

SOME STUDY ON PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH IN CONCRETE

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DOI: <https://doi.org/10.5281/zenodo.22226623>

Keywords**Article History**

Received: 31 January 2026

Accepted: 16 March 2026

Published: 30 March 2026

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Abstract

The use of alternative materials in concrete is becoming more common due to environmental concerns. Rice husk ash (RHA), a byproduct of rice milling, is one such material that can partially replace cement in concrete. RHA is rich in silica, which helps improve the strength and durability of concrete. This study explores how different percentages of RHA affect concrete's strength, durability, and workability. The results show that using the right amount of RHA can enhance concrete properties while also reducing cement use and environmental impact. This study highlights the potential of RHA as a sustainable material in construction.

By replacing cement with rice husk, less cement is used, which is advantageous for the environment and the economy. This group project's goal was to examine the effects of using Rice husk ash in place of certain cement. Acquired rice husk was used to prepare various trial mixes named, RHA2.5, RHA5, RHA7.5, RHA10 and RHA15 with partial replacement of cement by 2.5%, 5%, 7.5%, 10%, 15% respectively. The samples behavior and strength characteristics were compared to an identical mix of plain cement concrete with no addition of rice husk ash. In addition, 1% superplasticizer named chemrite 520 was added. Specimens were divided into two categories with designated curing period 14 and 28 days. And results were compared between them.

It indicates that the cement replaced with the Rice husk ash in concrete showed the best physical and mechanical improvement. After performing all necessary Tests such as compressive strength, split tensile strength, ultrasonic pulse velocity, and flexural strength, it was observed that the 5% partial replacement of cement with RHA at both 14- and 28-days curing periods showed the best improvements. It is economical and can be used for improving concrete properties, at certain percentage RHA can be used for lowering use of cement. It can be helpful in lowering the carbon footprints which is produced in manufacturing of cement.

1. Introduction

Background:

Concrete is one of the most widely used materials in construction due to its strength, durability, and ease of use. However, cement, a key ingredient in concrete, has a major environmental impact. Cement production releases a large amount of carbon dioxide (CO₂) into the atmosphere, contributing to global warming. With the growing demand for concrete in construction, finding eco-friendly alternatives to cement is necessary.

Rice husk ash (RHA) is one such alternative. It is obtained by burning rice husks, which are the outer coverings of rice grains. Since rice husks make up about 20% of harvested rice, they are often treated as waste. However, when burned properly, they produce RHA, which is rich in silica. This silica reacts with cement components to improve the strength and durability of concrete. Using RHA in concrete also helps in reducing waste and promoting sustainability in the construction industry.

Adding RHA to concrete has many benefits. It improves mechanical strength, increases durability, and enhances resistance to chemical attacks. It also helps in reducing cement consumption, which in turn lowers construction costs and environmental impact. Research has shown that using RHA in the right proportion can lead to stronger and more durable concrete.

While RHA has many benefits, it also comes with certain drawbacks. The quality and effectiveness of RHA depend on the burning process and fineness of the ash. If the rice husks are burned at an improper temperature, the resulting ash may contain too much unburned carbon, reducing its effectiveness as a cement replacement. Additionally, achieving uniform quality in RHA production can be challenging, as different sources of rice husks and burning methods lead to variations in chemical composition. Another drawback is that high percentages of RHA in concrete can reduce workability, making the mixture harder to handle and place. This may require the use of additional water or chemical admixtures which in our case a chemical chemrite 250 a super plasticizer was added which increases the costs. Furthermore, limited awareness and availability

of high-quality RHA

restricts its widespread adoption in construction practices.

General:

Concrete is one of the most widely used construction materials in the world. It is known for its high strength, durability, and versatility. The key ingredient that gives concrete its binding properties is cement, specifically Ordinary Portland Cement (OPC). However, cement production is highly energy-intensive and contributes significantly to environmental pollution. It is estimated that cement manufacturing accounts for approximately 8% of global CO₂ emissions, making it one of the largest industrial contributors to climate change. The high demand for cement and its negative environmental impact have led researchers and engineers to explore alternative materials that can partially replace cement while maintaining or even improving the performance of concrete. With the rapid growth in infrastructure development worldwide, the demand for concrete is increasing, leading to higher cement consumption. This has resulted in concerns related to environmental degradation, resource depletion, and rising construction costs. The construction industry is now focusing on sustainable solutions to reduce carbon emissions, utilize waste materials, and improve energy efficiency in building practices. One effective approach is the partial replacement of cement with supplementary cementitious materials (SCMs), such as fly ash, silica fume, ground granulated blast furnace slag (GGBS), and rice husk ash (RHA).

Rice husk ash (RHA) is obtained by burning rice husks, which are the outer shells of rice grains. Rice is a major agricultural product, and rice husks account for about 20% of the total weight of harvested rice. If not properly disposed of, rice husks contribute to environmental waste. However, when burned under controlled conditions, rice husks produce ash that is rich in amorphous silica, a key component that can react with cement to enhance concrete properties.

The use of RHA in concrete is gaining attention due to its pozzolanic properties, meaning it reacts with the calcium hydroxide in cement to

form additional compounds that improve the strength, durability, and long-term performance of concrete. RHA not only helps in reducing cement consumption but also recycles agricultural waste, promoting sustainable construction practices.

Properties and Benefits of Rice Husk Ash in Concrete

- **Increased Strength:**

The silica in RHA reacts with cement to form additional binding compounds, increasing compressive and tensile strength.

- **Improved Durability:**

RHA reduces permeability, making concrete more resistant to water absorption, chemical attacks, and sulfate exposure.

- **Lower Carbon Footprint:**

By replacing a portion of cement, RHA reduces CO₂ emissions from cement production.

- **Waste Utilization:**

Rice husks, which are otherwise discarded as waste, are effectively used in construction, reducing landfill problems.

- **Enhanced Workability:**

Properly processed RHA can improve the workability of concrete, making it easier to handle.

Challenges and Limitations of RHA in Concrete

Despite its advantages, there are some challenges associated with using RHA in concrete:

- **Burning Conditions:**

The effectiveness of RHA depends on how it is produced. If rice husks are burned at high temperatures, they may form crystalline silica, which does not react well in concrete.

- **Workability Issues:**

A high percentage of RHA in concrete can make the mix less workable, requiring the use of water-reducing admixtures.

- **Quality Variation:**

Different sources and processing methods of RHA can lead to variations in its chemical composition and performance.

- **Limited Awareness:**

The use of RHA in

concrete is not widely known in many regions, and proper research is needed to optimize its application.

To evaluate Rice husk ash's potential as a partial cement substitute in concrete is to figure out the replacement levels which were (2,5%,5%,7.5%,10%,15%). Components were precisely quantified and mixed (cement, Rice husk ash, aggregates, super plasticizer and water) in accordance with the modified mix design. Slump test was performed to determine whether the fresh concrete is workable. Testing for compressive strength tests were performed on the cast and cured specimens at 14 and 28 days. Point load beam, split tensile strength tests were also performed on the specimens. All the test results were compared with plain cement concrete with 0% replacement of cement. After that it was Determined that how well Rice husk ash concrete performs in comparison to the control mix by analyzing the data and adjusting the Rice husk ash content to get the ideal blend of strength, durability, and sustainability and economically better mix design. This procedure guarantees a methodical evaluation of Rice husk ash's suitability as a sustainable substitute in the manufacturing of concrete.

Problem to statement:

From the 20th century, there had been an increase in the economic consumption of mineral admixtures by the cement and concrete industries. The increasing demand for cement and concrete is conformed to by partial replacement of cement. Significant cost savings can result when by-products are used as a partial replacement for the energy acute Portland cement. The use of by-products also reduces the pollution and proved as an environmentally friendly method of disposal of large quantities of waste materials that would otherwise pollute land, air and water. Typically, RHA contains 80 - 90% of amorphous silica, 1 2 % Potassium oxide (K₂O) and remaining being sunburn carbon.

The workability and w/c ratio of concrete increase with respect to increase the quantity of Rice husk ash. To optimize the result and to check the accuracy of mix design Concrete cubes of size 150 mm × 150 mm × 150 mm were

cast and cured using potable water with a pH value around 7. Curing was conducted for 14 and 28 days to evaluate strength development.

Objectives:

- To improve the engineering properties of Concrete compressive strength, tensile strength and flexural strength.
- To make Concrete cost-effective by reducing the amount of Cement.
- To optimize the use of waste product like Rice Husk Ash (RHA) in preparation of Concrete.

Scope:

in this project many laboratory tests were carried out. Workability was Assessed using the slump cone test to determine the consistency of the concrete mix. Compressive strength test was performed to analyze and compare the compressive strength of concrete specimens. Point load beam test was performed to test the flexural strength of the concrete specimens. Split Tensile Strength was Evaluated using cylindrical specimens. Ultrasonic Pulse Velocity test was Conducted to evaluate the quality and integrity of the concrete. All this research work was carried out in the laboratory in controlled environment.

2. Literature review

General:

The main topic of this chapter is to give an overview of the different techniques used for the potential use of Rice husk ash at place of cement in concrete. Addition of Rice husk ash at the place of cement and its Effects on the engineering properties of concrete with different behavior in previous works by different researchers.

Literature review:

The environmental issues in the construction industry have garnered considerable attention in numerous studies. Ecologically sustainable green concrete addresses environmental challenges in the construction industry. This study investigates the impact of multi-walled carbon nanotubes (0–0.20%) in rice husk ash (15%) concrete to replace Portland cement. The mechanical and durability properties of four

concrete mixtures were analyzed. Adding 0.1% multi-walled carbon nanotubes and 15% rice husk ash yielded satisfactory results, significantly improving durability compared to concrete without multi-walled carbon nanotubes. With the addition of 0.1–0.2% multi-walled carbon nanotubes, the density and elastic modulus increased, the 28-d sportively decreased by 4.64–28.76%. The resistance ability of 111-d mass loss and compressive strength loss increased by 50.93–61.71% and 25.28–48.47% under sulphate attack, respectively. The resistance ability of mass loss increased by 3.7–35.97% under acid attack. And 120-d drying shrinkage resistance improved by 3.08–9.23%. The predicted and experimental results were compared using the Sakata, GL 2000, B3, ACI 209, and CEB-FIP models. Sakata and B3 provided the most accurate early-stage and long-term drying shrinkages with variation coefficients of 0.13–0.33 and 0–0.05, respectively. Moreover, the sustainability of rice husk ash concrete containing multi-walled carbon nanotubes was evaluated, and its environmental friendliness was confirmed. Thus, the viability of multi-walled carbon nanotubes in rice husk ash sustainable concrete significantly contributes to sustainable construction. (Yi Jing, 2025)

An immense amount of rice is cultivated globally, leading to the generation of large amounts of rice husk. Unfortunately, this husk is often disposed of in natural settings and lagoons. The alternative use of this material encourages replacing traditional building materials. Rice husk production in India is 31.40 million tonnes, which fills landfills and causes environmental problems. Concrete with this substance helps solve environmental and economic problems. This material's high silica content makes it pozzolanic. Extensive studies have been carried out in recent decades to evaluate the viability of incorporating it into different building construction methods. The sustainable development of the environment and economy of nations has benefited greatly from such research and innovations. Key findings indicate that this material has a positive impact on the strength and durability of concrete, while also contributing to a reduction

in carbon emissions. It implications that this material has the potential to reduce construction expenses and encourage environmentally conscious building methods through the reuse of agricultural waste This study summarizes historical research on rice husk-based concrete in infrastructure projects. Its physical and chemical features increase compressive, tensile, workability, durability, flexural strength, and water absorption. VOS viewer was used for bibliometric analysis of country and keyword data. The purpose of increasing the compressive strength when using rice husk ash as a replacement in cement is to enhance the durability and load-bearing capacity of concrete. (M. Indumathi, 2024)

