Eco-Friendly Innovation for Enhancing Durability of Concrete - A Way Out to reduce Environmental Carnage by Cement

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Abstract: ***Modern world is enjoying the benefits of an industrialized society with little thought to ecological repercussions. Among various ecological and environmental hazards being faced by fragile ecology, industrial contamination is the most severe. Among this class, Cement industry, being an energy-intensive industry, produces many environmental denigrating emissions. Therefore, understanding the environmental implications of concrete and cement industry are becoming increasingly imperative. Extensive research has established that the most direct, technically sound, economically attractive and environmentally optimum solution to the problems of reinforced concrete durability lies in the incorporation of finely divided siliceous materials in concrete. In simpler terms, rice husk ash can be blended with Portland cement for the production of durable concrete. Moreover addition of Rise Husk Ash (RHA) to Portland cement not only improves the strength of concrete, but also forms a calcium silicate hydrate gel around the cement particles which is highly dense and less porous and may increase the strength of concrete against cracking. This work investigates the effects of adding residual rice husk ash (RHA) on the strength of concrete. The result of the work reveals that the 30% RHA sample is not able to maintain the tempo and in fact only tends to show a promise of attaining similar strength as the control mix with curing age with insignificant Effect Size of 0.58-0.66 over the curing period of 7-28 days, Whereas RHA level at 20% Presents a good tendency of concrete and can at the moment be adopted for construction of masonry walls and simple foundations activity.***

Keywords: Rice husk ash; Cement; Strength; Concrete; Agro-waste; Chi Square; Hedge's effect size

1. Introduction

The environmental impact of cement industry is complex. Because of its abundance in the world market, understanding the environmental implications of concrete and cement manufacturing are becoming increasingly important [1]. The cement industry is one of the primary producers of carbon dioxide, a potent greenhouse gas [2]. Actually this industrial sector is thought to represent 5-7% of the total CO_2 anthropogenic emission [3]. Producing one ton of portland cement requires about 4 GJ energy, and portland cement clinker manufacture releases approximately 1 ton of carbon dioxide into the atmosphere [4, 5]. In addition to the generation of CO_2 the cement manufacturing process produces millions of tons of the waste product cement kiln dust each year contributing to respiratory and pollution health risks [1]. Furthermore, the mining, processing, and transport operations consume considerable amounts of energy, and adversely affect the ecology of forested areas and riverbeds.

The environmental impact of the concrete industry can be reduced by conserving materials and energy for concrete-making and by improving the durability of concrete products. Extensive research has established that the most direct, technically sound and economically attractive solution to the problems of reinforced concrete durability lies in the incorporation of finely divided siliceous materials in concrete. Rice husk burnt into ash fulfills the characteristics and chemical composition of mineral admixtures. Pozolanic activity of (RHA) depends on silica content, silica crystillation phase and size and surface area of ash particles. It is well known that the reductions in the water to cementitious materials ratio and the use of pozzolans are proper ways to produce a denser, more impermeable matrix [6]. This helps to contributes to the sustainable development economic position of the concrete industry.

The characteristics of this concrete are very high strength (in excess of 150 MPa) and very low permeability Béton Fibrés Ultra Performant (BFUP, AFGC, 'Ultra High Performance Fibre-Reinforced Concretes, Interim Recommendations. RHA after complete combustion of the husk in controlled conditions contains 90-96% silica in amorphous forms. The average particle size of RHA ranges in general from 5 to 10 μm, which is much larger than that of silica fume. However, due to its extremely porous structures, it has a very high surface area (even more than 250 m^2/g) (Bui 2001) whereas the specific surface area of SF is 18-20 m^2/g. Both SF and RHA have been considered as "highly active pozzolans" [7]. When incorporated in cement, both SF and RHA affect the rate and the extent of hydration [8]. Bui et al. [9] published a paper in which they burnt Vietnam rice husk in a drum incinerator for RHA production and researched the particle-size effect on the strength of RHA blended gap graded portland cement concrete.

The general objective of the research was to assess the possibility of using of RHA to produce UHPC in order to get the cost benefits, sustainability and service life of construction, for this reason, this study investigates the strength and durability of concrete by adding RHA that is generated when burning rice husk pellets.

2. Materials and Methods

The materials used in this study were silica sand with a mean size of 225 µm, Portland cement CEM M-30 grade, condensed silica fume, rice husk ash, 150mm cube mould, ramming rod, mixer, washing machine, 200 tons compressive testing machine and bucket and base plate. Following parameters influences behavior of the rice husk ash concrete so these parameters are kept constant for the experimental work.

- Percentage replacement
- Fineness of rice husk ash
- Chemical composition of rice husk ash
- Water to cementing ratio (w/b ratio)
- Type of curing

For performing the test IS-code method was used for mix design of M-30 grade of concrete.

3. Results and Discussion

Mix design

In this method IS-code method was used for mix design of M-30 grade of concrete. Three replacements of Cement i.e., 20%, 30%, and 40% of cement with Rice husk ash (RHA) are done, whereas the total binder content remains the same (Table 1).

