PAGES: 1-19
10/4/23
JOURNAL OF SCIENTIFIC RESEARCH AND TECHNOLOGY(JSRT) VOLUME-1 ISSUE-7 OCTOBER
Registered under MSME Government of India ISSN: 2583-8660

Partially Replacement of Cement by Rice Husk Ash and Saw Dust Ash in Concrete

Nitin Kumar[1], Prof. Venkatesh Kalkote[2]

[1]*Student, Department of Civil Engineering, Sharnbasva University Kalaburagi, Kalaburagi, India*
nitinainoor@gmail.com
[2]*Associate Professor, Department of Civil Engineering, Sharnbasva University Kalaburagi, Kalaburagi, India*
venkatesh.cv090@gmail.com.

ABSTRACT

This abstract summarizes research on the use of rice husk ash (RHA) and sawdust ash (SDA) as partial cement replacements in concrete manufacturing as a means of conserving resources. The building sector is looking for greener options to lessen its carbon footprint as the environmental effects of conventional cement manufacturing become more apparent. Agriculture and wood industry byproducts RHA and SDA are being considered as potential additives to concrete that would improve its qualities while reducing its environmental effect.

In this study, we test how replacing a portion of the cement with RHA and SDA affects the mechanical, durability, and sustainability properties of the resulting concrete. To evaluate the efficacy of various concrete combinations, we run a battery of tests in the lab that measures their compressive strength, tensile strength, and durability Split tensile strength. Life cycle evaluations also examine the positive effects on the environment, such as lower carbon emissions and less waste.

The results of this research shed light on the use of RHA and SDA as sustainable additives in concrete manufacturing, providing a greener and more cost-effective option for the building sector. This study adds to the continuing efforts to create greener building techniques that are in line with global sustainability objectives by minimizing the use of typical cement and recycling agricultural and industrial leftovers. Here, we show that it is possible to use RHA and SDA in concrete, opening the door to a greener manner of building infrastructure.

Keywords: **Rice Husk ash, Saw dust ash, Compressive strength, Split tensile, Flexural Strength.**

I. INTRODUCTION

Concrete is the most extensively manufactured commodity in the construction industry due to its widespread use as a building's structural base. Its rudimentary make-up Cementitious materials have a high tensile strength at the split, indicating their ability to bind together and form a cohesive whole. Cement, water, and aggregates are the main components of a conventional concrete mixture. Portland cement usage fluctuated widely during a 130-year period, from 1880 to 2010, from 2 million tons to a stunning 1.6 billion tons. large amounts of consumption have resulted in serious environmental damage, such as

Cement manufacturing is the third biggest industrial sector in the world. The estimation of environmental consequences is a major contributor to emissions that cause the greenhouse effect. more than half of all factory emissions. Greenhouse gases produced during cement production are around 21.25 tons each manufactured ton of cement.

The production of one ton of cement uses up around 1.6 tons of raw materials.

Environmental concrete like this one shows why we need eco-friendly cement alternatives. Rice husk ash (RHA) stands out among other possible binder options. The estimation of environmental effect is one of the main sources of greenhouse gas emissions. substances with potential. Significant potential lies in rice husk, an agricultural byproduct of the rice milling process. The United Nations Food and Agriculture Organization

(2008) estimates that worldwide rice production reached 649.7 million tons in 2007, with the agricultural residue associated with rice husk accounting for around 20% of this output. Expression factors such paddy type, crop year, climate, and geographical variables may all affect the chemical composition of rice husk. Ash generated from burning rice husk at high temperatures consists largely of amorphous silica. RHA's amorphous silica content is the defining feature that determines its pozzolanic activity. Particularly well suited for use in lime- pozzolana blends and as a Portland cement replacement, RHA is a highly reactive pozzolanic material. The presence of non-crystalline silica and its specific surface area both contribute to RHA Split's tensile strength, and both are necessary for the material to react with lime.

Altering the cement amount in concrete is the primary focus of our study. When making concrete blocks, we have effectively replaced cement with rice husk ash in a variety of percentages. We have conducted extensive experiments to find the ideal percentage of rice husk ash to use as a substitute. This innovative process not only reduces the environmental impact of concrete production, but it also aligns with sustainability goals by making use of a carbon-neutral and eco-friendly material product and a lightweight material that is readily available in free of cost, all of which contribute to inexpensive building components.

According to this report, a concrete mixture that included rice husk ash fuel from an unsupervised fire. Examples of mechanical parameters analyzed include compressive strength and splitting tensile strength. We evaluated the performance of the concrete samples by evaluating them at 7-day, 14-day, and 28-day intervals.

1.1 Rice Husk Ash:

Acquiring RHA is as simple as carefully burning rice husks in a way that causes as little pollution as possible. When properly burnt, it yields a high percentage of silicon dioxide ($SiO2$)—around 90%. In addition, it has a carbon content of around 5% and a potassium oxide content of about 2%. RHA generally has a surface area with characteristics between 40 and 100 square meters per gram. The pozzolanic properties of rice husk ash make it a desirable additive for concrete due to the positive effects it has on the material's strength and impermeability.

One of the world's largest rice producers is India. yearly produces 132,013,000 metric tons of paddy rice. Amounting to around 40 kilos per metric ton of paddy, rice husk ash (RHA) is a byproduct of the rice production process. This opens up the possibility of making use of a useful pozzolanic material with properties quite similar to microsilica.

1.2 Saw Dust Ash:

While sawdust may be used as an additive in concrete, its poor compressive strength has limited its widespread use. Knowing these restrictions is essential before using it. Sawdust concrete has various benefits within these parameters, the most notable being a substantial decrease in the structure's weight, which lessens the load transferred to the base. As a consequence, the price per cubic foot is lower than it would be for regular concrete. It prevents decay and increases the lifespan of Because of the lower pressure it encounters during handling, mixing, and placing compared to other concrete kinds, the formwork lasts longer. The higher vacancy ratio and wood aggregate addition improve thermal insulation and lower thermal conductivity, and the material also displays excellent sound-absorption properties. From 0–10% wood aggregate mass percentage, thermal conductivity decrease rises, reaching a maximum at 35% concrete–sawdust mixture.

Recent years have seen a rise in the popularity of using sawdust in lightweight concrete. Sawdust concrete's structural qualities have shown promise in research. The advent of cutting-edge information technology and widespread concern for the environment have sparked an international renaissance in this area of study. In addition, new uses are appearing that take advantage of wood's exceptional physical and structural properties, such as its durability.

1.3 Objective:

The primary goal of this study is to evaluate the potential for making use of byproducts such as burned rice husks and sawdust ash. Substitutes for cement that have similar pozzolanic characteristics. It is also believed that using these ashes to make concrete would increase the material's durability. With the goal of meeting a variety of structural requirements and, in particular, focusing on the improvement of compressive strength, this research also seeks to advance the development of concrete by including rice husk ash and sawdust ash as alternatives for cement.

II. LITERATURE REVIEW

Hima Hemant, et.al: To better understand how different proportions of Rice Husk Ash (RHA) may efficiently replace cement in the building of concrete pavements, decreasing coSplit tensile strength, this study analyzed the influence of RHA on concrete characteristics. In this investigation, seven different concrete recipes were developed, all based on the M30 grade concrete mix, with cement substitutions ranging from 10% to 70% through the use of RHA.

Mauro M. Tashima, et.al: Exploring the impact of RHA on various concrete characteristics required a large-scale, in-depth research project. Researching the impact of varying quantities of RHA substitution for cement in concrete on attributes such moisture absorption, crushing resistance, splitting tensile strength, and elasticity modulus was the major motivation for this study. For this study, researchers painstakingly mixed together two batches of concrete with slightly different ratios of RHA and superplasticizers. To be clear, the M40 grade concrete mix was the focal point.

