CHAPTER 134

Sustainable Concrete

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ABSTRACT

The construction industry faces a disaster due to the declining supplies of virgin materials, in addition to the environmental degradation associated with the existing construction practices. This makes it necessary to seek alternatives such as construction and demolition (C&D) waste and event-related materials like rice husk ash (RHA) as partial substitutes of Portland cement. This study explored the effects of replacing Portland cement with RHA at various ratios (0, 5, 10, and 50%) in combination with different water-cement ratios (0.3, 0.5, and 0.7) towards strength and durability of concrete. The experimental findings reveal that compressive strengths are improved by the addition of fine RHA particles; however, higher water-cement ratios lead to decreased strength due to the increased tendency for porosity. Higher RHA content would exhibit with time higher compressive values to a level of excess and have adverse consequences on concrete attributes. Fine RHA particles in the concrete mixture increase bulk density and impart better features to the concrete. The application of C&D waste, together with RHA and similar material, could be a way out of material scarcities and environmental pollution and create a scenario for a future sustainable construction environment. The study also suggests more research effect of varying water-cement ratios on the concrete mixes re-placed with RHA.

Keywords: Construction and demolition waste materials; Rice husk ash; Sustainable construction practices.

1.0 Introduction

The construction industry is a core element of contemporary infrastructure, boosting both the economy and cities. There are, however, some very obvious challenges, particularly the fast exhaustion of virgin resources, which can, in their own way, harm the environment due to traditional construction practices. These parameters call out for a transition to more sustainable options and remedies like recycling construction and demolition (C&D) waste or using it in cement production. These problems illustrate why there is a need to shift to greener alternatives, namely, using C&D waste or cement substitution in cement reduction procedures. Building or construction processes are mainly dependent on the first extracted unprocessed raw materials; so-called virgin materials.

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Construction infrastructure requires a significant amount of minerals, metals, and even wood. But these administrators continuously exploit these resources, thereby questioning the sustainability of such actions. As these resources are limited, the construction sector is susceptible to exorbitant pricing and project cancellation delays. Other than these minerals, the case for a sustainable construct of these extractive methods is raised; for these constructive mining methods adversely tip the scales of nature, tend to destroy habitat systems, and hence lose out on biodiversity.

2.0 Literature Review

Safe disposal of construction and demolition (C&D) waste is paramount in attempting to protect the environment and promote sustainability. Different approaches proposed in this field include life cycle assessment (LCA), estimation systems, and recycling programs. The LCA research showed that the major contributors towards environmental impacts are associated with transportation, sorting, and disposal of the wastes, whereas recycling of plastics, metals, and aggregates could alleviate some of these impacts. Some materials, including wood and cardboard, may still contribute to global warming potential, although they might be recycled. Estimating systems can predict the quantities of wastes and thus assist in the development of policies and operational plans by means of spatial data and statistical models. Fast urban growth in developing countries has obviously caused the increase in construction and demolition waste, but in fact, so many areas still suffer from weak regulatory systems.

Construction solely depends on landfills for these wastes. Certainly, application of "3R" concepts (Reduce, Reuse, Recycle) would play an important role in the effective management of wastes and, therefore, mitigates their impacts to the environment. Innovative management practices for C&D waste differ from one part of the globe to another. Developed areas have instituted policies that require C&D waste to be managed for recycling; however, developing nations suffer challenges due to a lack of regulatory support. Initiatives to curb waste from the source will assist in limiting contamination and increasing material recovery rates, thus improving recycling performance.

Construction of effective scrap-recycling plants with improved logistics of waste transportation will also have the potential to reduce energy consumption with corresponding lessening of greenhouse gas emissions. Research states recycling C&D waste is seen to save energy heavily and reduces emissions. Everything that will create durable sustainability should be the creation of good models to predict waste generation, improvement in pertinent regulatory systems, and the infusion of funds into innovative recycling technologies. Traditionally known as a by-product stemming from milling rice, rice husk ash (RHA) has aroused much interest when used as an additional cementitious material in concrete. RHA is an ideal partial cement substitute but highly pozzolanic and rich in silica as well. According to various studies, RHA helps enhance durability, mechanical resistance, and harsh-weather resistance in concrete. It has

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been found that in the finely powdered form, RHA fills the voids in the concrete matrix, making the mix denser by utilizing the pozzolanic reaction that happens inclusively into the setting of concrete; these, in turn, attribute to the improvement in the sulphate resistance, alkali-silica reaction, and chloride attack resistance along with decreasing permeability. Researchers recommend that for these parameters to influence the performance of RHA in concrete applications, the proper grinding and controlled burning procedures should be employed to ensure RHA attains desired reactivity.

