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SUSTAINABLE PRODUCTION OF CONCRETE USING RICE HUSK ASH AND STEEL FIBRES: DURABILITY PARAMETERS

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ABSTRACT
Concrete in construction, is a structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel) that is bonded together by cement and water. Concrete is good in compression but weak in tension, hence new advancements are implemented like using steel fibres (SF) in concrete which will strengthen the tensile zone. An increased compressive, splitting tensile and flexural strength, flexural toughness, surface hardness, and abrasion resistance, and a decreased water absorption and sorptivity of concrete with an increased steel fibre content from 1% to 2% can be observed (Kaplan et al.2021). The rice husk itself has a very rough surface which is abrasive in nature so, it cannot be degraded naturally. This would result in improper disposal problems. Hence the usage of RHA will be a sustainable approach. For the current study, 5%, 10% and 15% of cement will be replaced with RHA and a constant SF of 1.75% as total volume of concrete will be added. The fresh, mechanical and durability parameters of the modified concrete will be studied to know the combined effect of SF and RHA. Moreover, non-destructive tests will also be performed to know the in-depth hardened concrete properties

Key Words: Concrete , Strength, Fibers, Mechanical properties

1. Introduction:

The world at the end of the 20th century that has just been left behind was very different to the world that its people inherited at the beginning of that century. The latter half of thelast century saw unprecedented technological changes and innovations in science andengineering in the field of communications, medicine, transportation and informationtechnology, and in the wide range and use of materials. The construction industry has been no exception to these changes when one looks at the exciting achievements in the design and construction of buildings, bridges, offshore structures, dams, and monuments, such as the Channel. Tunnel and the Millennium Wheel. The world at the end of the 20th century that has just been left behind was very different to the world that its people inherited at the beginning of that century. The latter half of thelast century saw unprecedented technological changes

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and innovations in science andengineering in the field of communications, medicine, transportation and information technology, and in the wide range and use of materials. The construction industry hasbeen no exception to these changes when one looks at the exciting achievements in thedesign and construction of buildings, bridges, offshore structures, dams, and monuments, such as the Channel. Tunnel and the Millennium Wheel.

2. Literature Review:

Ghassan Abood Habeeb, Hilmi Bin Mahmud, The compressive strength of the blended concrete with 10% RHA has been increased significantly, and for up to 20% replacement could be valuably replaced by cement without adversely affecting the strength. Increasing RHA fineness enhances the strength of blended concrete. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz, Mohamad Amran Mohd Salleh, RHA blended concrete can decrease the temperature effect that occurs during the cement hydration. RHA blended concrete can improve the workability of concrete compared to OPC, Godwin A. Akeke, Maurice E. Ephraim, Akobo, I.Z.S and Joseph O. Ukpata. The compressive strength and workability tests suggests that RHA could be substituted for OPC at up to 25% in the production of concrete with no loss inworkability or strength, G.A. Habeeb, M.M. Fayyadh, The mechanical properties in terms of flexural and tensile strength have been significantly improved with the addition of RHA, with the coarse RHA showing the least improvement. On the other hand, the value of Static modulus was comparable with slight increase in the RHA concrete mixtures, Yunusa A. Alhassan and Danladi Egbunu, The concrete incorporating PFA did not show any increase in the compressive strength compared to the RHA and the control Portland cement concrete. The higher strength of the RHA at all the replacement level compared to the PFA is due probably to its reduced porosity, reduced Ca(OH)2 content and the reduced width of the interfacial zone between the paste and the aggregates.A.M. Shende1 , A.M. Pande2 , M. Gulfam Pathan, It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibers as compared to that produced from 0%, 1% and 2% fibers. Yuanxun Zheng, Xiaolong Wu, Guangxian He, Qingfang Shang, Jianguo Xu and Yikai Sun, With the increase in steel fiber content, all of these mechanical properties such as compression strength, flexural strength, and splitting tensile strength improve gradually; especially for flexural strength and splitting tensile strength, the steel fiber reinforcement effect is obvious. At the same fiber + content, reinforcement effect of mechanical properties of high-strengthconcrete is better.

3.Materials:

3.1 Cement:

Ordinary Portland cement of 53 grades was used in this project.

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3.2 Coarse Aggregate:

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are being used. The Flakiness and Elongation Index were maintained well below 15%. Physical property evaluation and gradation of coarse aggregate were carried out and the test results are presented below: Aggregates are the major ingredients of concrete. They constitute 70-80% of the total volume, provide a rigid skeleton structure for concrete, and act as economical space fillers. Because at least threequarters of the volume of the concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. The properties of aggregate greatly affect the durability and structural performance of concrete..

