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PERFORMANCE EVALUATION OF CONCRETE WITH RAW RICE HUSK AND FLY ASH AS PARTIAL REPLACEMENT MATERIALS

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ABSTRACT

Despite being the most popular material in modern construction, concrete's reliance on cement and sand has created problems for the economy and ecology. This study looks at how concrete behaves mechanically when sand is replaced with two easily accessible waste from industry and agriculture materials: fly ash (FA) and raw rice husk (RRH). Utilizing a ratio of water to cement of 0.55 as well as mixed proportions of M20 with a ratio of 1:1.5:3, nine virgin concrete specimens and three distinct samples corresponding to each proportion were cast. Sand was replaced with RRH and FA at percentages of weight for 12% (6% RRH + 6% FA), 16% (8% RRH + 8% FA), 20% (10% RRH + 10% FA), and 24% (12% RRH + 12%FA). Cube samples were used to assess compressive strength after seven, fourteen, and twenty-eight days. This investigation's main focus is concrete performance; it also examines density, water absorption, compressive strength, and performs a slump test. In addition to the maximum slump value of 43mm with 0%RRH + 0%FA and the lowest slump value of 18mm for 12%RRH as well as 12%FA, the water absorption for 12% RRH + 12% FA was determined to be 48.5%, where our compressive strength rose from 14.6% to 17.2%. Concrete that is both economical and ecologically beneficial is produced by partially substituting FA and RRH for fine aggregates, which reduces the environmental impact.

Keywords: M20 Concrete, Casting, water absorption, slump test, compressive strength.

I. INTRODUCTION

Concrete is widely utilized in man-made substances. Because of its flexibility and cost-effectiveness, it is seen as a strong option for construction materials. Concrete is made up of cement, small stones or gravel, and water. The small stones and gravel make up around 75-80% of concrete's total size, which influences how wet and dry concrete behaves and how well it works. Making cement has some drawbacks, including being expensive to produce and needing a lot of energy. Producing cement also results in large amounts of CO2 and additional greenhouse gases. Making one ton of cement releases 1 to 1.25 tons of CO2, uses roughly 1.60 megawatt-hours of energy, and hence it is viewed as a costly and harmful process for the environment [1]. As mentioned in [2], people generate over 5,000 tons of solid waste each year, containing materials like silica fumes FA, and ash from corncobs [2]. Significant reductions in expenses and energy use could be obtained by using these by-products to partially replace sand [3]. In order to cut expenses, waste, and carbon dioxide emissions, the study investigated the use of agricultural waste such as millet husk, fly ash, sugarcane bagasse ash, rice husk ash, and waste glass powder. Industrial and agricultural waste disposal practices are a major issue [4]. Fly ash and rice husk ash are dangerous byproducts of agricultural that are frequently burned. Fly ash and rice husk both have potent pozzolanic qualities and can be used in place of Portland cement. These materials have high silica levels and are inexpensive, making them promising options for creating secondary cementing materials. Each year, around 120 million tons of rice husk is produced [5]. Rice husk ash contains 85% silica, known as amorphous silica, which can be used as a cement-forming material in concrete [6]. Fly ash is produced by the combustion of coal. These days, with the implementation of pollution control technologies like electrostatic precipitators and other filtering systems, fly ash is collected before smoke can escape through the chimney of a coal-fired power facility. In the US, more than 43 percent of fly ash produced from coal-fired power stations is collected and utilized to make concrete. This study's main goal is to evaluate the characteristics of freshly mixed and hardened concrete utilizing fly ash and rice husk as cement substitutes [8]. Using industrial by-products instead of the energy-intensive Portland cement can result in significant cost and energy savings. Using rice husk ash that is standard in the making of structural concrete is one of the many wastes and by-products that are accessible, and it is very important for India [9]. As the second-largest producer of rice paddy globally, India has a unique opportunity. The technical benefits of integrating riche husk into structural concrete, along with social advantages stemming from a decrease in ash disposal issues in the environment have sparked interest in researching the possibilities of this material [10]. A significant quantity of agricultural waste is produced by many tropical countries, especially those in Asia including Malaysia, Thailand, India, and the Philippines. Improper management of such garbage might result in environmental and societal problems. Recycling the abandoned products is one way to deal with agricultural waste. One possible usage is to use rice husk ash to make a composite material that may be used in building. Rice husk ash may be harmful to the environment if improperly disposed [11].

