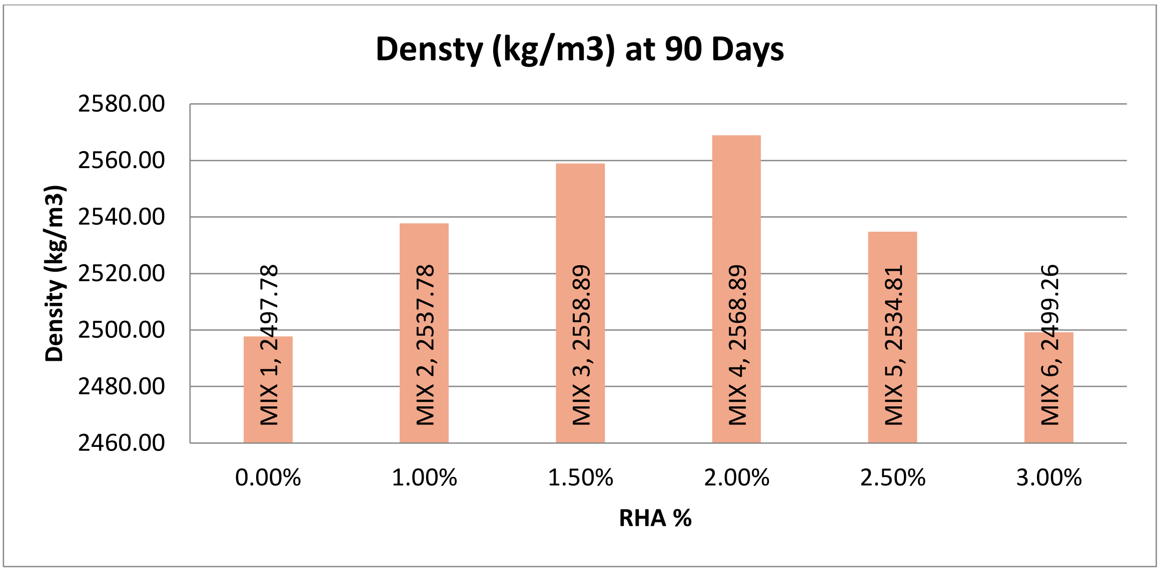


Fig. 13. Effect of RHA on the concrete density.

The test results showed in **Fig. 14,15,16.** that concrete's compressive strength increases with increasing density. Increasing the RHA in the concrete mix to 2% increases the concrete density significantly. The most pronounced increase in the concrete's density was reached when RHA was added at 2%, while the most pronounced decrease in the concrete's density was reached when RHA above 2% was added.