Environmentally speaking, RHA is another very attractive option. RHA uses this agricultural waste to reduce CO2 emissions and cement use and to encourage sustainable building practices. The research indicates that RHA not only enhance the lifespan of concrete structures in rice husk waste tailing areas but also saves construction costs significantly. Its viability for sustainable construction materials is further enhanced by research being conducted into its potential applications into advanced concrete technologies, such as high-performance concrete and self-compacting concrete.

Table 1: Chemical properties of Rice Husk Ash

Compound/element (constituent)	Weight percent
Silica (SiO_2)	91.56
Carbon	4.8
Calcium oxide CaO	1.58
Magnesium oxide, MgO	0.53
Potassium oxide, K_2O	0.39
Haematite, Fe_2O_3	0.21
Others	0.93

The ability of polypropylene (PP) fibers to enhance concrete performance has been an extensively researched field. The research indicates that PP fibers provide considerable resistance to cracking in the concrete, particularly against drying shrinkage and plastic shrinkage cracks. These fibers are able to improve the tensile strength and energy absorption capacity of the concrete; hence, they serve as micro-reinforcements. It is reported that PP fibers enhance the ductility, toughness, and impact resistance of the concrete without any significant effect on workability. Polypropylene fibers also contribute to a certain extent to the fire resistance of concrete by becoming molten at elevated temperature and forming micro-channels that relieve the build- up of internal pressure, thereby preventing spalling during fire exposure. A consideration of the desired properties will influence the optimum amount of fiber to use. Enhancing fire- resistance properties is generally said to be accomplished with 0.1-0.3% fiber volume of concrete mix. The review of literature suggests that polypropylene fibers make low-cost improvements in concrete durability, especially for applications such as pavements, industrial floors, and precast structures.

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3.0 Objective

- Development of Sustainable Concrete Using Recycled Materials.
- Promoting a Circular Economy in Construction by Minimizing Reliance on Virgin materials
- Assessing the effectiveness of rice husk ash (RHA) as a pozzolanic alternative to partially replace Portland cement.

4.0 Research Methodology

The research methodology of sustainable concrete development starts with a literature review that studies the construction and demolition (C&D) waste, rice husk ash, and polypropylene fibres based on literature surveys of the past work. Then comes Material Selection and Procurement, which is set to avail the optimum raw materials like recycled aggregates and rice husk ash. Material Testing is further differentiated into test categories: Physical Tests and Chemical Tests for composition analysis. Once the materials are approved for the quantity required, Blocks Casting follows with some optimized mix proportioning, moulding, and curing. Block Testing and Analysis evaluate the durability and mechanical performance based on compressive strength and water absorption.

5.0 Experimental Methodology

Experimental methodology gives an insight into the characterization tests undertaken on C&D waste aggregates, rice husk ash, and polypropylene fibres. The casting process of concrete blocks involves the steps of batching, mixing, moulding, compacting, and curing. Mechanical properties, including compressive strength and flexural strength, were tested with water absorption tests for the assessment of durability. The methodology aims at comparing the nominal mix with conventional concrete blocks to see the possibility of large-scale implementation.

5.1 Selection of materials

The selection of appropriate materials is essential for developing blocks with enhanced mechanical properties and sustainability. This study focuses on incorporating construction and demolition waste aggregates as a replacement for natural aggregates and Replacement of cement with RHA and Polypropylene Fibers. The RHA binder system, eliminates the Partial need for conventional cement, significantly reducing carbon emissions. The integration of C&D waste aggregates reduces environmental pollution, while fibres enhance toughness, impact resistance, and durability. The material is sourced from processed Construction and Demolition (C&D) waste, primarily consisting of crushed concrete, bricks, and tiles. It is carefully graded to a

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particle size range of 10mm to 12mm, in compliance with IS 383:2016, which specifies the grading requirements for coarse aggregates.

