# Characteristics of Fibre-Reinforced Rice Husk Ash Concrete on Strength

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**Abstract -** *Concrete is a worldwide accepted construction material. Cement is one of the constituents of concrete and its manufacturing leads to environmental pollution. The present study focuses on enhancing strength properties of concrete made of cement which is partially replaced with different percentages of Rice Husk Ash (RHA). RHA having rich silica and it is a waste material obtained from burning rice husk. Cement is partially replaced with RHA in different percentages of 7.5%, 10%, 12.5%, 15% and 17.5%. It is found that 15% replacement of cement with RHA gives higher strength and it is the Optimum RHA (ORHA) replacement. Further, the present study aims at increasing the strength of ORHA replaced cement concrete. For that two varieties of fibres namely lathe waste fibres and steel fibre was added in small quantities to the total weight of concrete.*

***Key Words*: Concrete; Rice Husk Ash; lathe waste fibres; steel fibres; strength.**

## 1. INTRODUCTION

Concrete is the most sought-after construction material for the development of infrastructure which includes buildings, industrial structures, bridges, and highways etc. Concrete is recognized as the basis of a nation's infrastructure due to its structural stability and strength. Cement is the most important ingredient in the concrete. Production of Ordinary Portland Cement (OPC) involves high energy consumption and leads environmental pollution. The demand for cement is ever increasing and it is true that the raw materials required for the cement production are relatively scarce. Apart from a rich process of cement production, the environmental impact due to the release of Carbon dioxide ($CO_2$) is drastic, since it takes hold of the major share in causing global warming. Over 5% of global $CO_2$ emissions can be credited to Portland cement production. All the raw materials required for producing cement comes from the earth's crust. One of the efficient methods to conserve the natural resources and reduce the impact on the environment is to go for reducing the quantity of OPC in concrete. The increasing demand for cement use in concrete is met by partial cement replacement. To reduce the limitations of cement (OPC), it can be partially replaced with green materials which have pozzolanic characteristics. Substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intense Portland cement. The use of by-products is an environmentally friendly method of disposal of large quantities of materials that would otherwise pollute land, water, and air. Human activities on the Earth produce solid wastes including industrial wastes, agricultural wastes, and wastes from rural and urban societies. Recent technological development has shown that these materials are valuable as inorganic and organic resources and can produce various useful products. Amongst the solid wastes, the most prominent ones are fly ash, blast furnace slag, and rice husk ash. An increase in the consumption of mineral admixtures by the cement and concrete industries had been started since the middle of 20$^{th}$ century.

Globally rice paddy of about 600 million tons is being produced, accounting for an annual production of 120 million tons Rice Husk. It is estimated that India is the second largest producer of rice in the world with a production of 132 million tons per year annually. The milling of rice produces rice husk as a waste material. This husk is used as fuel and is converted into ash during the firing process, which is known as rice husk ash (RHA). Rice husk ash contains 90%-95% of reactive silica. Rice Husk Ash is a Pozzolanic material. RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing of it by making commercial use of this RHA. In recent years significant work has been carried to investigate rice husk ash as a beneficial addition to concrete, either as a partial replacement for cement or as an additive. Krishna and Sandeep, 2016 has tried four different replacement levels namely 5%, 10%, 15% and 20%. From the experimental investigation, it was found that optimum replacement of Rice Husk ash in cement was near to 10% with respect to workability and strength. Kulkarni, et al., 2014 studied that with an addition of 20% RHA in normal M30 grade concrete strength is running parallel or more than of normal concrete. Thus 20% RHA is the optimum content for getting nearly equal strength at 28days. Kartini et al. 2012 used the partial replacement cement with RHA in percentages of 10%, 20%, 30%, 40% and 50% of by cement weight, and with an addition of Superplasticizer. They concluded that 10% replacement of cement with RHA was found to be the optimum replacement in achieving the targeted strength. Padmarao et al., 2014 studied feasibility to use Rice Husk Ash as an admixture to an already replaced Cement with fly ash in Concrete. Five different replacement levels namely 5%, 7.5%, 10%, 12.5% and 15% are chosen for the study. The optimum replacement level is found to be 7.5%. Busra et al., 2016 stated that when RHA is used at 3% of cement by weight it can prevent explosive spalling. Muthadhi and Kothandaraman (2013) have done experiments on concrete in which ordinary Portland cement was partially replaced with RHA content of 10 to 30% of cement and found that 20% replacement of cement by RHA addition is found to be the optimum dosage in concrete making. In the present investigation, Ordinary Portland cement (OPC) was replaced by rice husk ash at various percentages to study compressive, splitting tensile and flexural strength.

