"Effect of Rice Husk Ash and Ground Granulated Blast-Furnace Slag on Mechanical Properties and Resistance to Chloride Penetration of High Strength Concrete"

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Abstract

This research work investigates the effect of rice husk ash (RHA) and grounds granulated blast furnace slag (GGBFS) on the mechanical properties of high-strength concrete (HSC). The HSC with different proportions of RHA and GGBFS have tested the compressive strength at 7, 14, and 28 days, split tensile strength, and flexural strength at 28 days. The ordinary Portland cement was partially replaced by a weight ratio of RHA (10%, 15%, 20%), and GGBFS (10%, 20%, 40%). Experimental work was completed to restore at 20°C and 65 percent relative humidity. A total of 90 cubes, 30 cylinders, and 30 beams were cast for different mixes for compressive strength, split tensile strength, and flexural strength of concrete. The test results reported that of RHA the compressive strength increases by 6.62 percent compared to the conventional mix at 28 days split tensile strength and flexural strength increases by 6.23 and 5.21 percent. Also, the optimum percent of GGBFS compressive strength increases by 6.81 percent, and split tensile strength and flexural strength increase by 6.89 and 5.61 percent.

The RHA and GGBFS-based concrete are emerging construction materials with carbon dioxide (CO_2) emissions compared to conventional cementitious materials. This research studied to investigate the mechanical strength characteristics of blended with RHA and GGBFS. It was observed that the addition of 30 percent GGBFS in concrete increases the compressive strength by 23 percent compared to the control mix. The experimental results showed the inclusion of GGBFS with RHA to attain compressive strength. It was accomplished that the GGBFS and RHA mixture did tend to form stable concrete.

Keywords: *High Strength Concrete (HSC); Compressive Strength; Split Tensile Strength; Flexural Strength*

1. Introduction

Concrete is the utilized development material throughout the world taking into account its strength aspect, deformed ability in shape, and stability against structural loads. In the here study the focus is to determine the optimum use of different mineral admixtures with partial replacement of OPC in a mixture of proportions to evaluate. Geopolymer technology has shown a potential move towards the sustainable use of industrial wastes in cement-less construction materials. Industry across the world, concrete has a major role in the effects of construction on our environment. HPC is usually having a high strength compared to normal-strength concrete. The majority of well-known characteristics of HPC are modulus of elasticity is high along with durability i.e. long lasting service life in the built environment. The chemical admixture is further classified as Naphthalene based water-reducing admixture and polycarboxylate Ether-based superplasticizer. Moreover, mineral admixtures are RHA, Metakaolin, SF, FA, etc. The GGBFS content rises the temperature of HPC is reduced along with cracking stress and cracking age decreased. Furthermore, silica fume is generated from the silicon industry and it is a noncrystalline powder form. The RHA contains 85 to 90% of silica in it obtained from the rice milling industry. GGBFS is having lower heat of hydration when used in concrete [16]. The optimal content of GGBFS should not exceed 20% to assess early-age cracking and the proportion of GGBFS including 0%, 20%, 35%, and 50% and early-age cracking of HPC goes on increasing up to 20% under adiabatic conditions [1]. By using local materials available U-HPC was developed and there was no increase in compressive strength by using silica fume and fine sand [2]. Resistance to seawater was accessed by influencing different mineral admixtures and microstructure paste is denser than without mineral admixture cement paste [3]. Max. Compressive strength at 28 days increases by 0.1% when 20% SF and 10% glass fiber [4]. As compared to flash; GGBFS showed superior mechanical performance at 28 and 91 days [5]. Flyash is generated from industries like thermal power plants as waste which is generally used in concrete to reduce carbon dioxide emission as it is replaced with cement and also improves the workability of concrete. Flyash is classified as calcium content such as type C & type F. On partial replacement of 10% and 20% with Flyash and SF the foam concrete was tested for 7 & 28 days and found the most superior property with less water absorption and high compressive strength [6]. Rice Husk ash also improves the mechanical property and is effective for a sustainable environment in the replacement of 8 to 10% cement [7]. The huge decrease of $Ca(OH)_2$ in cement and its greatest pore sizes and normal pore size become smaller & the improvement of its pore structure are the primary purposes behind the compressive strength increment of RHA concrete. [8]. The best way of utilizing the rice husk ash in concrete is based on optimized proportion as approximately 18–19% RHA can be yielded from raw husk [9]. Impacts of GGBFS substitution proportion from 50% to 80% and compressive strength diminished with the increase of slag content. [10]. around 50% & above the proportion of GGBFS there is no improvement in the compressive strength of concrete [11]. Partial replacement of SF up to 10% does not reduce the workability and also up to 20 percent SF content the maximum strength is obtained [12]. The cement was replaced by Silica fume in the proportion of 5% & 10% and it is observed that maximum compressive strength was obtained at 10% replacement of SF [13]. The scope of the present investigation is limited to determining the effect of different mineral admixtures like RHA (10%, 15%, 20%), SF (10%, 15%, 20%), and GGBFS (10%, 20%, 40%) on performance-based M40 grade of concrete and compare the test results with control mix for 7,14 & 28 days of curing. The pozzolanic reaction can be represented as;