E.B.Oytelaand M.Abdullahi: This study investigated the effects of adding Rice Husk Ash (RHA) to sand blocks, specifically examining the effects of varying RHA-to-cement ratios on the w/c ratio and compressive strength. In the production of 1:8 sand concrete blocks, five different combinations were developed, varying the percentage of cement replaced with RHA from 10% to 50%.

There were numerous major findings that came out of the experimental research. The first step was to increase the water-to-cement (w/c) ratio as the RHA replacement % increased. This change was crucial. RHA's increased specific surface area increased the need for dissolved H2O in the formulation. Adjustments to the w/c ratio were required to maintain adequate workability, with the final value for the mix containing 50% RHA replacement reaching 0.58%.

G.A.Habeeb, M.M.Fayydh: The purpose of this study was to investigate the effects of Using Rice Husk Ash (RHA) in place of cement in the M20 grade concrete mix, spanning all three grades (F, F2, and F3). The study's major objective was to evaluate the effects of various RHA substitutions on the workability, density, crushing resistance, bending resistance, tensile strength, drying shrinkage, and water/cement ratio of concrete.

M.U. Dabai : Six mortar cubes were fabricated and tested for their compressive strength and tensile strength using a range of cement substitutions using RHA, from 0% to 50%. These tests were performed at 3, 1, 2, and 4 weeks after the curing process had begun.

Compressive strength tests showed that when cement was replaced by RHA at a rate of 10%, the resulting cubes had a crushing resistance of 12.60 N/mm2 after 3 days, 14.20 N/mm2 after 7 days, 22.10 N/mm2 after 14 days, 28.50 N/mm2 after 28 days, and 36.30 N/mm2 after 3 days, 1 week, 2 weeks, and 4 weeks of curing time, respectively. Nonetheless, research has shown that as the proportion The strength under compression dropped as the percentage of RHA in the mixtures rose.

III. MATERIALS AND METHODOLOGY

RHA: In this text, we will discuss the steps required to make Rice Husk Ash (RHA). The gist is as follows:

Material: Rice Husk Ash (RHA)

Processing Method: Uncontrolled burning in airBurning Duration: Approximately 72 hours Temperature Range: 400-600 degrees Celsius

Particle Size: Using a 75-micron sieve (the International Standard) Dark or dingy rice husk is the color. Ash is a common byproduct of burning rice husks. Depending on its specific properties, it may find usage in a wide range of sectors, such as agricultural and building materials. The acquired RHA seems to have a black hue and a tiny particle size of 75 microns. Further investigation is required to identify the chemical composition and other features of this RHA in order to determine its particular use.

For cement : Ordinary Portland Concrete (OPC) of grade 43 was used extensively throughout the project, and its qualities are in line with those established by the Indian Standard Association. Concrete is a crucial component in building assembly; it is a binding medium with strong and adhesive capabilities that may join different types of construction materials, such as the white and gray limestone found on the Island of Portland. One of the most popular types of Portland cement is grade 43 OPC, so named in 1824 by Joseph Aspdin for its likeness in color and strength to Portland stone after it has set.

Fine Aggregate: Concrete and mortar are made by combining fine aggregate (usually sand, crushed stone, crushed hydrated-bonded cement, or iron blast furnace slag) with a hydraulic binding agent (often cement). Primarily, it consists of everything that passed through a 4.75mm (No. 4) sieve.

Alternatively, coarse aggregate Particles have a split tensile strength that allows them to pass through a 9.5mm (3/8 inch) sieve yet stay on a 4.75mm (1 3/8 inch) sieve. Instead, fine aggregate is made up of materials that are too small to be retained on a sieve with a 75-micron opening size (4.75mm).

Sawdust Ash: Sawdust, also known as wood dust, is a byproduct of many woodworking processes such sawing, milling, drilling, and sanding. The porosity structure of sawdust particles means they absorb plenty of water, which slows down the cement setting process. Sawdust was obtained for the experiment from a neighboring sawmill, and extreme caution was used during sample collection to avoid sand contamination. Using a shovel, we collected the newly produced sawdust and placed it in bags.
Ten days of drying in the sun made the sawdust suitable for use in the following burning procedure. The sawdust samples were After that, a drum of it was heated to a temperature of 200 degrees Celsius to undergo open combustion. After the substance had cooled after the burning process, it was finely powdered. This process yielded sawdust ash, which was further screened using an IS sieve with a mesh size of 90 microns. We conducted experiments with the stuff that got through the sieve.

Coarse Aggregate: The materials used in this study consisted of machine-crushed stone with an angular shape. The stone was sieved using a 20mm IS sieve, and the particles that were retained on a 4.75mm sieve were selected for further analysis.

Water : Mixing water is the amount of water used in the concrete recipe, and it plays a crucial part in the creation of concrete via a chemical process known as hydration. To a large extent, it determines the concrete's consistency, or "slump." In addition, the ratio of water to cementitious materials (w/cm) in the concrete mix is an important aspect in achieving the required concrete qualities, and this ratio is established during the mixing process.

3.1 Methodology

3.1.1 Overview

The purpose of this work is to promote a positive impact on the use of rice husk ash and sawdust ash in concrete applications in the field of civil engineering construction. Several critical parameters significantly affect the behavior and performance of Concrete that contains rice husk ash and sawdust ash. For the sake of consistency and accuracy in our experimental efforts, we have settled on a stable set of conditions.

Cement Replacement Percentage: Throughout the course of the trial, the ratio of cement to rice husk ash and sawdust ash replacements stays the same.

Fineness of Ashes: The fineness of both RHA and SDA is maintained at a consistent level.

Chemical Composition: The chemical makeup of both rice husk ash and sawdust ash remains unaltered throughout the experiments.

Water-to-Cementitious Material Ratio (w/c ratio): All of the mixes used in the experiment had the same proportion of w/c ratio.
Type of Curing: In all of our trials, we use the same curing procedure for our concrete samples. It's worth noting that our analysis of the current literature reveals discrepancies between the settings advised by various studies and the results they obtained. Differences in the materials used in the research likely account for the observed discrepancies. Therefore, based on preliminary research, we have decided to fix a constant % for cement replacement utilizing RHA and SDA, together with a particular mix design strategy. The goal of this choice is to provide a constant and reliable outcome.

Results of some of the test on material

1. Fineness Modulus Of Natural Sand = 3.77
2. Fineness Modulus Of Coarse Aggregate =4.11
3. Normal Uniformity Of Cement= 32%.
4. Specific Gravity Of Cement = 3.12
5. The Cement's Setting Time
   (a) Initial Setting Cement's Duration = 65 Min.
   (b) Final Setting Cement's Duration = 220 Min.
6. Particle Size Of Cement =2 Percent.
7. Specific Gravity Of C.A = 2.85
8. Specific Gravity Of Natural Sand = 2.73
9. Specific Gravity Of Coarse Aggregate = 2.72
10. Water Absorption Coarse Aggregate = 0.003%

3.2. Casting Process:

(i) To start, make sure the molds are spotless and oiled so the concrete doesn't cling.

(ii) Pour the concrete mixture into the molds in layers, each measuring about 5 centimeters in thickness.

(iii) A tamping rod, consisting of a 16mm diameter by 60cm long steel bar with a pointed end on the underside, should be used to compact the concrete between layers. Use at least 35 tamping rod strokes on each layer to compact it. This guarantees that there are no air pockets in the concrete.

(iv) Once all the layers are in place and compacted, you can finish off the top by smoothing it with a trowel and bringing it to a uniform level. This crucial procedure ensures a smooth, even surface in the end product.

