E-ISSN: 1116 - 2759 P-ISSN: 3027-
INTERNATIONAL JOURNAL – EDIR
MPRI-EDIR | INTERNATIONAL JOURNAL OF EARTH DESIGN AND INNOVATION RESEARCH
VOL. 07 NO. 4 – JANUARY, 2025

ENHANCING CONCRETE DURABILITY: THE ROLE OF SUPPLEMENTARY CEMENTITIOUS MATERIALS IN ACID RESISTANCE

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DOI: https://doi.org/10.70382/mejedir.v7i4.031

Abstract

Acid attacks are compromising the durability of concrete more and more, especially in urban and industrial settings. By reducing the amount of calcium hydroxide in the concrete, these attacks have an impact on its mechanical qualities. This study examines the impact of supplemental cementitious materials (SCM) such as rice husk ash (RHA) and cassava peel ash (CPA) on the acid resistance of concrete, given the low resistance of traditional hydraulic cement to such conditions. The goal of the study is to determine the ideal ratio of RHA to CPA in order to improve the durability of concrete in acidic conditions. Ordinary Portland cement and locally available aggregates were used in a methodical

Keywords: Sulfuric Acid, Cassava Peel Ash (CPA), Rice Husk Ash (RHA), Compressive Strength, Durability

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experimental approach. In addition to a control mix, concrete mixes with constant CPA percentages of 5% and variable RHA percentages of 0%, 5%, 10%, and 15% were made. Slump tests for workability, density measurements, and compressive strength evaluations of cubes cured in diluted sulfuric acid and plain water were all part of the study. The SCM oxide composition was evaluated by X-ray fluorescence (XRF) analysis, which showed that RHA was more reactive than CPA and that its combined SiO2, Al2O3, and Fe2O3 content was higher than the 70% threshold. The results showed that adding SCM increased durability in acidic environments. According to the study's findings, RHA considerably increases concrete's resistance to acid, indicating that it may be able to increase structural durability under harsh conditions. Future studies should examine how well these SCMs function over the long run in a variety of scenarios and look into other therapies to improve acid resistance even more.

Introduction

When combined with water (hydrated), cement, a binding substance based on calcium silicate or aluminate, exhibits cohesive and adhesive qualities (Kalinichev and Kirkpatrick, 2002; Alonso et al., 2016). According to Neville (1981) and Naik (2008), it is the most important building material in the world for making concrete, which is utilized extensively in the construction sector. From the Egyptian era to the Roman era, cement has historically made a substantial contribution to the structural civilization of the ancient world.

According to research, the Romans and Greeks used lime by calcining limestone (Moropoulou et al., 2001; Böke et al., 2008; Rodríguez-Navarro, 2012), which was combined with sand or coarse stones to create mortar and concrete. In contrast, the Egyptians used calcined gypsum as cement for construction (Felsing and Potter, 1930; Karni, 1995; Platnick, 1983). The demand for necessities including food, shelter, electricity, and water has increased dramatically over time due to the growing world population. As a

result, both the demand for and the price of essential building materials like cement have significantly grown.

In addition, the production of cement has resulted in an increase in energy consumption and emissions of pollutants throughout time. According to estimates, every kilogram of cement produced worldwide produces one kilogram of carbon dioxide (CO_2) (Ellis et al., 2020). This suggests that the global cement industry produces 3–4 billion tonnes (Giga tons) of CO_2 each year (Worrell et al., 2001; Ali et al., 2011). According to their calculations, scientists believe that the annual manufacture of cement is responsible for 8% of all carbon-based emissions.

Thus, requests for alternative renewable and sustainable building materials have been sparked by the combined effects of cement's high demand, energy consumption, and greenhouse gas emissions (Ogunbode et al., 2021; Ali et al., 2020).

Making and using pozzolanic materials from sustainable and renewable resources, such trash, is one possible strategy. In many agrarian communities nowadays, agricultural wastes make up a sizable component of the waste profile (Nyakuma et al., 2020; Wong et al., 2020; Mahlia et al., 2019). Therefore, the twin problems of waste management and greenhouse gas emissions will be addressed by the collection, conversion, and use of such agricultural wastes into sustainable building or construction materials (Nyakuma et al., 2020; Oladokun et al., 2016). In many nations worldwide, rice husks (RH) today make up a significant amount of the many agricultural by-products that are obtained from processing rice (Williams and Besler, 1993; Eziefula, 2018).