Calcium hydroxide + Silica = Tricalcium silicate (C_3S) + water 3Ca $(OH)_2$ + Silica (SiO_2) = $3CaO.SiO_2 + 3H_2O$ (1)

1.1. Objectives of the study

- To find the optimum percent of RHA, & GGBFS by partial substitution of ordinary Portland cement.
- To determine the effect of RHA and GGBFS.

1.2. Research significance

This research work in the field of partial replacement of cement as the cementitious material is gradually increasing manufacture of concrete has different environmental issues. Use of partial replacement of the cement has two reimbursements with industrial waste product like RHA, and GGBFS that need land and avoid extreme use of cement. By incorporating different supplementary cementitious materials in concrete, CO_2 emissions connected to the concrete are decreased.

2. Materials and experimental Procedure

- Various materials used for making HSC are characterize and tested for different properties.
- Cement: It was used as per IS 269: 2015.
- Water: Potable water is used in this research work.
- Fine Aggregate: Different properties were determined as per IS 383: 1970. Fine Aggregate (Sand) belongs to Zone-II. Sp. gravity of fine aggregate (sand) was determined as 2.67 and fineness modulus is 3.14.
- Coarse Aggregate: It was used as per It was used as per IS: 2386 was determined properties are found.
- Super plasticizer: Different properties found as per IS: 9103 of polycarboxylate ether based super plasticizer.

Table1. Physical Properties of Cement, RHA and GGBFS

Material	Specific Gravity	Fineness (μm)	Specific surface (m^2/kg)	Mean Grain Size
OPC	3.15	82	300	24
RHA	1.71	90	890	5.21
GGBFS	1.82	105	904	5.86

Table 2. Chemical Properties of Cement and RHA

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
OPC	21.55	5.69	3.39	64.25	0.85	0.33	0.59	2.47	1.80
RHA	86.73	0.04	0.61	0.39	0.08	1.32	9.76	-	0.54
GGBFS	32.25	12.14	1.10	44.7	4.23	0.87	-	0.84	1.91

Table 3. Mix design of M30 Grade Concrete

Mix Id	Cement (Kg/m^3)	RHA	GGBFS	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	W/C ratio	Water (kg/m^3)
M000	350	0	0	680	1040	0.54	166
M01A	315	35	0	680	1040	0.54	166
M01B	297.5	52.5	0	680	1040	0.54	166
M01C	280	70	0	680	1040	0.54	166
M02A	315	0	35	680	1040	0.54	166
M02B	280	0	70	680	1040	0.54	166
M02C	210	0	140	680	1040	0.54	166

3. Experimental Procedure

Table 3 shows the mix proportion of different mixes. M00 represents the control mix and M01A, M01B, and M01C represent the incorporation of RHA proportion, and M02A, M02B, M02C represents the incorporation of GGBFS proportion. The proportions of the mixture for all of the periods of cement are shown in Table 3. All mix ratios have been modified with the aid of the particles, the density of each component of the mixture, to obtain a yield of one cubic meter. The cement by weight was partially replaced with RHA (5%, 10%, 15%), and GGBFS (15%, 20%, 30%).