3.3 Curing Procedure:

1. Put the first 12 test samples into a humid environment for 24 hours to start. After this time has passed, label the samples and take them out of the molds.

2. Put the labeled samples in a container of clean water and make sure they stay submerged until it's time to examine them.

3. After demolding the first set of test specimens, cast another set of 12 and let them sit in the molds for 24 hours.

4. The next step is to unmold the second set.

5. Keep the second set of samples, like you did with the first, in a container of clear moisture until you're ready to analyze them.

IV. MATERIAL TESTING

4.1 Overview

In this article, we will systematically examine both newly mixed and cured/hardened concrete. The primary goal of such testing is to guarantee the efficacy and durability of concrete, particularly concrete's strength and resilience, and thus plays an indispensable role in any quality control program.

Concrete samples are carefully formed in standardized molds, with common sizes including 150mm 150mm 150mm cubes, 150mm 300mm 75mm cylinders, and 500mm 100mm 75mm beams. Concrete mixes created from the mix design process are poured into these molds.

We use specialist equipment, such as the Compression Testing Machine (CTM) and the Universal Testing Machine (UTM), to conduct extensive tests on concrete cubes, cylinders, and beams in order to gauge the material's performance. These evaluations are performed after the specimens have been allowed to cure for 7 days, 14 days, and 28 days, respectively. The main goals of these tests are to determine the concrete's. Resistance to crushing, splitting, and bending tensions.

All tests are conducted in accordance with BIS (Bureau of Indian Standards) guidelines. Following these guidelines allows us to accurately evaluate the concrete's quality and performance since the testing is consistent and reliable.

Compressive Strength Test : Compressive strength (CST) is the maximum load-bearing capacity per unit area that a material can withstand before rupturing under compression.

Here, we test the compressive strength of cubes made from various concrete mixtures. The dimensions of the cube-shaped test specimens are 150mm on all sides. These samples go through three distinct curing times: 7, 14, and 28 days. After a specific amount of time has passed, they are crushed with a CTM. We have data on the compressive stress at which the cubes begin to crack.

Fig 1: Compression test in CTM

Split Tensile Strength Test:

This test, commonly known as the "Brazilian Test," offers an indirect means ofdetermining The resistance to tension of concrete. It involves preparing cylindrical specimens measuring 200mm in length and 100mm in diameter, which are then curing for either 7 or 28 days before undergoing crushing to determine the corresponding loads at the point of ultimate (break) split tensile strength.

Flexural strength test

The F S T is a procedure used to determine the flexural strength of concrete, which measures its ability to resist deformation under load. Here is a brief overview of theprocedure:

Equipment:

- The testing apparatus features a bed designed with two sturdy steel rollers, each measuring 38mm in diameter. These rollers serve as support for the concrete specimens during testing.
- Additionally, the machine is equipped with Pair of loading rollers strategically positioned at specific locations along the supporting span. For a measurement of 15.0 cm specimens, these loading rollers are spaced at intervals of 20 cm, while for a dimension of 10.0 cm specimens, they are spaced at intervals of 13.3 cm.
- The specimens being tested are made of concrete and have specific dimensions and characteristics relevant for the examination process.

Fig 2: Flexural strength testing machine

V. RESULTS AND DISCUSSIONS

In this study, our main focus was to create a concrete mix with a target strength of M20, following the mix proportions established using the ISM (Indian Standard Method) of mix design. The resulting mixture composition was determined to be 1 part cement, 1.8 parts Fine Aggregate (FA), and 2.93 parts Coarse Aggregate (C.A), while maintaining a water-cement (w/c) ratio of 0.5.

To explore the influence of Rice Husk Ash (RHA) on the concrete mixture, we introduced varying amounts of RHA percentages relative to the weight of cement in the mix, specifically 0%, 10%, 20%, and 30%.

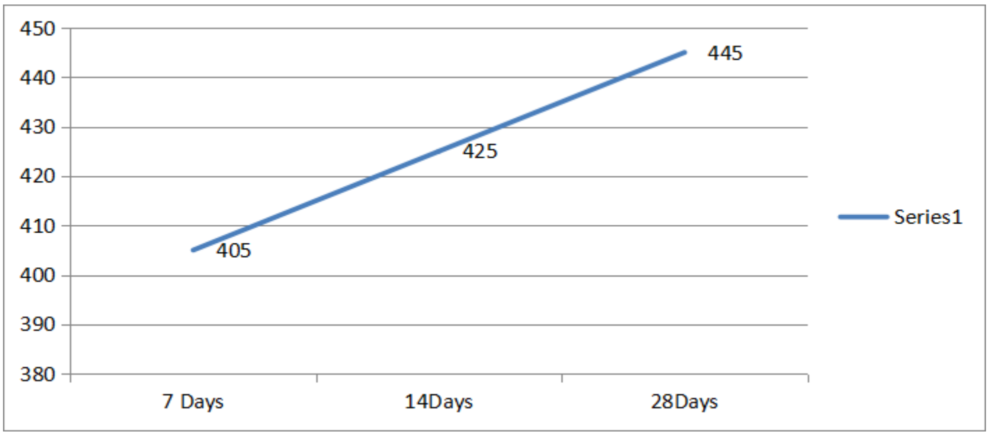
5.1 Compressive strength test:

CST are performed to verify that the specific mix meets the required minimum strength standards. Cube specimens measuring 150mm × 150mm × 150mm are utilized to determine the compressive strength.

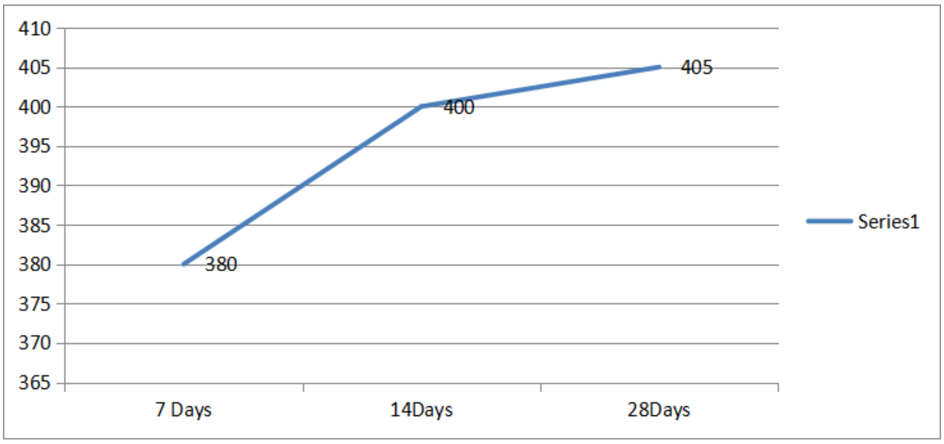
Fig 3: Failure of cubes due to compressive strength

Table 1: Compressive Strength Test Results at Vary per of R H A After 7,14 and 28 days of curing.