Further, the present study aims at increasing the strength of ORHA replaced cement concrete. For this two types fibres namely steel fibres and lathe waste fibres were added in small quantities to the total weight of concrete. As the Steel fibre are expensive we could not able to maintain the economy of construction. Addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. As lathe waste is harmful in terms of environmental effects it can be used in concrete. Murali et al. (2012) have done an experimental investigation on understanding the influence of addition of lathe waste at a dosage of 1% of total weight of M25 grade concrete. The lathe waste was deformed into the rectangular strips of 3mm width and 10mm length. The results were compared with conventional concrete it was observed that concrete blocks incorporated with steel powder increased its compressive strength by 41.25% and tensile strength by 40.81%. Pooja and Joshi (2014) conducted experiments on M20 grade concrete containing fibre contents 0 to 2 %. The compressive strength of scrap steel fibre reinforced concrete slightly increases 3% as compared to plain concrete. Tensile strength increases up to 20% and flexural strength effectively increase nearly 40 % after 28 days. But all these mechanical properties increase up to 1.5% fibre contents, on further increasing fibre contents tends to decrease in strength. Ashok et al. (2012) made fibre reinforced concrete using steel scrap obtained from lathe machine in M20 concrete. The results of tests done on Steel Scrap Fibres having a different proportion of 0.5%, 1.0%, 1.5%, 2.0% by weight of cement has been taken into account. The study proves that the mechanical properties of the concrete are increased by increasing the proportion of the steel scrap up to 1.5%. From 1.5% to 2.0%, it shows a slight decrease in mechanical strength. Joy and Rajeev, (2015) has been made an investigation to study the performance of addition of steel lathe waste fibre from a workshop at a dosage of 0.5%, 1% and 1.5% of total weight of M25 grade concrete. The optimum value was obtained by adding scrap by 1% weight of concrete for turn fibre in compression, tension, and flexure. The present investigation was carried out to study the feasibility of using lathe waste fibres in concrete. Waste fibre from lathe industry was collected and used in this investigation.

Further Experiments were conducted on ORHA replaced cement concrete reinforced with steel fibres. Steel fibres are used for relative comparison of the efficacy of lathe waste fibre. Several investigators worked on steel fibre reinforced concrete. Sivakumar & Southararajan, (2013) has done RHA as a partial cement substitute at replacement levels of 10% and 20% by weight of cement, with different dosages of steel fibres of 0.5 and 1.0% volume fraction. Experimental results demonstrated that 10% RHA substitution led to improved compressive properties compared to plain concrete. The addition of rice husk ash at a level of 10% and steel fibres of up to 1% provides a remarkable improvement of compressive strength, tensile strength, and flexural strength. Priyank et al. (2015) studied properties of M40 grade concrete in which cement is replaced by fly ash, rice husk ash with an addition of steel fibre. Three different replacements levels namely 10%, 20%, and 30% of fly ash and rice husk as well as with combined replacement of fly ash and rice husk ash chosen for the study concern to replacement method and steel fibre substitute in concrete was 0%, 0.25%, 0.50%, 0.75%, and 1.0% respectively. It was seen that the workability of concrete had been found to decrease with increasing the percentages of fly ash, rice husk ash, and steel fibre. The combination of 20% fly ash+10% rice husk and 0.75% of steel fibre gives optimum strength results. Padmanabha Rao, (2009) stated that addition of steel fibres in concrete can slightly enhance the compressive strength and modulus of elasticity but remarkably improve flexural strength, flexural toughness, and ductility. There is an increase of 30% to 120% was observed in flexural capacities when fibre content is increased from 0.5% to 1.5% by volume. Maheshbhai and Jayeshkumar (2016) reported that the optimum % of replacement of cement with RHA is 15% for M30 grade concrete. The compressive strength of about 40 MPa is achieved with the addition of 2% of steel fibre to 15% RHA replaced cement concrete.