Figure 1: Pictures of Construction & Demolition Plant at Pune

The material is sourced from crushed C&D waste fines and Manufactured Sand (M-sand), with a particle size below 4.75mm as per IS 383:2016 for fine aggregates. It plays a crucial role in the paver block matrix by filling voids, enhancing workability, improving particle

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bonding, and facilitating better strength development. Additionally, it contributes to durability, reduces permeability, and promotes sustainable utilization of recycled materials. Rice husk ash (RHA In concrete, rice husk ash (RHA), a very potent pozzolanic substance, can partially substitute cement. Its chemical makeup, fineness, and burning method are among of the important criteria that determine whether it is chosen as a cement substitute. The silica (SiO_2) found in RHA combines with calcium hydroxide during cement hydration to create more calcium silicate hydrate (C-S-H) gel, which increases the strength and durability of the concrete.

RHA's performance is largely dependent on its quality. Superior pozzolanic activity is provided by amorphous silica, which is produced by controlled combustion at temperatures between 500°C and 700°C. Achieving fine particle sizes that increase packing density and reduce voids in the concrete matrix also requires proper grinding. Concrete block mixes frequently contain polypropylene (PP) fibers to improve its durability and mechanical qualities. By decreasing crack development, increasing tensile strength, and boosting impact resistance, 15 mm polypropylene fibers serve as an efficient reinforcement. In concrete blocks, where surface stability and structural integrity are essential, these longer fibers are especially advantageous.

Figure 2: Raw Materials Used for Concrete

Table 2: Mix Design

Mix Design	RCA (kg)	RFA (kg)	Cement(kg)	RHA(kg)	P Fibers (g)
M1(0%)	4.1	2.025	2.025	0	12
M2(5%)	4.1	2.025	1.924	0.101	12
M3(10%)	4.1	2.025	1.822	0.202	12
M4(15%)	4.1	2.025	1.721	0.303	12
M5(20%)	4.1	2.025	1.620	0.405	12
M6(25%)	4.1	2.025	1.518	0.506	12
M7(30%)	4.1	2.025	1.417	0.607	12
M8(40%)	4.1	2.025	1.215	0.810	12
M9(50%)	4.1	2.025	1.0125	1.0125	12

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Figure 3: Mixing Casting and Curing Process

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5.2 Mix design

The mix design of concrete blocks is crucial for achieving optimal strength, durability, and sustainability. In this study, Construction & Demolition (C&D) waste, recycled aggregates, RHA, Cement Polypropylene fibers, and water are used to produce environmentally friendly concrete blocks.

5.3 Production of concrete blocks

After selecting the materials and designing the mix proportions, the next critical phase involves the mixing, casting, and curing process. Proper execution of these steps ensures uniformity, strength, and durability in the final blocks. The mixing process plays a vital role in ensuring the homogeneous distribution of materials without any lumps. Proper mixing directly influences the concrete's quality, ensuring improved strength, durability, and performance in structural applications.

5.4 Testing of concrete blocks

- The blocks should undergo proper curing for 7 and 28 days to ensure strength development before testing begins.
- The specimens must be free from cracks, voids, or defects that could negatively impact the accuracy and reliability of test results.
- A measuring scale should be used to measure the exact length, width, and thickness of each paver block accurately.
- The loaded area (A) in mm^2 should be calculated using the formula: A = Length × Width (mm^2) to determine stress distribution.
- The paver block should be centrally placed on the lower platen of the Compression Testing Machine (CTM) to ensure uniform load application.
- Steel or rubber pads can be placed on top of the specimen if necessary to distribute the applied compressive load evenly.