Supplementary cementitious materials (SCMs) have been known to improve the properties of fresh and hardened concrete, and at the same time enhance the sustainability of concrete. Rice husk Ash (RHA), is one such material, but has neither been widely studied nor applied in practice. This work investigated the effect of the density of RHA on the workability and compressive strength of fresh and hardened RHA-replaced concrete respectively. Cement was replaced with RHA in concrete by weight (RHA-W) and by volume (RHA-V) at steps of 0%, 5%, 7.5%, 10%, 15%, 20%, 25% and 30%. The 0% replacement was used as the reference point from which performances were measured. Results showed that unlike the characteristic of other established pozzolans, RHA significantly reduced the workability of wet concrete and the rate of compressive strength gain over curing time due to a high-water demand that is caused by the increased volume of replaced concrete, which results from its low density. Workability reduced with increased replacement for both RHA-W and RHA-V. Replacements of above 15% were not possible for the RHA-W due to the high-water demand. However, replacements of up to 30% were achieved for the RHA-V. RHA-W specimens achieved lower compressive strengths and were observed to gain strength at a lower rate over the 28 to 91-days period of curing compared to RHA-V specimens. This behavior was attributed to the shortage of water that is necessary for the hydration of cement and subsequent pozzolanic reaction, which is the basis of the contribution that is made to the

strength and performance of concrete by SCMs. However, the compressive strengths achieved were above the study's target concrete strength of class C32/40 at 91 days, which is among those classes that are listed as being durable and suitable for structural applications. A conclusion that RHA should supplement cements by volumetric replacement rather than simple substitution by weight was drawn. (John Kamau, 2017)

The pervious study on rice husk ash suggests that optimum level of replacement of rice husk ash in concrete is 10% of total weight of cement. This paper aims for maximum optimum value within 10% of replacement for better compressive strength and durability. RHA exhibits high pozzolanic characteristics and shows good pozzolanic behavior due to its high silica content. Rice husk ash (RHA) essentially consists of amorphous silica (90% SiO₂), 5% carbon, and 2% K₂O. Rice husk ash has been partially replaced at different percentages (0%, 5%, 6%, 7%, 8%, 9% and 10%) by weight of cement for mix and cured for different curing periods (28 days, 60days, 90 days). This study suggests that at 6% replacement of OPC with RHA Exhibits good compressive strength, because of its high pozzolanic activity. Effect of Sulphuric acid (H₂SO₄) on properties of replaced RHA concrete and compressive strength of cement concrete is taken as study area. The study reviles that the rate of development of compressive strength decreased with increase in concentration of H₂SO₄ at 28 days, 60 days and 90 days. But at 6% replaced RHA shows good resistance to sulphuric acid attack. (PV Rambabu, 2015)

Increase in the demand of conventional construction materials and the need for providing a sustainable growth in the construction field has prompted the designers and developers to opt for 'alternative materials' feasible for use in construction. For this objective, the use of industrial waste products and agricultural byproducts are very constructive. These industrial wastes and agricultural by products such as Fly Ash, Rice Husk Ash, Silica Fume, and Slag can be replaced instead of cement because of their pozzolanic behavior, which otherwise requires large tract of lands for dumping. In the present investigation,

Rice Husk Ash has been used as an admixture to cement in concrete and its properties has been studied. An attempt was also done to examine the strength and workability parameters of concrete. For normal concrete, mix design is done based on Indian Standard (IS) method and taking this as reference, mix design has been made for replacement of Rice Husk Ash. Four different replacement levels namely 5%, 10%, 15% and 20% are selected and studied with respect to the replacement method. (N Kaarthik Krishna, 2016)

The production of cement (key binding component of concrete) is costly, consumes high energy, depletes natural resources and emits huge amounts of greenhouse gases (1 ton of cement production emits ~1 ton of CO₂). Consequently, environmental degradation, serious pollution and health hazards associated with cement and concrete industries, have come under intense scrutiny from environmentalists and the governments. Developed and some developing nations, are already using industrial and agricultural wastes in concrete. These wastes also pose several environmental problems. Partial inclusion of waste instead of 100% cement has been found to be environmentally safe, stable, durable as well as economical. The present study used rice-husk ash (RHA) as a partial replacement of cement in concrete. X-ray diffraction analysis, scanning electron microscopic examination, compressive strength (without and with superplasticizers), flexural strength, resistance to aggressive chemicals and cost analysis were carried out. Concrete and mortars containing 25% RHA as a replacement of cement, exhibited same or better results compared to conventional concrete. Moreover, it leads to substantial cost savings not to mention benefits to the environment. (Rawaid Khana, 2011)

Alternative construction materials derived from agricultural waste, such as rice husk ash (RHA) and groundnut shell ash, have enhanced the sustainability and performance of concrete structures. The use of these ash materials, with their inherent pozzolanic and mineral admixture properties, has received much attention in the construction industry due to their potential benefits. In this experimental investigation, we assessed the attributes of

cement paste incorporating RHA as a pozzolanic substitute. Various replacement ratios, ranging from 0% to 25% by weight of the binder, were examined at different water-to-binder ratios (0.40, 0.45, 0.50, and 0.55). Cementitious specimens were cast in 50mm x 50mm x 50mm cube molds, cured for seven days, and subjected to compressive strength testing. The findings highlight the impact of water-to-binder ratios and cement replacement levels on the compressive strength of cement paste. Higher water-to-binder ratios were associated with reduced compressive strength in the hardened paste. The optimal cement replacement levels were observed at 15% for the hardened blended paste specimens for all water-to-binder ratios. Two empirical regression models (polynomial and power) were employed to analyze the relationships between the paste's replacement ratios, water-to-binder ratios, and compressive strength. The models revealed consistent findings, with the power model demonstrating an inverse relationship between compressive strength and water-to-binder ratios, while the polynomial model's coefficients indicated a positive correlation between replacement ratios and compressive strength. (Alieu Jallow, 2024)

There are both economical and practical benefits to employing industrial and agricultural wastes in addition to more traditional building materials, despite the fact that their use has historically led to issues with pollution and waste management. Since the manufacture of one ton of ordinary Portland cement (OPC) produces nearly one ton of CO₂, the demand for cement has surged in the last several decades, posing a serious ecological threat. The cement and building industries are linked to serious air pollution and harm to human health. As a result, governments and environmentalists have mandated the use of more environmentally friendly supplemental cementing materials in order to strictly regulate emission rates. Massive amounts of rice husk are harvested as a by-product material from the rice plant. The wastes have cheap transportation costs because they are typically easily accessible locally and have no commercial use. The woody coating that envelops the kernel or grain is called rice husk ash (RHA), and it is composed of two

interlocking portions. Husk is a byproduct of yielding grain since it has to be manually removed by threshing or milling after rice is harvested. Wastes from the rice business, such as rice husks, are usually disposed of in the open, harming the environment and providing no economic advantages. Research on the application of rice husk ash (RHA) in concrete is crucial due to its potential to enhance concrete properties and reduce environmental impact. The potential of RHA for waste management and the construction industry is demonstrated by a thorough examination of the potential benefits and applications of rice husk ash in concrete, supporting research studies as well as practical applications in building and environmental projects. (Ritesh Jain, 2024)

A circular economy based on symbiotic relationships among sectors, where the waste from one is resource to another, holds promise for cost-effective and sustainable production. This research explores such a model for the agriculture, energy, and construction sectors in California. Here, we develop new an understanding for the synergistic utilization mechanisms for rice hull, a byproduct from rice production, as a feedstock for electricity generation and rice hull ash (RHA) used as a supplementary cementitious material in concrete. A suite of methods including experimental analysis, techno-economic analysis (TEA), and life-cycle assessment (LCA) were applied to estimate the cost and environmental performance of the system. TEA results showed that the electricity price required for break even on expenses without selling RHA is \$0.07/kWh, lower than the market price. As such, RHA may be available at little to no cost to concrete producers. Our experimental results showed the viability of RHA to be used as a supplementary cementitious material, meaning it can replace a portion of the cement used in concrete. LCA results showed that replacing 15% of cement with RHA in concrete can reduce carbon dioxide equivalent (CO_2e) emissions by 15% while still meeting material performance targets. While the substitution rate of RHA for cement may be modest, RHA generated from California alone could mitigate 0.2% of total CO_2e from the entire cement production sector in the

United States and 1%

in California. (Jin Wook Ro, 2024)

Cement manufacturing and utilization is one of the majorly responsible factors for global CO_2 emissions. In light of sustainability and climate change concerns, it is essential to find alternative solutions to reduce the carbon footprint of cement. Secondary cementitious materials (SCMs) are helpful in reducing carbon emissions from concrete. One such solution is the use of agricultural waste as SCMs to reduce carbon emissions from concrete. Especially rice husk ash (RHA) is a silica-rich, globally available agricultural waste material. The compressive strength (CS) of concrete is important and is used to evaluate the material's strength and durability. Predicting CS using a laboratory method is a costly, time-consuming, and complex process. ML-based prediction models are the modern solution to these problems. In this study, a total of 407 datasets are used to develop an ML-based model by using the ANN algorithm to predict the CS of concrete containing RHA. Cement, coarse aggregates, fine aggregates, water, rice husk ash, superplasticizer, and type of sample are used as input parameters to predict CS at 28 days. Various statistical parameters including correlation coefficient (R), root means square error (RMSE), mean absolute error (MAE), mean absolute percentage error (MAPE), Nash-Sutcliffe (NS), and the a20-index have been used to assess the performance of the developed ANN model. The R and RMSE values of training, validation, and testing samples are 0.9928, 0.9864, and 0.9545, and 1.6471 MPa, 2.7149 MPa, and 4.4334 MPa, respectively. The results obtained from this study have been found to be promising and enrich the available literature. This work will nudge civil engineering and material science researchers toward opting for sustainable computing techniques. However, the study's limitations include the need for additional research into the material's long-term behavior as well as the consideration of other characteristics that may affect its strength, such as environmental conditions like temperature and humidity. (Sharanjit Singh, 2023)

This study conducted an extensive literature review on rice husk ash (RHA), with a focus on its particle properties and their effects on the

fresh, mechanical, and durability properties of concrete when used as a partial cement replacement. The pozzolanic property of RHA is determined by its amorphous silica content, specific surface area, and particle fineness, which can be improved by using controlled combustion and grinding for use in concrete. RHA particle microstructures are typically irregular in shape, with porous structures on the surface, non-uniform in dispersion, and discrete throughout. Because RHA has a finer particle size than cement, the RHA blended cement concrete performs well in terms of fresh properties (workability, consistency, and setting time). Due to the involvement of amorphous silica reactions, the mechanical properties (compressive, tensile, and flexural strength) of RHA-containing concrete increase with increasing RHA content up to a certain optimum level. Furthermore, the use of RHA improved the durability properties of concrete (water absorption, chloride resistance, corrosion resistance, and sulphate resistance). RHA has the potential to replace cement by up to 10% to 20% without compromising the concrete performance due to its high pozzolanic properties. The use of RHA as a partial cement replacement in concrete can thus provide additional environmental benefits, such as resource conservation and agricultural waste management, while also contributing to a circular economy in the construction industry. (Solomon Asrat Endale, 2022)

The purpose of this study was to investigate the properties of Rice Husk Ash (RHA) as a partial cement replacement material in concrete production based on analysis of its contribution to strength in comparison with Ordinary Portland Cement (OPC). The analysis was focused on: the chemical properties of RHA, workability, density, compressive strength, and tensile strength of concrete. The RHA was obtained from Mwea, Kirinyaga County, Kenya and burned in a kiln to produce white ash which was tested. Chemical analysis to determine the pozzolanic properties of RHA was done using the Gravimetric method, Flame Photometry and Atomic Absorption Spectroscopy while particle size distribution of RHA was carried out using sieve analysis and hydrometer analysis. Concrete mixes with different ratios of OPC to