However, there are still poor or egregiously inefficient methods for managing, disposing of, or valuing RH. Recently, though, a number of researchers have looked into its application as pozzolanic materials following ashing (Chandrasekhar, 2006; Roychand et al., 2021). (Xiong et al., 2009; Liu et al., 2014; Ubana, 2022) Rice husk ash (RHA) is the material that is left over

when RH is ashed. Because of its pozzolanic qualities, RHA has also been the subject of several research that have attempted to investigate its partial replacement of cement. Adesanya et al. (2008) state that, particularly when peeling by hand, the cassava peel makes about 20–35 percent of the tuber's weight.

The existence of vast amounts of cassava peel waste near garri processing sites is a source of concern and pollution, as attempts to eliminate them through combustion or natural decomposition are oftentimes ineffective. The rate at which cassava peelings are dumped is five to eight times greater than the rate at which they biodegrade in open-air disposal sites (Ettu et al., 2013b).

However, until it was found to be a useful mineral ingredient for concrete, rice husk was frequently dumped into water streams, polluting and contaminating springs (Sua-iam and Makul, 2012; Krishna et al., 2016).

It is a super-pozzolana with a high silicon dioxide (SiO_2) content that is advised for use in the manufacturing of concrete (Sheth et al., 2014; Aboshio et al., 2018; Abdul Wahab et al., 2022).

Recycling these agricultural wastes into new building materials could therefore be a practical solution to the environmental contaminant.

By taking into account three distinct mineral acids, this study examined the impact of the water-to-binder ratio and the presence of supplemental cementitious materials (SCM) on concrete's resistance against acidic assault.

MATERIALS AND METHOD

Material

Ordinary Portland Cement (Dangote brand), which complies with BSEN 197-1:2000 specifications, was obtained from Offa, Kwara State, Nigeria, and used in this investigation. The Afelele River in Offa provided the fine aggregate, which meets BS 882:1992 requirements. The 12 mm coarse material that was used came from a nearby quarry in Offa. Throughout the investigation, clean

tap water that complied with BSEN1008:2002 was used. Rice Husk Ash (RHA) and Cassava Peel Ash (CPA) were also obtained locally. We purchased sulfuric acid from Akure in the state of Ondo.

Method

In order to focus on a control scenario with 0% (both RHA and CPA) and different amounts of RHA (0%, 5%, 10%, and 15%) while maintaining a constant CPA (i.e., 5%), the experimental design involved batching the components according to weight. The mix design was created using the COREN guidelines in order to reach a characteristic strength of 20 N/mm^2. In order to ensure adequate compaction and remove cavities, concrete was cast into 150-mm cubes. The cubes were cured for 7, 14, and 21 days in two different conditions: plain water and a diluted sulfuric acid solution.

The CPA and RHA utilized in this investigation were assessed for their chemical and physical characteristics. Slump, specific gravity, and compressive strength tests were among the tests used to evaluate the properties of both fresh and hardened samples. Understanding how the material performs in various scenarios requires these assessments.

RESULTS AND DISCUSSIONS

Oxide Composition

The XRF analysis of rice husk ash (RHA) and cassava peel ash (CPA) is displayed in Table 1. greater reactivity for RHA is shown by the total SiO_2, Al_2O_3, and Fe_2O_3 content of 67.178% for CPA and 82.743% for RHA, which is greater than the suggested threshold of 70%. The K_2O levels for CPA and RHA are 6.434% and 2.976%, respectively, beyond the cement's 1.2% limit, which may lengthen the time it takes for concrete to set. Both pozzolans have MgO levels below the ASTM C618-12 5% limit, which may improve the strength and durability of concrete.

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Slump

Figure 1 displays the slump values, which, in accordance with ASTM C 143, gauge a concrete batch's fluidity, consistency, or workability. The graph shows that slump values decreased when CPA and RHA were added as partial substitutes for regular Portland cement.

Specifiv Gravity

For CPA and RHA, the average specific gravity was 1.78 and 1.75, respectively. Accordingly, a certain volume of CPA and RHA weigh 1.78 and 1.75 times as much as an equivalent volume of water, respectively. This implies that RHA and CPA are both comparatively light materials.

