International Journal of Research in Civil Engineering and Technology

E-ISSN: 2707-8272
P-ISSN: 2707-8264
Impact Factor (RJIF): 5.44
IJRCET 2025; 6(2): 17-23
[Journal's Website]
Received: 13-05-2025
Accepted: 17-06-2025

Sahil
Research Scholar, Department of Civil Engineering, Om Sterling Global University, Hisar, Haryana, India

Sumesh Jain
Research Supervisor, Department of Civil Engineering, Om Sterling Global University, Hisar, Haryana, India

NP Kaushik
Professor, Department of Civil Engineering, School of Engineering and Technology, Om Sterling Global University, Hisar, Haryana, India

Corresponding Author:
Sahil
Research Scholar, Department of Civil Engineering, Om Sterling Global University, Hisar, Haryana, India

An analysis of concrete's behavior with rice husk ash

Sahil, Sumesh Jain and NP Kaushik

DOI: https://doi.org/10.22271/27078264.2025.v6.i2a.91

Abstract
Concrete is the most widely used construction material worldwide, yet its heavy dependence on cement production poses serious environmental challenges due to the high release of carbon dioxide and depletion of natural resources. The work aims to identify an optimum replacement level that achieves maximum strength and serviceability while minimizing environmental impact. This study uses an unfired compressed dirt block stabilised by solid waste as the test subject. Experimental investigations were conducted by partially substituting cement with RHA at varying proportions ranging from 0% to 30%. Concrete specimens were tested for workability, compressive strength, split tensile strength, and flexural strength at different curing ages (7, 14, and 28 days), along with durability parameters such as water absorption, rapid chloride penetration, and resistance to chemical attack. The results demonstrated that incorporating RHA up to 15% significantly enhanced compressive and flexural strength, refined pore structure, and improved durability due to the pozzolanic reaction forming additional calcium silicate hydrate (C-S-H) gel. The mechanical properties of a block containing R-h ash are also increased.

Keywords: Rice husk ash Ash (R-H Ash), ordinary Portland cement, compressive strength

Introduction

The concept of replacing cement in concrete with rice husk ash (RHA) was derivative from the concept to utilize pozzolanic materials, like fly ash (FA), in concrete. FA, which is a waste material from the burning of coal in thermal power plants, has been well researched and commonly utilized as a "supplementary cementitious material (SCM)" for concrete. FA has pozzolanic characteristics, that is, it will react with the calcium hydroxide (resulting from cement hydration) to create additional cementitious products, which enhance the strength and durability of concrete (Mehta, 1977) [2]. Specimen is indeed a diverse mixture of cement, water, & particles, as is widely known concrete. The specimen is a diverse mixture of cement, water, and particles, as is widely known as concrete. Admixtures are substances that may be mixed into concrete to improve specific qualities. Concrete is a combination of paste & particles in its most basic form. To create concrete with the necessary properties, various ingredients, including rice husk and additives, are added. The composition of the paste determines the nature of the concrete. The mix proportion & tamping of the elements are crucial to generating a strong, long-lasting concrete. The specimen is a diverse mixture of cement, water, and particles, as is widely known as concrete. Admixtures are substances that may be mixed into concrete to improve specific qualities (Buenfeld and Newman, 1984) [4]. Various ingredients, including rice husk and additive, are added to create concrete with the necessary properties. The composition of the paste determines the nature of the concrete. The mix proportion, tamping & curing of the elements is crucial to generating robust and long-lasting concrete (Jerzy and Zemajtis, 2004) [6]. Architectural or building work was done mainly with mudstone, first from industries throughout ancient times. Benifits of using cementitious materials including R-h ash, as well as the social benefits that come with a reduction in the amount of waste disposal current environmental problems. All tropical nations, particularly in Asia, rid of a huge volume of biomass residues. By using R-h ash as a component in creating nanocomposites for building. R-h ash is a kind of dangerous for ecological system & enviroment. A rice mill's by-product is R-h. It may be the most common agricultural waste product (Mehta, 1977) [2]. R-h ash is produced when R-h is burned. R-H Ash is mainly of non-crystalline and amorphous silica with minor levels of inorganic salts. Gupta *et al*. (2024) [8] assessed the durability properties of RAC containing RHA and found lower water absorption, improved resistance to chloride penetration, and improved resistance to carbonation. Collectively, these studies show the potential of RHA in improving the durability properties of concrete, contributing to high-strength concrete using waste materials at an affordable cost. When R-H Ash is burned in the presence of air, it produces silica ash that ranges from grey to white, as well as a residue of inorganic element oxides. In addition to enhancing concrete's mechanical and durability features, there are other environmental and economic benefits to using RHA as a partial cement substitute in concrete. Concrete made with RHA has a less carbon impact than cement made without it. Cement manufacturing is the source of the largest amount of greenhouse gases, producing around 8% of global CO2 emissions (Andrew, 2018) [7]. To study the high-strength concrete of RHA and micro silica in terms of durability and mechanical properties, Zareei *et al*. (2017) [5] conducted the analysis. The experimentation was done on RHA as a partial substitute of cement at various percentages (0%, 5%, 10%, and 15%) with micro silica. The findings indicated that RHA and micro silica highly enhanced constructive strength, breaking tensile strength (TS), and modulus of elasticity of concrete. It Givi *et al*. (2010) [1], investigated the influence of particle size of RHA on the strength, water permeability, workability of binary blended concrete. A partial substitution of cement with RHA of various particle sizes (fine, medium and coarse) in concrete was also performed by the study. Researchers have reported substantial improvements in the CS of concrete with the addition of RHA. Jamil *et al*. (2023) [3] studied the combined effects of RHA and FA on the performance of high-performance concrete (HPC) and reported that the inclusion of the two materials together increased CS greater than the control mix.