RHA binder were cast into cuboid and cylindrical samples. The binder was made by replacing OPC with RHA at intervals of 10% by mass to a maximum of 50% replacement. A binder, sand, and ballast ratio of 1:1.5:3 was maintained with a constant water-cement ratio of 0.6. The cast samples were subjected to water curing on the third day at room temperature. Workability tests were performed on fresh concrete while compressive strength tests and tensile strength tests were performed on hardened concrete in all the mixes. The results were compared with OPC concrete. Results indicated that Kenyan RHA has high silica, alumina, and iron oxide content of about 92%. The workability slightly improves with 10% partial replacement of OPC with RHA but decreases with further addition of RHA. It was also deduced that the optimal binder mix was 10% partial replacement of OPC with RHA however the compressive strength was lower than the OPC concrete by 2.3%. The tensile strength of concrete increased with the addition of RHA up to an optimum of 10%. (John Alex Muthuri Njagi, 2022)

To reduce the consumption of cement in construction industry has been a hot area of consideration now days due to high evolution of CO₂ gases during its production. Since decades efforts are made to replace cement with cementitious materials; minerals, agricultural, industrial by products etc. A few are fly ash, ground granulated blast furnace slag, silica fume, rice husk ash etc. These cementitious materials are often adopted as partial replacement of cement. However, their effectiveness and suitability as cementitious material depends upon their properties and the source of the production. Pakistan is an agricultural country and one of the major crops is Rice crop. It produces a substantial amount of rice husk during the processing of the rice. A substantial amount of Rice Husk Ash (RHA) is produced on the burning of rice husk used as fuel in the rice mills while generating steam for parboiling process of rice grains. This ash causes the environmental problems also if not dumped properly. RHA is believed to have siliceous properties which may be used as supplementary cementitious material in concrete. As the suitability of supplementary cementitious

materials is dependent upon the source of rice husk, temperature of burning of husk, its fineness and other properties. This study is focused on to determine the effect of rice husk ash produced by burning of the rice husk obtained from the local rice mills. Experimental investigation carried includes the determination of workability and compressive strength of concrete with different dosage of RHA from 5% to 30% with an increment of 5% tested at 1day, 3days, 7days and 28 days of the age of concrete. The results are compared with corresponding concrete without RHA and tested at the same ages. The results show the reduction in both the parameter; workability and compressive strength due to RHA particularly at its higher dosage beyond 10% by weight of cement. (Aftab Hameed Memon, 2022)

Over the last decade, there has been a surge in research into possible cement substitute materials in concrete that are environmentally friendly, cost-effective, and socially beneficial. The alternatives include industrial and agricultural wastes, and their potential advantages can be achieved through recycling, repurposing, and renewing processes. With the use of these wastes as additional and replacement materials, significant energy savings and a reduction in cement use can be achieved, which helps to reduce carbon dioxide (CO₂) emissions in the environment. Therefore, the use of rice husk ash (RHA) and wheat straw ash (WSA) as ternary cementitious material (TCM) in concrete can help reduce the impact on the environment and minimize the use of Portland cement (PC) in the concrete mixture. This research work is performed on the concrete blended with 0%, 5%, 10%, 15%, and 20% of RHA and WSA as TCM in the mixture. However, the purpose of this experimental work is to investigate the influence of RHA and WSA as TCM on the fresh (slump), physical (water absorption and density), and hardened properties (compressive strength, splitting tensile strength, and flexural strength) and drying shrinkage of concrete. In this regard, a total of 240 concrete samples (cylinders, cubes, and beams) were prepared with 1:2:4 mix proportions at 0.50 water-cement ratio and cured at 7 and 28 days, respectively. Moreover, the workability of green concrete is getting

reduced as the quantity of TCM increases in the mixture. Besides, the compressive strength, splitting tensile strength, and flexural strength are enhanced by 12.65%, 9.40%, and 9.46% at 10% of TCM (5% RHA and 5% WSA) on 28 days consistently. Furthermore, the density and water absorption of concrete are reduced with the increase in the dosages of TCM on 28 days, respectively. In addition, the drying shrinkage is reduced with the increase in the quantity of TCM in concrete. (Naraindas Bheel, 2021)

Supplementary cementitious materials (SCM) can reduce the total amount of Portland cement clinker in concrete production. Rice husk ashes (RHA) can be converted from an agricultural by-product to a high-performance concrete constituent due to a high amount of reactive silica with pozzolanic properties if they are burnt under controlled conditions. The way and duration of combustion, the cooling process as well as the temperature have an effect on the silica form and thus, the chemical and physical performance of the RHA. Various studies on the best combustion technique have been published to investigate the ideal combustion techniques. Yet, the process mostly took place under laboratory conditions. Investigating the difference between the performance of RHA produced in a rural environment and laboratory conditions is useful for the assessment and future enhancement of RHA production, and its application both as building material, for example in rural areas where it is sourced in large quantities, and as additive for high performance concrete. Thus, the paper presents a comparison between RHA produced under rudimentary conditions in a self-made furnace in the rural Bagamoyo, Tanzania and under controlled laboratory conditions at the Technical University of Munich, Germany, with different combustion methods and temperatures. In a second step, RHA was ground to reach particle size distributions comparable to cement. In a third step, cement pastes were prepared with 10%, 20% and 40% of cement replacement, and compared to the performance of plain and fly ash blended cement pastes. The results show that controlled burning conditions around 650 °C lead to high reactivity of silica and, therefore, to good

performance as SCM. However, also the RHA burnt under less controlled conditions in the field provided reasonably good properties, if the process took place with proper burning parameters and adequate grinding. The knowledge can be implemented in the field to improve the final RHA performance as SCM in concrete. (Mareike Thiedeitz, 2020)

In this study, the role of a locally available rice husk ash (RHA) in reducing early-age shrinkage of high-performance concrete (HPC) after evaluating its pozzolanic reactivity was evaluated. The X-ray diffraction (XRD) and energy dispersive X-ray (EDX) analyses were performed after burning rice husk to 700 and 950°C. Presence of relatively high deposits of amorphous siliceous phases in RHA at 700°C indicated its pozzolanic potential. Subsequently, this RHA was ground to desired fineness, followed by sieving through sieve No. 200. Eventually, the fine RHA was used as a substitute of cement in different percentages (10, 15, and 20%) to evaluate its influence in mitigating autogenous shrinkage in concrete. Prismatic concrete beams (100 × 100 × 800 mm) were cast to measure autogenous shrinkage along with cylinders (150 mm dia. x 300 mm height) to test compressive strength of concrete. The results indicated a slight increase in compression strength with addition of 10% RHA, which however, reversed and slightly reduced in concretes containing 15 and 20% RHA. Unlike strength results, the trend of autogenous shrinkage was rather uniform as the rate as well as the amount of early-age autogenous shrinkage continued to decrease with increasing percentage of RHA. Moreover, despite of reduced rate during first 24 h, thereafter, the effect of 20% RHA on further reduction of autogenous shrinkage was insignificant and ended up only slightly lesser than the 15% RHA concrete at 7 days. Finally, the control cement sand mortar and mortar containing 15% RHA were cast to further validate the pozzolanic reactivity of RHA through scanning electron microscopy (SEM), EDX and thermogravimetric analysis (TGA) tests. An observation of reduced amount of calcium hydroxide (Ca(OH)₂) in RHA mortar samples indicating its excellent pozzolanic potential when used as a partial substitute of

cement in HPC.

(Muhammad Nasir Amin, 2019)

The preliminary and inevitable interest in the use of partial replacements or by products as complementary pozzolanic materials was mostly induced by enforcement of air pollution control resulted from cement production industry. Rise husk is by product taken from rice mill process, with approximately the ratio of 200 kg per one ton of rice, even in high temperature it reduces to 40 kg. This paper presents benefits resulted from various ratios of rice husk ash(RHA) on concrete indicators through 5 mixture plans with proportions of 5, 10, 15, 20 and 25% RHA by weight of cement in addition to 10% micro-silica (MS) to be compared with a reference mixture with 100% Portland cement. Tests results indicated the positive relationship between 15% replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength and durability properties generally gain with addition up to 20%, beyond that is associated with slight decrease in strength parameters by about 4.5%. The same results obtained for water absorption ratios likely to be unfavorable. Chloride ions penetration increased with increase in cement replacement by about 25% relative to the initial values (about less than one fifth). (Seyed Alireza Zareei, 2017)

This work investigates the effects of adding residual rice husk ash (RHA) from South Vietnam, generated when burning rice husk pellets in the boiler, to cement. To improve pozzolanic reactivity, RHA was ground for 1 h. The non-ground RHA and ground RHA were used to test strength activity index according to ASTM C311. The properties of the concrete were investigated, including compressive strength, concrete electrical resistivity, and ultrasonic pulse velocity. Results show that the non-ground RHA can be applied as a pozzolanic material. Decreasing the non-ground RHA average particle size provides a positive effect on the compressive strength of mortar. Compressive strength of cylindrical concrete in the 47–66 MPa range was obtained in this study. The results also indicate that up to 20% of ground RHA could be advantageously blended with cement without adversely affecting

the strength and durability properties of concrete. (Hwang Chao-Lung, 2011)

3. Methodology

Ordinary Portland Cement (OPC) of Grade 43 was used in mix design, it was stored in a dry environment to prevent moisture absorption. River or quarry sand, analyzed for particle size distribution using sieve analysis (IS: 2386) to ensure proper grading. Crushed angular aggregates with a maximum nominal size of 20 mm, sourced from local suppliers and tested for specific gravity and water absorption. Rice Husk Ash (RHA) was collected, burned, and processed to ensure it meets the required pozzolanic properties, Specific gravity of RHA was determined to be 2.28. A total of six concrete mixes were prepared with varying RHA replacement percentages 0%, 2.5%, 5%, 7.5%, 10%, and 15% of the weight of cement. The design mix followed the guidelines for M20 grade concrete, with a minimum cement

content of 320 kg/m³

and a maximum water-cement ratio of 0.45. Concrete cylinders of size 12" height and 6" diameter were casted and cured using potable water with a pH value around 7. Curing was conducted for 14 and 28 days to evaluate strength development. Workability was Assessed using the slump cone test to determine the consistency of the concrete mix. Compressive Strength Tests were conducted using a 3000 kN Compression Testing Machine at 14 and 28 days. Split Tensile Strength was Evaluated using cylindrical specimens. Flexural Strength was Tested using beam specimens to assess the bending performance of the concrete. Ultrasonic Pulse Velocity was Conducted to evaluate the quality and integrity of the concrete. After all necessary tests were performed, Results were analyzed to determine the optimal percentage of RHA for enhancing mechanical properties while maintaining workability. Chemrite 520 as a Superplasticizers (1% by weight) was added.