Table 1: Chemical composition analysis of Cassava Peel Ash and Rice Husk Ash

Oxide (%)	CPA	RHA	OPC
Na_2O	0.421	0.061	0.710
MgO	4.726	2.400	1.690
Al_2O_3	11.323	1.814	5.700
SiO_2	51.755	79.864	14.98
P_2O_5	4.890	7.428	_
SO_3	2.173	0.880	2.670
Cl	0.660	0.102	_
K_2O	6.434	2.976	0.100
CaO	6.890	2.898	68.30
TiO_2	2.419	0.198	0.220
Cr_2O_3	0.020	0.002	0.010
Mn_2O_3	0.308	0.236	_
Fe_2O_3	7.863	1.065	4.100
ZnO	0.082	0.058	_

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SrO	0.034	0.017	_

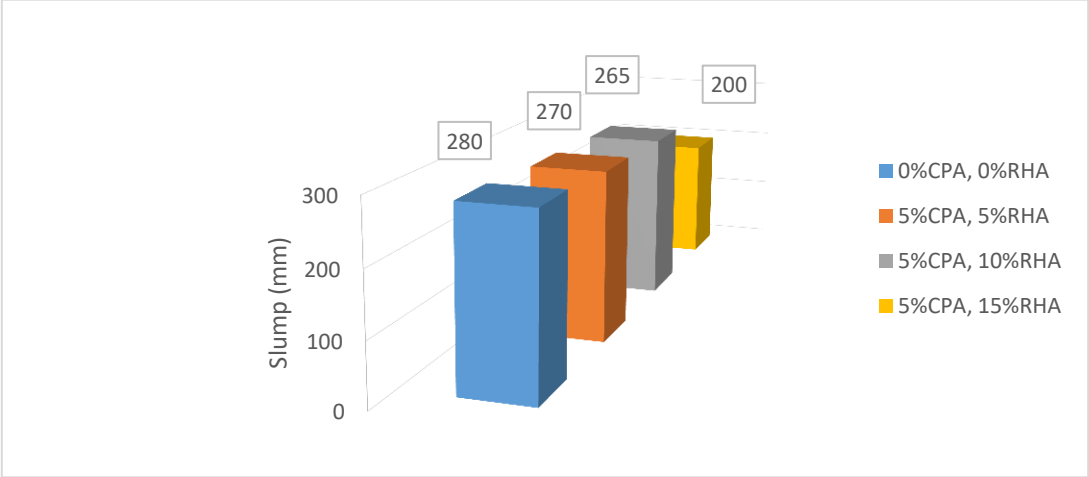


Figure 1: Slump

Compressive Strength (Fcu)

On the effect of exposure of samples to sulphuric acid on compressive strength at varying CPA and RHA replacing Cement. This investigation analyzes the compressive strength (Fcu) of concrete samples subjected to water and acid curing methods, alongside varying proportions of CPA and RHA. For samples with 0% CPA and 0% RHA (Figure 2), water-cured samples show initial strength gains from 7