The following tests have been conducted on coarse aggregates.

- Specific Gravity
- Fineness modulus

3.3 Fine Aggregates:

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand and crushed sand is being used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand is wash and screen, to eliminate deleterious materials and over size particles. The fine aggregate shall consist of natural sand or, subject to approval, other inert materials with similar characteristics, or combinations having hard, strong, durable particles. The use of concrete is being constrained by urbanization, zoning regulations, increased cost and environmental concern. The following tests have been conducted on fine aggregates

- Specific Gravity
- Sieve Analysis (Fineness Modulus)

3.4 **Water [IS: 456-2000]:**

Water used for both mixing and curing should be free from injurious amount of deleterious materials such as acids, alkalies, salts, organic materials etc. Potable water is generally considered satisfactory for mixing and curing concrete. In present work potabletap water was used.

3.5 Rice Husk Ash:

Table 3.6: Composition of Rice Husk Ash

1	Silicon Dioxide	86.94%
2	Aluminium Oxide	0.2%

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3	Iron Oxide	0.1%
4	Calcium Oxide	0.3 - 2.25%
5	Magnesium Oxide	0.2 - 0.6%
6	Sodium Oxide	0.1 -0.8%
7	Potassium Oxide	2.15- 2.30%

3.6 Steel Fibre

Steel fibres are low carbon , cold drawn steel wire fibres is one of promising areas of science. The use of steel fibre in concrete is new revolution. Steel fibre like crimped steel fibres and hooked end steel fibres etc.…which are presently used in concrete to modify its flexure strength properties. In the present study strength properties such as Compressive strength, split tensile strength and flexural strength of M35 grade of concrete with the use of steel fibre (1.75%) as additional with cement and sand were studied. It was found from the experimental study that concrete composites with superior properties can be produced using Steel fibre

3.7 Chemical Admixtures

Admixture is defined as materials, other than cement, water and aggregates, that isused as an ingredient of concrete and it is added to the batch immediately before or duringmixing.

4. Methodology:

4.1 Test for Compressive Strength Of Concrete (Is: 516-1959):

The compressive strength of concrete is one of the most important Properties of concrete in most structural application concrete is implied primarily to resist compressive stress.

In the investigation, conventional concrete Rice husk ash(RHA), Sugarcane Bagasse Ash (SBA), composite, concrete cubes of 150mm x 150mm x 150mm sizes were used for testing the compressive strength. The cubes are tested in a compression-testing machine of capacity 2000kn. The load has been applied at a rate of 315kn/mm. The load applied in such a way that the two opposite sides of the cubes are compressed. The load at which the control specimen ultimately fail is noted. The average of three cubes is taken as compressive strength.

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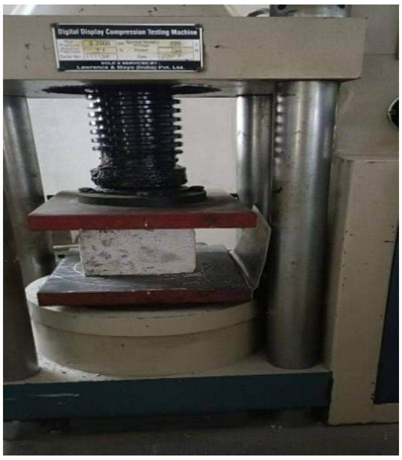

Fig 5.2: Compressive strength test for cement cube

5: Test To Find Density of Concrete Specimens: (BS EN 12390-7:2009)

At first, the mass (weight) of the concrete cube specimen is measured and then the side dimension of the cube is measured using which the volume ofthe cube is measured using the below mentioned formula

volume = $side^3$

Now, density of the cube is calculated using the formula given belowdensity = mass/volume