3.1 Methodology flowchart

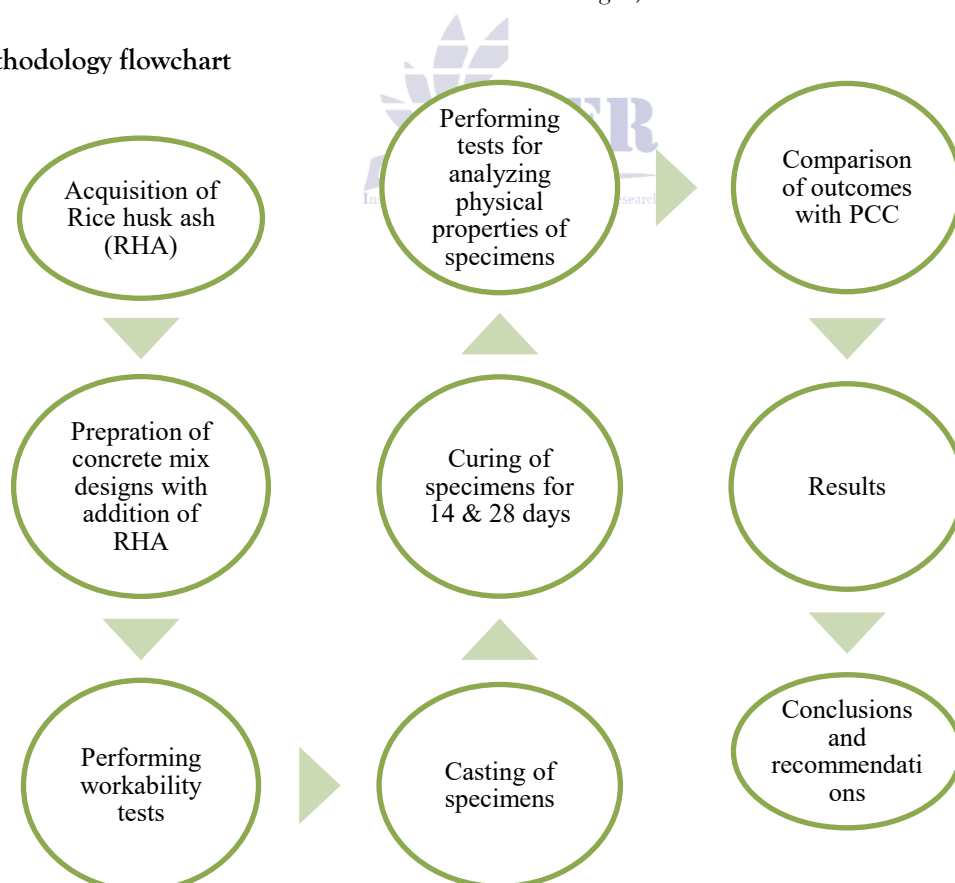


Figure 1 Methodology Flow Chart

3.2 Procedure:**Sieve analysis for particle size distribution:**

To determine the particle size distribution of aggregates, sand, sieve analysis was performed. It ensured that the material satisfies construction standards and aids in size classification. Important details regarding the material's gradation, which affects the workability, strength, and durability of soil or concrete structures, are also revealed by the test.

Procedure:

- 1000g of coarse aggregate and 1000g of fine aggregate were taken.
- The samples were dried in an oven at $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$ until a constant weight was achieved, and then they were allowed to cool.
- The dried samples were weighed accurately and the total weight was recorded.
- The sieves were arranged in order:
- for coarse aggregates (25mm, 20mm, 16mm, 12.5mm, 10mm, 4.75mm, pan)
- For fine aggregates (4.75mm, 2.36mm, 1.18mm, 600 μm , 300 μm , 150 μm , pan).

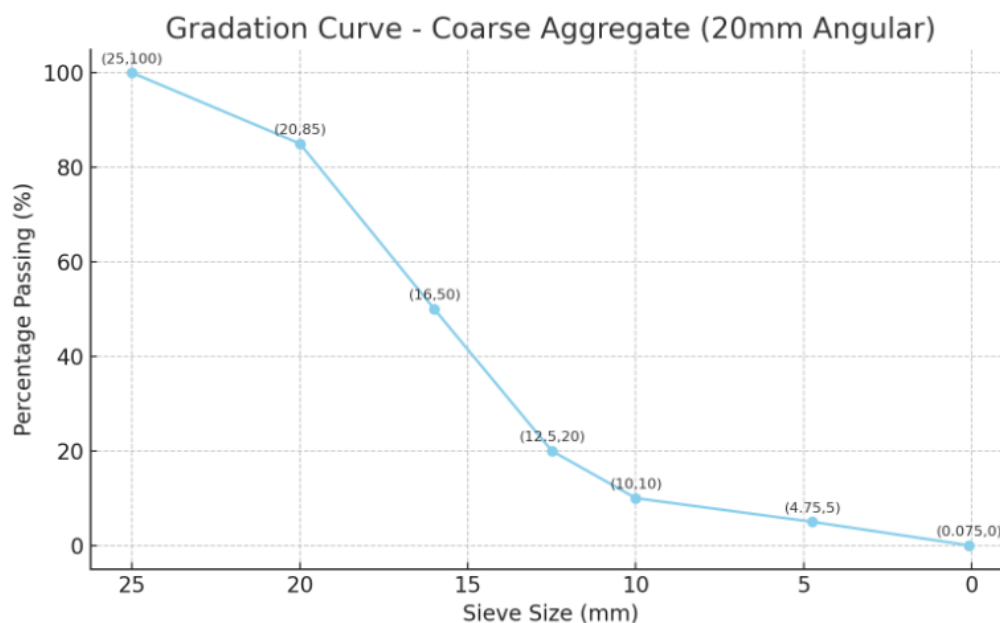
- The sample was placed on the top sieve and covered.
- The sieves were shaken either manually for 10–15 minutes.
- After sieving, each sieve was carefully removed and the material retained on each sieve was weighed.
- The weight retained on each sieve was recorded.
- The percentage retained on each sieve was calculated by dividing the weight retained by the total weight and multiplying by 100.
- The cumulative percentage retained was determined by successively adding the percentages retained.
- The percentage passing for each sieve was obtained by subtracting the cumulative percentage retained from 100.
- A gradation curve was plotted by taking sieve size on the x-axis and percentage passing on the y-axis.

Observation Table for sieve analysis of coarse aggregates:

Table 1 Sieve analysis of coarse aggregates

Sieve Size (mm)	Mass Retained (g)	% Retained	Cumulative % Retained	% Passing
25	0	0	0	100
20	150	15	15	85
16	350	35	50	50
12.5	300	30	80	20
10	100	10	90	10
4.75	50	5	95	5
Pan	50	5	100	0

Gradation Curve of coarse aggregates:



Graph 1 Gradation curve for coarse aggregates

Observation Table for sieve analysis of fine aggregates:

Table 2 Sieve analysis of fine aggregates

Sieve Size (mm/ μm)	Mass Retained (g)	% Retained	Cumulative % Retained	% Passing
4.75	20	2	2	98
2.36	50	5	7	93
1.18	100	10	17	83
600 μm	200	20	37	63
300 μm	300	30	67	33
150 μm	250	25	92	8
Pan	80	8	100	0

Gradation Curve of fine aggregates:

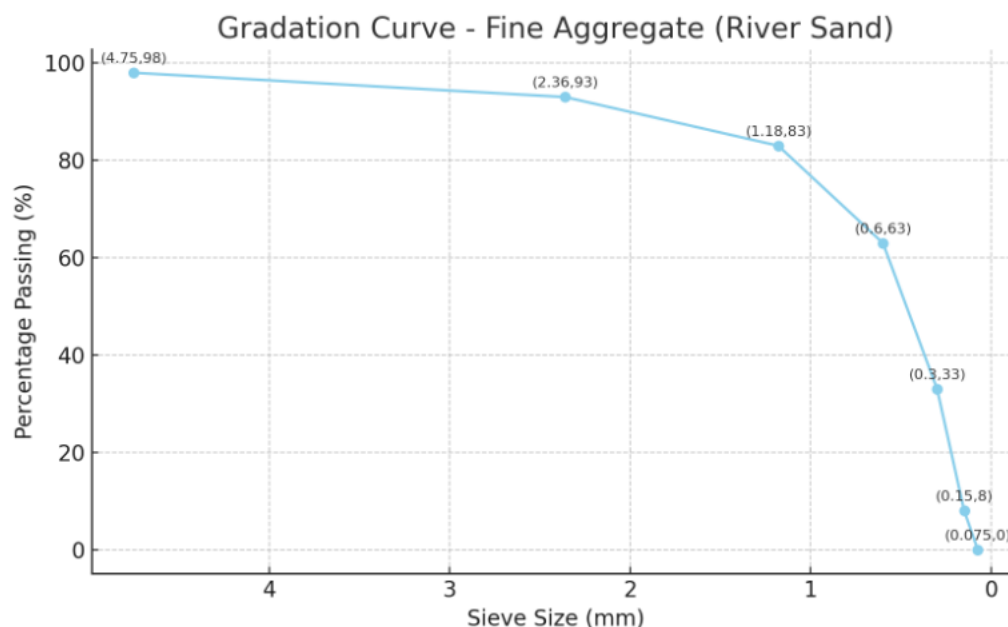


Figure 2 Gradation curve for fine aggregates

3.2.1 Preparation of concrete mix:

Concrete mixture was prepared properly according to the concrete mix design and cement was replaced with Rice husk ash (RHA) at certain percentages of 0%, 2.5%, 5%, 7.5%, 10%, and 15% and chemrite 520 was used as a superplasticizer for each specimen's concrete mix.

Materials needed:

- Rice husk ash (RHA)
- Cement (Grade 43)
- Coarse aggregate
- Fine aggregate
- Water
- super plasticizer (chemrite 520)

Preparation of concrete mixture:

Measure the Materials:

The quantity of aggregates, sand, RHA, Chemrite 520 and cement was determined according to the mix design.

Dry Mix:

At first Cement and RHA were mixed dry until a consistent color was reached. Then coarse and fine aggregates were added with addition of chemrite 520.

Water Addition:

Water was slowly poured into the dry mixture while mixing constantly. It was made sure that the water is added in moderation according to mix design so as not to oversaturate and lose the appropriate consistency. Water to cement ratio was 0.45.

Mixing:

Concrete was mixed continuously until it reached at a consistent, usable consistency.



Figure 3 Rice Husk Ash



Figure 4 Chemrite 520 (Superplasticizer)



Figure 5 preparation of mix design

Testing:

Concrete's other qualities and workability were evaluated with slump test according to water to cement ratio to ensure it meets the required standards. In our performed test the result was true slump.



Figure 6 slump test

Table 3 Observations from slump tests

Percentage of RHA	Slump height (mm)
0	91
2.5	89
5	83
7.5	79
10	75
15	71

3.2.2 Casting of concrete:

After preparation of concrete mixture of every mix design of M20 from RHA0 to RHA15 the concrete specimens were casted for testing purposes. A total of 24 specimens having size 150mm*150mm*150mm were casted. While

casting the specimens it was made sure that concrete was being placed correctly in molds and no voids are left in casting process, for this purpose vibrators were used in controlled environment.



Figure 7 Casting of concrete specimens



Figure 8 After removing the specimens from molds

3.2.3 Curing process:

After the concrete specimens were hardened in molds they were taken out of molds and was submerged in water tubs for process of curing. For this purpose, specimens were divided into 2

categories according to their age cycle of 14 and 28 days. When the curing process was according to specimen's age cycle then further tests were performed to analyze the physical properties of concrete mix with Rice Ash Husk (RHA).



Figure 9 Curing process of specimens

3.2.3 Compressive strength:

The compressive strength test of the RHA and plain cement concrete specimens was observed and analyzed with the help of testing machine. Because concrete is reliable in compression so it was important to observe the compressive strength of the concrete specimens made out of concrete mixed with RHA and these results were compared with the compressive strength of the plain cement concrete specimen cured at 14 and 28 days.

Procedure:

- The cylinders were taken out of the curing tub and the moisture was completely let dry.
- Then one by one concrete cylinders were positioned at lowest platen at testing apparatus.
- Load was applied on the specimens till the points where they failed.
- And the readings were observed and noted.

3.2.3.1 Compressive strength of 14 days cured specimens:

At first the compressive strength test was performed at 14 days cured plain cement concrete's specimen to set a benchmark for comparison with other RHA concrete's

specimens. It was observed that the PCC cylinder failed at the maximum load of 222KN and Compressive strength was 10.96MPa. Others observations were compared with this value.



Figure 10 Compressive strength of PCC

Compressive strength of Specimen mixed with 2.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 2.5% of RHA and superplasticizer Chemrite

520 tend to failed at the maximum load of 279KN and compressive strength was 15.35MPa. Which was higher as compared to PCC.



Figure 11 Compressive strength of 2.5% RHA specimen

Compressive strength of Specimen mixed with 5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 5% of RHA and superplasticizer Chemrite 520,

failed at the maximum load of 297KN and its compressive strength was 16.86.



Figure 12 Compressive strength Of 5% RHA concrete specimen

Compressive strength of Specimen mixed with 7.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 7% of RHA and superplasticizer Chemrite 520,

failed at the maximum load of 213KN and compressive strength was 16.72 MPa. Its compressive strength was less as compared to 5% RHA concrete specimen and PCC.