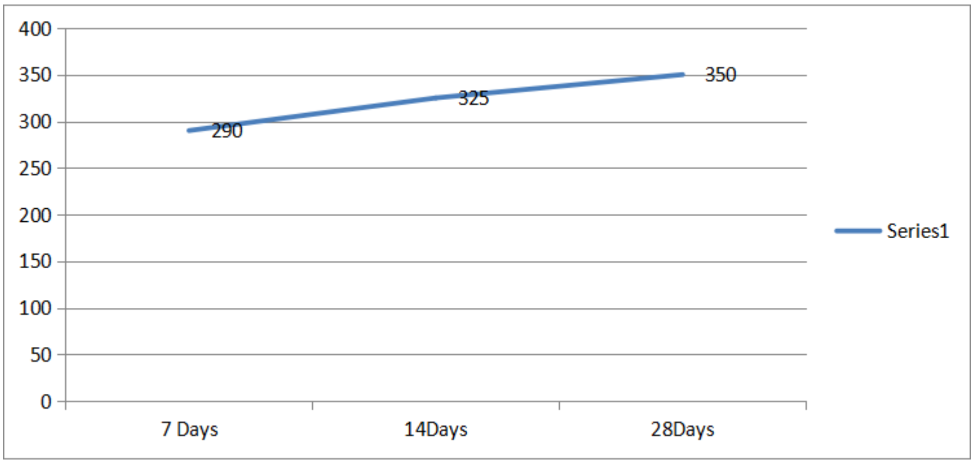
Conventional Mix N/mm^2				
Prop R H A	0%	10%	20%	30%
7 Days	405	380	290	285
14Days	425	400	325	290
28Days	445	405	350	300



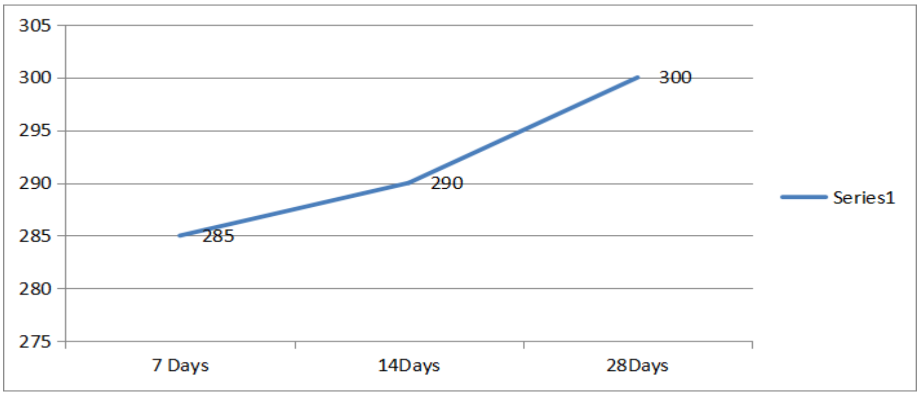
Graph 1: Compressive Strength of Normal Concrete



Graph 2: Compressive Strength of 10% RHA



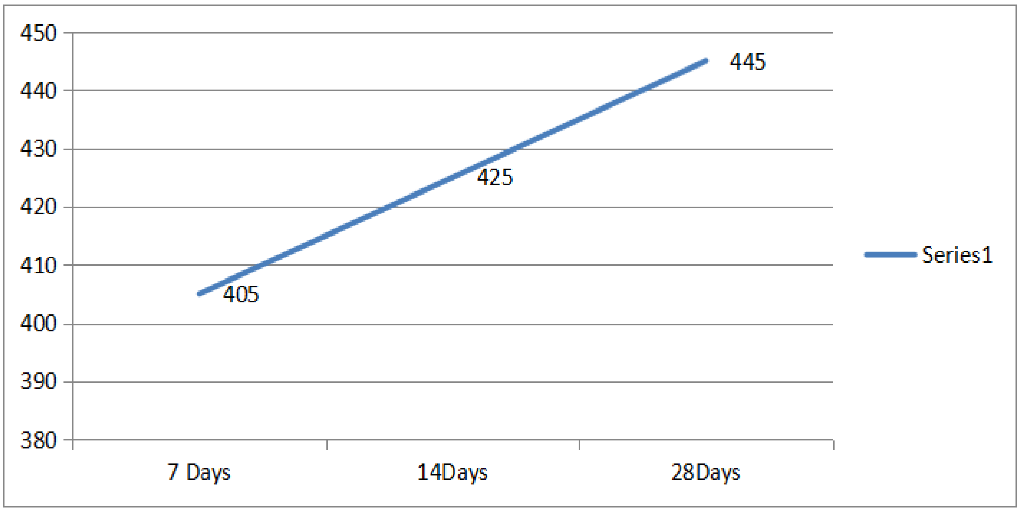
Graph 3: Compressive Strength of 20% RHA



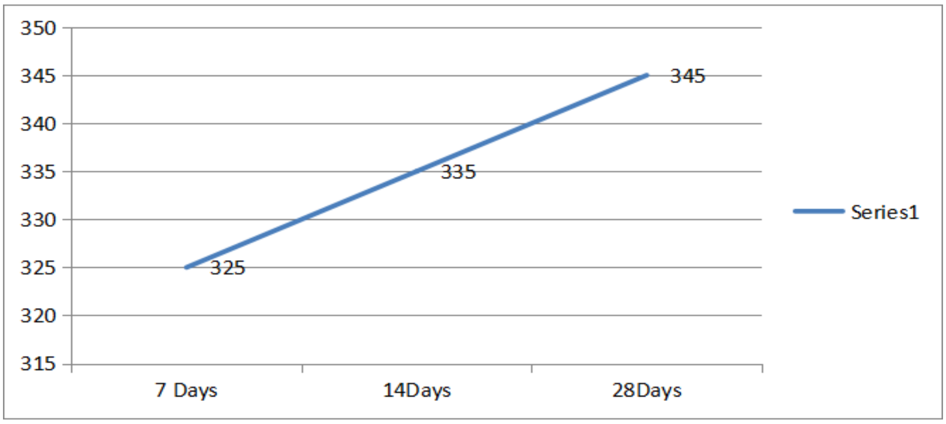
Graph 4: Compressive Strength of 30% RHA

Table 2: Saw Dust Ash

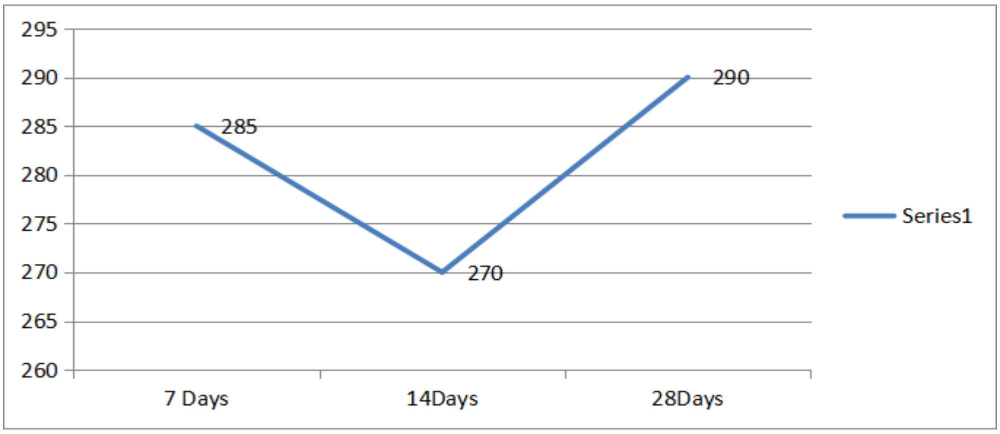
Conventional Mix N/mm^2				
Proportion of Saw dust ash	0%	10%	20%	30%
7 Days	405	325	285	270
14 Days	425	335	270	275
28 Days	445	345	290	285