5.1 Durability Properties:

5.1.1 Test to find the Sorptivity:

Remove the specimen from the storage container and record the mass of the conditioned specimen to the nearest 0.01 g before sealing of side surfaces. Measure at least four lengths of the specimen at the surface to be exposed to water. Measure the length of the sides to the nearest 0.1 mm and calculate the average side dimension to the nearest 0.1 mm. Seal the side surface of each specimen with a suitable sealing material. The sealing material that is used here is liquid wax. Seal the end of the specimen that will not be exposed to water using a loosely attached plastic sheet . The plastic sheet can be secured using an elastic band or other equivalent system. Conduct the absorption procedure with tap water conditioned to the same temperature. Measure the mass of the sealed specimen to the nearest 0.01 g and record it as the initial mass for water absorption calculations. Place pan and fill the pan with tap water so that the water level is 3 to 5 mm above the top of the support. Maintain the water level 3 to 5 mm above the top of the support for the duration of the tests Record the time and date of initial contact with water. Record the mass at the intervals after first contact with water. The first point shall be at 60s and the second point at 5 mins. Subsequent measurements shall be within an acceptable error of 2 min of 10 min, 20 min, 30 min, and 60 min. The actual time shall be recorded to within 6 10 s. Continue the measurements every hour, with an acceptable error of 5 min, up to 6 h, from the first contact of the specimen with water and record the time within 6 1 min. After the initial6 h, take measurements once a day up to 3 days, followed by3 measurements at least 24 h apart during days 4 to 7; take a final measurement that is at least 24 h after the measurement at 7 days. The actual time of measurements shall be recorded with an acceptable error of 1 min. This will result in seven data points for contact time during days 2 through 8. Table 1 gives the target times of measurements and the tolerances for the times.

5.1.2 Water Absorption Test:

Water absorption on concrete cubes of 100 mm size was done as per the guidelines in BS 1881-122 after 28 days of normal water curing. Oven dried samples were kept in water for 24 hours and their initial and final weights were noted to find out the percentage water absorption as per the rules given in code.

5.1.3 Chloride Penetration Test:

For the permeability, the concrete samples' chloride penetration depth was analyzed through the silver nitrate ($AgNO_3$) squirting test (Baroghel-Bouny et al. 2007). The28-day cured cube samples were dipped in 3% NaCl solution.

The specimens were periodically withdrawn from the solution and were split into two halves at 7 and 28 days after dipping. The chloride penetration depth was then measured by squirting 0.1 N $AgNO_3$ solution on thesplit concrete surfaces. The color changes on the boundary indicated the depth of chloride permeability. The difference in the white color is due to the formation of AgCl when silver nitrate reacts with chloride ion present in the hardenedconcrete matrix whereas, Ag_2O (dark brown color) is formed at higher depth when silver nitrate reacts with hydroxyl ion present .

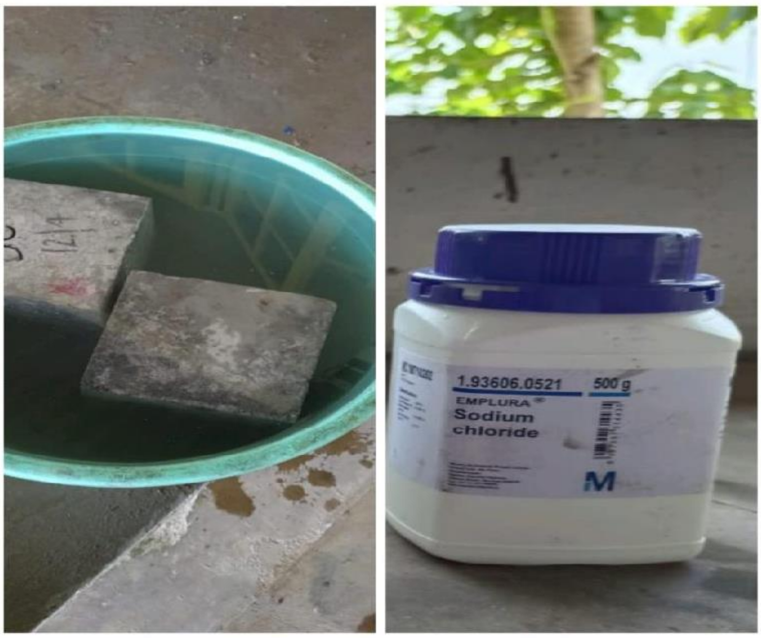

Fig 5.4.3: Chloride Penetration Test

5.1.4 Acid Attack Test:

Acid attack test was conducted for 7, 28 and 90 days as per ASTM C 267-97 [22]. As per its recommendation the test method is intended to evaluate the chemical resistance of hydraulic cement concrete under predicted service condition for which 3% hydrochloric acid was used to estimate acidic resistance. The oven dried concrete cubes (150 mm) were weighed first and then completely submergedin Hydrochloric acid solution. The solution was changed after every 3 weeks. Three cubes of each mix were tested after each exposure period. Change in weight was compared with the initially measured weight. Compressive strength of acid cured specimens has been conducted at respective ages. The load of 140 kg/cm2/min was applied gradually without any shock as per IS: 516-1959 [23]. The achieved results were then compared with the compressivestrength of 28-days water cured concrete cubes.