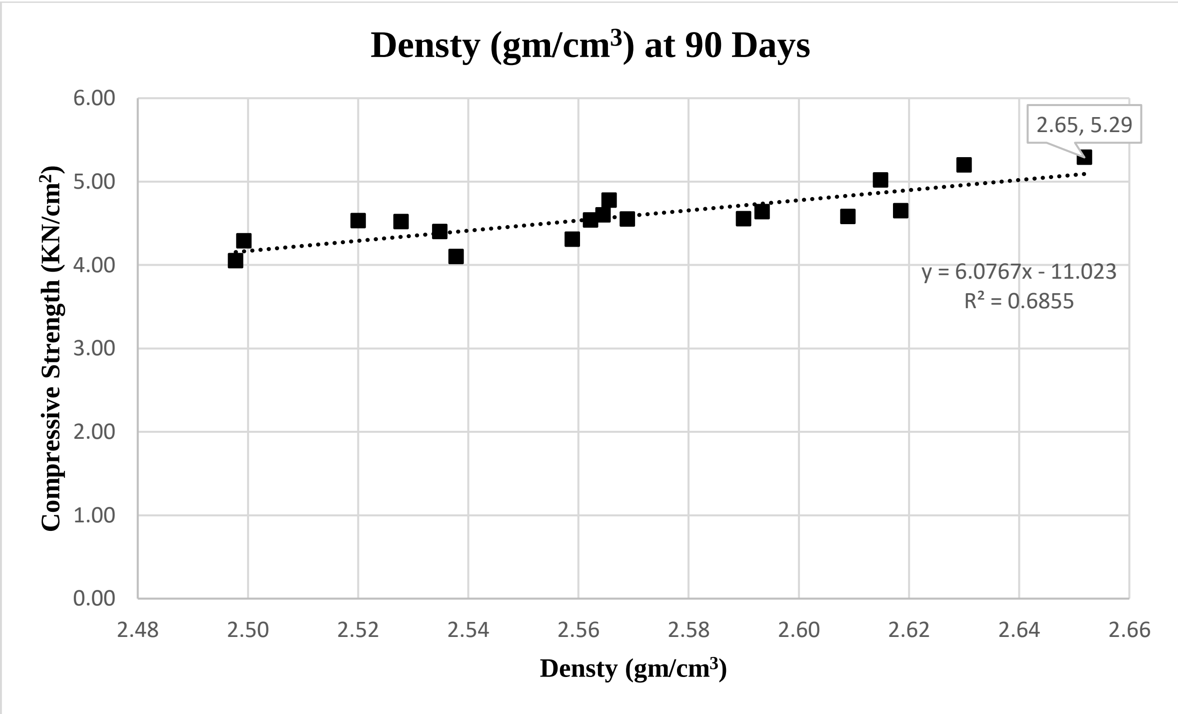


Fig. 14. Effect of Compressive strength on the concrete density.

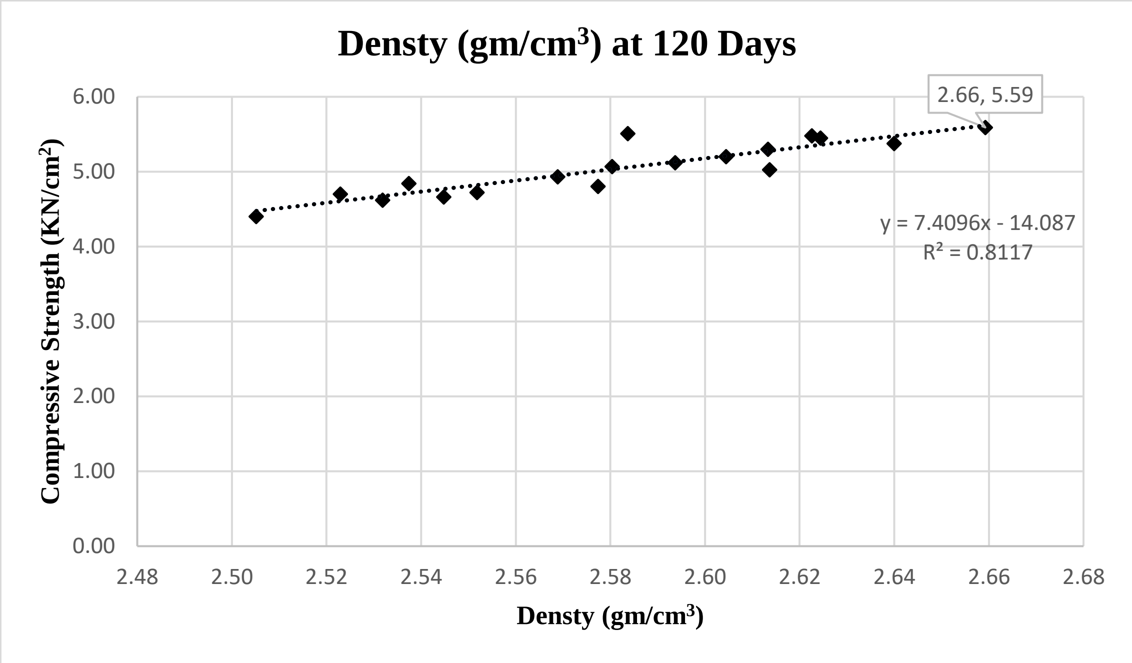


Fig. 15. Effect of Compressive strength on the concrete density.

