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Effect on Concrete Strength Due to Partial Replacement of Cement by Rice Husk Ash

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Abstract

Concrete is well known as a heterogeneous mix of cement, water, and aggregates. Various materials are added to obtain concrete of the desired property. Rice husk ash is the byproduct of burned rice husk at higher temperatures and is commonly used nowadays to improve the mechanical properties of concrete. The main objective of this Research is to study the suitability of the RHA (both blue ignition and yellow ignition brunt Rice husk ash) as a pozzolanic material for cement replacement in concrete. However, it is expected that the use of RHA in Concrete improves the strength property of concrete. Also, it is made to develop the concrete using rice husk ash as a source material for partial replacement of cement which satisfies the structural properties of concrete like compressive strength. In this study IS code was considered for the test of material and concrete and compare with code. It provides several advantages, such as improved strength and durability properties and environmental benefits related to the disposal of waste materials and to reduce carbon dioxide emissions. Up to now, little research has been done to investigate the use of RHA as a supplementary material in cement and concrete production. The compressive strength of RHA concrete studied shows that the maximum compressive strength can be found for a mix with 5 to 15 percent of RHA in both blue ignition and yellow ignition brunt Rice husk ash, beyond this value, the strength goes on decreasing for all age of concrete.

Keywords: *Compressive Strength, Replacement, Rice Husk Ash*

1. Introduction

Rice Husk can be burnt into ash that fulfills the physical characteristics and chemical Composition of a mineral admixture. Rice husk ash is the byproduct of burned rice husk at higher temperatures and is commonly used nowadays to improve the mechanical properties of concrete. Considerable efforts are being taken worldwide to utilize natural waste and by-products as supplementary cementing materials to improve the properties of cement concrete. RHA is a by-product of the paddy industry. Rice husk ash is a highly reactive pozzolanic material produced by controlled burning of rice husk. Rice Husk is one of the waste materials in the rice growing regions. This not only makes the Purposeful utilization of agricultural waste but it will also reduce the consumption of energy used in the production of cement.

Some of these mineral admixtures have cementitious properties, some act like filler materials and some are pozzolanic. From the engineering point of view, the incorporation of these by-products enhances the properties of concrete not only in its fresh state but also in its hardened state. Also, the disposal of these waste materials creates a great problem for land acquisitions as well as environmental pollution.

The proper utilization of these by-products as supplementary cementing materials minimizes these problems to some extent. From an economic point of view utilization of siliceous mineral admixtures can directly contribute to the conservation of material resources and better energy usage. Hence this study is focused on investigating the possibilities of using Rice Husk Ash as mineral admixtures in concrete in the condition of Nepal.

Test results indicated a positive relationship between a 15% replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength and durability properties generally gain with an addition of up to 20%, beyond that is associated with a slight decrease in strength parameters by about 4.5%. The same results obtained for water absorption ratios are likely to be unfavorable (Zareei et al., 2017). When malic acid (MA) solutions are added to ordinary Portland cement (OPC), rapid heat evolution takes place, but the hydration is retarded considerably at all the MA concentrations the retardation of the hydration of Portland cement may be attributed to the formation of this new compound (Rai et al., 2004). 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 (Krishna et al., 2016). RHA was used to partially replace cement with ratios of 10 %, 20 % and 30 %. The 20 % cement replacement mix produced the optimum 18 MPa concrete strength results at a 0.5 water/binder ratio. This translated into a cost reduction of concrete by 12.5 %, which is particularly significant for higher concrete volumes (Muleya, F. et al., 2021). The optimum results are achieved with a 6% replacement of cement with rice husk ash (Tariq et al., 2021). It not only addresses the challenge of waste management in rice mills but also helps in mitigating the impact of concrete production on the environment. The addition of rice husk ash in concrete can enhance the strength and durability of the material while providing additional environmental benefits and contributing to the circular economy (Phatak et al., 2024).