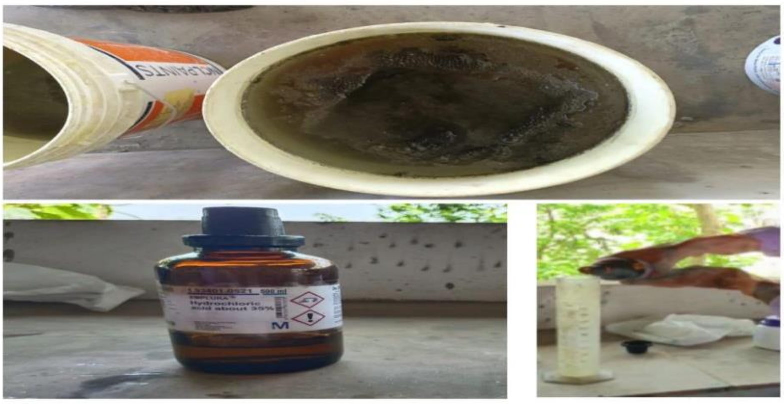

Fig 5.4.4: Acid Attack Test

6. Results and Discussion

6.1 Fresh Property

6.1.1 Workability:

The slump of concrete mixed using the M35 mix proportion was found to be a True slump. The value of slump has found to be varying with increase in the percentage of rice husk ash replacement. The steel fibers withhold the wet concrete together and decreases the workability. The height of slump is decreasing gradually with increase in percentage of rice husk ash, thus workability also increases with increase in percentage of rice husk ash.

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Mix no.	Slump Value(mm)
CC	84
MRHA5	83
MRHA10	82
MRHA15	81

TABLE6.1: SLUMP CONE

6.2: Hardened Properties

6.2.1Compressive strength :

The below shown results are obtained by testing the cube specimens of size 150mm under compressive testing machine (CTM), for a curing period of 7, 28 and 56 days, it is observed that when compared to the controlled concrete each and every replacement proportions there is a decrease in strength, for every increase in percentage replacement of rice husk ash there is a decrease in strength of the concrete. Maximum results were obtained at 5% replacement and the minimum results were obtained at 15% replacement.

TABLE6.2.1 : COMPRESSIVE STRENGTH

Mix.	Compressive Strength (Mpa)		
	7 days	28 days	56 days
CC	29.33	39.87	46.17
MRHA5	21.68	30.53	32.07
MRHA10	18.80	27.57	30.87
MRHA15	17.63	26.60	28.58

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6.2.2 : Density:

The mean densities of concrete cubes made with different replacement level of ss for age 28 days curing(hydration period).The density test comforms to BS EN 12390-7:2009.

The density of concrete in which 5%replacement of cement with RHA is made is greater than that of controlled concrete, it is also observed that the minimum density is obtained for MRHA10 and the maximum density is obtained for the mix MRHA

Table 6.3.2 DENSITY OF CUBES

Mix.	**DENSITY**
	28 days
CC	2130.333
MRHA5	2164
MRHA10	2113
MRHA15	2122.33

6.2.3 : Water Absorption:

Fig. 6.2.3.1 presents that water absorption increases with increase in the percentage of RHA in concrete mixes. The water absorption of RHA concrete at 28-days of curing for 15% replacement is 2.66%, however for control samples water absorption is 1.41%.The increase in water absorption might be due to percentage of silica that is present in RHA, which is highly porous structure and is lightweight, with high specific surface area angul This leads to reduction in adhesive strength between RHA and cement paste. The increased percentage of void sand cracks gives passage for water to penetrate inside the concrete. It is clear from Fig. 6.2.3.1 that with increase in substitution level, percentage of voids also increases. Relation between water absorption and voids ratio at the age of 28-days of curing shown in Fig. 6.2.3.1.

Table 6.2.3 WATER ABSORPTION TABLE

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Design Mix	WATER ABSORPTION (%)
	28 Days
CC	1.47
MRHA5	1.38
MRHA10	2.37
MRHA15	2.66

6.2.4 : Sorptivity:

It has been observed that the sorptivity values are getting increased as the age of the specimens and the percentage of RHA that is being used is increasing as shown in the table