## 2. MATERIAL USED

### 2.1 Cement

Cement used in the experimental work is Ordinary Portland Cement (OPC- 53 grade) and tested as per IS 12269-1987. The physical and chemical properties of the cement obtained on conducting appropriate tests as per IS 269/4831. Specific Gravity, Bulk density, and Fineness of cement are 3.12, 1440 kg/m$^3$ and 8% respectively.

### 2.2 Rice Husk Ash (RHA)

Rice husk ash used was obtained from the local hotel. Rice husk ash has slight black in color. The properties of RHA are presented in Table 1. Specific Gravity of RHA is 2.34.

### 2.3 Fine Aggregate

Locally available Krishna river sand passing through 4.75mm IS sieve conforming to grade zone II of IS 383-1970 was used as fine aggregate. Sand used in the present study has cubical or rounded shape with smooth surface texture. Being cubical, rounded and smooth texture it gives good workability. The properties of fine aggregate are presented in Table 2. Specific Gravity of and fineness modulus of fine aggregate are 2.626 and 2.732 respectively.

### 2.4 Coarse Aggregate

Crushed granite of 20 mm maximum size has been used as coarse aggregate. 60% of the aggregate used is of 10-12 mm size and remaining 40% are of 20mm size. Physical properties of coarse aggregate like fineness modulus, specific gravity are 6.88 and 2.69 respectively.

### 2.5 Water

Potable tap water was used for the preparation and curing of all concrete specimens. Its pH value should be lies in between 6-8.

### 2.6 Lathe Waste fibre

Lathe waste fibre is collected from nearby foundry used as fibres in concrete. Lathe waste fibre of 0.45 mm average width has been used in this investigation. The average length of 40 mm and of aspect ratio about 90 has been used in this experimental work. The lathe waste fibre used in the present study is shown in Fig. 1.

**Fig. 1: Lathe Waste fibre**

### 2.7 Steel Fibre

The steel fibre of 0.5 mm diameter, 60 mm length and aspect ratio 120 has been used in this experimental work. All the steel fibres are Double Hooked Steel Fibres (shown in Fig. 2).

**Fig. 2: Steel fibre**

## 3. EXPERIMENTAL PROGRAMME

The present work explores the suitability of using Rice husk ash as a replacement of cement partially in M20 grade concrete. The mix proportion was done as per IS: 10262-2009. The target mean strength was 26.0 MPa. Water binder ratio of 0.45 was taken in the present investigation. The compressive strength was found for 7 and 28 days. The splitting tension and flexural strength were found for 7 and 28 days.

Test series-1 was planned and conducted in order to determine the optimum RHA replaced with weight of cement as 7.5%, 10%, 12.5%, 15% and 17.5%.

Test series-2 was designed and carried out by adding lathe waste fibres in percentages by weight of optimum RHA replaced cement concrete in 0.5%, 1.0%, 1.5% and 2.0%.

Test series-3 was intended by adding steel fibres in percentages by weight of optimum RHA replaced cement concrete in 0.5%, 1.0%, 1.5% and 2.0%.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Optimum Content of RHA

Strength tests were conducted on concrete in which cement is partially replaced with RHA in percentages of 7.5%, 10%, 12.5%, 15% and 17.5% by weight of cement. The results of compression, splitting tension and flexural tests are conducted on specimens cured for different curing periods are presented in Tables 1, 2 and 3 respectively.

