

Experimental Investigation on Strength and Durability Properties of M25 Grade Concrete Using Fly Ash, Rice Husk Ash and Egg Shell Powder.

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Abstract: The purpose of the study is to assess the combined impact of eggshell powder (ESP) and fly ash (Class F) and rice husk ash (RHA) as additional cementitious materials in concrete applications. Fly ash is widely used in concrete works due to its ability to improve mortar and concrete properties. The usage of eggshells, a biodegradable waste product from bakeries, fast food establishments, and chick hatcheries, is also examined in this study. It assesses the fly ash-f, RHA, and ESP blended cements' chemical makeup, physical characteristics, consistency, beginning and final setting times, pH level, and compressive strength. The strength property of ESP blended cement mortars is also evaluated. The study also compares the strength properties of ESP concrete mixes and a control mix. The study also assesses the coefficient of water absorption, sorptivity, resistance to chloride ion penetration, and diffusion coefficient. The findings will help determine how much fly ash and rice husk ash should be replaced in concrete.

- a) Water permeability decreased by around 56.8%.
- b) A drop in chlorine penetration of about 75.55 percent.
- c) A decrease in chloride diffusion of about 49%
- d) For 28, 56, and 90 days in an acid solution, the rate of deterioration of RA0 cement concrete (control samples) exposed to acid resistance (HCl & H₂ SO₄) and sulfate resistance was significantly higher than that of RA4 cement concrete (15FA15RHA5ESP).
- e) A decrease in corrosion of almost 88.72% (Good corrosion inhabiting)

Keywords: Rice husk ash, Egg shell powder, Fly ash

I. Introduction

To ensure a comfortable and safe lifestyle for people living in congested cities, traffic and accident management are crucial. People can avoid becoming stranded in traffic jams by using this technology, which provides real-time information on traffic conditions throughout the city. Ground-based solutions are currently frequently utilized to monitor traffic conditions in a narrow, stationary, short-view coverage region.

Khan and Khan (2020), for instance, investigate the effectiveness of fly ash and rice husk ash in blended concrete, emphasizing their combined impact with egg shell powder as an additional cementitious element. Determining the ideal level of replacement and assessing the mechanical characteristics of hardened concretes are the goals [1]. In order to suggest an environmentally friendly material, Arokiaprakash et al. (2018) investigated the characteristics of concrete formed from recycled concrete aggregate, quarry dust, and rice husk ash. They evaluated specimens of various sizes using M25 grade concrete as a reference mix. According to the study, at an ideal mix proportion (M15), the inclusion of tiny particles enhanced strength in compression, tension, and flexure [2]. Binyamien et al. (2017) investigated how Rice Husk Ash (RHA) affected the durability and strength of concrete. Three distinct RHA kinds with varying chemical compositions and physical characteristics were employed. The findings demonstrated that RHA characteristics had a direct impact on strength growth over an extended period of time. Concrete demonstrated improved strength and durability performance even with 50% RHA substitution, presumably as a result of decreased porosity. The study emphasizes how crucial RHA is to concrete building. [3].

In a 2017 study, Akhter examined the usage of rice husk ash (RHA) as a partial cement substitute. According to the study, RHA can be added to concrete in several weight percentages—5%, 10%, 15%, and 20%—and utilized as a waste. According to the findings, RHA might replace up to 10% of the weight of cement. [4]. The environmental effects of manufacturing 4 million tonnes of RHA and 20 million tonnes of rice husk per year were examined by Kumar et al. (2017). They discovered that organic stuff is eliminated during burning, leaving behind residue that is rich in silica. The purpose of the study was to investigate the mechanical characteristics of concrete utilizing M25 grade steel and polyester fibers [5]. Florida Atlantic University's D.V. Reddy, Ph.D., P.E., studied 10% and 20% alternative replacements and measured the hardened concrete's compressive, flexural, and break-up tensile strengths [6]. Marcelina Alvarez and D.V. Reddy talk about the use of rice husk ash (RHA) in the production of concrete, emphasizing how it can cut down on power use and carbon dioxide emissions. RHA, which is made by burning rice husk, has demonstrated better results in concrete when 10%–20% of the cement is substituted. This strategy may lessen greenhouse gas emissions and the cost of producing concrete [7]. Mehta, P.K. investigated the durability and strength of cement mortar using 10%,