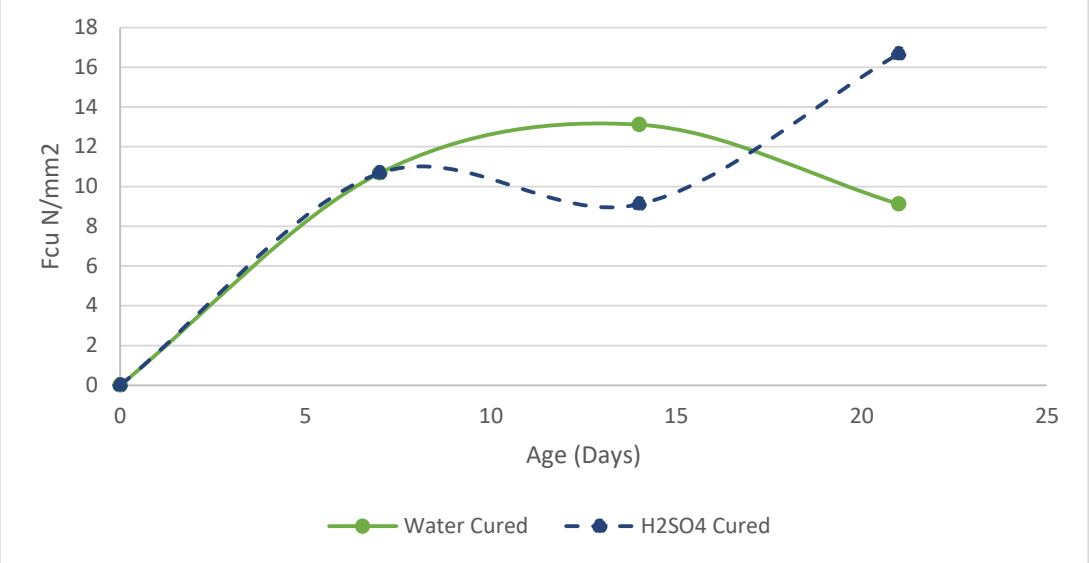


Figure 2: Fcu at 0%CPA and 0%RHA

to 14 days but drop by 21 days, probably due to over-curing. Acid-cured samples initially lose strength but recover considerably by 21 days, showing improved chemical bonding. Water curing falls to 9.12 N/mm² after 21 days, but acid curing reaches 16.67 N/mm².

Compared to water-cured samples, which decrease to 8.00 N/mm² after 14 days, acid-cured samples with 5% CPA and 5% RHA reach 14.89 N/mm² at 7 days.

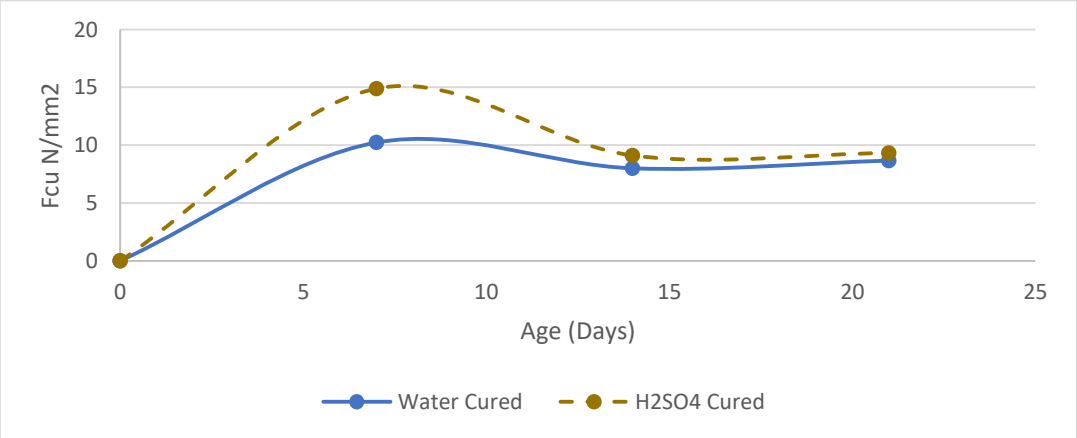


Figure 3: Fcu at 5%CPA and 5%RHA

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In the 5% CPA and 10% RHA (Figure 4) group, water curing shows initial strength (14.22 N/mm²) but declines severely

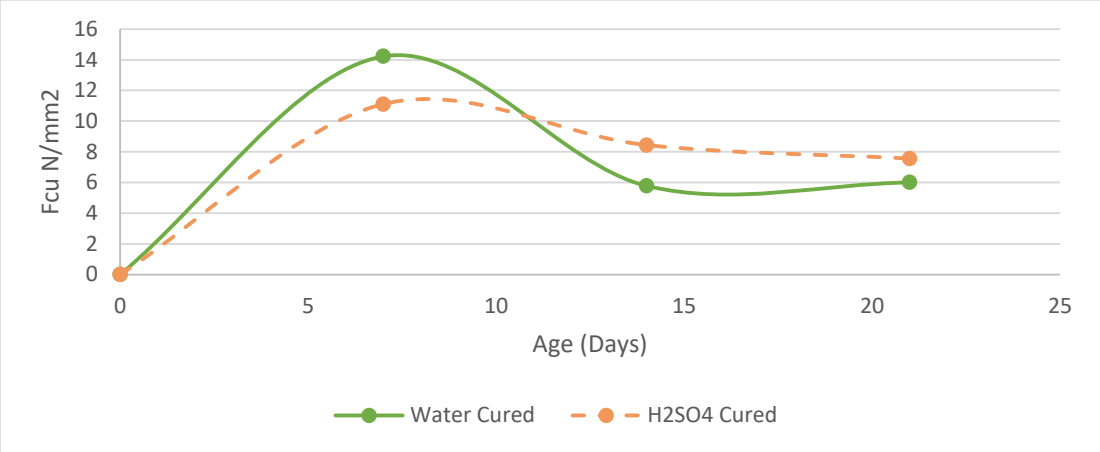


Figure 4: Fcu at 5%CPA and 10%RHA

to 5.78 N/mm² by 14 days; acid curing improves steadily, reaching 7.56 N/mm² by 21 days. Similar trends are observed in the 5% CPA and 15% RHA samples (Figure 5).