4. Compressive Strength, Split Tensile Strength, Flexural Strength and RCPT Procedure

Mechanical strength calculation as per IS 516:1959 and Value of RCPT calculation as per RCPT-ASTM C 1202.

The test specimens shall be procured from hardened concrete in the method determined as per IS 1199:1959.

The RCPT determines the resistance to penetration of chloride ions. The RCPT-ASTM C 1202 is used to calculate the resistance of concrete to chloride ions ingress. The RCPT is calculated in Coulombs.

Table 4. Test of Cement

S. No.	Cement property	Experimental values	Acceptable Limits
1.	Sp. Gravity	3.15	3.15
2.	Standard Consistency	34	30 % to 40%

3.	I.S.T.	32	Not less than 30 min
4.	F.S.T.	600	Not more than 60 min

Table 5. Coarse Aggregate Properties

S. No.	Coarse Aggregate test	Values	Acceptable limit as per IS:2386
1.	Specific gravity	2.74	2.7 to 2.8
2.	Sieve analysis	-	It should be good
3.	Water absorption	1.15%	It should be less than 1.50%
4.	Impact value	20%	It should be less than 30%
5.	Crushing value	22%	It should be less than 30%

Table 6. Average Compressive Strength (MPa) Partial Replacement of RHA

S. No.	Mix Designation	7 Days	14 Days	28 Days
1.	M00	31.23	42.56	46.31
2.	M01A	32.34	43.56	48.53
3.	M01B	34.12	46.32	50.42
4.	M01C	34.49	44.87	49.23

Table 7. Average Compressive Strength (MPa) Partial Replacement of GGBFS

S. No.	Mix Designation	7 Days	14 Days	28 Days
1.	M00	31.23	43.57	46.31
2.	M02A	32.89	44.59	48.53
3.	M02B	35.23	46.82	50.42
4.	M02C	36.48	47.23	51.19

The procedure of experimental in that shows Table 3 the mix proportion of various mixes. M00 represents the control mix. Mix M01A, M01B, and M01C represent the incorporation of RHA proportion, and M02A, M02B, M02C shows GGBFS proportion. The proportions of the mixture, of all of the periods of cement are shown in Table 3. All blend ratios have been adapted with the aid of the particles, the density of each component of the mixture, to obtain a yield of one cubic meter.

Table 8. Concrete Mix Design

S. No.	Mix Designation	Cement	FA	CA	Water	Admixture	RHA	GGBFS
1.	M00	410	761	1110	154	4.31		
2.	M01A	410	761	1110	154	4.31	0	
3.	M01B	410	761	1110	154	4.31	0	
4.	M01C	410	761	1110	154	4.31	0	
5.	M02A	410	761	1110	154	4.31		0
6.	M02B	410	761	1110	154	4.31		0
7.	M02C	410	761	1110	154	4.31		0

The effect of RHA and GGBFS percentage on strength of high strength concrete (HSC)

The comp. strength was higher due to the enhanced reactivity and the filler effect of RHA, the replacement level of 10 percent resulted in rather lower comp. strength values. Based on that, it can be seen that the RHA here when 10 percent replacement is utilized is inadequate to advance the strength. The amount of C-S-H released from the pozzolanic reaction was constrained to a small amount of the C-H released from the hydration process reacted. In this case, the amount of silica existing in the hydrated blended cement matrix is reliably too high and the amount of the produced C-H is inadequate to react. The strength values when RHA was supplemented by 10 percent were found to be comparable to 10 percent replacement.

The strength of concrete attained levels that was similar to the OPC control mixture when 10 percent of OPC was introduced for RHA. In this study, increasing replacement to a level above 10 percent was avoided as this would result in SP content exceeding manufacturer recommendations which could harm the produced concrete by acting as a retarder and rising cost. The reduction in cement amount results in a decrease in strength while RHA replacement levels are increased, and as a result, the amount of C-H released during the hydration process is insufficient to react with all of the silica available by the addition of RHA.

Rapid chloride penetration test (RCPT)

The RCPT was conducted using concrete discs size 100mm dia. × 50 mm ht at 28 days of curing period.