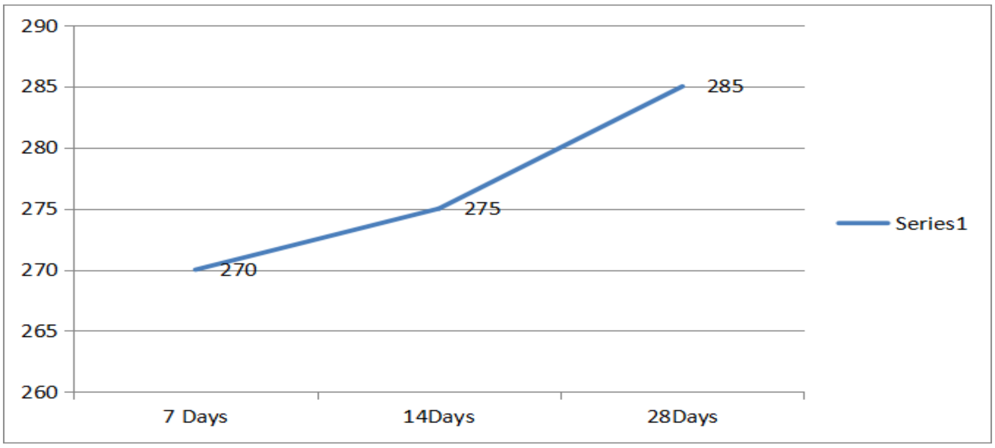
Graph 5: Compressive Strength of Normal Concrete



Graph 6: Compressive Strength of 10% S D A



Graph 7: Compressive Strength of 20% S D A



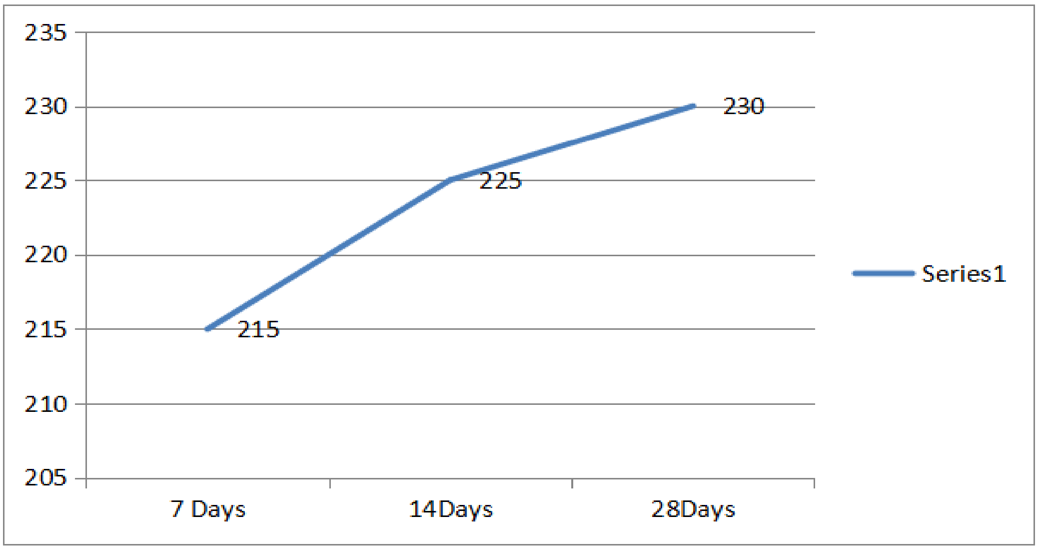
Graph 8: Compressive Strength of 30% SDA

5.2. SPLIT TENSILE STRENGTH TEST RESULTS

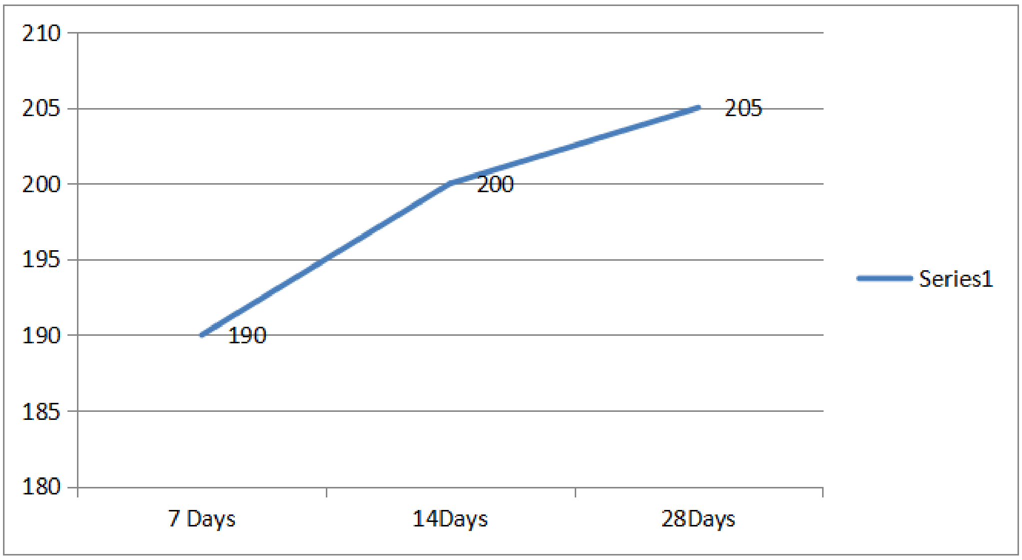
Testing concrete's Split Tensile Strength requires a cylinder specimen 300 mm in length and 150 mm in diameter. We are using a Concrete Testing Machine (CTM) to perform a compression test on this sample. For in-depth guidance on administering this evaluation, please see the corresponding earlier chapter. Below is a table containing the outcomes of the tests.

Table 3: Split Tensile Strength Result At Vary Percentage Of E-Plastic Waste After 7, 14 and 28 days of curing.

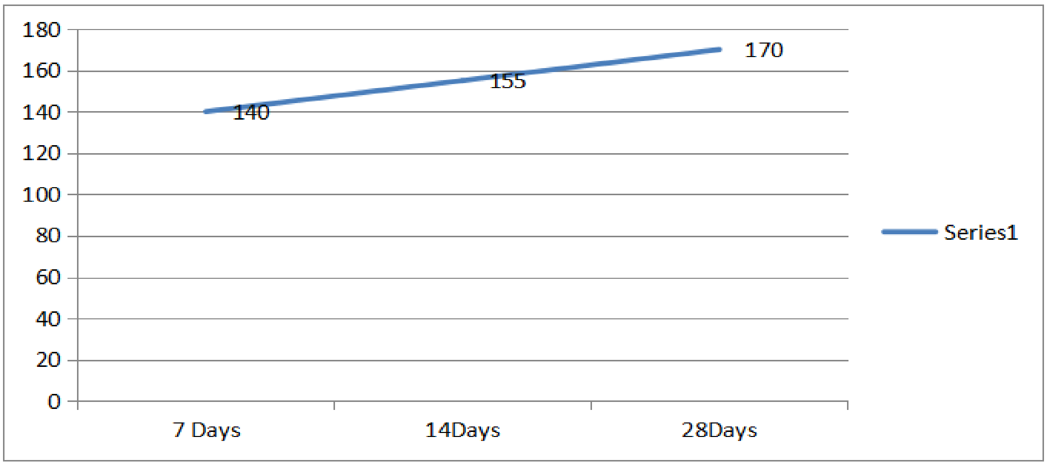
Conventional MIX N/mm^2				
Prop .R.H.A	**0%**	**10%**	**20%**	**30%**
7 Days	215	190	140	125
14Days	225	200	155	130
28Days	230	205	170	145