An adverse impact was found to increase the water-cement ratio, which is assigned to the effect of water on RHA and as a result on the porosity of the concrete (Al-Alwan et al., 2024). RHA as a partial replacement to cement improved the strength properties and durability properties that remained within limits of up to 20% replacement (Chopra et al., 2015). Sugar cane bagasse and rice husk ashes are used as pozzolan. Ordinary and high-strength concrete with binary and ternary mixtures. The ashes caused improvement in rheology, strength, and durability. Ternary mixture decreased the adiabatic temperature rise (G.C. et al., 2012). However, some areas such as the bending and shear responses (and allied properties) of reinforced concrete slabs and beams with RHA are presently not yet covered by researchers; they are therefore recommended for future investigation (Christopher, 2017). The workability test results prove, the replacement of RHA, does not affect the flow of concrete. And the compression strength test proves concrete with 7.5% RHA attains maximum strength (Harihanandh et al., 2022).

2. Materials and Methods

Design mix concrete is the type of concrete used in construction, to produce the grade of concrete having the required workability and characteristic strength nominal mix, which will reduce the cement content which is used in concrete reduce the water-cement ratio also will increase the Strength. In this, general procedure has been given for the concrete of grades vary from this procedure of M20 grade of concrete.

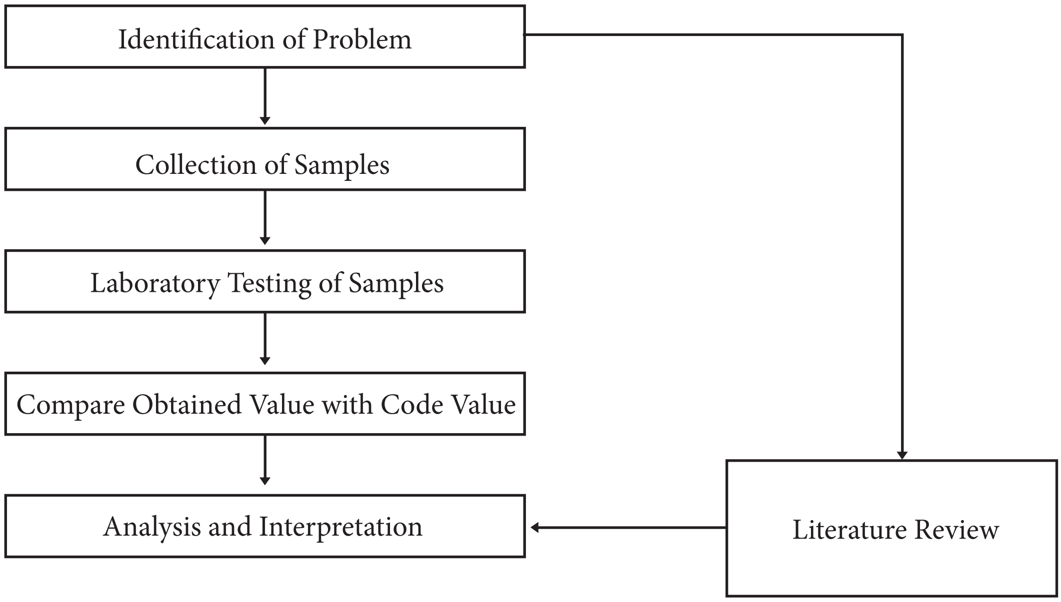

Figure 1: Research Diagram

It is also expected that the outcome of the study shows an overall beneficial effect on the utility of rice husk ash concrete in the field of civil engineering construction work. Also from the literature survey, it is observed that the parameters suggested by different researchers and their results do not match each other; It was due to variations in the properties of different materials considered in the work. Therefore, the percentage replacement of cement rice husk ash and method of mix design is fixed after a preliminary investigation. The materials used in this research work are cement, fine and coarse aggregates, rice husk ash, and water. As this research work is concerned with RHA as a local mineral admixture in the context of Nepal, no tests were carried out on the physical and chemical properties of cement, coarse, and fine aggregates. Both coarse and fine aggregates used are of Kotre, Kaski and they were used in as-it-is conditions. Ordinary Portland cement confirming to Nepal Standard and Rice husk from the local source at Kaski as admixture have been used for the study. Studied RHA from Blue Ignition RHA (sample 1) and Yellow Ignition RHA (sample 2) vary in color from light grey to dark grey. Particle size distribution carried out by the sieve shows that 60 percent of the processed RHA from both sources is greater than 75 microns and the rest – is less than 75 microns. Concrete incorporating RHA is generally darker grey in color than normal Portland cement concrete, owing to the grey color of RHA. This color difference is more evident on the surface of wet hardened concrete and in fresh concrete. All the physical test of coarse and fine aggregate was carried as per IS 383:2016. Concrete sample was prepared by following IS code 456:2000 and partial replacement was cement viz., 0%, 5%, 10%, 15% 20% 25% 50% with Rice Husk Ash (yellow and blue ignition) were tested on 7 and 28 days compressive strength.