Hydration age	MRHA0	Weights	MRHA5	Weights4	MRHA10	Weights2	MRHA15	Weights3
0 secs	0.1	8.43	0.19	8.19	0.26	7.53	0.29	7.59
60 secs	0.24	8.29	0.28	8.1	0.35	7.44	0.41	7.47
300 secs	0.26	8.27	0.29	8.09	0.39	7.4	0.46	7.42
600 secs	0.42	8.11	0.45	7.93	0.51	7.28	0.58	7.3
1200 secs	0.56	7.97	0.61	7.77	0.58	7.21	0.65	7.23
1800 secs	0.59	7.94	0.63	7.75	0.68	7.11	0.72	7.16
3600 secs	0.65	7.88	0.69	7.69	0.73	7.06	0.78	7.1
7200 secs	0.74	7.79	0.78	7.6	0.84	6.95	0.86	7.02
10800 secs	0.81	7.72	0.83	7.55	0.89	6.87	1.01	6.87
14400 secs	0.83	7.7	0.85	7.53	0.91	6.88	1.03	6.85
18000 secs	0.85	7.68	0.87	7.51	0.93	6.86	1.04	6.84
21600 secs	0.87	7.66	0.89	7.49	0.95	6.84	1.06	6.82
86400 secs	0.88	7.65	0.91	7.47	0.96	6.83	1.08	6.8
172800 secs	0.94	7.59	1.01	7.37	1.14	6.65	1.23	6.65
259200 secs	1.03	7.5	1.12	7.26	1.2	6.59	1.26	6.62
345600 secs	1.15	7.38	1.22	7.16	1.26	6.53	1.29	6.59
518400 secs	1.51	7.02	1.62	6.76	1.67	6.12	1.73	6.15
604800 secs	1.59	6.94	1.76	6.67	1.79	6	1.86	6.02

6.2.5 : Acid Attack:

1) Compressive Strength:

As the percentage of RHA is increasing it is observed that the loss in compressive strength is also increasing and it is greater than the loss incurred in compressive strength of controlled concrete cubes due to the same acid attack. It has also been observed from Fig. 6.2.5.1 that concrete surfaces gets pulpified which results into development of cracks and erosion of surface layers

2) Loss in mass:

As shown in the table 6.2.5 and figure as the amount of replacement of cement with rice

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husk ash is increasing the percentage of loss in mass is also increasing. This might be due to the greater reactivity percentage of RHA which is about 300%

Table 6.2.5 Acid Attack Test Results

Mix.	**Loss in Compressive Strength (%)**			**Loss in mass due to disintegration**		
	7 days	14 days	28 days	7 days(%)	14 days(%)	28 days(%)
CC	-4.5	-9.56	-15.55	2.45	3.67	4.86
MRHA5	-5.4	-12.55	-20.41	2.77	4.42	5.45
MRHA10	-7.8	-14.65	-25.41	3.66	4.59	5.48
MRHA15	-6.69	-19.55	-26.45	3.89	4.89	5.96

6.2.6 : Chloride Penetration:

After 7 days of curing the chloride penetration test values is in proportion with the amount of rice husk ash added but in the test results of specimens which are cured for 14 days and 28 days the maximum penetration values are obtained for 10% replacement of RHA. The evolution of compressive strength, weight loss, and reduction in strength was monitored for up to 6 months. Generally, the compressive strength test has been shown that use of RHA in blended cement has a significant influence on chloride concentration. When increasing the replacement level of RHA, the strength of concrete also increases in comparison to controlled concrete even subjected to sodium chloride. In addition, increasing the percentage replacement of RHA tends to reduce the compressive-strength loss due to increased pozzolanic reaction. It is concluded that the incorporation of RHA in cement significantly improved the resistance to chloride penetration of concrete.

Table 6.2.6: Chloride Penetration values

DesignMix	Penetration(mm)		
	7 days	14 days	28 days
CC	2.88	3.98	8.95
MRHA5	3.58	6.45	7.98
MRHA10	4.32	5.68	8.32
MRHA15	4.56	5.52	7.56

7. Conclusion:

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RHA is economical, the strength might be less when compared to the control concrete, but can be used for constructions in rural areas to decrease the construction cost. By using this rice husk ash in concrete as replacement, the emission of green house gases can be decreased to a greater extent. As a result there is greater possibility to gain more number of carbon credits. The technical and economic advantages of incorporating rice husk ash in concrete should be exploited by the construction and rice industries, more so for the rice growing nations of Asia lie India. The compressive strength of the concrete cubes made with partial replacement of RHA is observed as lower than that of controlledcubes. It is observed that the compressive strength is decreasing as the percentage of RHA is increasing.

Density of concrete cubes made with 5% replacement of cement with RHA is greater than that of the controlled concrete cubes. But it got decreased as the percentage of RHA that is used in increased. Sorptivity is increasing a the percentage of RHA is increasing and/or the age of the specimens is getting increased. Percentage of loss in compressive strength due to acid attack got increased as the percentage of RHA that is used is increasing. The same trend is followed in the case of loss of mass due to disintegration when cure in acid solution. The Chloride penetration values got increased as the percentage of RHA and/or the age of the specimens is increasing. As the percentage of RHA is increasing, the water absorption values got increased due to the intake of water by the excess of RHA that is not used in pozzolanic reactions.

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