Objectives of the study

- To study the perfect amount of RHA as a pozzolanic material for cement additional in concrete to attain maximum strength
- To study the "energy dispersive X-ray (EDX) analysis & X-ray diffraction (XRD) analysis" for RHA.
- To find the Analysis of Concrete's Behavior with Rice Husk Ash

Scope of the study

The area of this research study is geared towards examining the possibility of RHA as an additional cementitious material (SCM) in high-strength concrete and assessing its contribution to the mechanical properties, durability, and microstructure of the produced concrete. It hopes to shed a wide understanding of RHA-modified concrete behavior and performance that corresponds to the existing knowledge gaps detected through an intensive literature review. One of the key components of the scope is to perform XRD and EDX on RHA samples in order to determine their crystalline phases, amorphous structure, and elemental composition. XRD analysis will be carried out with a suitable diffractometer to record the diffraction patterns of RHA samples. These patterns will be interpreted to determine the crystalline phases present in RHA and assess their relative abundances. The existence of amorphous silica, the main contributor to the pozzolanic reactivity of RHA, will also be determined through XRD analysis. EDX analysis will be done by a scanning electron microscope (SEM) with an EDX detector to identify the elemental nature of RHA samples. The EDX spectra obtained will reveal the relative abundance of elements like silicon, potassium, and carbon in RHA. RHA silica content is of special interest since it directly affects its pozzolanic reactivity and SCM potential in concrete. EDX analysis will assist in the quantification of the silica content and determination of the purity of RHA samples. To determine the performance of the RHA-modified concrete a number of mechanical tests will take place, compression tests and flexural tests. To carry out compression experiments, standard concrete cubes of dimensions 150 mm x 150 mm x 150 mm according to the specifications of the Indian Standard (IS) will be used. The casted cubes will then be cured and tested out at various ages i.e., after 7, 28 and 90 days to determine the strength of the cubes as it increases with age. The flexural tests will be conducted on the standard concrete beams of dimension of 100 mm 100 mm 500 mm as given in the IS specifications. Each beam will then undergo a two-point system of loading with the help of a flexural testing machine and the greatest weight that the specimen can hold and not fail should be noted. The mechanical tests will present important information about compressive forces and FS of the RHA-modified concrete in various levels of replacement and old ages. The comparison of results will be made with control concrete (without RHA), to measure the influence of RHA on the strength development and performance of concrete. This will be done in an attempt to deliver viable knowledge to concrete producers, designers, and practitioners to enable them to embrace the use of RHA as a cost effective and sustainable SCM in high-strength concrete project settings.