20%, and 30% rice husk ash (RHA) in place of regular Portland cement (OPC). According to the study, RHA added to 20% alternate stage OPC produced better 90-day results. The surface area of the ash was directly correlated with the reactivity of amorphous silica. Additionally, the study discovered that time and temperature play a significant role in the combustion process [8]. The use of rice husk ash (RHA) in concrete for pavements was investigated by Ramakrishnan S, Velraj Kumar G, and Ranjith S. They discovered that RHA greatly increased concrete's flexural strength, which made it more appropriate for pavements. In order to produce concrete for rigid pavements that is affordable, the study also investigated the effects of RHA on several concrete characteristics [9]. OBILADE, I.O. The project looks into using rice husk ash (RHA) in concrete as a partial replacement for regular Portland cement (OPC). According to the results, the compressive strength of hardened concrete reduces along with the compaction component as the percentage of OPC substitution with RHA rises. To better understand the efficacy of RHA in concrete, the study suggests more research [10]. When compared to OPC concrete, Mehta and Perth's (2000) study on the use of ORS to lower the temperature of high electrical concrete mass revealed that the RHA might be extremely effective in doing so [11]. Later research by Malhotra and Mehta (2004) shown that RHA samples with finer particle length OPC enhance concrete homes. This includes improved substitution results in lower water absorption values and an increase in compressive power due to the addition of RHA [12]. In a lab investigation, Dr. A.M. Pandel and S.G. Makarande employed rice husk ash, which was burned, cremated, ground, and examined with an electron microscope and XRD. Sand mining, coarse mixture, and Portland cement were utilized as aggregates; their respective fineness moduli were 4.61 and 2.43.[13]. The compressive strength of concretes containing rice-husk ash (RHA) for up to 91 days was investigated in a study conducted by Gemma de Sensale et al. (2005). According to the study, RHA had a favorable effect on compressive strength at young ages, but the long-term behavior of concretes made with RHA was more important. As the ratios of cementitious to water increased, so did the compressive strength [14]. RHA was added as a micro filler to concrete mixtures by Maisarah Ali et al. (2015), producing lighter, less permeable concrete. For a target strength of 50 MPa, they employed 5% RHA, which showed greater calcium silicate hydrate production and a higher silica content. The goal was accomplished even though compressive strength and water absorption were decreased [15]. Malkit Singh et al. (2016) investigated how bacteria affected the characteristics of rice husk ash (RHA) concrete. They discovered that adding bacteria improved characteristics by lowering permeability, porosity, and water absorption. 10% RHA produced the greatest results, with a 28-d compressive strength of 40.0 MPa [16]. Satish H. Sathawane et al. (2013) looked into how the mechanical qualities of concrete were affected by fly ash (FA) and rice husk ash (RHA). In addition to lowering environmental impact, they discovered that a blend of 22.5% FA and 7.5% RHA enhanced compressive strength by 30.15%, flexural strength by 4.57%, and split tensile strength by 9.58% [17]. The effects of using rice husk ash (RHA) in place of cement in SCC were investigated by Divya Chopra et al. (2014). They discovered that the RHA content improved durability, mechanical strength, and strength. Additionally, the study discovered that the mixes had low to very low range chloride penetration and were less porous. According to the study, RHA can enhance the qualities of concrete [18]. The mechanical properties of concrete mixtures containing Class F fly ash were assessed by Ramafat Siddique in 2003. The results showed that for all fly ash percentages, the modulus of elasticity, flexural strength, splitting tensile strength, and compressive strength of fly ash concrete that was replaced with fine aggregate increased with age [19].

II. Methodology & Materials Testing

The purpose of this study is to examine the effects of partially substituting cement in M25 grade concrete with fly ash (FA), rice husk ash (RHA), and eggshell powder (ESP). The main objective is to assess the amended concrete's strength and durability properties.