3. Results and Discussion

The specific gravity of RHA varies from 1.76 to 1.97. The fineness modulus of raw RHA from samples 1 and 2 were found as 2.26 and 3.70. After processing the fineness modulus of both of the RHA was found to be 1.50. When concrete is tested for compression, the interior of the broken specimens exhibits a deep darker grey color. After sufficient exposure to air, the color disappears. The degree of color was found dependent upon the percentage of RHA used, curing condition, and age of the concrete.

In order to identify the effect of RHA on the strength of concrete, 84 cubes was casted 6 cubes for each replacement cement viz., 0%, 5%, 10%, 15% 20% 25% 50% with Rice Husk Ash (yellow and blue ignition) were tested on 7 and 28 days and reflected results are tabulated below.

Table 1: Blue and yellow ignition compressive strength at 7 and 28 days

% of Replacement	Blue Ignition Compressive Strength 7 days	Compressive Strength 28 days	Yellow Ignition Compressive Strength 7 days	Compressive Strength 28 days
0	14.87	23.24	14.87	23.24
5	15.11	23.85	15.04	24.07
10	14.59	24.52	14.44	24.52
15	14.59	24.52	14.52	24.30
20	12.59	17.70	12.52	18.07
25	7.48	13.04	8.37	13.63
50	2.81	5.93	3.04	6.22

It was observed that the compressive strength of 15 % RHA replacement in concrete has almost similar value compared to the compressive strength of concrete with variation in binder ratio for both Sample 1 and Sample 2 concrete. All the tested result was compared with the IS code 456:2000.

4. Conclusions

Based on various experimental works studied on 0 to 50 percent of RHA in concrete, it has been observed that the performance of concrete through physical and mechanical properties is good enough to be used as structural concrete for 15 % of RHA with replacement of cement. Hence it can be recommended that up to 15 % of RHA (both yellow and blue ignition) can be used as replacement of cement successfully. The compressive strength of RHA concrete studied shows that the maximum compressive strength can be found for a mix with 5 to 15 percent of RHA, beyond this value, the strength goes on decreasing for all ages of concrete. Cement production emits carbon dioxide. Thus, limiting the use of cement will greatly help to reduce environmental pollution where 15% of carbon dioxide produced from the production of cement can be controlled through the use of RHA.

Cement is a costly material and rice husk ash is a waste material, so the partial use of 15% Rice husk ash of cement, reduces the cost of concrete. Which ultimately reduces the cost of construction. Moreover, with the use of rich husk ash, the weight of concrete reduces, thus making the concrete lighter which can be used as a lightweight construction material. The technical advantages offered by structural concrete containing rice husk ash and the social benefits related to the decrease in the number of problems of ash disposal in the environment have simulated the development of research into the potentialities of this material.

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Declaration of Competing Interest

The authors assert that they have no known competing financial attention or personal relationships that could have appeared to compel the work reported in this paper.

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I. TEST REPORT of COMPRESSIVE STRENGTH at 7 DAYS

Cement Brand : OPC NS Standard; Aggregate source : Kotre; Sand Source : Kotre

Dimension (L*B*H)(cm): 15*15*15; Surface Area (cm²): 225; Volume (cm³) : 3375

a. For Concrete Grade : M20/20 (0 % yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.369	8.451	8.321
Density (kg/m³)	2479.70	2504.00	2465.48
Breaking Load (kN)	310	330	355
Breaking Strength (N/mm²)	15.78	13.78	14.67
Av.Breaking Strength (N/mm²)	14.74		

b. For Concrete Grade : M20/20 (5 % yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.100	8.050	8.080
Density (kg/m³)	2400.00	2385.19	2394.07
Breaking Load (kN)	330	340	345
Breaking Strength (N/mm²)	14.67	15.11	15.33
Av.Breaking Strength (N/mm²)	15.04		