METHODOLOGY

Five distinct mixtures — 0%RRH + 0%FA, 6%RRH + 6%FA, 8%RRH + 8%FA, 10%RRH + 10%FA, & 12%RRH+12%FA—were used to analyze the properties of both fresh and cured concrete. Using a mix ratio of 1:1.5:3 (1 part cement, 1.5 parts sand, and 3 parts aggregates) and a water to cement ratio of 0.55, 45 concrete samples measuring 150 x 150 x 150 mm were cast. Nine of the samples were virgin concrete, and the remaining 36 were cast with varying proportions of RRH along with FA (0%RRH + 0%FA, 6%RRH + 8%FA, 10%RRH+10%FA, and 12%RRH+12%FA). In accordance with the ASTM C192 Standard, testing was carried out utilizing an universal testing machine (UTM) in order to evaluate the concrete mixes' characteristic strength. Concrete cubes (150 x 150 x 150 mm) were used to assess compressive strength as the average mean of three samples for varying RRH and FA fractions. Similarly, the samples' density and the absorption of water rates were assessed after 28 days. Three concrete samples have been prepared for each mixing ratio, and an average strength was determined using these three findings. These findings were obtained in a college laboratory.

II. MATERIALS USED

i. **Cement:** The binding agent was ordinary Portland cement, of Grade 43, which was purchased locally and sold under the brand name Ultra Tech Cement. Table 1 shows the experimental physical parameters, whereas Table 2 lists the cement composition.

ii. **Fine & Coarse Aggregates:** JK Stone Crusher, a local supplier in the Jammu area, provides the materials. Coarse aggregates were created of 12 mm crushed stone, whereas fine aggregates were taken from hill slopes and sieved through a 4.75 mm sieve. Table 1 displays the attributes for these aggregates determined by laboratory test findings.

iii. **Rice Husk:** The rice husk used in this study came from a nearby rice mill in Sohanjana, Jammu, J&K. The bulk density for the raw rice husk is 696 kg/m2, and its specific gravity is 2.01. Significant pozzolanic properties and reactivity are displayed by RRH. IS 456-2000 encourages the use of standard RRH in concrete but does not specify how much. Table 1 shows the experimental physical features, whereas Table 2 lists the composition of RRH.

iv. **Fly Ash:** The Building Center in the Jammu region provided the fly ash, which is a very fine powder that passes through thirty sieves. Every year, this factory generates around two million metric tons of fly ash, which is disposed of at a landfill. This waste might be reduced by using the fly ash produced by the power plant in instead of sand. Table 1 shows the experimental physical features, whereas Table 2 lists the composition of FA.

v. Water: We employ portable water.

Table 1: Proportions of Admixtures used in study

Mix Code	Mix Proportions	C : S : A : RRH : FA
M0	0% RRH : 0% FA	4 : 6 : 12 : 0 : 0
M1	6% RRH : 6% FA	4 : 5.28 : 12 : 0.36 : 0.36
M2	8% RRH : 8% FA	4 : 5.04 : 12 : 0.48 : 0.48
M3	10% RRH : 10% FA	4 : 4.8 : 12 : 0.6 : 0.6
M4	12% RRH : 12% FA	4: 4.56 : 12 : 0.72 : 0.72

Table: 2– Physical Properties of the materials used

Properties	Cement	Fine Aggregates	Coarse Aggregates	RRH	FA
Specific Gravity	3.12	2.6	2.7	2.01	2.07
Sieve Analysis	-	Zone II	Zone II	-	-
Fineness	$348m^2/kg$		-	$3460m^2/kg$	527m2kg
Consistency	31%	-	-	-	40%
Initial Setting Time	45min	-	-	-	-
Final Setting Time	225min	-	-	-	-
Bulk Density	-	$1693kg/m^2$	$1527kg/m^3$	$696kg/m^3$	$1190 kg/m^3$

Table: 3 – Composition of the materials used

Materials	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI	SO_3	K_2O	Na_2O_3
Cement	19.71	5.20	3.73	62.91	2.54	0.96	2.72	0.90	0.25
Fly Ash	40	25	6	2.0	3.71	3.0	1.74	0.80	0.96
Raw Rice Husk	78.21	(SiO2+ Al2O3+Fe2O3) =82.64		0.99	4.89	-	-	-	-