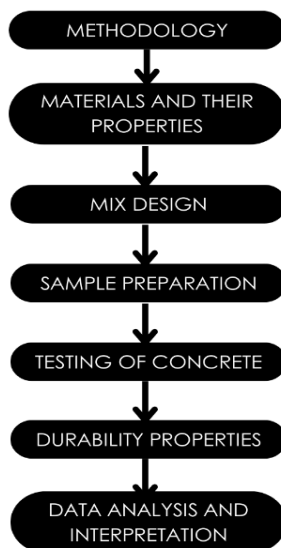


Table 1 Physical properties of materials

Materials	Name of properties	obtained Value
Ordinary Portland Cement	Specific gravity	3.12
	Fineness	348 m ² /kg
	Consistency	31 (%)
	Initial setting time	45(min)
	Final setting time	225 (min)
	Soundness	2 mm
Fine aggregates	Specific gravity	2.6
	Finesse modules	2.63
	Bulk density	1693 Kg/m ³
Coarse aggregates	Specific gravity	2.7
	Finesse modules	6.26
	Bulk density	1527 Kg/m ³

Table 1 Physical properties of materials (table continued)

Materials	Name of properties	obtained Value
RHA grain size of 3.8 µm	Specific gravity	2.01
	Fineness	3460 m ² /kg
	Bulk Density	696 kg/m ³
Egg Shell Powder (ESP)	Specific gravity	1.89
	Fineness	290 m ² /kg
	Bulk Density	1081kg/m ³
fly ash – F	Specific gravity	2.07
	Fineness	527m ² /kg
	Bulk Density	1190kg/m ³

Mix Proposition

The proportioning of the components that make up concrete is the primary determinant of its quality. The design mix, not the regular mix, determines the precise behavior of concrete. A control mix with a water-to-cinder W/C ratio of 0.5 and a design cube compressive strength of 25 MPa was made for this study in accordance with IS 10262-2009. Mix ratios of 1:1.604:2.94 were used to make the M25 grade control concretes. OPC (43 Grade) was partially substituted with double pozzolans (fly ash and rice husk ash) at dosages ranging from 0 to 40% by weight of cementitious materials, with a 5% addition of egg shell powder (ESP) at each replacement. Table 2 provides the concrete mix concept in detail for the inquiry. Appendix I contains the concrete mix design processes.

Table 2 Mix proposition

Mix designation	Symbol	Cement (%)	Replacement		Additive
			(%)		(%)
			FA	RHA	ESP
RA ₀	OPC	100	-	-	-
RA ₁	2.5FA2.5RHA5ESP	95	2.5	2.5	5
RA ₂	5FA5RHA5ESP	90	5	5	5

RA ₃	10FA10RHA5ESP	80	10	10	5
RA ₄	15FA15RHA5ESP	70	15	15	5
RA ₅	20FA20RHA5ESP	60	20	20	5
FA – Fly Ash, RHA – Rice Husk Ash & ESP – Egg Shell Powder					

III. Result and Discussion.

Fresh Concrete Tests

The fresh properties of concrete determine its workability, consistency, cohesiveness, and ease of placement. The following tests will be conducted to evaluate the fresh concrete characteristics when incorporating Fly Ash (FA), Rice Husk Ash (RHA), and Egg Shell Powder (ESP):

Table 3 Fresh concrete test results

Mix	Consistency (%)	Setting time (min)		Soundness value (mm)
		Initial	Final	
RA ₀	31	65	265	1
RA ₁	33	95	275	3.5
RA ₂	33	115	290	3
RA ₃	37	120	295	2.5
RA ₄	39	130	320	1.5
RA ₅	42	135	355	2

Hard Concrete Tests

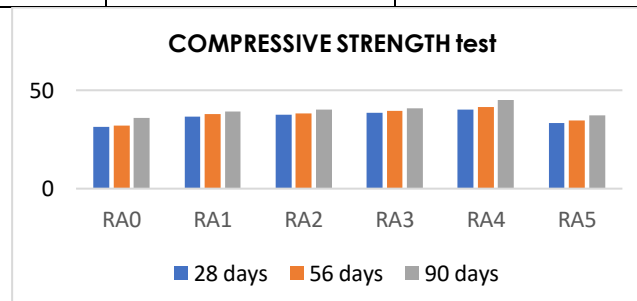
Once the concrete has hardened, various tests are conducted to evaluate its **strength, durability, and structural performance**. The key hardened concrete tests include:

Compressive Strength Tests

The compressive strength of ESP cement mortars increases with curing time, reaching RA₄. The optimum mix proportion is RA₄, which yields high compressive strength at all ages. This is due to the gradual increase in compressive strength in the absence of carbon content in RHA & FA showing table 4

Table 4 Compressive strength test results

Mix designation	Curing Periods		
	28 days	56 days	90 days
RA ₀	31.51	32.17	35.93
RA ₁	36.49	37.93	39.2
RA ₂	37.53	38.36	40.12
RA ₃	38.67	39.57	40.98
RA ₄	40.18	41.49	45.2
RA ₅	33.2	34.71	37.24

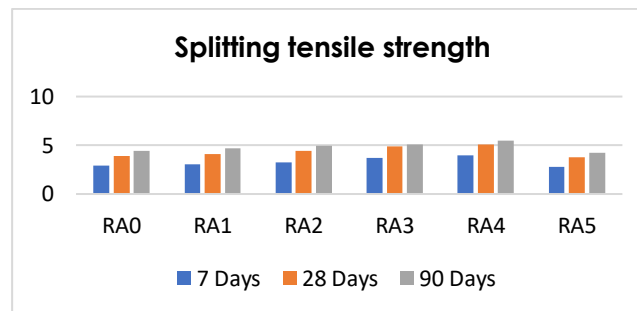


Splitting Tensile Strength

The splitting tensile strengths of ESP blended concrete after curing show table 5 a peak at RA4 content, which is the finest limit, with RA4 content being the maximum strength compared to RA0.

Table 5 Splitting tensile strength test results

Mix designation	Curing periods		
	7 Days	28 Days	90 Days
RA ₀	2.91	3.9	4.4
RA ₁	3.05	4.11	4.72
RA ₂	3.27	4.42	4.97
RA ₃	3.7	4.9	5.1
RA ₄	3.98	5.09	5.5
RA ₅	2.77	3.8	4.26

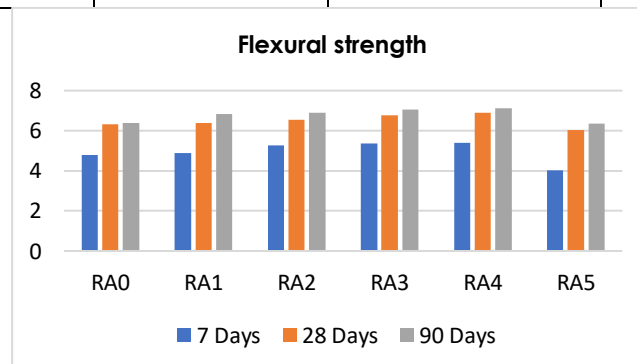


Flexural Strength Tests

The study shows that the table 6 highest flexural strength of ESP concrete is achieved at RA4, and it reaches roughly identical strength to OPC concrete at RA5.

Table 6 Flexural strength test results

Mix designation	Curing Periods		
	7 Days	28 Days	90 Days
RA ₀	4.79	6.32	6.4
RA ₁	4.87	6.4	6.84
RA ₂	5.28	6.55	6.91
RA ₃	5.35	6.78	7.06
RA ₄	5.4	6.91	7.13
RA ₅	4.02	6.04	6.36



Durability Tests

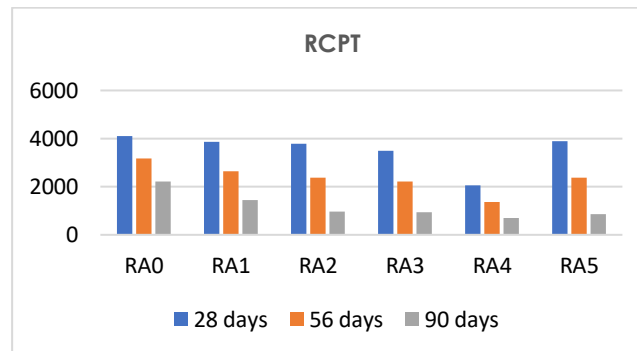
Durability testing is essential to ensure that the concrete maintains its **strength and performance** over time, especially when exposed to harsh environmental conditions. Below are the key durability tests conducted as per **Indian Standards (IS) and ASTM** for assessing concrete's resistance to water, chemicals, and environmental effects.