Figure 13 Compressive strength Of 7.5% RHA concrete specimen

Compressive strength of Specimen mixed with 10% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 10% of RHA and superplasticizer Chemrite 520,

failed at the maximum load of 204KN and its compressive strength was 15.93MPa. Its compressive strength was less as compared to 7.5% RHA concrete specimen and PCC.



Figure 14 Compressive strength of 10% RHA concrete specimen

Compressive strength of Specimen mixed with 15% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 15% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 139KN and its

compressive strength

was 13.71MPa. Its compressive strength was less as compared to 10% RHA concrete specimen and PCC.



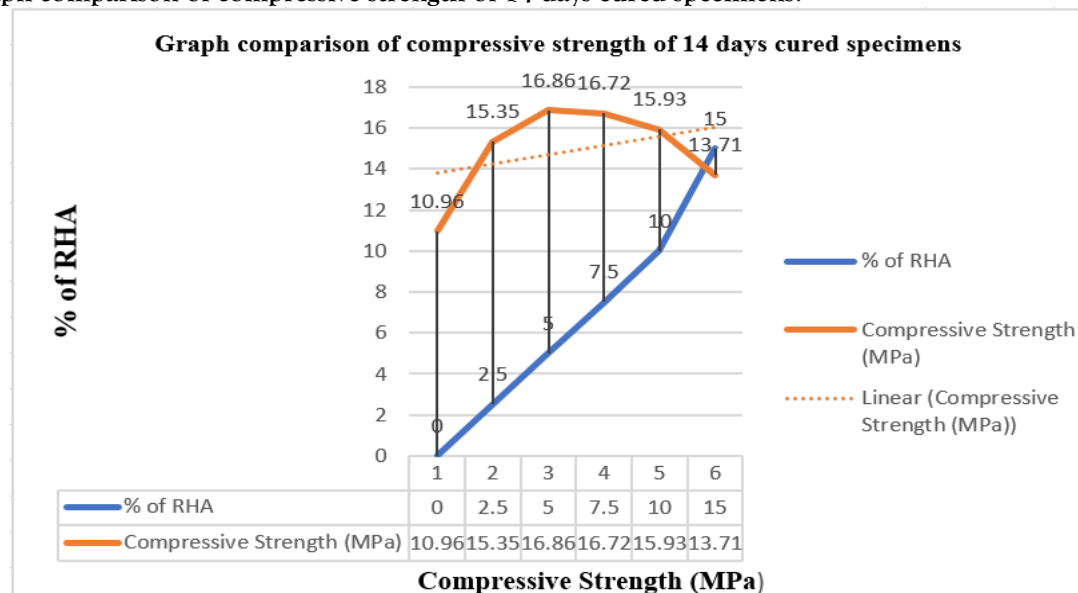
Figure 15 Compressive strength of 15% RHA concrete specimen

Observation table:

% of RHA	Peak Load (KN)	Compressive strength (MPa)
0	222	10.96
2.5	279	15.35
5	297	16.86
7.5	213	16.72
10	204	15.93
15	139	13.71

Table 4 Compressive strength observations of 14 days cured specimens

Graph comparison of compressive strength of 14 days cured specimens:



Graph 2 14 days cured RHA and PCC specimens' Compressive strength

3.2.3.2 Compressive strength of 28 days cured specimens:

At first the compressive strength test was performed at 28 days cured plain cement concrete's specimen to set a benchmark for comparison with other RHA concrete's specimens. It was observed that the PCC cylinder failed at the maximum load of 422KN and its strength was 20.82MPa. Others observations were compared with this value.

Compressive strength of Specimen mixed with 2.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 2.5% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 530KN and its strength was 29.15MPa. Its compressive strength was higher as compared to PCC specimen.

Compressive strength of Specimen mixed with 5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 5% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 563KN and its strength was 32.28MPa. Its compressive strength was higher as compared to 2.5% RHA mix design and PCC specimen.

Compressive strength of Specimen mixed with 7.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 7.5% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 403KN and its strength was 31.74MPa. Its compressive strength was less as compared to all previous specimens.

Compressive strength of Specimen mixed with 10% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 10% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 387KN and its strength was 30.18MPa. Its compressive strength was less as compared to all previous specimens.

Compressive strength of Specimen mixed with 15% of RHA and Chemrite 520:

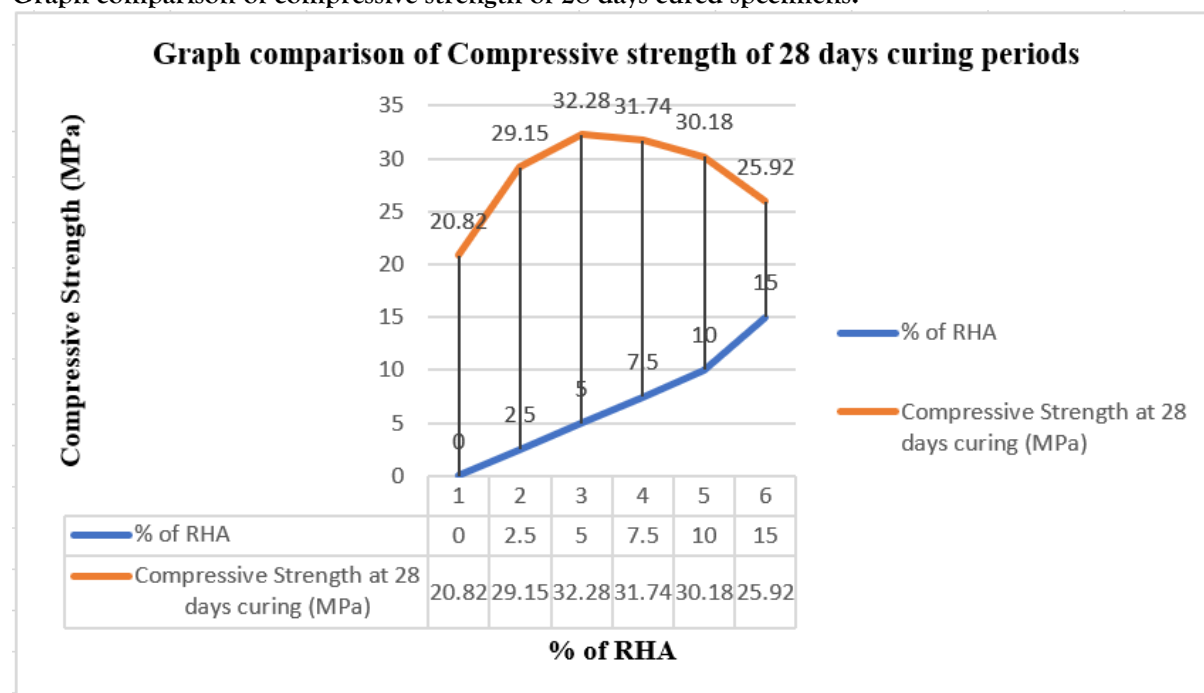
The cylinder which was prepared with mixing of 15% of RHA and superplasticizer Chemrite 520, failed at the maximum load of 263KN and its strength was 25.92MPa. Its compressive strength was less as compared to all previous specimens.

Observation table:

% of RHA	Peak load (KN)	Compressive strength (MPa)
0	422	20.82
2.5	530	29.15
5	563	32.28
7.5	403	31.74
10	387	30.18
15	263	25.92

Table 5 Compressive strength observations of 28 days cured specimens

Graph comparison of compressive strength of 28 days cured specimens:



Graph 3 28 days cured RHA and PCC specimens' Compressive strength

3.2.4 Split Tensile strength:

Split tensile strength was performed to determine the tensile strength of concrete specimens prepared with addition of Rice husk ash and superplasticizer (chemrite 520) and having size 150mm*150mm*150mm. It was important to assess the indirect tensile strength of concrete specimens to observe and analyze the behavior of Rice husk ash concrete under tension such as in case of cracking and splitting. Then the tests results were compared with split tensile strength of plain cement concrete specimen.

Procedure:

- The concrete specimens were taken out of curing tank and was left to dry moisture at optimum room temperature.
- After the moisture was dried. The specimens were placed one by one in

compressive strength testing apparatus along their length.

- Load was applied uniformly and shocked free till the specimens fail.
- The maximum stress at which the specimens failed were observed and noted. Manual calculations were done and results were compared with plain cement concrete specimens.
- Test was performed at different cured ages of Rice husk ash concrete's specimens.

Split Tensile strength of plain cement concrete specimen cured for 14 days:

At first the tensile strength test was performed at plain cement concrete's specimen to set a benchmark for comparison with other RHA mixed concrete's specimens. It was observed that plain cement concrete's specimen failed at the peak load of 40KN and maximum stress of 0.54 MPa.



Figure 16 Split Tensile strength of Plain cement concrete specimen

Split Tensile strength of Specimen mixed with 2.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 2.5% of RHA and superplasticizer Chemrite

520, failed at the peak load of 59KN and maximum stress of 0.80 MPa. Its tensile strength was lower as compared to PCC specimen.



Figure 17 Split Tensile strength of 2.5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 5% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 90KN and maximum stress of 1.23 MPa. Its tensile strength was higher as compared to previous all specimens.



Figure 18 Split Tensile strength of 5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 7.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 7.5% of RHA and superplasticizer Chemrite

520, failed at the peak load of 20KN and maximum stress of 0.204 MPa. Its tensile strength was less as compared to previous all specimens.



Figure 19 Split Tensile strength of 7.5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 10% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 10% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 64KN and maximum stress of 0.88 MPa. Its tensile strength was less as compared to previous all specimens.



Figure 20 Split Tensile strength of 10% RHA concrete specimen

Split Tensile strength of Specimen mixed with 15% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 15% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 21KN and maximum stress of 0.287 MPa. Its tensile strength was less as compared to previous all specimens.



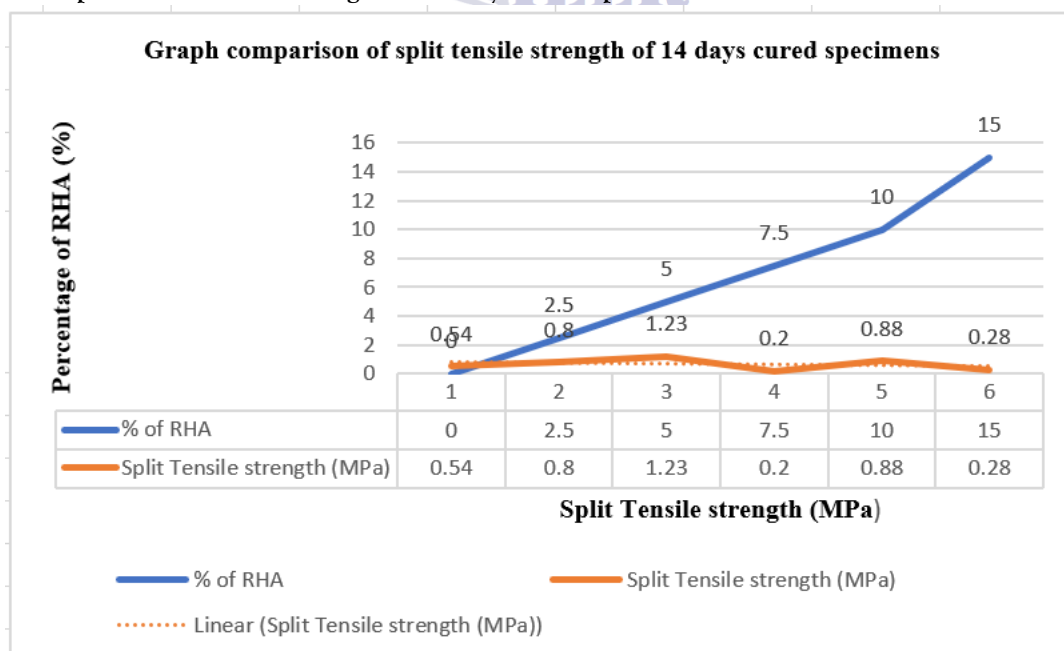
Figure 21 Split Tensile strength of 15% RHA concrete specimen

Observation table:

% of RHA	Curing period (days)	Peak load (KN)	Split Tensile strength (MPa)
0	14	40	0.54
2.5	14	59	0.8
5	14	90	1.23
7.5	14	20	0.20
10	14	64	0.88
15	14	21	0.28

Table 6 Split Tensile strength observations of 14 days cured specimens

Graph comparison of tensile strength of 14 days cured specimens:



Graph 4 14 days cured RHA and PCC specimens' Split tensile strength

Split Tensile strength of plain cement concrete specimen cured for 28 days:

At first the tensile strength test was performed at plain cement concrete's specimen to set a benchmark for comparison with other RHA

mixed concrete's specimens. It was observed that plain cement concrete's specimen cured for 28 days was failed at the peak load of 100KN and maximum stress of 1.37 MPa.