Research Methodology

The research methodology for the study follows a systematic experimental framework aimed at evaluating the potential of RHA as a partial cement replacement to improve concrete properties. The process begins with material selection, where components like Ordinary Portland Cement (OPC), fine and coarse aggregates, water, superplasticizer (Conplast SP430), and RHA are carefully chosen and characterized. The RHA is produced under controlled and uncontrolled burning conditions to achieve various forms and is chemically analyzed to confirm its pozzolanic properties. Following this, mix design calculations are performed using varying RHA replacement levels (0%, 5%, 10%, 15%, and 20%) to optimize the concrete mix. Specimens are cast and cured under standard conditions. The next phase involves testing on hardened concrete to evaluate mechanical properties—such as compressive, split tensile, and flexural strength—at multiple curing ages (up to 108 days). The figure 1 represents the framework of the experiments based on Study & Behavior of Concrete Using Rice Husk Ash (RHA) on how RHA can be incorporated into the concrete mix in an attempt to enhance the strength and durability characteristics of concrete. These are Cement, Fine Aggregates, Coarse Aggregates, RHA, Superplasticizer and Water. Out of these, RHA is a supplementary cementitious material which leads to pozzolanic activity and hence improves the overall performance of the concrete. The Superplasticizer also enhances workability of the cement without having to add water-cement ratio which is vital when you use mineral admixtures such as RHA. The materials are chosen, after which the Testing Process commences with one of the most important processes of Testing of Materials which is done to verify that the materials are of standard specifications to use in concrete. Mix Design Calculation is then carried out to come up with the best concrete mix proportion using various percentages of RHA after verification. After determination of the mix design, Casting and Curing of Cylinder and Cube Specimen is carried under controlled conditions. The hardened specimens are afterwards taken through a variety of mechanical and durability tests at the Test on Hardened Specimens stage. The process taken as a whole is a systematic way of studying the behaviour and the performance of RHA- blended concrete under different conditions.