c. For Concrete Grade : M20/20 (10% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.020	8.000	7.900
Density (kg/m³)	2376.30	2370.37	2340.74
Breaking Load (kN)	320	330	325
Breaking Strength (N/mm²)	14.22	14.67	14.44
Av.Breaking Strength (N/mm²)	14.44		

d. For Concrete Grade : M20/20 (15% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.880	7.950	7.900
Density (kg/m³)	2334.81	2355.56	2340.74
Breaking Load (kN)	325	335	320
Breaking Strength (N/mm²)	14.44	14.89	14.22
Av.Breaking Strength (N/mm²)	14.52		

e. For Concrete Grade : M20/20 (20% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.850	7.950	7.800
Density (kg/m³)	2325.93	2355.56	2311.11
Breaking Load (kN)	275	290	280
Breaking Strength (N/mm²)	12.22	12.89	12.44
Av.Breaking Strength (N/mm²)	12.52		

f. For Concrete Grade : M20/20 (25% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.400	7.300	7.450
Density (kg/m³)	2192.59	2162.96	2207.41
Breaking Load (kN)	180	190	195
Breaking Strength (N/mm²)	8.00	8.44	8.67
Av.Breaking Strength (N/mm²)	8.37		

g. For Concrete Grade : M20/20 (50% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.400	7.200	7.100
Density (kg/m³)	2192.59	2133.33	2103.70
Breaking Load (kN)	70	50	85
Breaking Strength (N/mm²)	3.11	2.22	3.78
Av.Breaking Strength (N/mm²)	3.04		

II. TEST REPORT of COMPRESSIVE STRENGTH at 28 DAYS

Cement Brand : OPC NS Standard; Aggregate source : Kotre; Sand Source : Kotre

Dimension (L*B*H)(cm): 15*15*15; Surface Area (cm²): 225; Volume (cm³) : 3375

a. For Concrete Grade : M20/20 (0 % yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.210	8.250	8.280
Density (kg/m³)	2432.59	2444.44	2453.33
Breaking Load (kN)	520	535	580
Breaking Strength (N/mm²)	23.11	23.78	25.78
Av.Breaking Strength (N/mm²)	24.22		

b. For Concrete Grade : M20/20 (5% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.080	8.120	8.100
Density (kg/m³)	2394.07	2405.93	2400.00
Breaking Load (kN)	540	535	550
Breaking Strength (N/mm²)	24.00	23.78	24.44
Av.Breaking Strength (N/mm²)	24.07		

c. For Concrete Grade : M20/20 (10% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.050	8.100	8.050
Density (kg/m³)	2385.19	2400.00	2385.19
Breaking Load (kN)	540	555	560
Breaking Strength (N/mm²)	24.00	24.67	24.89
Av.Breaking Strength (N/mm²)	24.52		

d. For Concrete Grade : M20/20 (15% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.000	7.998	8.050
Density (kg/m³)	2370.37	2369.78	2385.19
Breaking Load (kN)	570	540	530
Breaking Strength (N/mm²)	25.33	24.00	23.56
Av.Breaking Strength (N/mm²)	24.30		

e. For Concrete Grade : M20/20 (20% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.950	7.900	8.000
Density (kg/m³)	2355.56	2340.74	2370.37
Breaking Load (kN)	410	390	420
Breaking Strength (N/mm²)	18.22	17.33	18.67
Av.Breaking Strength (N/mm²)	18.07		

f. For Concrete Grade : M20/20 (25% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.300	7.400	7.240
Density (kg/m³)	2162.96	2192.59	2145.19
Breaking Load (kN)	320	290	310
Breaking Strength (N/mm²)	14.22	12.89	13.78
Av.Breaking Strength (N/mm²)	13.63		

g. For Concrete Grade : M20/20 (50% yellow ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.300	7.240	7.150
Density (kg/m³)	2162.96	2145.19	2118.52
Breaking Load (kN)	125	140	155
Breaking Strength (N/mm²)	5.56	6.22	6.89
Av.Breaking Strength (N/mm²)	6.22		