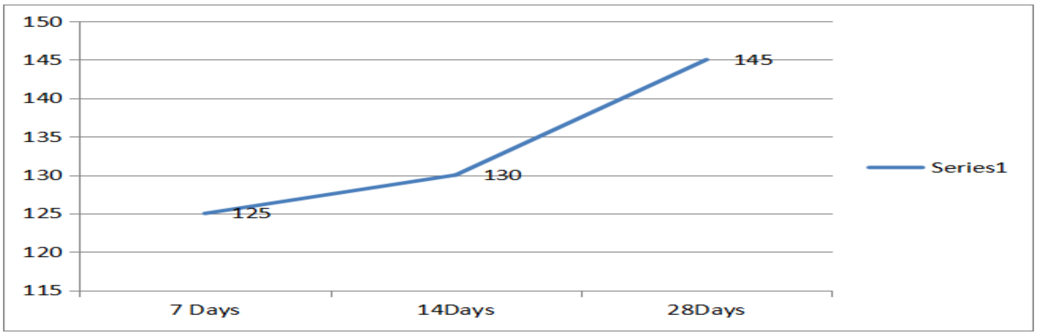
Graph 9: Split Tensile Strength of normal Concrete



Graph 10: Split Tensile Strength of 10% RHA



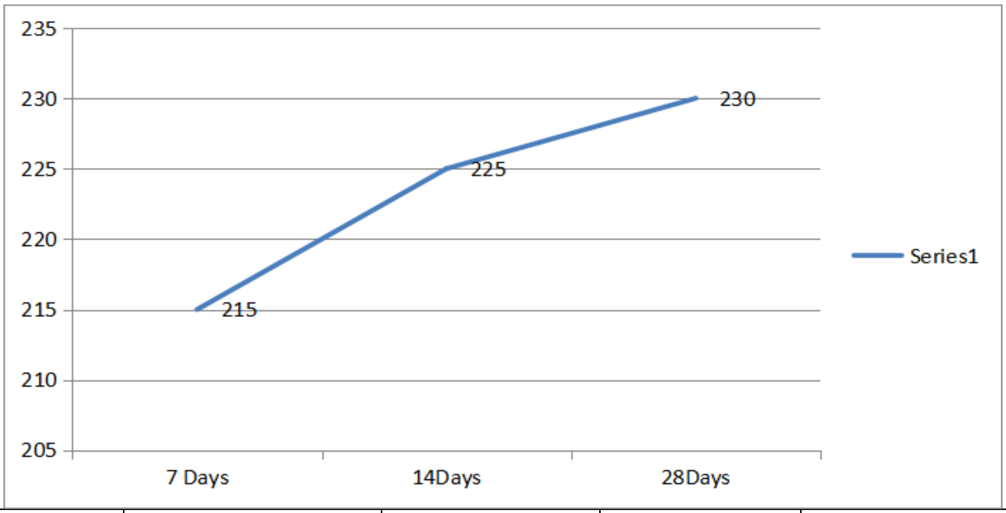
Graph 11: Split Tensile Strength of 20% RHA



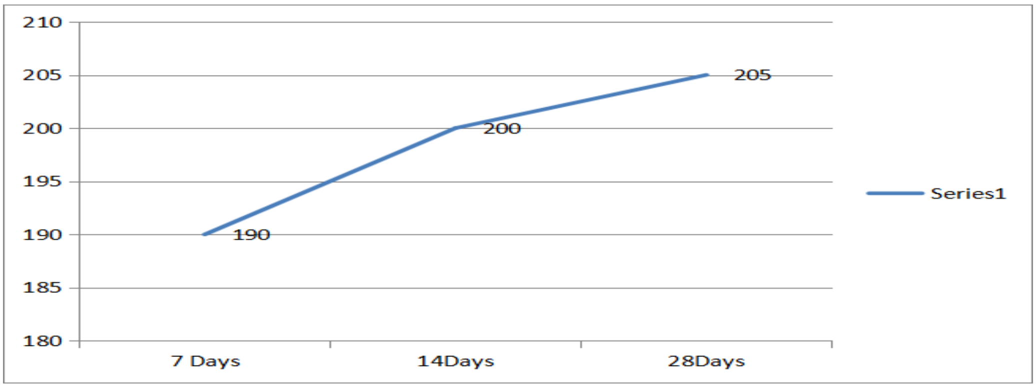
Graph 12: Split Tensile Strength of 30% RHA

Table 4: Saw dust ash

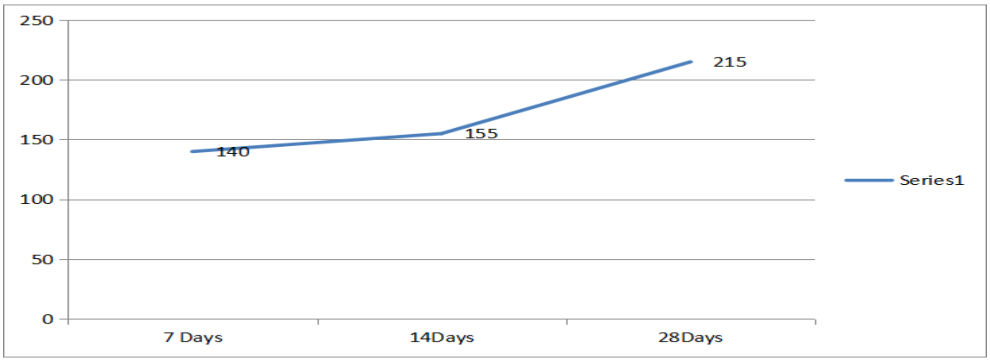
Conventional Mix N/mm^2				
Proportion of Saw dust ash	**0%**	**10%**	**20%**	**30%**
7 Days	215	190	140	135
14 Days	225	200	155	130
28 Days	230	205	215	145



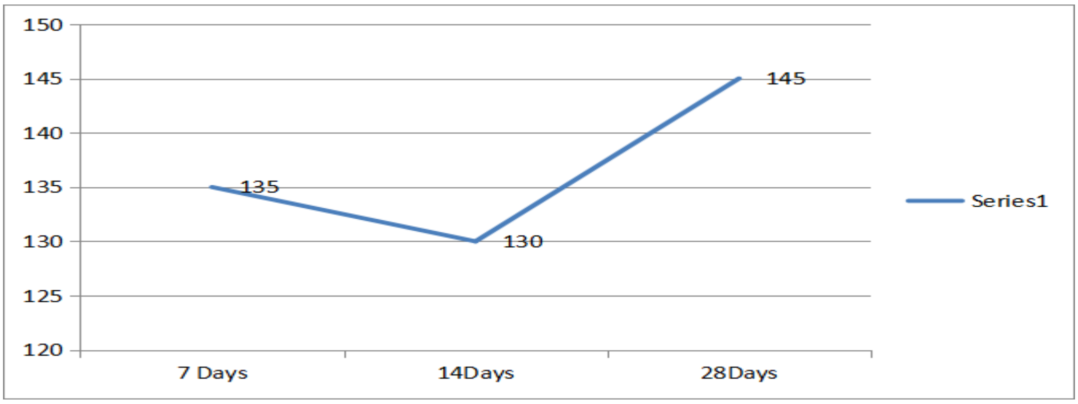
Graph 13: Split Tensile Strength of Normal Concrete