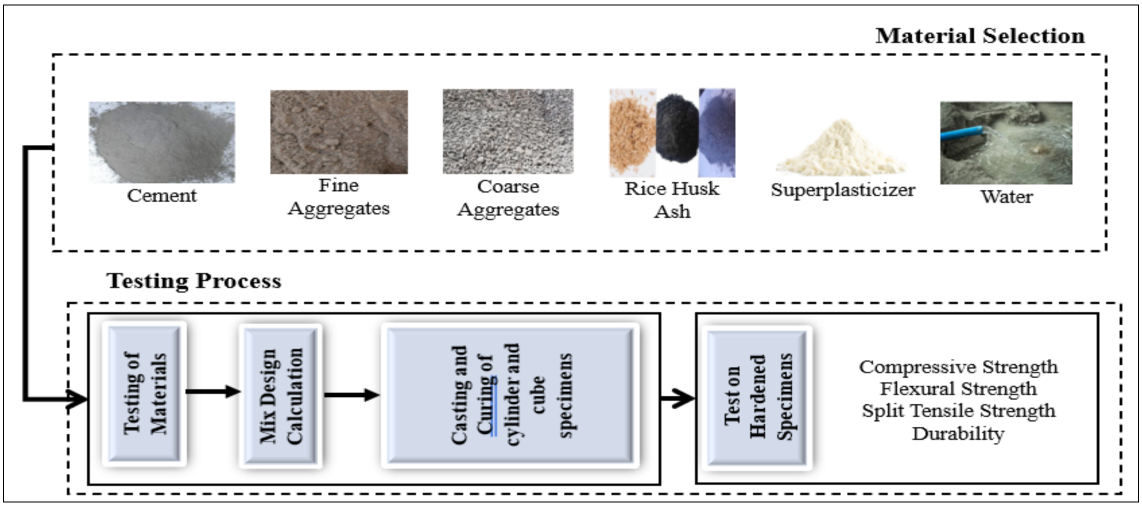


Fig 1: Flowchart of proposed work

Material Selections

Cement

In all concrete mix designs used in this research work "Ordinary Portland Cement (OPC)" was taken as the main binding agent. In particular, the Type I OPC was chosen, also called general-purpose cement by ASTM C150 standard, according to which the Portland cement is classified into a number of categories according to the chemical composition and performance features. The cement is commonly used in general construction without any special properties that were not needed but high early strength, resistance to the sulfate attack, or low heat of hydration. Experimental work was performed by using OPC of 43-grade. OPC is the primary hydraulic binder; in other words, it is converted to calcium silicate hydrate (C-S-H) gel and other compounds due to a chemical reaction with water in a process known as hydration, resulting in the achievement of strength and durability of the solidified concrete. Strong oxides usually found in OPC are "calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), and magnesium oxide (MgO)" among others (C. Marthong 2012). These oxides have an impact on the strength development, hydration properties and durability of the cement.

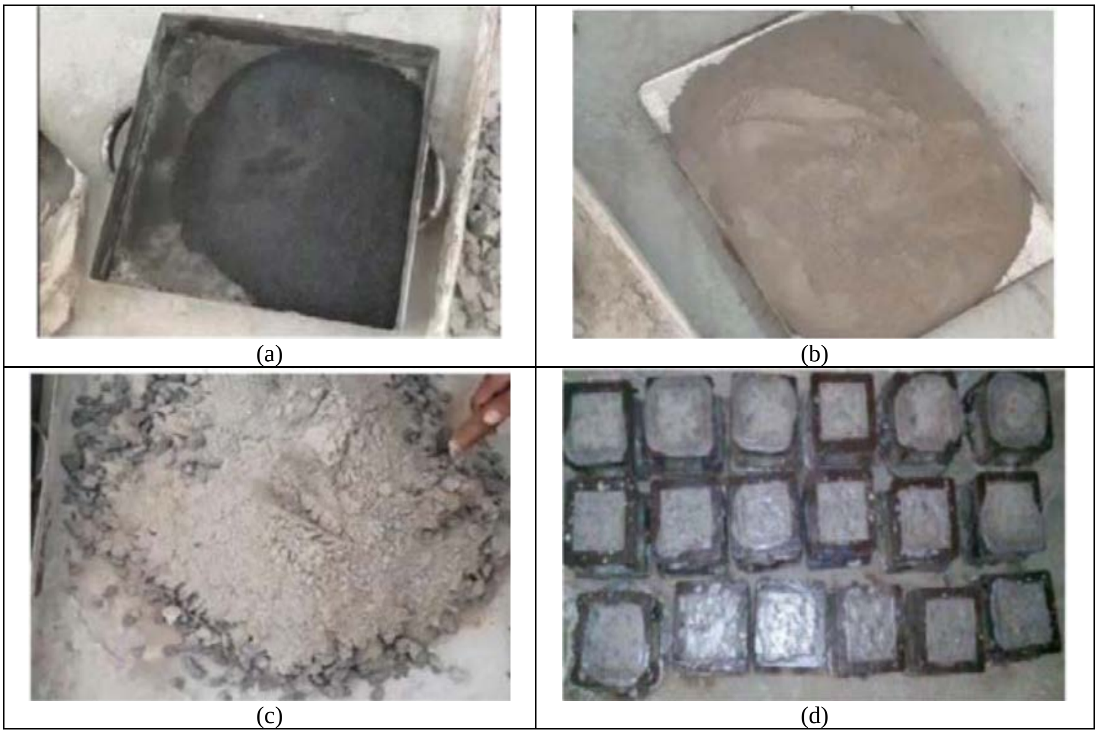
Table 1: Chemical and Physical Properties of OPC (Type I)

Chemical Property	Percentage (%)	Physical Property	Results
CaO	63.10	Size	≤ 75 µm
SiO_2	20.45	Fineness	92%
Al_2O_3	5.60	Normal Consistency	28%
Fe_2O_3	4.62	Initial Setting Time	38 min
MgO	1.03	Final Setting Time	412 min
SO_3	2.85	Specific Surface Area	322 m^2/kg
K_2O	0.41	Soundness	1.70%
Na_2O	0.66	108-day Compressive Strength	42 MPa

Besides the chemical composition, the following physical factors also contribute significantly to the performance of OPC in concrete; "fineness, specific gravity, initial setting time, final setting time and CS". Table 1 summarizes these properties so that the material is within the required standards and to establish a baseline with which to compare certain modified concrete mixes to which RHA will be added. In such a manner, the Type I OPC used in the study, produced to the requirements of ASTM standards, guarantees no issues of consistency, reliability, and conformation to the industry standards and provides the possibility to assess the influence of the alternative materials on the concrete behavior accurately.