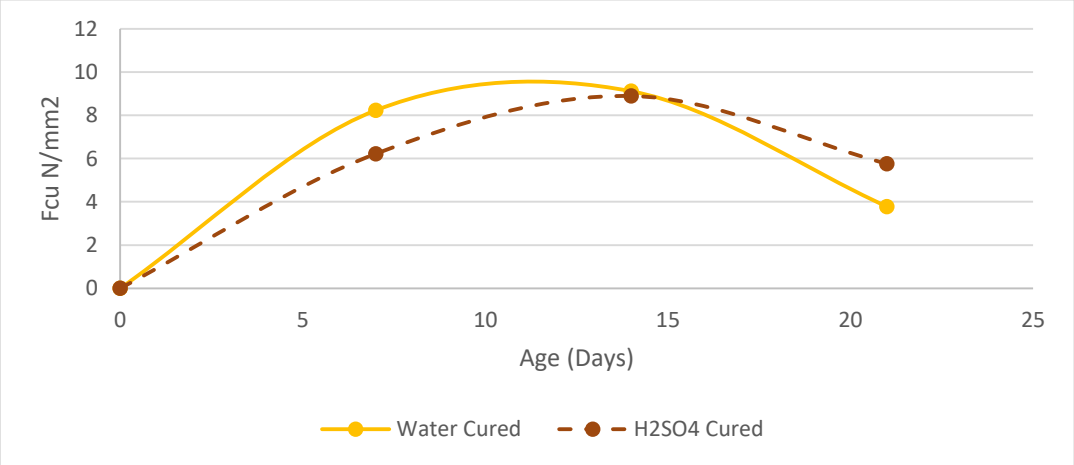


Figure 5: Fcu at 5%CPA and 10%RHA

Examining how different CPA and RHA replacements affect the samples' compressive strengths in various curing media. Variable performance at varying replacement percentages is revealed by the study of compressive strength in water-cured samples (Figure 6). Control specimens

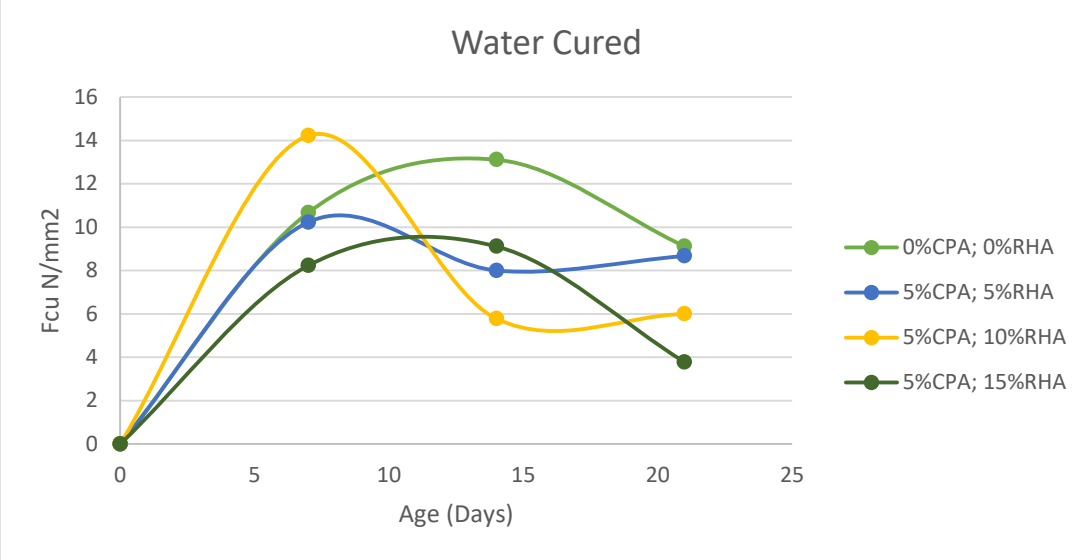


Figure 6: Compressive Strength of Water Cured Samples

reached a compressive strength of 14.22 N/mm² after 7 days with 0% replacement, meeting grade 20 requirements of BS 8110-2 (1985). A significant drop to 8.23 N/mm² was achieved by adding 15% RHA and 5% CPA. At the 10% replacement level, compressive strength increased; but, at greater ratios, it decreased. This pattern continued at 14 days, indicating that while large proportions have a detrimental effect on strength, limiting replacement can be advantageous.