Figure 4: Concrete Blocks Testing

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5.5 Test Results

For this study, 150*150*150 mm cubes of design mix M25 grade were assessed. After seven and twenty-eight days of curing, the specimens were assessed. Rice husk ash was used to partially replace cement in the first three standard concrete cubes. To substitute cement, different amounts of rice husk ash and C&D waste aggregate were used: 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40%, and 50%. Four cubes were cast for each percentage.

Table 3: Compressive Strengths after 7, 28, Days of Curing. (Nominal Concrete)

Days	Compressive Strength in MPA
7	16.9
28	26.31

Table 4: Compressive Strengths after 7, 28, Days of Curing. (0% RHA)

Days	Compressive Strength in MPA
7	16.22
28	25.91

Figure 5 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With no Replacement of Cement Using C&D Waste.

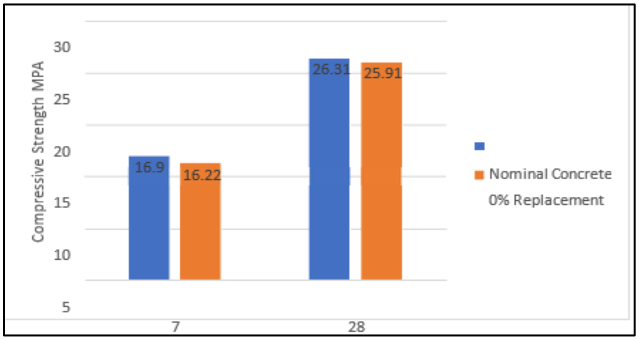

Figure 6 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 5% Replacement of Cement with RHA Using C&D Waste.

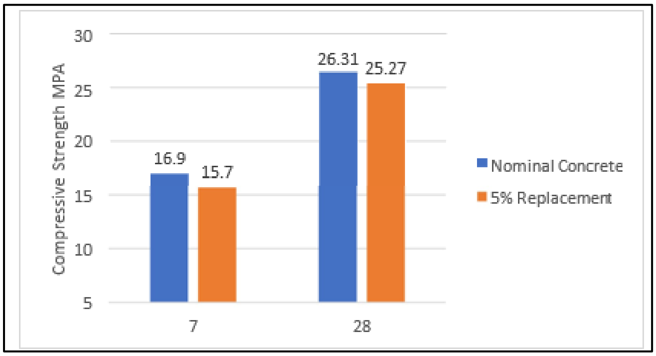

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Table 5: Compressive Strengths after 7, 28, Days of Curing. (5% RHA)

Days	Compressive Strength in MPA
7	15.7
28	25.27

Table 6: Compressive Strengths after 7, 28, Days of Curing. (0% RHA)

Days	Compressive Strength in MPA
7	12.22
28	24.13

Figure 7 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 10% Replacement of Cement with RHA Using C&D Waste.

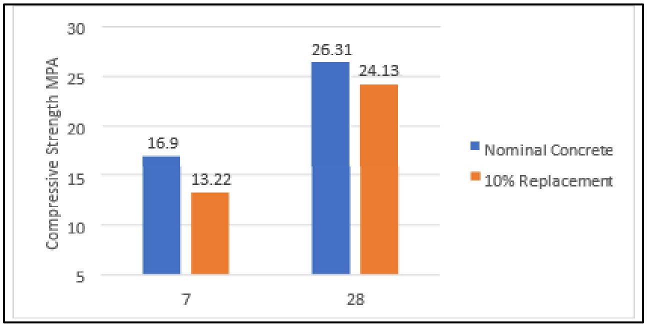

Figure 8 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 15% Replacement of Cement with RHA Using C&D Waste.

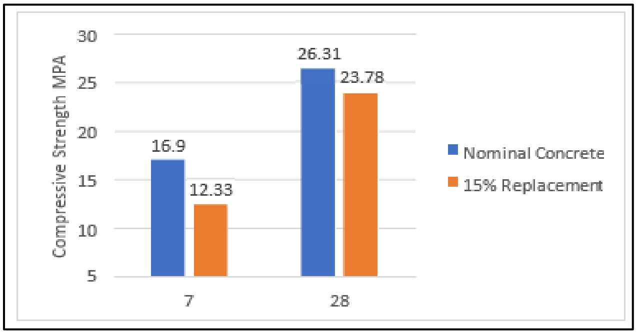

Table 7: Compressive Strengths after 7, 28, Days of Curing. (15% RHA)

Days	Compressive Strength in MPA
7	12.33
28	23.78

Table 8: Compressive Strengths after 7, 28, Days of Curing. (20% RHA)

Days	Compressive Strength in MPA
7	11.17
28	21.86

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Figure 9 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 20% Replacement of Cement with RHA Using C&D Waste.