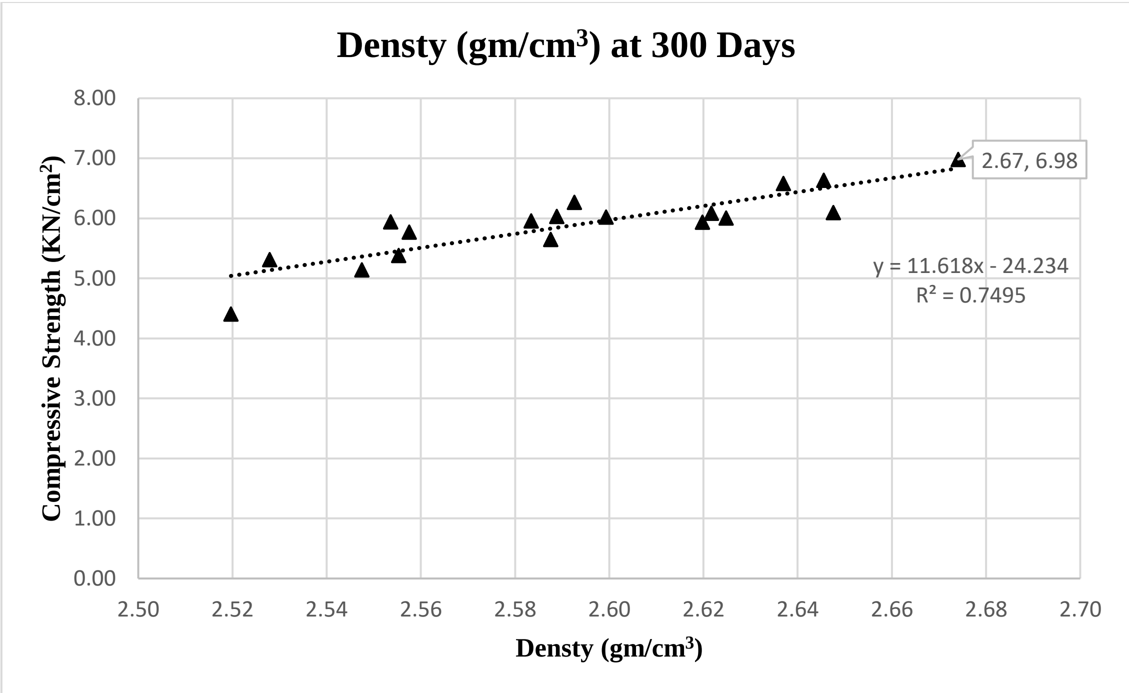
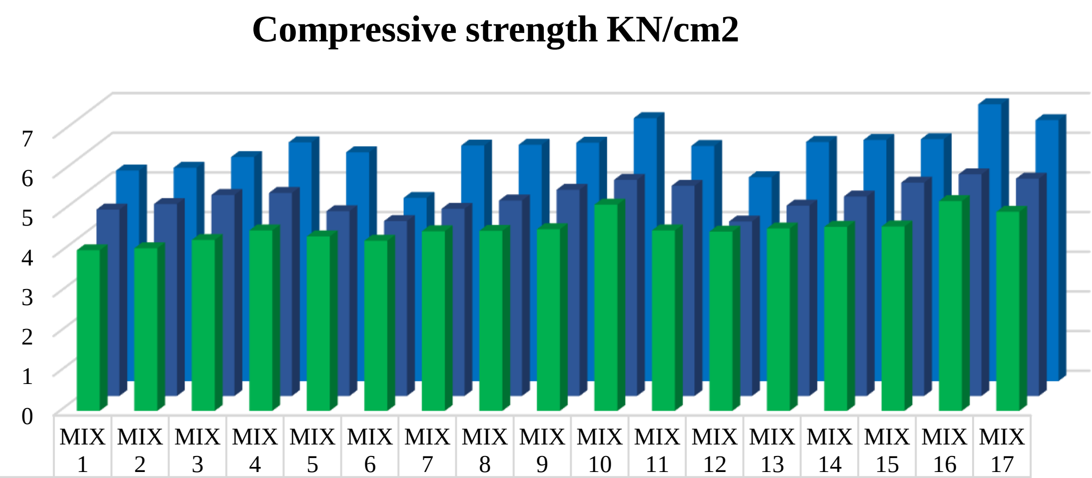


Fig. 16. Effect of Compressive strength on the concrete density.