Rapid Chloride Ion Permeability Tests

The study reveals that the resistance to chloride ion penetration in ESP concrete specimens decreases with increasing ash substitution content up to RA4 at all ages, with total charge passing through OPC mortar decreasing show in table 7.

Table 7 Rapid Chloride Permeability test results

Mix designation	RCPT Charge passed / coulombs		
	28 days	56 days	90 days
RA0	4110.69	3161.66	2212.63
RA ₁	3850.99	2641.12	1431.24
RA ₂	3784.21	2376.41	968.61
RA ₃	3487.41	2212.59	937.76
RA ₄	2056.27	1376.10	695.92
RA ₅	3894.38	2374.11	853.84

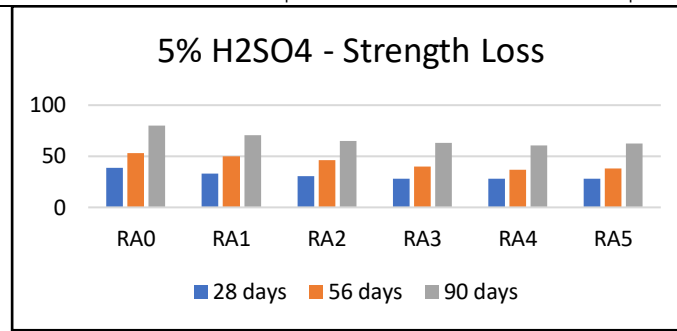


Chemical Exposure to Sulphuric Acid Tests

The study reveals that concrete containing FA and RHA (RA4) exhibits higher acid resistance and lower weight loss and strength loss compared to OPC concrete show in table 8. This is due to the denser packing of the mixture and the stable product formed by FA and RHA.

Table 8 Sulphuric acid test test results

Mix designation	5% H ₂ SO ₄ - Strength Loss		
	28 days	56 days	90 days
RA0	38.72	53.05	80.23
RA ₁	33.21	49.85	70.61
RA ₂	30.57	46.03	65.12
RA ₃	28.11	39.68	63
RA ₄	27.94	37.02	60.57
RA ₅	28.16	38.25	62.32

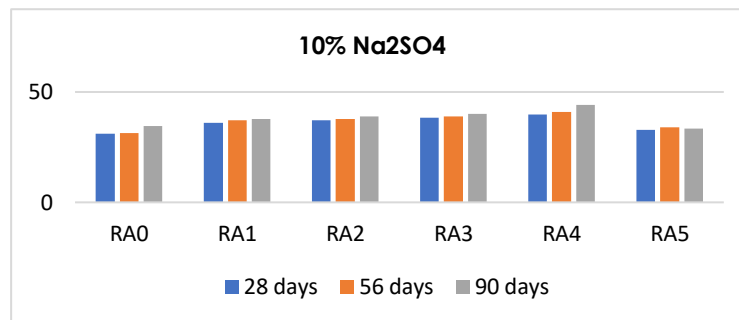


Strength of Concrete Specimens Due to Sulphate Attack

The study used sulphate attack to measure the chemical reaction between sulphate ions and hydration products, resulting in ettringite, which reduces bond strength and internal disintegration of concrete. After curing, concrete specimens were immersed in sulphate solution for 28, 56, and 90 days in table 10. The weight loss from conventional concrete decreased over time, while ESP blended mix saw gradual reduction.