III. TEST REPORT of COMPRESSIVE STRENGTH at 7 DAYS

Cement Brand : OPC NS Standard; Aggregate source : Kotre; Sand Source : Kotre

Dimension (L*B*H)(cm): 15*15*15; Surface Area (cm²): 225; Volume (cm³) : 3375

a. For Concrete Grade : M20/20 (5% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.150	8.100	8.050
Density (kg/m³)	2414.81	2400.00	2385.19
Breaking Load (kN)	325	345	350
Breaking Strength (N/mm²)	14.44	15.33	15.56
Av.Breaking Strength (N/mm²)	15.11		

b. For Concrete Grade : M20/20 (10% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.000	7.950	8.050
Density (kg/m³)	2370.37	2355.56	2385.19
Breaking Load (kN)	325	320	340
Breaking Strength (N/mm²)	14.44	14.22	15.11
Av.Breaking Strength (N/mm²)	14.59		

c. For Concrete Grade : M20/20 (15% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.850	7.900	7.950
Density (kg/m³)	2325.93	2340.74	2355.56
Breaking Load (kN)	320	340	325
Breaking Strength (N/mm²)	14.22	15.11	14.44
Av.Breaking Strength (N/mm²)	14.59		

d. For Concrete Grade : M20/20 (20% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.805	7.855	7.900
Density (kg/m³)	2312.59	2327.41	2340.74
Breaking Load (kN)	270	295	285
Breaking Strength (N/mm²)	12.00	13.11	12.67
Av.Breaking Strength (N/mm²)	12.59		

e. For Concrete Grade : M20/20 (25% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.300	7.355	7.405
Density (kg/m³)	2162.96	2179.26	2194.07
Breaking Load (kN)	160	165	180
Breaking Strength (N/mm²)	7.11	7.33	8.00
Av.Breaking Strength (N/mm²)	7.48		

f. For Concrete Grade : M20/20 (50% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.355	7.205	7.100
Density (kg/m³)	2179.26	2134.81	2103.70
Breaking Load (kN)	55	65	70
Breaking Strength (N/mm²)	2.44	2.89	3.11
Av.Breaking Strength (N/mm²)	2.81		

IV. TEST REPORT of COMPRESSIVE STRENGTH at 28 DAYS

Cement Brand : OPC NS Standard; Aggregate source : Kotre; Sand Source : Kotre

Dimension (L*B*H)(cm): 15*15*15; Surface Area (cm^2): 225; Volume (cm^3) : 3375

a. For Concrete Grade : M20/20 (5% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.125	8.135	8.085
Density (kg/m^3)	2407.41	2410.37	2395.56
Breaking Load (kN)	550	525	535
Breaking Strength (N/mm^2)	24.44	23.33	23.78
Av.Breaking Strength (N/mm^2)	23.85		

b. For Concrete Grade : M20/20 (10% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.023	8.055	8.050
Density (kg/m^3)	2377.19	2386.67	2385.19
Breaking Load (kN)	550	565	540
Breaking Strength (N/mm^2)	24.44	25.11	24.00
Av.Breaking Strength (N/mm^2)	24.52		

c. For Concrete Grade : M20/20 (15% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	8.050	7.995	7.965
Density (kg/m^3)	2385.19	2368.89	2360.00
Breaking Load (kN)	560	550	545
Breaking Strength (N/mm^2)	24.89	24.44	24.22
Av.Breaking Strength (N/mm^2)	24.52		

d. For Concrete Grade : M20/20 (20% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.900	7.860	7.890
Density (kg/m^3)	2340.74	2328.89	2337.78
Breaking Load (kN)	400	385	410
Breaking Strength (N/mm^2)	17.78	17.11	18.22
Av.Breaking Strength (N/mm^2)	17.70		

e. For Concrete Grade : M20/20 (25% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.250	7.350	7.250
Density (kg/m^3)	2148.15	2177.78	2148.15
Breaking Load (kN)	290	285	305
Breaking Strength (N/mm^2)	12.89	12.67	13.56
Av.Breaking Strength (N/mm^2)	13.04		

f. For Concrete Grade : M20/20 (50% blue ignition RHA)

Description	Sample No.		
	1	2	3
Weight (kg)	7.125	7.200	7.150
Density (kg/m^3)	2111.11	2133.33	2118.52
Breaking Load (kN)	115	135	150
Breaking Strength (N/mm^2)	5.11	6.00	6.67
Av.Breaking Strength (N/mm^2)	5.93		