Figure 22 Split Tensile strength of Plain cement concrete specimen

Split Tensile strength of Specimen mixed with 2.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 2.5% of RHA and superplasticizer Chemrite

520, failed at the peak load of 162KN and maximum stress of 2.21 MPa. Its tensile strength was higher as compared to PCC specimen.



Figure 23 Split Tensile strength of 2.5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 5% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 115KN and maximum stress of 1.57 MPa. Its tensile strength was higher as compared to PCC specimen and lower than 2.5% RHA specimen.



Figure 24 Split Tensile strength of 5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 7.5% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 7.5% of RHA and superplasticizer Chemrite

520, failed at the peak load of 98kN and maximum stress of 1.34 MPa. Its split tensile strength was lower as compared to previously tested specimens.



Figure 25 Split Tensile strength of 7.5% RHA concrete specimen

Split Tensile strength of Specimen mixed with 10% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 10% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 70kN and maximum stress of 0.47 MPa. Its split tensile strength was lower as compared to previously tested specimens.



Figure 26 Split Tensile strength of 10% RHA concrete specimen

Split Tensile strength of Specimen mixed with 15% of RHA and Chemrite 520:

The cylinder which was prepared with mixing of 15% of RHA and superplasticizer Chemrite 520,

failed at the peak load of 100KN and maximum stress of 1.37 MPa. Its split tensile strength was equal to plain cement concrete specimen.



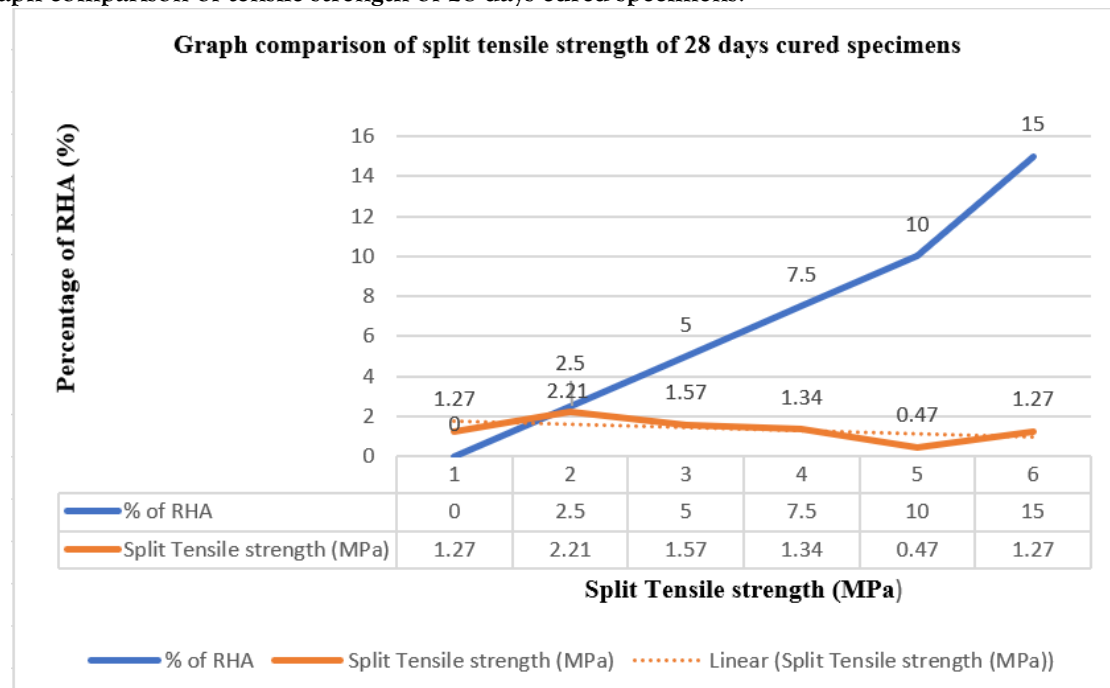
Figure 27 Split Tensile strength of 15% RHA concrete specimen

Observation table:

% of RHA	Curing period (days)	Peak load (KN)	Split Tensile strength (MPa)
0	28	100	1.27
2.5	28	162	2.21
5	28	115	1.57
7.5	28	98	1.34
10	28	70	0.47
15	28	100	1.27

Table 7 Split Tensile strength observations of 28 days cured specimens

Graph comparison of tensile strength of 28 days cured specimens:



Graph 5 28 days cured RHA and PCC specimens' Split tensile strength

3.2.5 Flexural strength test:

Flexural strength test is important to evaluate to tensile strength or point of rupture for concrete specimens. This test was performed at 12 beams of size 450mm * 150mm * 150mm. All these specimens were having different concrete mix design and percentage of Rice husk ash. The results were compared with plain cement concrete's flexural strength.

Place of testing:

The testing was done outside the institute at the "Arab Civil Engineering Study Saudi Arabia, Riyadh".

Procedure:

- Specimens were removed from the water tank and moisture was dried.
- Dimensions of specimens were measured accurately.
- Specimens were placed accurately at supporting rollers in testing apparatus.
- It was ensured that span length is appropriate for the beam length.
- Load was applied continuously and uniformly without shock until specimens were failed.
- The readings were noted and calculations were done manually.
- Flexural strength test was performed at third point loading.
- Tests were performed at different mix design's specimens to determine how flexural strength changes over time at different cycles of curing ages.

3.2.5.2 Flexural strength of 14 days cured specimens:

At first the flexural tensile strength of plain cement concrete's specimen was tested. It failed at the peak load of 25.7KN and its flexural strength was 5.17MPa. It was the benchmark to compare with other specimens of this cured age cycle.

Flexural strength of 2.5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 23.8KN and its flexural strength was 4.76MPa. Its strength was lower than the PCC specimen.

Flexural strength of 5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 26.7KN and its flexural strength was 5.34MPa. Its strength was higher than the 2.5% RHA and PCC specimens.

Flexural strength of 7.5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 24.6 KN and its flexural strength was 4.92MPa. Its strength was lower than PCC, 5% RHA specimens and higher than 2.5% RHA Specimen.

Flexural strength of 10% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 22.3KN and its flexural strength was 4.46MPa. Its strength was lower than PCC and every other RHA mixed specimen.



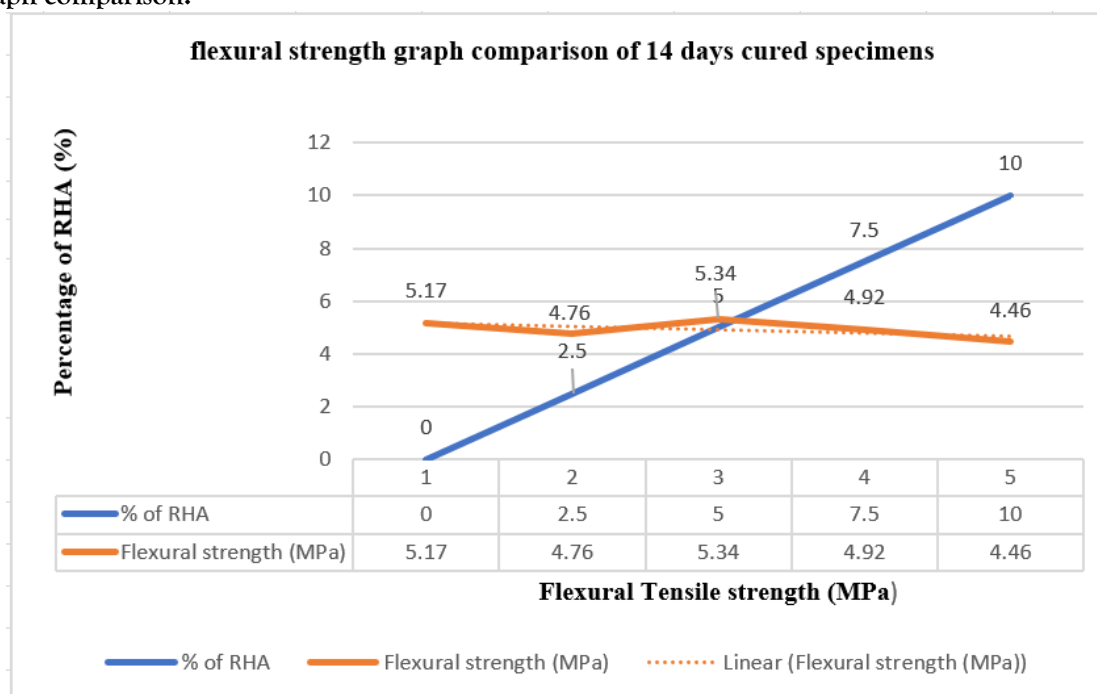
Figure 28 Point load beam test for 14 days cured specimen

Flexural strength observations and calculations for 14 days cured specimens:

% of RHA	Curing Period	Peak Load (KN)	Flexural strength (MPa)
0	14	25.7	5.17
2.5	14	23.8	4.76
5	14	26.7	5.34
7.5	14	24.6	4.92
10	14	22.3	4.46

Table 8 Flexural strength observations for 14 days cured specimens

Graph comparison:



Graph 6 flexural strength graph comparison of 14 days cured specimens

3.2.5.3 Flexural strength of 28 days cured specimens

At first the flexural tensile strength of plain cement concrete's specimen was tested. It failed at the peak load of 39.5KN and its flexural strength was 7.92MPa. It was the benchmark to compare with other specimens of this cured age cycle.

Flexural strength of 2.5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 40.8KN and its flexural strength was 8.23MPa. Its strength was higher than the PCC specimen.

Flexural strength of 5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 41.2KN and its flexural strength was 8.26MPa. Its strength was higher than the 2.5% RHA and PCC specimens.

Flexural strength of 7.5% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 40.3KN and its flexural strength was 8.02MPa. Its strength was lower than 2.5%RHA and 5% RHA specimens and higher than PCC specimen.

Flexural strength of 10% RHA specimen and 1% chemrite 520:

This specimen failed at the peak load of 38.1KN and its flexural strength was 7.62MPa. Its

strength was lower than PCC and every other RHA mixed specimen.