Data Analysis and results

Casting and curing: Each of the samples was made using the same amounts of the combination. They made sure that each of these composite samples had the correct quantities. This research study discusses the casting of samples for different qualities. The specimens used for the compressive strength test were cubes measuring 150 mm x 150 mm x 150 mm. Researchers used the mix% to determine the relative importance of each component. Cement, RHA, coarse, and fine aggregates were first dry mixed to get a uniform colour. Then, after whisking rapidly for three or four minutes, half of the total water needed was added to the mixture. Then, the cross was quickly supplied with 40% of the remaining water. To keep the samples from drying out after casting, a polythene covering was quickly placed over them. 40 full RHA blocks, including both controlled and unregulated burn options, were made. Curing concrete at high temperatures increases its strength during the curing process, but it could decrease its 90-day strength. Figure 2 shows the samples after casting and curing.



(a) (b) (c) (d)

Fig 2: Casting of Specimen

Compressive Strength (CS)

CS data show the effect of different Rice Husk Ash (RHA) content and type of ash (Grey, White, Controlled) on long-term concrete performance (Table 2). For the controlled 0% Ash samples, there is a normal strength gain, which rises steadily from 40 MPa at 7 days to 55 MPa at 90 days. The addition of 5% RHA increases the early strength, with controlled samples indicating a significant increase over the 0% mix, to 58 MPa after 90 days. The grey ash type at 5% increases the early strength appreciably, increasing to 54 MPa at 28 days, then levelling off. The white ash increases marginally in strength, staying at a level of about 46 MPa.

Table 2: CS of concrete containing RHA created at different temperatures

Sample ID	RHA Type	7 Days	14 Days	28 Days	56 Days	90 Days
0% Ash	**Controlled**	40.0	44.0	48.0	52.0	55.0
5% Ash	Controlled	43.0	47.0	51.0	55.0	58.0
	Grey	52.0	53.5	54.0	53.0	50.0
	White	45.0	46.5	47.0	46.5	46.0
10% Ash	Controlled	41.6	45.4	49.2	52.2	55.2
	Grey	56.2	56.7	56.2	52.5	48.3
	White	47.8	48.0	47.8	47.5	47.2
15% Ash	Controlled	45.6	50.0	56.2	57.5	56.2
	Grey	61.4	62.0	61.4	54.5	47.8
	White	45.6	46.0	45.6	46.0	45.6
20% Ash	Controlled	42.4	47.0	61.4	62.5	61.4
	Grey	57.3	58.0	57.3	52.0	45.6
	White	31.6	33.0	31.6	32.0	42.4

At 10% RHA, grey ash has the highest initial strength (56.2 MPa at 7 days), but strength decreases after 28 days. Controlled and white samples exhibit the same trends, with white ash showing stable moderate strength values. At 15% RHA, grey ash is the highest compressive strength, with 61.4 MPa at 28 days controlled samples are also good, while that of white ash does not change. The results demonstrate that moderate RHA replacement, specifically with grey ash at about 10%-15%, improves CS considerably. High replacement (20%) or white ash content causes weakening in long-term strength.