III. RESULTS AND DISCUSSION

i. *Workability of concrete:*

Figure 1 shows how varying amounts of fly ash (FA) & raw rice husk (RRH) affect the tendency to slump values of conventional concrete mixtures. At around 42 mm, the control mixture—which contains 0% RRH and 0% FA—reveals the greatest slump value, indicating its greater workability. The slump value clearly decreases when the amounts of the RRH & FA are increased. Using

6% RRH and 6% FA, the slump value drops to about 38 mm, showing a moderate decrease in workability. When the proportions are further raised to 8% RRH + 8% FA and 10% RRH + 10% FA, the slump values fall to around 31 mm and 26 mm, respectively. The lowest recorded slump value is approximately 18 mm for a mix that includes 12% RRH and 12% FA, indicating a significant drop in workability. This decrease in slump can be mainly explained by the significant water absorption capability and fibrous nature of raw rice husk, which soaks up free water within the mix and hampers the flow of concrete. Furthermore, although fly ash particles are spherical, their presence increases the total surface area of the binding system at higher replacement rates, thus raising water requirements. The combination of RRH and FA results in less lubrication among aggregates, leading to tougher concrete mixtures. In summary, the graph illustrates that a greater share of RRH and FA negatively impacts the workability of concrete. Nonetheless, mixtures with up to 6% to 8% RRH and FA still show suitable slump values for real-world applications when compacted properly. Exceeding these percentages may necessitate the addition of chemical admixtures or more water to keep workability intact without undermining strength.

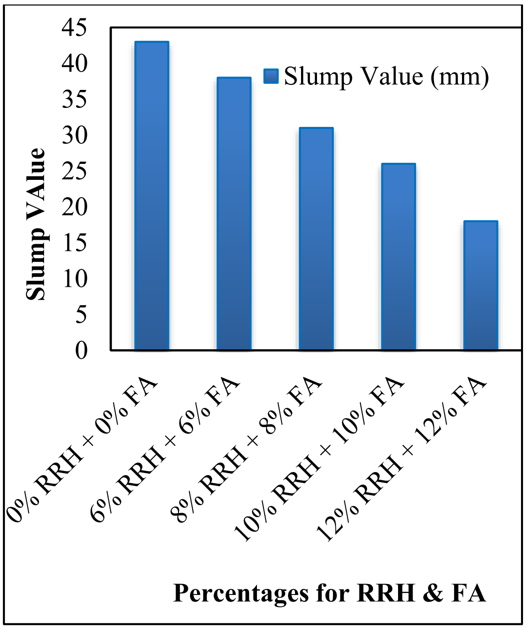

Figure 1: Workability test of Concrete

ii. *Water Absorption:*

The proportion of water absorption in concrete mixes including varying amounts of fly ash (FA) and raw rice husk (RRH) is depicted in Figure 2. At over 2.8%, the baseline mixture—which contains 0% RRH and 0% FA—records the lowest water absorption, indicating that this concrete is comparatively solid and has limited permeability. With increasing proportions of RRH and FA, a steady rise in water absorption is noted across all mixtures. With a combination of 6% RRH and 6% FA, the water absorption increases to around 3.2%. This trend continues with 3.7% for the mixture containing 8% RRH and 8% FA. When the replacements are raised to 10% RRH and 10% FA, and then to 12% RRH and 12% FA, the water absorption values become approximately 4.1% and 4.8%, respectively. This pattern signifies that adding more RRH and FA results in greater porosity in the concrete. The rise in water absorption is mainly due to the high porosity and ability of raw rice husk to absorb water, which adds extra voids in the concrete structure. In addition, at higher levels of replacements, fly ash might slow down early hydration processes, leading to a less dense microstructure. The combined impact of RRH and FA results in an increase in capillary pores, which facilitates more water penetration. In summary, the chart reveals that while adding RRH and FA promotes sustainability, it simultaneously raises the water absorption potential of concrete, potentially impacting its long-term durability. Mixtures with up to 6-8% RRH and FA display moderate water absorption and could be suitable for various practical uses, but higher replacement percentages might necessitate approach adjustments such as enhanced curing techniques, chemical admixtures, or surface treatments to manage permeability.