3.1.2 THE IMPACT OF AGE Increase ON COMPRESSIVE STRENGTH



	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5	MIX 6	MIX 7	MIX 8	MIX 9	MIX 10	MIX 11	MIX 12	MIX 13	MIX 14	MIX 15	MIX 16	MIX 17
At 90 days	4.05	4.1	4.31	4.55	4.4	4.29	4.53	4.54	4.58	5.2	4.55	4.52	4.6	4.64	4.65	5.29	5.02
At 120 days	4.7	4.84	5.07	5.12	4.66	4.41	4.72	4.93	5.2	5.45	5.3	4.4	4.8	5.03	5.38	5.59	5.48
At 300 days	5.31	5.38	5.65	6.02	5.77	4.62	5.94	5.96	6.01	6.63	5.93	5.14	6.03	6.08	6.1	6.98	6.58

Fig. 17. Effect of increasing age on resistance.

Fig. 17. shows the compressive strength of concrete with different replacement ratios of RHA at 90, 120 and 300 days. As shown, Rice Husk Ash increases the compressive strength of concrete compared to normal concrete without RHA. In the third group (N.M.S. 20 mm) coarse aggregate the compressive strength of mix 16 with the replacement ratio of 2% at 90, 120, and 300 days are 5.29kN/cm2, 5.59kN/cm2, and 6.98kN /cm2, exceeding that of the control group by 15%, 16.45% and 15.75%, respectively. While, in the second group (N.M.S. 15 mm) coarse aggregate the compressive strength of mix 10 with the replacement ratio of 2% at 90, 120, and 300 days are 5.20kN /cm2, 5.45kN /cm2, and 6.63kN/cm2, surpassing those of control group by 14.79%, 15.47% and 11.62% respectively. Finally, in the third group (N.M.S. 10 mm) coarse aggregate the compressive strength of mix 4 with a 2% replacement ratio at 90, 120 and 300 days was 4.55kN /cm2, 5.12kN /cm2, and 6.02kN /cm2, exceeding that of the control group by 12.25%, 8.94% and 13.37%, respectively.

CONCLUSION

The following findings were observed as a result of the investigation.

Rice husk Ash increased concrete's compressive strength by up to 2% at low values, but resistance decreased with increased rice husk percentage, remaining higher than controls. Rice husk Ash with large aggregates (N.M.S. 20 mm) provides superior resistance to concrete containing coarse aggregates (N.M.S. 10, 15 mm). The compressive strength of concrete including (N.M.S. 20 mm) coarse aggregate was greatly increased utilizing RHA at low levels. The maximum strength was attained at 2% RHA, representing a 15%, 16.45%, and 15.75% increase, respectively. The cubes were crushed after 90, 120, and 300 days.

The compressive strength of concrete increases with density, with 2% RHA significantly enhancing its density. The largest increase was observed when RHA was added at 2%, raising density from 2.50 to 2.57 kg/cm^2, while 3% RHA reduced it to 2.49 kg/cm2. Concrete's compressive strength improves as its density increases. Increasing the RHA in the concrete mix to 2% greatly enhances its density. The most significant increase in concrete density occurred when RHA was added at a rate of 2%, while the greatest reduction occurred when RHA was applied at a rate of more than 2%. The most significant increase in concrete density occurred when RHA was added at a rate of 2%, while the greatest reduction occurred when RHA was applied at a rate of more than 2%.

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