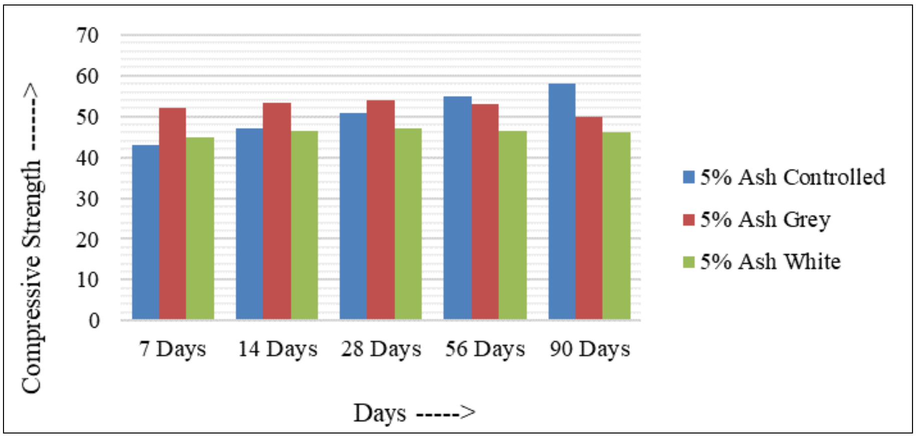


Fig 3: CS having 5% RHA

It can be seen in Figure 3 that the highest CS reached was 58MPa at 90 days by the 5% Ash Controlled specimen. The 5% Ash Controlled specimen continued to demonstrate a trend of increasing strength with time, providing the highest strength of the samples at the later ages. The 5% Ash Grey specimen had a maximum strength value of approximately 54MPa at 28 days, with a very slight decrease at 90 days. Overall, the data presented indicates that 5% controlled burn RHA replacement did provide some increase in CS at longer curing periods, thus, it would be the most effective ash type tested to improve concrete strength.

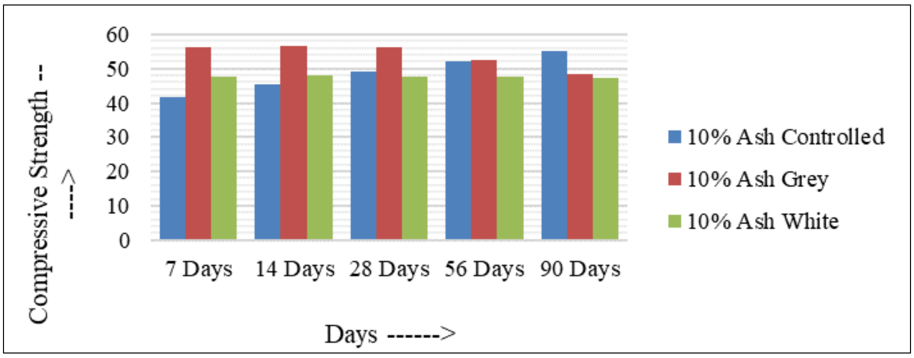


Fig 4: CS having 10% RHA

Figure 4 illustrates that the maximum CS value of 55.2 MPa at 90 days is obtained by the specimen with 10% Ash Control. The 10% Ash Control specimen exhibited a slow development of CS concerning curing age, with a maximum CS at 90 days. The 10% Ash Grey specimen, although having a high value at early ages, had its maximum achieved of approximately 56.7 MPa at 14 days, and afterwards this value had a slow decline. The 10% Ash White specimen had a lower CS value than the other two mixes, which had a maximum of approximately 47.8MPa at 28 days, after which the strength remained constant value.