In reinforced concrete structures, penetration of chloride ions is measured to be a key cause of corrosion of reinforcing bars. The CC fails to prevent the interference of moisture and aggressive ions efficiently. The use of supplementary cementing composite materials has been report to increase the resistance of concrete to deterioration by aggressive chemicals.

Table 9. Value of Charge Passed in Coulombs

Sr. No.	Chloride Ion Penetrability	Charge Passed in Coulombs
1.	High	Moe than 4000
2.	Moderate	2000 to 4000
3.	Low	1000 to 2000
4.	Very low	100 to 1000
5.	Negligible	Less than 100

RCPT test results for different cylindrical concrete specimens with partial replacement of RHA and GGBFS are as given in table.

Table 10. Total charge value in Coulombs of M-30 incorporating of RHA via RCPT

Sr. No.	Mix	Total charge passed through in coulomb at 28 days
1.	M00	412.126
2.	M01A	387.347
3.	M01B	354.381
4.	M01C	317.862

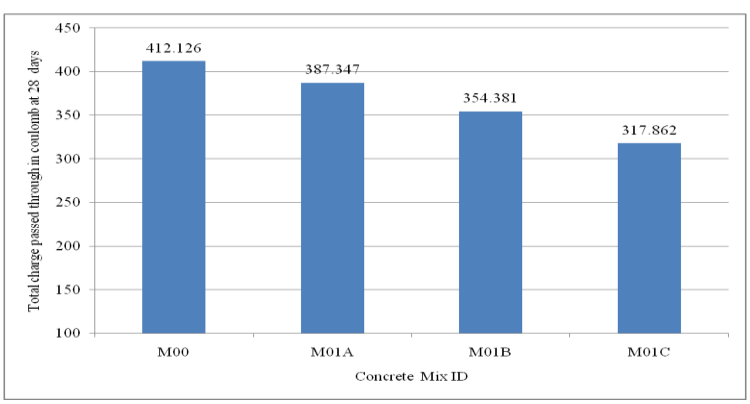

Figure 01: Total charge vale in Coulombs of M-30 incorporating of RHA via RCPT

Table 11. Total charge vale in Coulombs of M-30 incorporating of GGBFS via RCPT

Sr. No.	Mix	Total charge passed through in coulomb at 28 days
1.	M00	412.126
2.	M02A	394.367
3.	M02B	382.259
4.	M02C	324.843