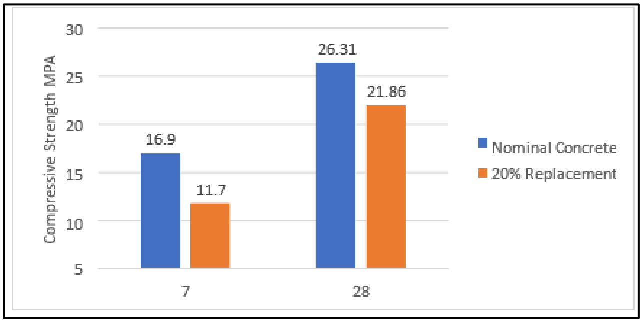

Figure 10 Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 25% replacement of Cement with RHA Using C&D Waste.

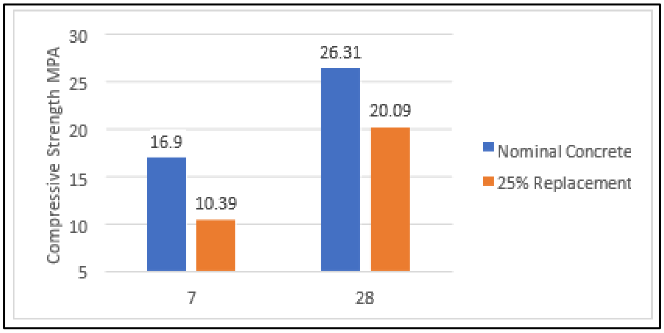

Table 9: Compressive Strengths after 7, 28, Days of Curing. (25% RHA)

Days	Compressive Strength in MPA
7	10.39
28	20.09

Table 10: Compressive Strengths after 7, 28, Days of Curing. (30% RHA)

Days	Compressive Strength in MPA
7	9.72
28	19.93

Table 11: Compressive Strengths after 7, 28, Days of Curing. (40% RHA)

Days	Compressive Strength in MPA
7	7.95
28	18.90

Table 12: Compressive Strengths after 7, 28, Days of Curing. (50% RHA)

Days	Compressive Strength in MPA
7	6.1
28	18.02

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Figure 11: Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 30% Replacement of Cement with RHA Using C&D Waste.

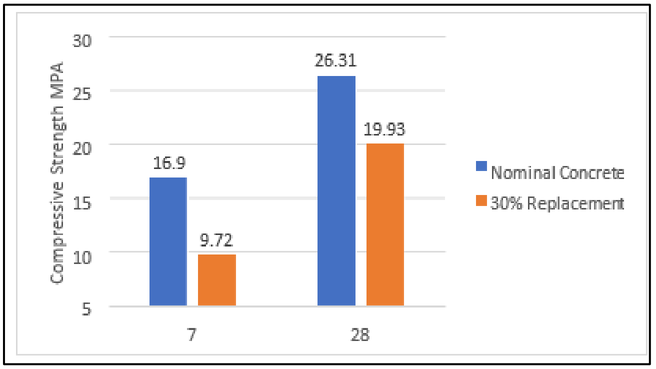


Figure 12: Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 40% Replacement of Cement with RHA Using C&D Waste.