On the other hand, samples that were acid-cured (figure 7) showed an initial compressive

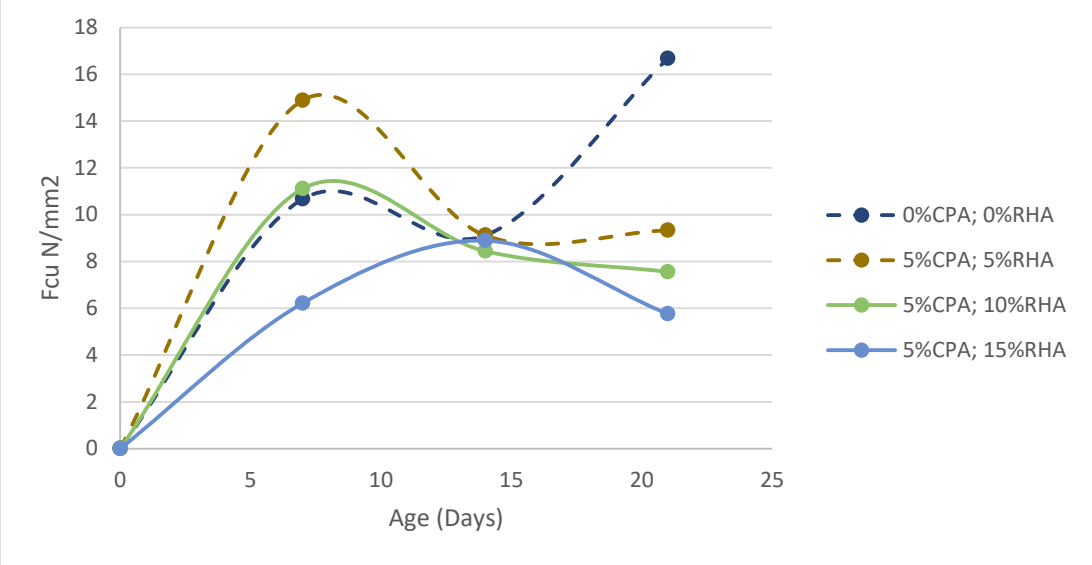


Figure 7: Compressive Strength of Sulfuriv Acid Cured Samples

After seven days, the strength was 14.89 N/mm² at 0% replacement, slightly increasing at lower replacement levels (5% RHA and 5% CPA). But when replacements increased, strength declined. At 16.67 N/mm2, the control samples showed the highest strength at 21 days, whereas the 5% replacement samples showed a drop. According to these results, acid curing may improve strength retention at low replacement levels while maintaining sensitivity to higher replacement levels.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Two primary conclusions can be drawn from the study:

1. According to the study, water curing may improve strength at first, but it poses issues with durability over the long run. On the other hand, acid curing encourages the development of strength over time, which makes it beneficial for applications using precast concrete.
2. The findings suggest that, especially in water-cured samples, compressive strength often increases with decreasing replacement amounts of CPA and RHA, with control samples exhibiting the maximum

strength. In both curing techniques, there is a critical threshold beyond which further replacement (over 10%) dramatically lowers compressive strength. In accordance with BS 8110-2 (1985), the variations between water-cured and acid-cured samples highlight the significance of curing techniques and material proportions on concrete's mechanical qualities.

Recommendations

Future studies should concentrate on improving the formulations of CPA and RHA while comprehending the principles underlying strength differences across various curing techniques. Finding the ideal replacement percentages that successfully balance their advantages and disadvantages is part of this. To assess their combined effects on compressive strength and performance, thorough research should investigate a range of curing methods and replacement amounts.

In order to evaluate long-term strength development with different CPA and RHA concentrations, testing should also go beyond 21 days. To confirm the use of these materials in construction applications, it is also crucial to look into the possibility of increased durability and environmental resistance. We can develop a strong foundation for promoting the use of CPA and RHA in tangible products by coordinating these initiatives.

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