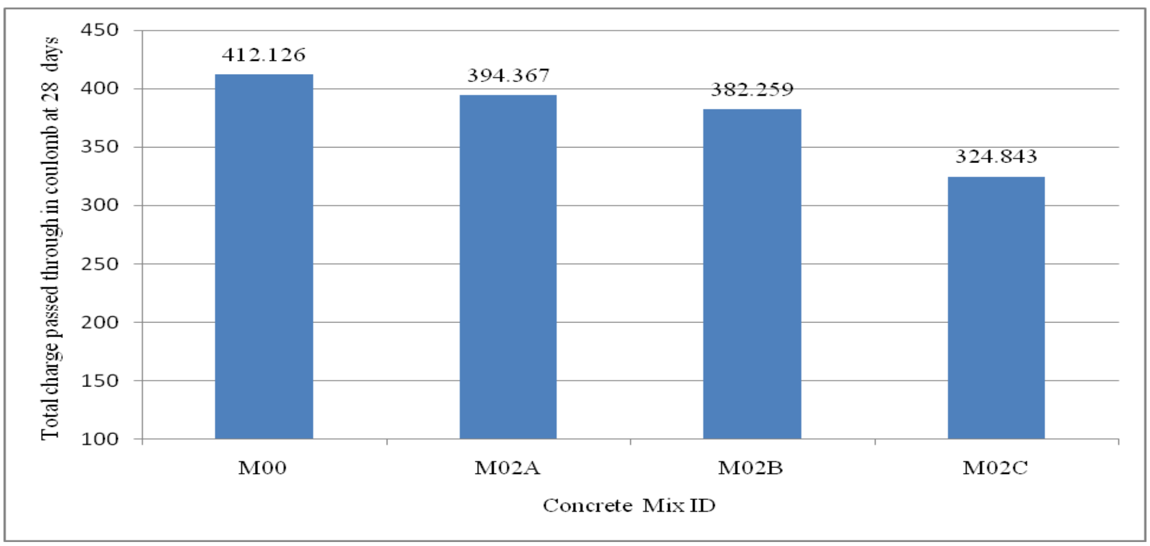

Figure 02: Total charge vale of M-30 Grade incorporating of GGBFS via RCPT

5. Results and discussions

5.1. Effect of Rice Husk Ash on Performance based concrete

Avg. compressive strength was determined by various partial substitutions of RHA in proportions of 5%, 10%, and 15% by weight of cement. The Mix M00 represents the control mix with 0 % replacement of RHA and an. compressive strength is 32.18 MPa, 43.4 MPa, and 46.5 MPa for 7, 14, and 28 days of curing respectively. Mix M1A represents 10% RHA and 90% cement and avg. compressive strength is 34.2 MPa, 44.7 MPa, and 49.8 MPa for 7, 14, and 28 days of curing. Mix M1B represents 15% RHA and 85% cement and avg. compressive strength is 33.25 MPa, 43.7 MPa, and 48.5 MPa respectively for 7, 14, and 28 days of curing. Mix M1C represents 20% RHA and 80% cement and avg. compressive strength is 31.7 MPa, 42.8 MPa, and 47.3 MPa for 7, 14, and 28 days of curing. The optimum percent RHA is 10% for Mix M1A and avg. compressive strength is 4.12% higher than the control mix. The amorphous phase content in RHA will affect the activity index of the strength of the ratio of the compressive strength of standard mortar cubes 80 percent made up of cement and 20% of additives, by mass, compressive strength of mortar are the standard cube operational information.

5.2. Effect of GGBFS on High Strength Concrete

Avg. compressive strength was determined by different partial substitutions of GGBFS in the proportion of 10, 20, and 40 percent by weight of cement as shown in Table 3. The M00 represents the control mix with no replacement of GGBFS and avg. compressive strength is 32.18 MPa, 43.4MPa, and 46.5MPa for 7, 14, and 28 days of curing. Mix M3A represents 10% GGBFS & 90% cement and avg. compressive strength is 31.8 MPa, 42.2 MPa, and 47.3 MPa for 7, 14, and 28 days of curing. Mix M3B (C80GGBFS20) represents 20% GGBFS and 80% cement and the avg. compressive strength is 33.4Mpa, 44.5 MPa, and 48.9 MPa respectively for 7, 14, and 28 days of curing. Mix M3C represents 40% GGBFS and 60% cement and avg. compressive strength is 34.8 MPa, 44.9 MPa, and 49.9 MPa for 7, 14 & 28 days of curing. The optimum % of GGBFS is 40% for Mix M3C and avg. compressive strength is 6.81% higher than the control mix M00. GGBFS has been used in the concrete mix for ages. The bulk of the work in making GGBFS concrete has established that it will give you an advantage of the fresh and reliable qualities like durability aspects. To ensure the protection of the environment and the economic benefits of the construction. Though, it is a normal issue associated with GGBFS is a slower rate of strength growth at an early age.

5.3 Rapid chloride penetration test (RCPT)

The RCPT reading after the 28th day of curing is given in Tables 5 and 6 respectively. From the above results, it was obvious that concrete containing RHA shows less penetration of chloride ions due to pozzolanic action. From the above results, it was obvious that concrete containing GGBFS shows less penetration of chloride ions due to pozzolanic action and converts it to calcium silicate hydrate (CSH) gel for making denser concrete.

6. Future recommendations

This research paper spotlights a way forward for further research and development in the construction field. First, the use of GC will lead to sustainable utilization of industrial by-products, and it can be used as a novel option for cementitious material, which has a lower CO_2 emission than CC. Second, more research is required on the fly ash-GGBFS-based GPC to produce bulk quantity and apply to all ready-mix plants. Third, it minimizes the use of cement-based concretes in the scope of civil engineering applications. Four, from the results, it is recommended to use GGBFS in the fly ash-based GC, to achieve durability properties.

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