Table 10 Sulphate attack test results

Mix designation	10% Na ₂ SO ₄		
	28 days	56 days	90 days
RA0	31.01	31.48	34.45
RA ₁	35.99	37.13	37.86
RA ₂	37.11	37.65	38.93
RA ₃	38.31	39.06	40.03
RA ₄	39.85	41.02	44.04
RA ₅	32.78	34.09	33.37



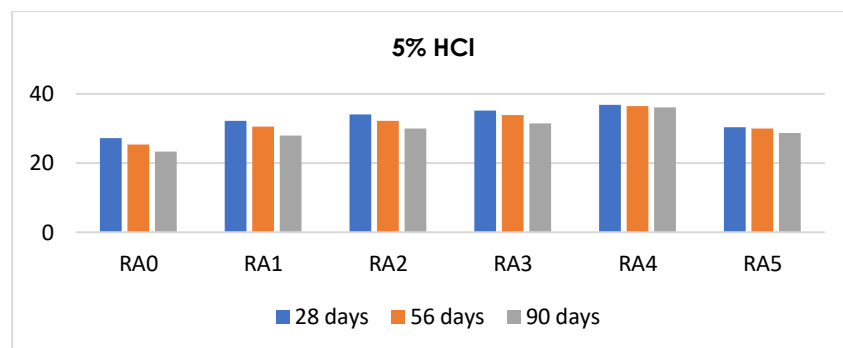
Chemical Exposure to Hydrochloric Acid Tests

Acid affects hardened concrete by converting calcium compounds into calcium salts. The chemical resistance of concrete was evaluated using weight loss and compressive strength loss. Control concrete showed 13.89%, 21.43%, 35.19%, and 60.54% strength loss, while concrete prepared with fly ash, rice husk ash, and egg shell powder showed 8.24% and 20.31% strength loss show in table 11.

Table 11 Hydrochloric acid test results

Mix designation	5% HCL		
	28 days	56 days	90 days
RA0	27.13	25.28	23.29
RA ₁	32.13	30.53	27.89
RA ₂	34.01	32.19	29.91
RA ₃	35.15	33.87	31.52

RA ₄	36.87	36.52	36.02
RA ₅	30.3	30.02	28.6



IV. Conclusions

Fly ash-F (FA) and rice husk ash (RHA) are good pozzolanic materials that have a relatively small decrease in ignition value and are fully loaded with unstructured silica content (87.65% and 58.68%). Calcium carbonate makes up 93.70% of egg shell powder (ESP).

- The values of the blend ratio of RA1 (2.5FA2.5RHA5ESP) to RA5 (20FA20RHA5ESP) range from 11.96 to 12.32, indicating that RA4 is preferred for concrete that is prone to corrosion.
- When compared to OPC concrete, compressive strength increases with an increase in the blend ratio of RA4 (15FA15RHA5ESP) by roughly 28% at 28 days of curing and 29% at 56 days of curing, respectively. This is followed by a decrease with the addition of RA5 (20FA20RHA5ESP) and RA6 (25FA25RHA5ESP). This was demonstrated by the EDAX/SEM analyses.
- Compared to the OPC control specimen, the concrete with blend mix designation RA4 (15FA15RHA5ESP) had 30.5% greater split tensile strength, 9.5% more flexural strength, and 14.5% more bond strength.
- When compared to the control system, the water absorption data showed that RA4 systems decreased the water absorption by roughly 13% at 28 days of concrete curing and 23% at 90 days.
- It is evident that sorptivity steadily decreases with improvement in the blended mix of RA1 to RA4 at 28 and 90 days of curing. The sorptivity increases at RA5, and these values are lower than those of the control concrete.
- In comparison to the control concrete, the chloride penetration results (RA4) revealed lower chloride ion penetrability values at the end of 28 and 90 days, respectively, of 2056.27 and 695.92 coulombs.
- After 28 and 90 days of curing, the chloride diffusion coefficient for RA4 dropped by 75% and 78%, respectively.
- In comparison to the control OPC concrete, the water permeability findings showed that the RA4 mix decreased the water permeability by roughly 33% and 52% at 28 and 90 cured concrete, respectively.
- ESP concrete demonstrated strong acid resistance (both Hcl and H2SO4) across all mix proportions (RA0 to RA5). When compared to control OPC concrete, the hardened concrete matrix of the ESP concrete mixtures is denser and more impermeable, increasing acid resistance.

V. Acknowledgement

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