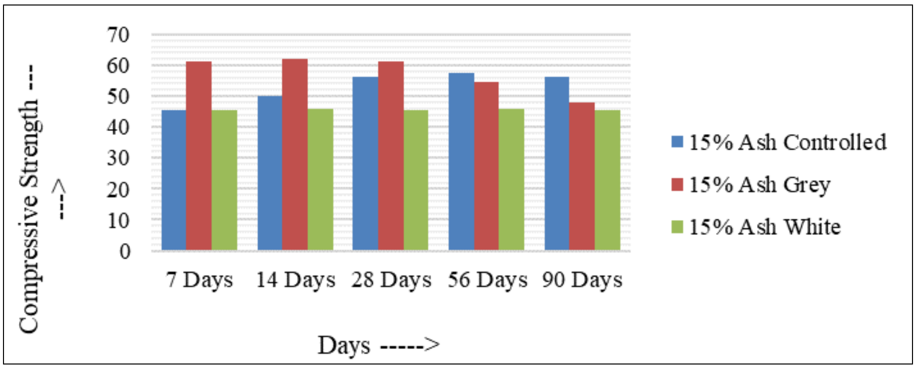


Fig 5: CS having 15% RHA

X-Ray Diffraction Analysis (XRD): In this case, XRD proved that RHA does in fact contain silica. Created amorphous phases for RHA at lower temperatures, 500 - 700℃. Burning RHA at high temperatures transforms amorphous silica into crystalline silica. There is evidence in the literature that cristobalite or tridymite could have been formed when RHA is burned at temperatures of 700℃ or higher. The several phases that formed on RHA were identified by XRD studies. Figure 6 shows that at 1000℃, RHA reacts very strongly; in this case, practically all of the silica is in an amorphous form, which greatly increases the strength. A single diffuse broad band was formed during

XRD examination of RHA burnt at 700℃, confirming the existence of amorphous silica. Hydrolysis improves the stiffness of RHA by reacting the crystalline silica with the $Ca(OH)_2$, which in turn generates more CSH gels. The concentration of various quartz crystalline forms influences the generation of extra CSH gels. Crystalline quartz produced at temperatures below 1472 degrees Celsius must thus be the most reactive and suitable ingredient for cement.

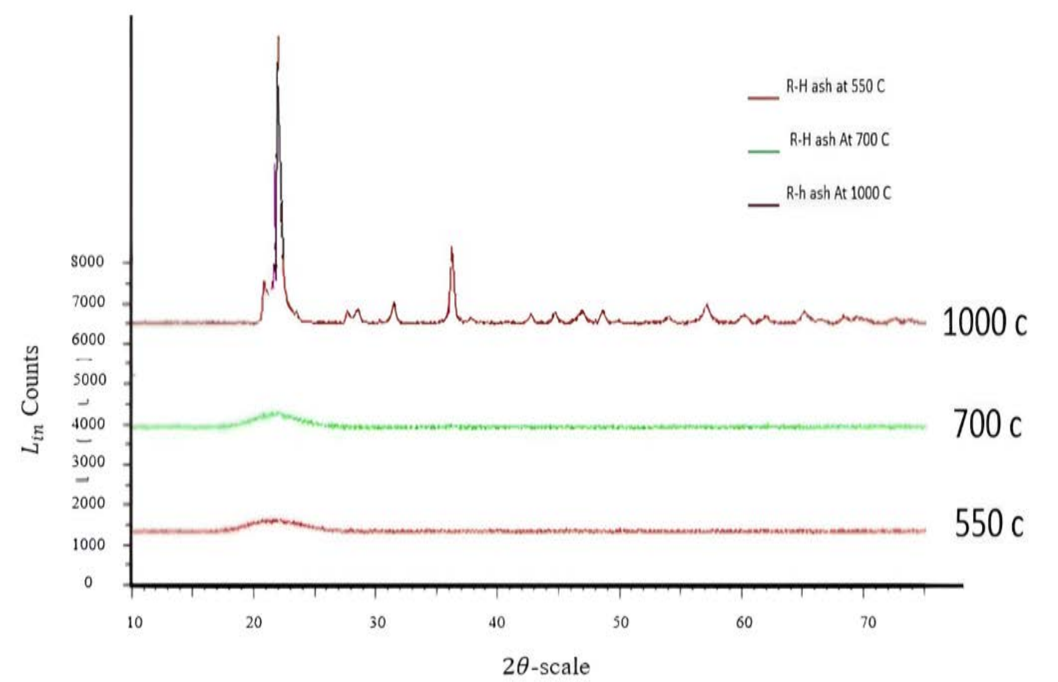


Fig 6: The XRD analysis of several RHAs burnt at different temperatures

Table 3: The maximum amorphous silica and crystalline values found in XRD analyses of several RRHAs burnt at different temperatures

Regulated & Unregulated RHA	Impulse
Amorphous silica in RHA at 550 ℃	1524
Amorphous silica in RHA at 700 ℃	4450
Amorphous silica in RHA at 1000 ℃	19557