Table. 1: Variation of Compressive strength with % of Rice Husk Ash replacement

| S.NO | % of RHA | Compressive Strength (MPa) | |
|---|---|---|---|
| | | **7 days** | **28 days** |
| 1 | 0 | 20.52 | 1 |
| 2 | 7.5 | 16.3 | 2 |
| 3 | 10 | 16.68 | 3 |
| 4 | 12.5 | 18.17 | 4 |
| 5 | 15 | 19.18 | 5 |
| 6 | 17.5 | 17.63 | 6 |

Table. 2: Variation of Flexural strength with % of Rice Husk Ash replacement

| S.NO | % of RHA | Flexural Strength (MPa) | |
|---|---|---|---|
| | | 7 days | 28 days |
| 1 | 0 | 0.78 | 2.74 |
| 2 | 7.5 | 0.81 | 2.52 |
| 3 | 10 | 0.82 | 2.08 |
| 4 | 12.5 | 0.78 | 2.21 |
| 5 | 15 | 0.95 | 2.94 |
| 6 | 17.5 | 0.77 | 2.45 |

Table. 3: Variation of Splitting Tensile strength with % of Rice Husk Ash replacement

| S.NO | RHA % | Split Tensile Strength (MPa) | |
|---|---|---|---|
| | | 7 days | 28 days |
| 1 | 0 | 2.87 | 4.12 |
| 2 | 7.5 | 1.86 | 2.99 |
| 3 | 10 | 2.17 | 3.32 |
| 4 | 12.5 | 2.38 | 3.68 |
| 5 | 15 | 2.59 | 3.95 |
| 6 | 17.5 | 2.14 | 3.3 |

All test results showed there is a remarkable improvement in strength characteristics up to 15% partial replacement of RHA in cement. The amount of cement replacement up to 15% with RHA, strength gain increases, and beyond this level of RHA addition the strength gain decreases. From the Tables 1, 2 and 3, it is noticed that the optimum percentage replacement of RHA (ORHA) was found to be 15% from the viewpoint of strength characteristics.

**4.2 Optimum Lathe Waste**

The replacement of cement partially with ORHA gives the desired strength but it is not very significant. Addition of fibres may help to enhance strength properties of concrete. Strength tests were conducted on ORHA replaced cement concrete added with lathe waste fibres in percentages of 0.5%, 1.0%, 1.5% and 2.0% by weight of concrete. Compressive strength, splitting tensile strength and flexure test results of specimens cured for different curing periods are presented in Table 4, 5 and 6 respectively.

Table. 4: Variation of Compressive strength with % of Lathe Waste Fibres added by weight of ORHA concrete

| S. No | RHA % | % of Lathe Waste Fibre | Compressive Strength (MPa) | |
|---|---|---|---|---|
| | | | 7 days | 28days |
| 1 | 15 | 0 | 19.18 | 29.07 |
| 2 | 15 | 0.5 | 21.64 | 31.87 |
| 3 | 15 | 1 | 21.84 | 33.41 |
| 4 | 15 | 1.5 | 22.15 | 34.73 |
| 5 | 15 | 2 | 20.53 | 32.53 |

Table. 5: Variation of Flexural strength with % of Lathe Waste Fibres added by weight of ORHA concrete

| S. No | RHA % | % of Lathe Waste fibre | Flexural Strength (MPa) | |
|---|---|---|---|---|
| | | | 7days | 28days |
| 1 | 15 | 0 | 0.95 | 2.94 |
| 2 | 15 | 0.5 | 1.12 | 3.29 |
| 3 | 15 | 1 | 1.28 | 3.67 |
| 4 | 15 | 1.5 | 1.65 | 4.12 |
| 5 | 15 | 2 | 1.24 | 3.44 |

Table. 6: Variation of Splitting Tensile strength with % of Lathe Waste Fibres added by weight of ORHA concrete

| S.NO | RHA % | % of Lathe Waste Fibre | Split Tensile Strength (MPa) | |
|---|---|---|---|---|
| | | | 7days | 28 days |
| 1 | 15 | 0 | 2.59 | 3.59 |
| 2 | 15 | 0.5 | 2.73 | 3.63 |
| 3 | 15 | 1 | 2.82 | 3.94 |
| 4 | 15 | 1.5 | 2.97 | 4.22 |
| 5 | 15 | 2 | 2.47 | 3.78 |

From the strength test results shown in Fig. 4, 5 and 6, the optimum percentage of adding lathe waste is found to be 1.5%. Addition of lathe waste fibres enhances the compressive strength, splitting tensile strength and flexural strength in percentages of 17.47 %, 17.54%, and 40.13% respectively for 28 days. As the fibres are added to the concrete the gain in splitting tension and flexural strength much pronounced than compressive strength.