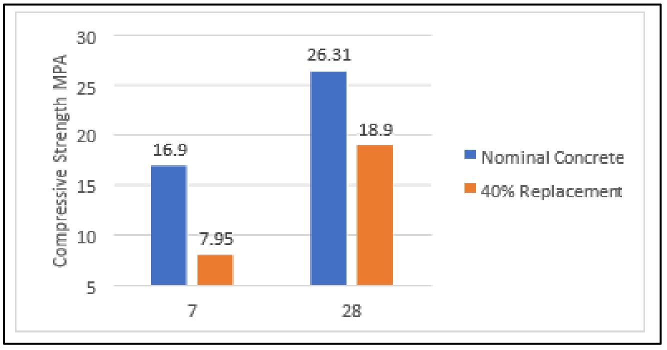
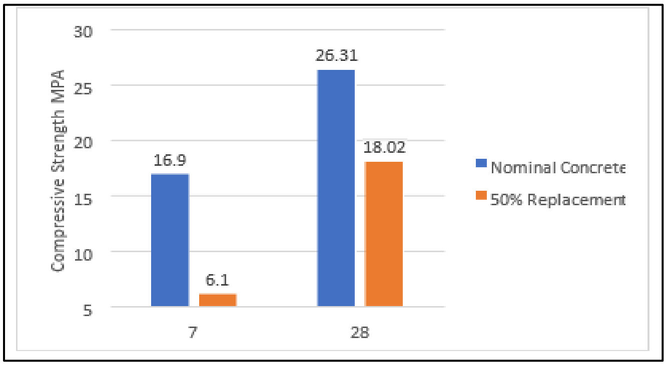


Figure 13: Shows the Compressive Strengths after Curing in MPA after 7 Days and 28 of Concrete. With 50% Replacement of Cement with RHA Using C&D Waste.



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5.6 Result declaration

From the test carried out and design following this can be concluded:

- It can be observed that with 5% replacement of RHA, the compressive strength drops by 15.7% and 25.27% at 7 & 28 days, respectively.
- At 10% replacement of RHA, a compressive strength loss of 13.22% and 24.13% was recorded at 7 & 28 days, respectively.
- At 15% replacement of RHA, there was a reduction of 12.33% and 23.78% in compressive strength at the ages of 7 and 28 days, respectively.
- At 20% replacement of RHA, a decrease of 11.17% and 21.86% in compressive strength was observed at 7 & 28 days, respectively.
- At 25% replacement of RHA, there was a decrease of 10.39% and 20.09% in compressive strength at 7 & 28 days, respectively.
- At 30% replacement of RHA, a decrease of 9.72% and 19.93% in compressive strength was observed at 7 & 28 days, respectively.
- At 40% replacement of RHA, the compressive strength decreases by 7.95% and 18.90% at 7 & 28 days, respectively.
- At 50% replacement of RHA, compressive strength was reduced by 6.1% and 18.02% at 7 & 28 days, respectively.

6.0 Conclusion

The experiment's findings shown that raising the RHA content lowers the slump value and raises the compressive values over time until a specific replacement percentage. An rise in the w/c ratio, however, has a negative effect since it raises the slump value and lowers the results of all strength tests. These behaviors were attributed to either an increase in the w/c ratio or a change in the pore structure of the concrete mix that resulted from the addition of RHA. The strength of the concrete decreased as the pore structure increased. By increasing the w/c ratio, the later dehydration rate rises, increasing the concrete's pores and reducing its strength and resilience to adverse environmental conditions. On the other hand, adding RHA may increase or decrease the strength of the resulting concrete based on the properties of RHA used. 5%,10% and 15% replacement mix values have compressive strength higher, it can be considered as optimum values, where the rest of the replacement values fall below the considerable limits.

The inclusion of tiny RHA particles in this experiment boosted the bulk density of the resultant concrete while decreasing its pore structure. In contrast to some other outcomes that are documented in the literature, the primary factor that improved the concrete's qualities after adding RHA was the use of fine particles. RHA with fine particles is therefore a viable partial substitute for Portland cement. Its inclusion can improve the concrete's strength, resilience to adverse environmental conditions, and durability. Compared to regular Portland cement, it

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offers additional financial and environmental benefits. According to the statistical study, there has been a notable increase in the strength measures. However, further investigation on the impact of w/c ratio change on the RHA replaced concrete mix is recommended.

- Using RHA could be economical because it is free and a waste.
- RHA will make the building industry more sustainable by conserving resources, particularly cement.
- It will address the issue of disposing of rice husk ash and have positive environmental effects.

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