Graph 14: Split Tensile Strength of 10% S D A



Graph 15: Split Tensile Strength of 20% S D A

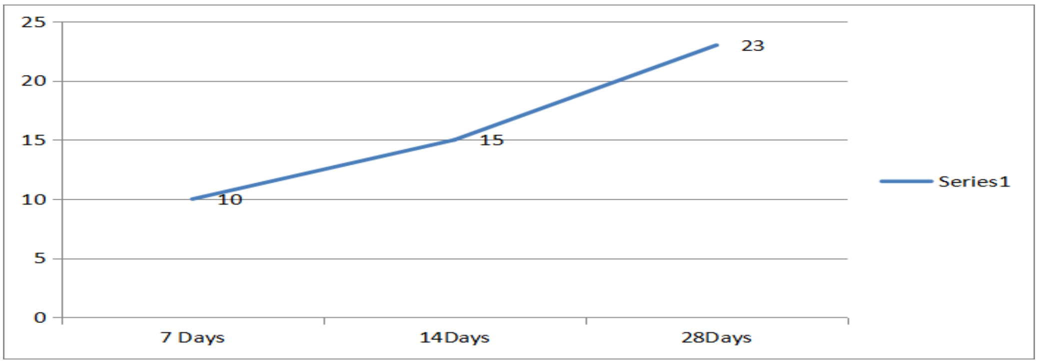


Graph 16: Split Tensile Strength of 30% S D A

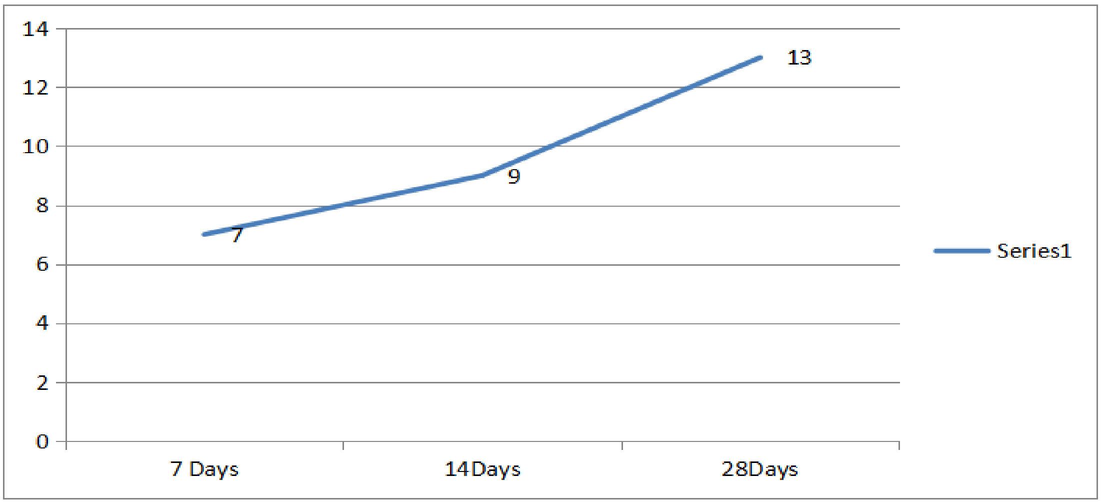
The flexural strength of the specimen is represented as the modulus of rupture (MR), and for testing purposes, beams measuring 500 × 150 × 75 mm were cast, curing in clean water for 28 days, and subsequently tested using a Universal Testing Machine (UTM).

Table 5: Flexural Strength Test Results at Vary Percentage Rice Husk Ash AFT 7, 14 and 28Days Of Curing

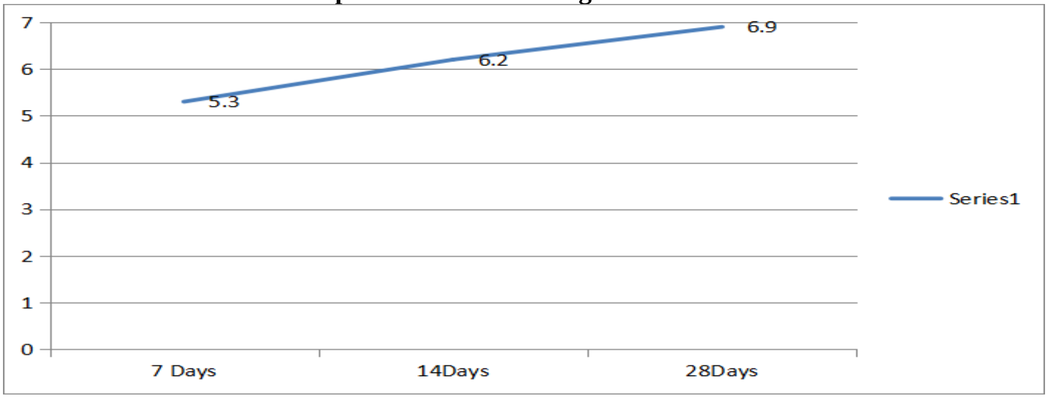
Conventional MX N/mm^2				
Prop.of R H A	**0%**	**10%**	**20%**	**30%**
7 Days	10	7	5.3	4.75
14Days	15	9	6.2	5.25
28Days	23	13	6.9	6.23



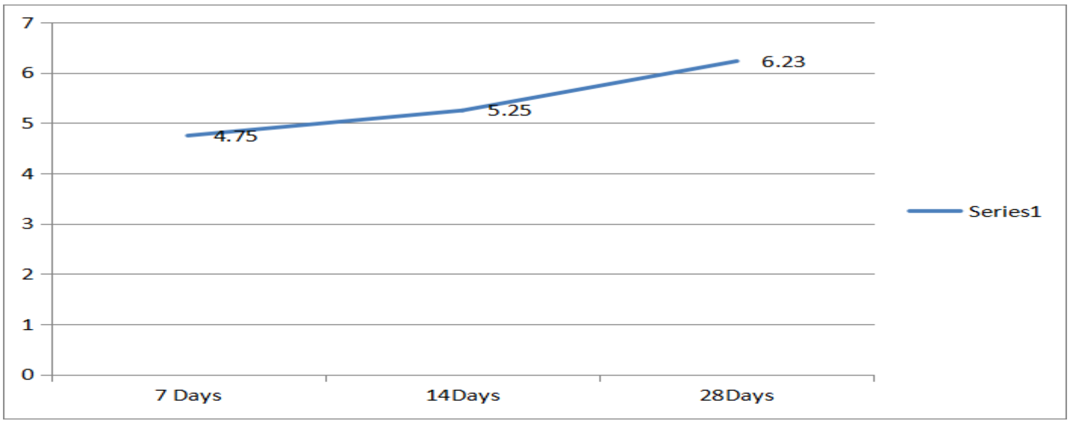
Graph 17 Flexural Strength of Normal Concrete