### 4.3 Optimum Steel Fibre

Strength tests were conducted on optimum RHA replaced cement concrete reinforced with steel fibres in percentages of 0.5%, 1.0%, 1.5% and 2.0% by weight of concrete. Test results are shown in Table 7, 8 and 9 respectively.

Table. 7: Variation of Compressive strength with % of Steel Fibres added by weight of ORHA concrete

| S. No | RHA % | % of Steel Fibre | Compressive Strength (MPa) | |
|---|---|---|---|---|
| | | | 7 days | 28 days |
| 1 | 15 | 0 | 19.18 | 29.07 |
| 2 | 15 | 0.5 | 21.64 | 33.47 |
| 3 | 15 | 1 | 22.54 | 36.81 |
| 4 | 15 | 1.5 | 23.15 | 37.73 |
| 5 | 15 | 2 | 21.83 | 34.83 |

Table. 8: Variation of Flexural strength with % of Steel Fibres added by weight of ORHA concrete

| S. No | RHA % | % of Steel Fibre | Flexural Strength (MPa) | |
|---|---|---|---|---|
| | | | 7 days | 28 days |
| 1 | 15 | 0 | 0.95 | 2.94 |
| 2 | 15 | 0.5 | 1.22 | 3.54 |
| 3 | 15 | 1 | 1.63 | 3.93 |
| 4 | 15 | 1.5 | 1.85 | 4.34 |
| 5 | 15 | 2 | 1.48 | 3.69 |

Table. 9: Variation of Splitting Tensile strength with % of Lathe Waste Fibres added by weight of ORHA concrete

| S.NO | RHA % | % of Steel Fibre | Split Tensile Strength (MPa) | |
|---|---|---|---|---|
| | | | 7 days | 28 days |
| 1 | 15 | 0 | 2.59 | 3.95 |
| 2 | 15 | 0.5 | 2.72 | 3.98 |
| 3 | 15 | 1 | 2.84 | 4.17 |
| 4 | 15 | 1.5 | 3.14 | 4.56 |
| 5 | 15 | 2 | 2.67 | 4.31 |

From the test results shown Table. 7, 8 and 9, the optimum percentage of adding steel fibres is found to be 1.5% from the viewpoint of strength characteristics.

From Table 7, 8 and 9, it is noticed that addition of steel fibres enhance the compressive strength, splitting tensile strength and flexural strength in percentages of 29.79%, 15.44%, and 47.61% respectively for 28 days. As the fibres are added to the concrete the gain in splitting tension and flexural strength much pronounced than compressive strength.

## 5. CONCLUSIONS

The following conclusions have been made based on the results obtained from the experimental investigation:

1. Cement replaced with 15% Rice husk ash has contributed to achieving desired strength of concrete. Allowing for the strength and cost-effectiveness 15% replacement of cement by RHA is found to be the optimum dosage in concrete making.
2. Addition of 1.5% lathe waste fibres to cement replaced ORHA concrete improves the compressive strength, splitting tensile strength and flexural strength in percentages of 17.47 %, 17.54%, and 40.13% respectively. Addition of 1.5% Lathe waste fibre to ORHA replaced concrete is the optimum fibre content.
3. The percentage gain in splitting tensile strength and flexural strength are much pronounced than compressive strength when lathe waste fibres are added.
4. Addition of 1.5% steel fibres to concrete enhances the compressive strength, splitting tensile strength and flexural strength in percentages of 29.79%, 15.44%, and 47.61%, correspondingly.
5. Strength in concrete is more when reinforced with steel fibres than lathe waste fibre. Addition of lathe waste fibres gives parallel results as steel fibres, but the addition of lathe waste fibre as a substitute of steel fibre in concrete is an inexpensive and recyclable activity.

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