Energy–Dispersive X-Ray Analysis (EDX): Tests for elemental analysis of RHA burned at temperatures ranging from 550 to 1000 ℃ were conducted in a central lab using EDX on specimens of RHA. Results, including chemical composition, are previously described in Table 4. This includes both RHA specimens treated at 550 and 1000℃. Regardless of the temperatures at which they were burned, all RHA specimens consisted mostly of silica. Silica content is marginally greater in RHA specimens fumed at lower temperatures (550 ℃ vs. 1000 ℃) than in RHA specimens burnt at higher temperatures. Cementitious materials are defined by ASTM C 618 as those containing at least 70% of the following elements: “Al2O3, SiO2, and Fe2O3”. The total “silica, alumina, and iron values” in Table 4 were found to be 20.33 and 96%, respectively, for RHA burnt at 550 and 1000 ℃.

Table 4: Mass % of Oxides in RHA

Elements	Mass %		
	OPC	**Grey RHA**	**White RHA**
$Si(O_2)$	20.33	96.5	96.0
Al_2O3	5.46	0.50	0.40
CaO	63.29	0.41	0.09
Fe_2O_3	4.58	0.08	0.08

Conclusions

The study was conducted for sustainability and possible improvement of mechanical properties like compressive strength (CS), flexural strength (FS) and split tensile strength (STS). R-H Ash, employed in this work as a cementitious material, is found in crystalline quartz. R-H Ash has a minimum specific gravity, resulting in a decrease in M/V, lowering the dead weight of the building. The usage of R-h ash assists in reducing exposure to harmful chemicals in the atmosphere when extra R-h ash is disposed of. Because cement is a pricey material, replacing some of it with R-H Ash decreases the expense of construction. Results came after our experimental work, using R-H ash as a limited substitution for cement. RHA samples were made from controlled and uncontrolled burning RHA at various temperatures which provided ash with varying properties (grey, white and controlled). The prime objective of the study was to explore how various percentages of RHA would affect the mechanical and microstructural behavior of concrete. Prepared in controlled as well as uncontrolled conditions, RHA was prepared and utilized to develop ash types such as grey, white and controlled ash. The RHA-containing concrete mixes were formulated with replacement of 0%, 5%, 10%, 15% and 20% of OPC by RHA. All blends were evaluated using a systematic program of casting and curing with subsequent mechanical testing for compressive strength, flexural strength, and split tensile strength (STS) and microstructural evaluation using methods like X-Ray Diffraction (XRD) and Energy-Dispersive X-ray (EDX) to identify the mineralogical and chemical variation of RHA and interaction with concrete matrix. Early workability tests were conducted with the slump test to assess workability equated to the feasibility of mixing and handling the concrete mixes.

References

1. Givi AN, Rashid SA, Aziz FNA, Salleh MAM. Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete. Constr Build Mater. 2010;24(11):2145-2150. doi:10.1016/j.conbuildmat.2010.04.045.
2. Mehta PK. Properties of blended cement made from rice husk ash. ACI J. 1977;74(9):440-442.
3. Jamil M, Khan MNN, Karim MR, Kaish ABMA, Zain MFM. Synergistic effects of rice husk ash and fly ash on the properties of high-performance concrete. Constr Build Mater. 2023;284:122768. doi:10.1016/j.conbuildmat.2023.122768.
4. Buenfeld NR, Newman JB. The permeability of concrete in the aquatic environment. Mag Concr Res. 1984;36:67-80.
5. Zareei SA, Ameri F, Dorostkar F, Ahmadi M. Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties. Case Stud Constr Mater. 2017;7:73-81. doi:10.1016/j.cscm.2017.05.001.
6. Zemajtis JZ. Role of concrete curing. Skokie (IL): Portland Cement Association; 2004.
7. Andrew RM. Global CO2 emissions from cement production, 1928–2018. Earth Syst Sci Data. 2018;10(4):2213-39. doi:10.5194/essd-10-2213-2018.
8. Gupta A, Singh S, Patel R. Influence of rice husk ash on the properties of recycled aggregate concrete. J Clean Prod. 2024;312:127823. doi:10.1016/j.jclepro.2024.127823.