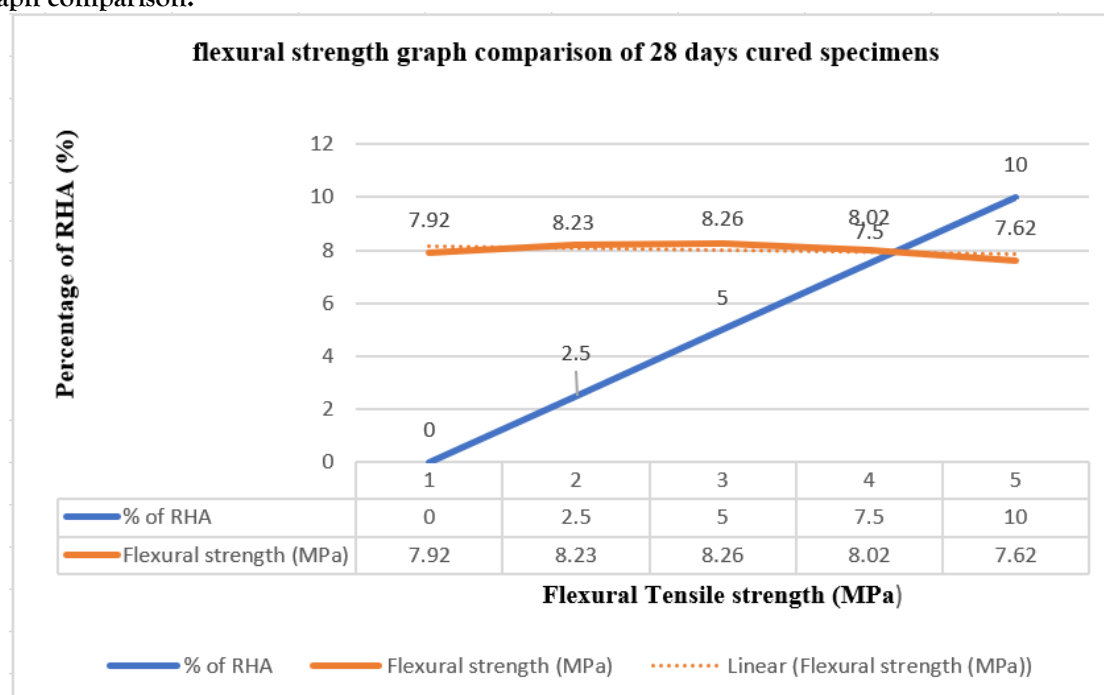
Figure 29 Point load beam test for 28 days cured specimen

Flexural strength observations and calculations for 28 days cured specimens:

% of RHA	Curing Period	Peak Load (KN)	Flexural strength (MPa)
0	28	39.5	7.92
2.5	28	40.8	8.23
5	28	41.2	8.26
7.5	28	40.3	8.02
10	28	38.1	7.62

Table 9 Flexural strength observations for 28 days cured specimens

Graph comparison:



Graph 7 flexural strength graph comparison of 28 days cured specimens

3.2.6 Ultrasonic pulse velocity test:

The Ultrasonic Pulse Velocity (UPV) test was performed to evaluate the quality, uniformity of concrete without causing any damage to the structure. It helped in detecting internal flaws such as cracks, voids, honeycombing, or changes in material properties. By measuring the speed at which ultrasonic waves pass through the concrete, density and elasticity of RHA concrete specimens were assessed, which are directly related to its strength and durability

Procedure:

- Placed the concrete cylinder horizontally on a non-reflective, vibration-free surface like foam or rubber mat.
- Placed one transducer on each end of the 12-inch cylinder (transmitter on one end, receiver on the opposite end). It was Ensured firm and stable contact using light pressure.

- Pressed the trigger button on the UPV device to send an ultrasonic pulse from the transmitting transducer.
- The receiver detected the pulse at the other end and the transit time (in microseconds) was displayed on the UPV device for each specimen.
- Readings were observed and noted.
- UPV test was performed on both 14 and 28 days cured Plain and RHA concrete specimens.

UPV test performed on 14 days cured specimen's observations and calculations:

The UPV test was performed on 14 days cured specimens and it was observed that plain cement concrete showed the best result as compared to RHA mixed specimens and at other hand result of the specimen of 5% RHA mixed specimen was satisfied as it was closed to PCC specimen.



Figure 30 UPV test performed on 14 days cured specimens

Calculation table:

% of RHA	Time (mS)	Distance (inch)	Pulse velocity (km/s)
0	72	12	4.2
2.5	79	12	3.8
5	74	12	4.2
7.5	76	12	4
10	79.4	12	3.8
15	83	12	3.6

Table 10 UPV of 14 days cured specimens

UPV test performed on 28 days cured specimen's observations and calculations:

The UPV test was performed on 28 days cured specimens and it was observed that 15% RHA concrete specimens showed the best result as

compared to PCC

and other RHA mixed specimens and at other hand 5% RHA mixed specimen was satisfied as it was closed to 15% RHA specimen.



Figure 31 UPV test performed on 28 days cured PCC specimens



Figure 32 UPV test performed on 28 days cured specimens with 2.5% RHA



Figure 33 UPV test performed on 28 days cured specimens with 5% RHA



Figure 34 UPV test performed on 28 days cured specimens with 7.5% RHA



Figure 35 UPV test performed on 28 days cured specimens with 10% RHA



Figure 36 UPV test performed on 28 days cured specimens with 15% RHA

Calculation table:

Table 11 UPV of 28 days cured specimens

% of RHA	Time (mS)	Distance (inch)	Pulse velocity (km/s)
0	96	12	3.17
2.5	95.2	12	3.20
5	91.4	12	3.33
7.5	95.4	12	3.19
10	92.7	12	3.28
15	83.5	12	3.65

4. Results, Discussions and Comparisons

This chapter describes the detailed results and discussions performed on concrete specimens. Every analysis is result of tests performed in laboratories. After all the tests were completed, a detailed comparison was done between plain cement concrete specimen and the specimens which were casted by adding RHA at different percentages. This comparison will show us that if the qualities of rice husk ash concrete's specimens are enhanced or not.

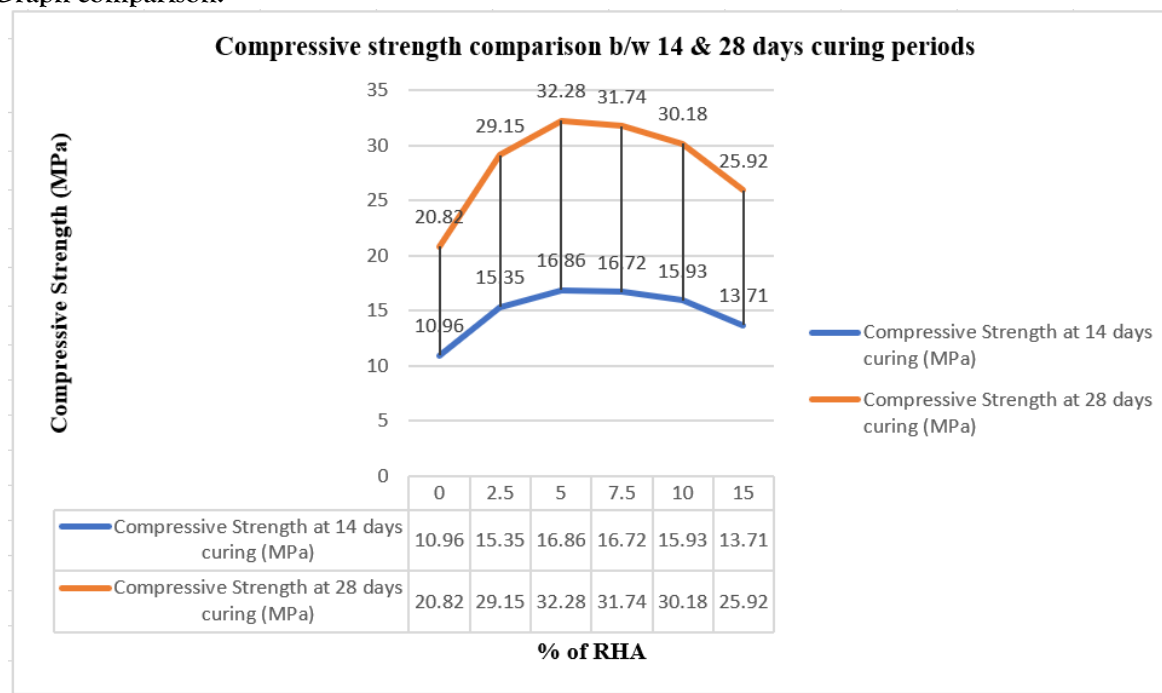
4.1 Compressive strength tests results and comparison between 14 and 28 days cured specimens:

At first the compressive strength test was performed at 14 days cured plain cement concrete specimen in which it was observed that its failure point was at maximum load of 222KN and compressive strength was observed as 10.96 MPa, after this test was performed at other specimens which were casted with the addition of rice husk ash at different percentages. The RHA05% showed comparatively high compressive strength as compared to plain cement concrete and other percentages. The

compressive strength of specimen with RHA05% was 16.86MPa. Other than this every RHA concrete specimen till the 15% showed very low compressive strength as compared to the plain cement concrete specimen.

For 28 days cured specimens, for plain cement concrete specimen in which it was observed that its failure point was at maximum load of 422KN and compressive strength was observed as 20.82 MPa. In this curing cycle RHA5% also showed the best compressive strength result, it failed at the peak load of 563KN and its maximum compressive strength was observed as 16.86 MPa. Other than that, every other RHA15% compressive strength was lower as compared to other specimens and RHA 2.5,7.5,10% compressive strength was higher than PCC concrete specimen. It was concluded that Rice husk ash can replace the cement as a binder in concrete but as certain percentage because if the quantity exceeds from a certain percentage the required compressive strength cannot be achieved. The graph mentioned below explains the overall compressive strength comparisons between 14- and 28-days plain cement concrete specimen and RHA concrete's specimen.

Graph comparison:



Graph 8 Compressive strength Results and graph comparison

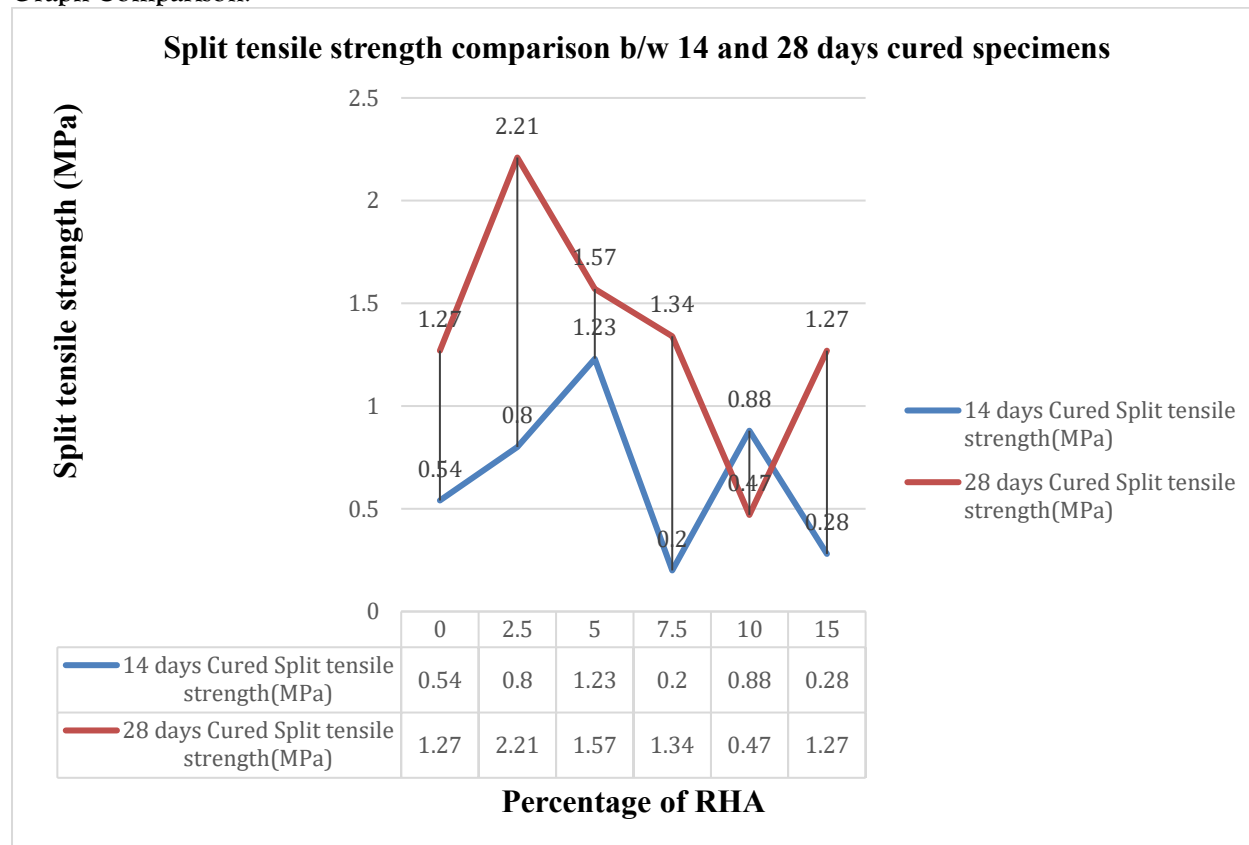
4.2 Split tensile strength tests result and comparisons:

At first the split tensile strength test was performed at 14 days cured plain cement concrete cylinder in which it was observed that its failure point was at maximum load of 40KN and maximum stress was noted 0.54 MPa, after this test was performed at other specimens which were casted with the addition of rice husk ash at different percentages. The RHA05% showed comparatively high split tensile strength as compared to plain cement concrete as its failure point was at maximum load of 90KN and maximum stress of 1.23 MPa. The split tensile strength of specimens with RHA2.5 and 10 and was recorded higher as compared to the plain cement concrete specimen and lower RHA5%. RHA7.5 and 15% specimen's split tensile

strength was very low 0.20 MPa and 0.28 MPa respectively.