Graph 18: Flexural Strength of 10% RHA



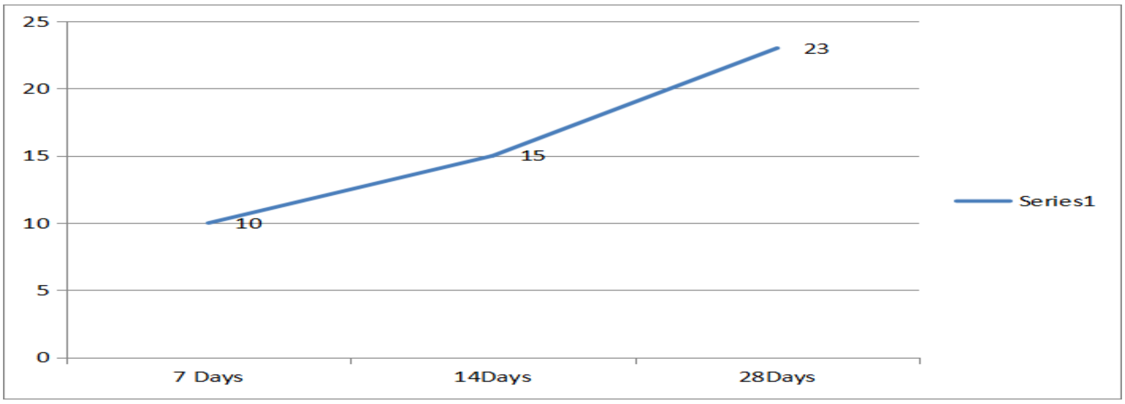
Graph 19: Flexural Strength of 20% RHA



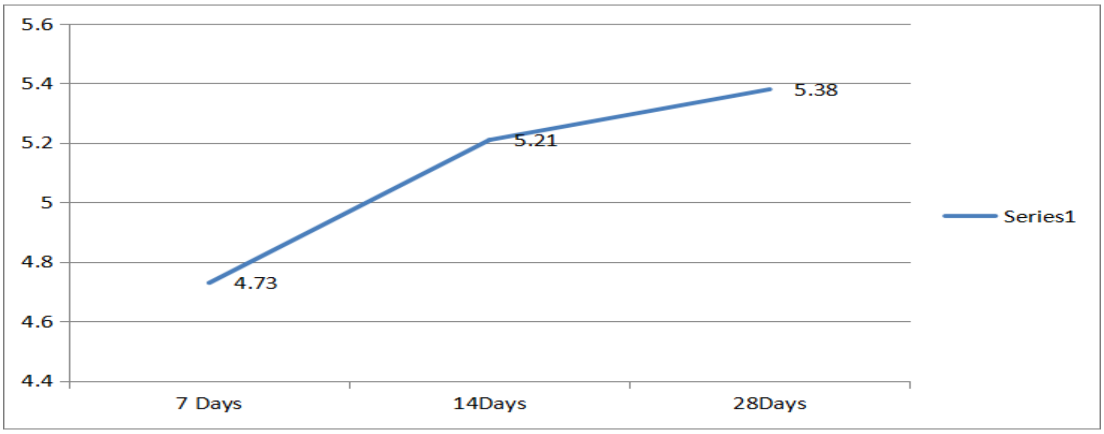
Graph 20: Flexural Strength of 30% RHA

Table 6: Saw dust ash

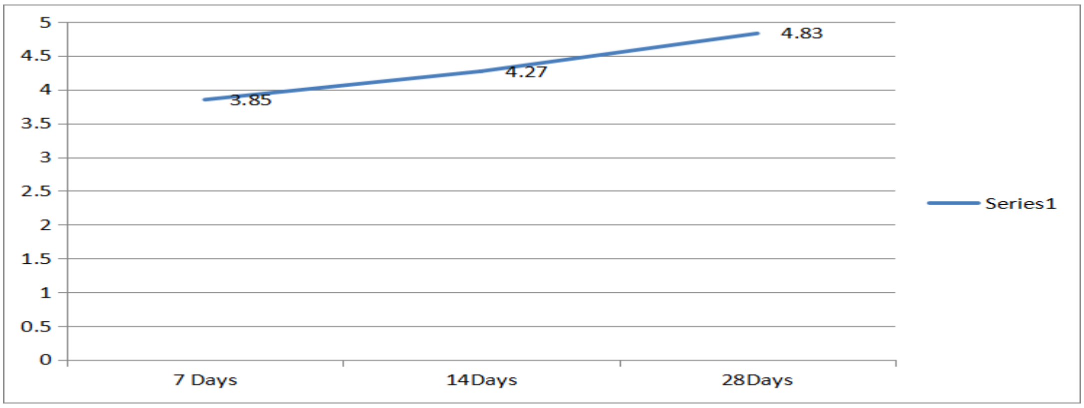
Conventional Mix N/mm^2				
Proportion of Saw dust ash	**0%**	**10%**	**20%**	**30%**
7 Days	10	4.73	3.85	3.54
14 Days	15	5.21	4.27	3.78
28 Days	23	5.38	4.83	4.21



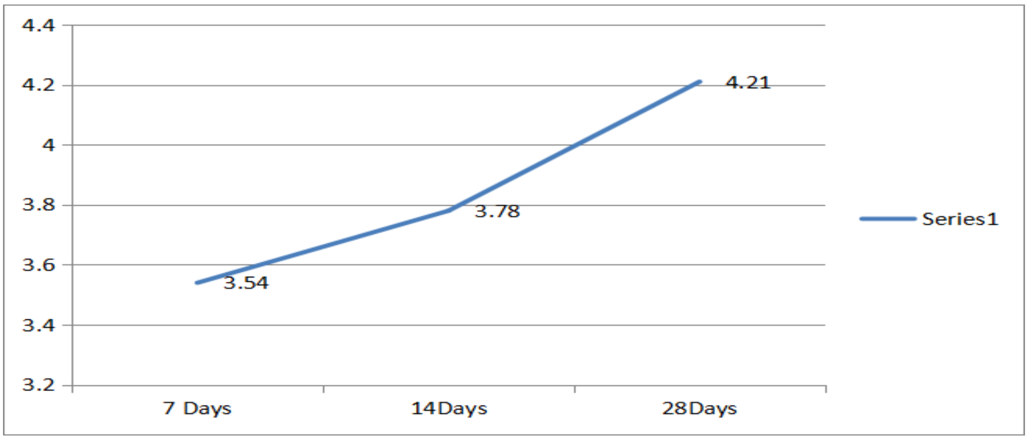
Graph 21: Flexural Strength of Normal Concrete



Graph 22: Flexural Strength of 10% S D A



Graph 23: Flexural Strength of 20% S D A



Graph 24: Flexural Strength of 30% S D A

VI. CONCLUSION

Drawing conclusion from the limited study conducted on the structural behavior of Rice Husk Ash (RHA) and sawdust ash in concrete, the following observations can bemade:

1. Compressive Strength : Compressive strength steadily rises with increasing rates of cement replacement by RHA. from 7 days to 14 days, with significant enhancement at 28 days. After the first 28 days, there is a further progressive rise.

2. Greenhouse Gas Emissions: There is a chance to earn more carbon credits via the use of Rice Husk Ash (RHA) and Silica Fume (SDA) in concrete, both of which have the potential to significantly reduce GHG emissions.

3. Technical and Economic Benefits: Especially in nations in Asia where rice is a major crop, the construction and rice industries would do well to investigate the technical and economic advantages of incorporating Rice Husk Ash (RHA) and Sawdust Ash (SDA) into concrete production.

4. Temperature Reduction: RHA and sawdust ash concrete blocks are an efficient way to lower indoor temperatures. Because of this, it may be possible to use the air conditioner less often, which would reduce energy consumption.
5. Lightweight Construction: Utilizing Rice Husk Ash (RHA) and Sawdust Ash (SDA) in concrete effectively reduces its weight, rendering it an ideal material for lightweight construction purposes.

6. Improved Impermeability: RHA and sawdust ash exhibit pozzolanic an activity that not only improves concrete strength but also improves its impermeability characteristics, making it more durable.

7. Cost Reduction: Since R H A and SDA are waste materials, their incorporation in concrete can help reduce construction Split tensile strength.

These discoveries imply that incorporating Rice Husk Ash (RHA) and Sawdust Ash (SDA) into concrete holds significant potential has various benefits, including enhanced strength, environmental advantages, energy savings, and cost reduction, Rendering them as potential materials for the construction industry, especially in regions with a significant rice industry presence.

REFERENCES

1. Strength characteristics of concrete and mortar containing flash with crushedrock powder as replacement of natural sand by Umesh G R
2. Department of Civil Engineeriong, Federal University of Technology, P.M.B65, Minna Nigeria, abdulapai@yahoo.com
3. RICE HUSK ASH AS A REPLACEMENT OF CEMENT IN PAVER BLOCKS, HimaHemant, JeevaRekha.P, D.P.Preet, Final Year, B.E. Students, Department of Civil Engineering, SonaCollege of Technology, Salem-5.

4. Department of Civil Engineering, Faculty of Engineering, University of Malaya, Malayasia

5. Mauro M. Tashima, Carlos A.R. Da Silva, Jorge L. Akasaki Michele BenitiBarbosa Civil Engineering Department, FEIS/USESP, Brazil

6. CONCRETE TECHNOLOGY by M.S Shetty.