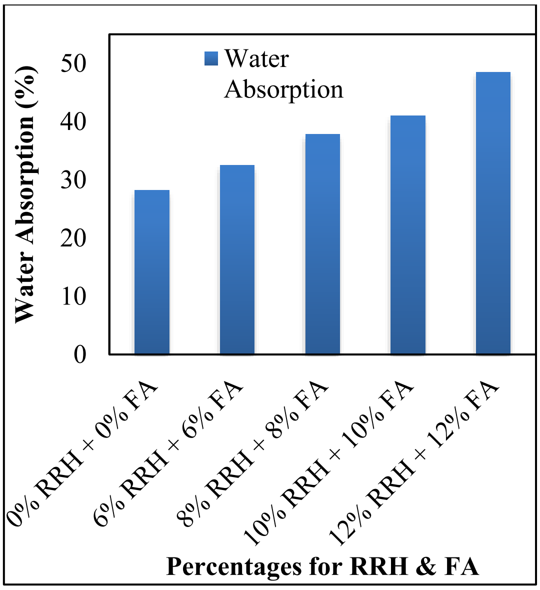

Figure 2: Water Absorption of Concrete

iii. *Density of Concrete:*

Figure 3 illustrates the changes in density (kg/m³) of concrete blends that include varying amounts of raw rice husk (RRH) and fly ash (FA). The reference mixture with no RRH or FA demonstrates the greatest density, around 2390 kg/m³, representing a dense and tightly packed concrete structure. An increase in the amounts of RRH and FA leads to a noticeable reduction in density across all modified mixtures. For a combination of 6% RRH and 6% FA, the density drops to roughly 2360 kg/m³, followed by a decrease to 2330 kg/m³ for the mix with 8% RRH and 8% FA. When the proportions rise to 10% RRH and 10% FA, and then to 12% RRH and 12% FA, the densities correspond to about 2305 kg/m³ and 2285 kg/m³, respectively. This ongoing decrease emphasizes the impact of these substitution materials on the concrete's unit weight. The reduction in density is largely due to the lighter weight and lower specific gravity of raw rice husk in comparison to standard cement and aggregates. Moreover, the presence of fly ash changes the arrangement of particles and may create more micro-voids, especially at elevated replacement rates. Consequently, the combination of RRH and FA results in a decline in mass per unit volume, yielding lighter concrete. From an engineering standpoint, the decline in density indicates the possibility of creating lightweight or semi-lightweight concrete, which could be beneficial in scenarios where a lower dead load is preferred. Nonetheless, this loss in density should be weighed against the necessary strength and durability standards. According to the observed patterns, mixtures with 6–8% RRH and FA retain densities similar to traditional concrete and might be applicable for practical structural or non-structural uses, while increased replacement rates are more fitting for lightweight or low-load scenarios.