As compared to split tensile strength of 28 days cured concrete specimen's PCC specimen failed at the peak load of 100KN and its split tensile was recorded as 1.27MPa. RHA 2.5% Showed the best result as its Spit tensile was measured at 2.21 MPa. Other than that, RHA5, 10 and 15 split tensile strength was not satisfied. As already plain cement concrete is considered weak in tensile strength, this concludes that at certain percentage and after properly designing concrete mix the required split tensile strength can be achieved but excess of Rice husk ash can reduce the split tensile strength of concrete at early ages. The graph mentioned below explains the overall split tensile strength results comparisons between 14 and 28 days cured PCC and RHA Mixed specimens.

Graph Comparison:



Graph 9 Split tensile strength results and graph comparisons

4.3 Flexural tensile strength's tests result and comparisons:

At first the flexural tensile strength test was performed at 14 days cured specimens. Beam was casted having dimensions 60mm by 15mm by 15mm. At first flexural tensile strength test was performed at plain cement concrete specimen in which the failure point was recorded at maximum load of 25.7 KN and strength of 5.17, after this test was performed at other specimens which were casted with the addition of rice husk ash at different percentages. The RHA05% showed comparatively high flexural tensile strength as compared to plain cement concrete and other RHA specimens mixed with different percentages. The flexural tensile strength of

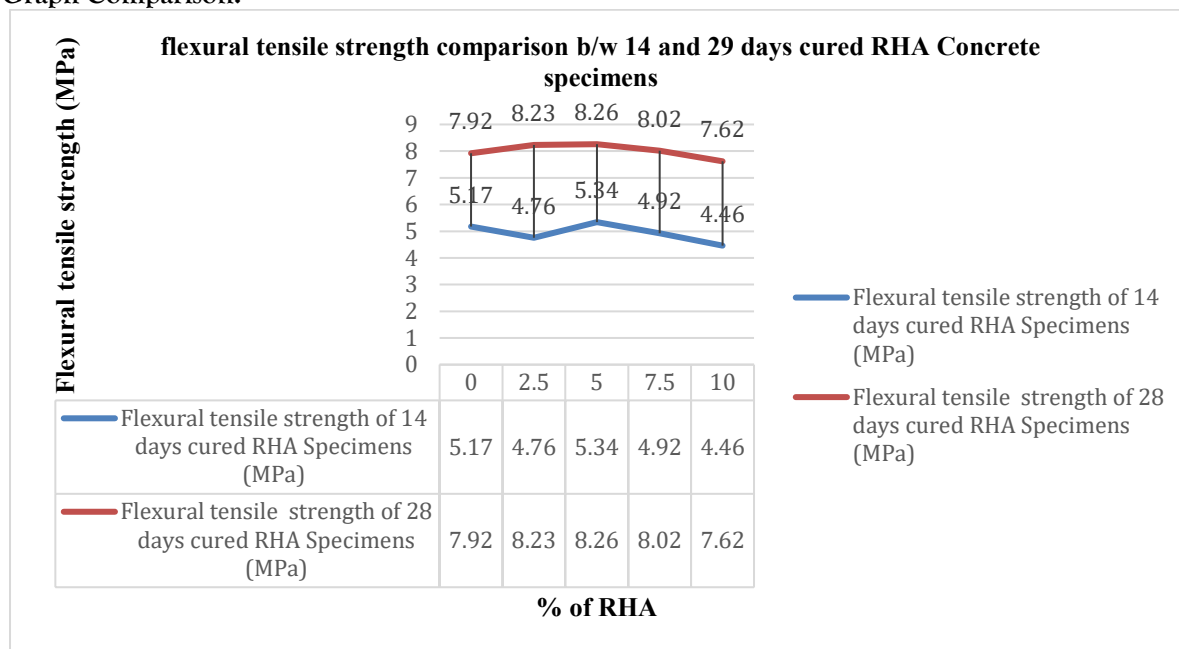
specimen with RHA10% was recorded lower than any other specimen.

After that this test was performed at 28 days curing age cycle specimens. The PCC specimen failed at the maximum load of 39.5 KN and its flexural strength 7.92 MPa. RHA5% Specimen's flexural strength was higher than any other specimen it failed at the maximum load of 41.2 KN and its flexural tensile strength was recorded 8.26MPa After that every RHA 2.5, 7.5% strength was recorded lower than other specimens. Flexural tensile strength is important as it helps to resist the load which can result in rupture of concrete components. A higher flexural strength can be achieved as compared to the plain cement concrete by replacing cement with Rice husk ash as in both curing cycle

RHA5% gain the higher flexural tensile strength. By improving mix design higher strength can be achieved. The graph mentioned below explains the overall flexural tensile strength's comparison

between plain cement concrete's specimen and RHA mixed concrete's specimen.

Graph Comparison:



Graph 10 Flexural tensile strength results and Graph comparison

4.2 Ultrasonic Pulse velocity tests results and comparison:

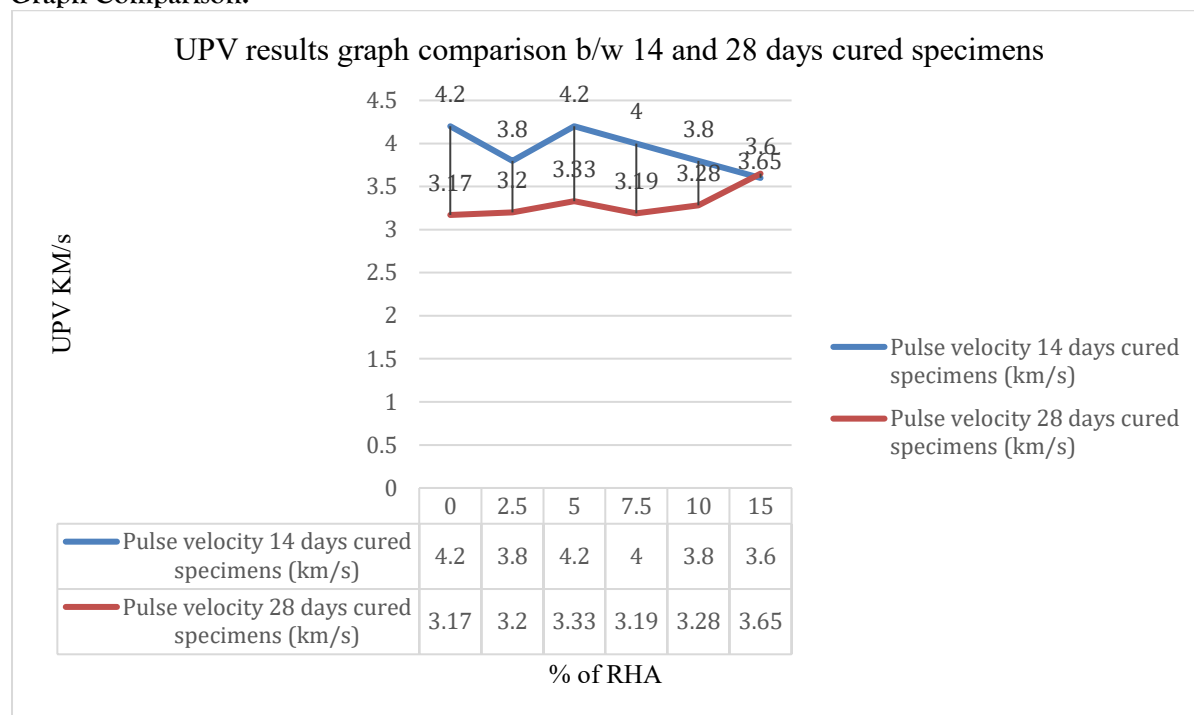
At 14 days, the Ultrasonic Pulse Velocity (UPV) results show that the 5% RHA specimen achieved the highest pulse velocity 4.2km/s among all mixes, indicating superior concrete quality and internal uniformity at this early stage. The 2.5% RHA mix also performed well at 3.8km/s, with UPV values slightly lower than the 5% RHA but still higher compared to plain concrete 0% RHA 4.2km/s. As the RHA percentage increased beyond 5%, a steady decline in UPV speeds was observed, especially at 10% and 15% RHA, where the pulse velocities dropped significantly. This reduction in UPV values reflected an increase in internal voids, suggesting that higher RHA content at 14 days leads to a less compact and lower-quality concrete structure.

At 28 days, the UPV results favored the 15% RHA mix 3.65km/s, which again showed the highest pulse velocity, confirming excellent

material quality and better continuity of the concrete matrix. The 5% RHA specimen also exhibited high UPV values 3.33km/s, reinforcing the benefit of low RHA replacement levels over time. However, with RHA content (2.5%, 7.5%, 10%), the UPV speeds decreased noticeably, indicating that slightly higher or lower RHA percentages negatively impact the long-term homogeneity and density of concrete. The 28-day readings generally showed improved UPV values across all mixes compared to the 14-day results, highlighting the continued hydration and refinement of the concrete microstructure over time.

To improve UPV results, ensured better compaction, reduced water-cement ratio, and use optimal RHA content (around 5%). Proper curing and minimizing voids or cracks in the concrete mix can enhance the ultrasonic pulse velocity by increasing material density and homogeneity.

Graph Comparison:



Graph 11 Ultra sonic pulse velocity results and Graph comparison

Conclusions and Recommendations**5.1 Conclusions:**

- The most efficient proportion was determined to be 5% cement replacement with rice husk ash, which produced optimal outcomes in all tests (compressive, tensile, flexural, and UPV).
- When utilized in the proper amount, RHA increased the concrete's early-age and long-term strength, suggesting that it could increase its durability over time.
- The concrete's higher internal quality and uniformity at 5% RHA, which indicated fewer voids and better bonding, was verified by the UPV results.
- Workability and mechanical qualities declined in mixes with RHA greater than 7.5%, most likely as a result of increased permeability and decreased cement content.
- RHA is a sustainable building solution since it reduced cement demand and CO₂ emissions when utilized as a part to replace cement.

5.2 Recommendations:

- Test results indicate that in order to balance strength, quality, and sustainability, 5%

RHA should be used to replace portion of the cement.

- In order to preserve amorphous silica and prevent unburned carbon, which lowers performance, RHA should be burned at precisely controlled conditions (about 600–700°C).
- Long-term performance should be the main focus of future studies, especially under harsh conditions like exposure to sulfate or chloride.
- Authorities should consider standardizing RHA usage by including guidelines in local construction codes and specifications.
- Engineers and contractors should be made more aware of the advantages of RHA, and field applications should be encouraged in order to verify laboratory results on a larger scale.

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