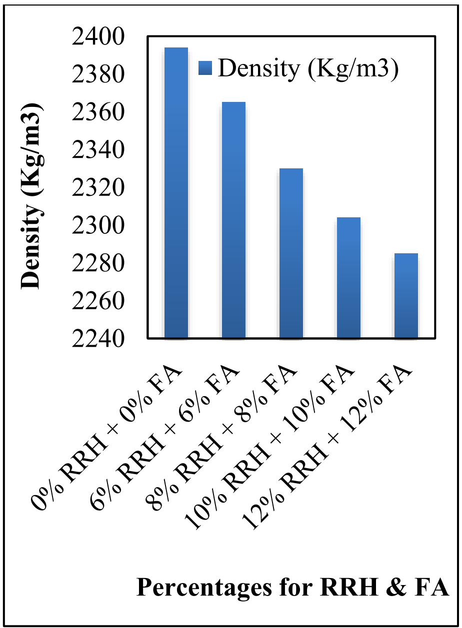

Figure 3: Density of Concrete

iv. *Compressive Strength:*

The compressive capacity of concrete mixes including fly ash (FA) and raw rice husk is shown in Figure 4 at 7, 14 and 28 days after curing. The proportions of RRH whereas FA replacements are shown on the x-axis, while the compressive strength values are shown on the y-axis. Three bars are used to represent the various curing durations for each blend. The image makes it evident that all combinations' compressive strength increases with longer curing durations, which is a typical feature of concrete because of continuous hydration and pozzolanic processes. Throughout all time periods, the control mix, which contains 0% RRH & 0% FA, exhibits the lowest strength. Compressive strength is significantly increased when levels of replacement reach 6% RRH & 6% FA or 8% RRH & 8% FA; the highest strength occurs at 8% RRH along with 8% FA at 7, 14 and 28 days. The pozzolanic qualities of fly ash & the filling effect of finely crushed rice husk are primarily responsible for this enhancement, which results in a denser and more durable concrete construction. Nevertheless, a reduction in compression strength is observed at all curing periods when the substitute reaches levels beyond this ideal limit at 10% RRH & 10% FA and 12% RRH & 12% FA. The misuse of cement, which reduces the quantity of material that binds accessible and increases porosity owing to the biological and lightweight properties of uncooked rice husk, is probably the source of this decrease. In conclusion, the graphic indicates that 8% RRH and 8% FA is the optimal mix ratio since intermediate amounts of RRH and FA enhance compressive strength while greater levels negatively impact concrete performance.

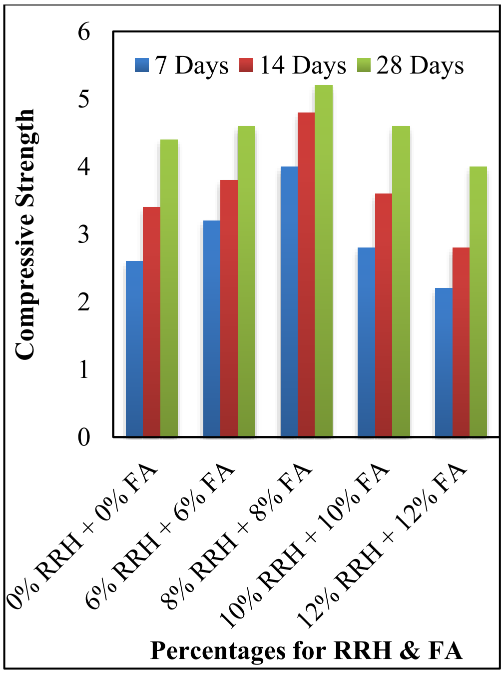

Figure 4: Compressive Strength of Concrete

IV. CONCLUSIONS

This research examined the physical characteristics of concrete that includes raw rice husk (RRH) and fly ash (FA) as substitutes for traditional cement materials, aiming to assess their viability for eco-friendly concrete creation. From the findings related to workability, density, water uptake, and compressive strength tests conducted at various curing durations, multiple significant conclusions can be made.

i. The workability of concrete diminished as the amounts of RRH and FA increased, leads to the high water absorption and the fibrous characteristics of raw rice husk.
ii. The density of concrete experienced a gradual decline with elevated replacement ratios, highlighting the potential for creating lighter concrete.
iii. As the ratios of RRH and FA rose, water absorption levels also increased, which indicates a greater porosity at higher replacement percentages.
iv. For all mixtures, compressive strength improved with the age of curing, affirming typical hydration processes and pozzolanic behaviors.
v. Moderate levels of RRH and FA led to enhanced compressive strength in comparison to the standard mix.
vi. The ideal replacement ratio was identified to be approximately 8 to 10% for RRH and FA, which resulted in the highest strength attained.
vii. Exceeding the optimal fraction resulted in a decrease in compressive strength due to excessive cement substitution and a rise in void spaces.
viii. The integration of RRH and FA plays a role in eco-friendly concrete production by minimizing cement use and repurposing waste from agriculture and industry.

In summary, the research finds that using a mix of raw rice husk and fly ash in concrete is practical and positive for the environment when applied in specific amounts. The best mixtures of RRH and FA showed good mechanical characteristics while encouraging sustainability by utilizing waste and decreasing cement usage. These results indicate that RRH and FA can be effectively used in both non-structural and moderately loaded structural components, as long as appropriate mix design and curing techniques are followed. Additional studies are suggested to analyze long-term durability, Microstructural properties, and the incorporation of additives to enhance workability and performance at increased replacement rates.

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