Table 1: Quantity of materials used for casting of cubes

S.no	Type of concrete	After 7 days	After 21 days	After 28 days
1	Simple cube			
1.1	Cube 1	11.9	13.6	15.9
1.2	Cube 2	12.3	13.9	15.6
1.3	Cube 3	12.1	13.7	16.1
2	Cube with RHA (10% of cement)			
2.1	Cube 1	14.7	18.4	21.3
2.2	Cube 2	14.9	18.8	21.4
2.3	Cube 3	14.6	18.6	21.9
3	Cube with RHA (20% of cement)			
3.1	Cube 1	16.3	20.1	23.8
3.2	Cube 2	15.9	20.3	23.1
3.3	Cube 3	16.4	19.8	23.9
4	Cube with RHA (30% of cement)			
4.1	Cube 1	13.1	13.8	15.4
4.2	Cube 2	12.4	13.4	15.8
4.3	Cube 3	11.8	13.6	15.9

Casting of samples

Cubic specimens of concrete with size 150 × 150 × 150 mm were cast for determination of all measurements (Table 2).

Testing of samples

In order to study the strength development of Rice husk ash (RHA) concrete in comparison to control concrete, compressive strength tests were conducted at the ages of 7, 21 and 28 days (Table 3).

Effect of rice husk ash on concrete strength

As it is observed from Figure 1 that the comprehensive strength of concrete a viz RHA Proportion increases after the addition of 20% of Rice Husk Ash and is the best combination among all mixes, which gives max, tensile, flexure and compression strength over normal concrete whereas 30% RHA attain similar strength as the control mix over the curing period of 7 days to 28.

Table 2: Comprehensive strength of concrete cubes versus time

S.no	Type of concrete cube	Cement (Kg)	Sand (Kg)	Aggregates (Kg)	Water (Kg)	RHA (Kg)
1	Simple cube					
1.1	Cube 1	1.6	3.2	6.4	0.8	0
1.2	Cube 2	1.6	3.2	6.4	0.8	0
1.3	Cube 3	1.6	3.2	6.4	0.8	0
2	Cube with RHA (10% of cement)					
2.1	Cube 1	1.44	3.2	6.4	0.8	0.16
2.2	Cube 2	1.44	3.2	6.4	0.8	0.16
2.3	Cube 3	1.44	3.2	6.4	0.8	0.16
2	Cube with RHA (20% of cement)					
2.1	Cube 1	1.28	3.2	6.4	0.8	0.32
2.2	Cube 2	1.28	3.2	6.4	0.8	0.32
2.3	Cube 3	1.28	3.2	6.4	0.8	0.32
3	Cube with RHA (30% of cement)					
3.1	Cube 1	1.12	3.2	6.4	0.8	0.48
3.2	Cube 2	1.12	3.2	6.4	0.8	0.48
3.3	Cube 3	1.12	3.2	6.4	0.8	0.48

Table 3: Percentage increase in Comprehensive Strength of the mixture at different RHA levels is summarized in given table

	After 7 days	After 21 days	After 28 days
Simple cube	12.10	13.73	15.87
Cube with RHA (10% of cement)	14.73	18.60	21.53
Increase (%) over simple mixture	22%	35%	36%
Cube with RHA (20% of cement)	16.20	20.07	23.60
Increase (%) over simple mixture	34%	46%	49%
Cube with RHA (30% of cement)	12.43	13.60	15.70
Increase (%) over simple mixture	3%	-1%	-1%

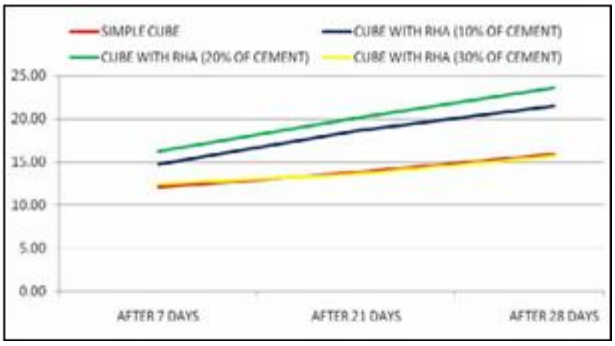

Figure 1: Compressive strength vs. % RHA Proportion

Effect of rice husk ash on 7 days compressive strength of normal concrete: 7 days compressive strength test results show after the addition of 10% of rice husk ash the compressive strength is increased by about 22%; similarly the strength is increased about 34% after addition of 20% rice husk ash, and it is about 3% gain of strength after addition of 30% rice husk ash to normal concrete (Table 4).

Effect of rice husk ash on 21 days compressive strength of normal concrete: 21 days compressive strength test results show after the addition of 10% rice husk ash the compressive strength is increased by about 35%; similarly the strength is increased about 46% after addition of 20% rice husk ash and it is a loss of about -1% of strength after addition of 30% rice husk ash to normal concrete (Table 5).

Effect of rice husk ash on 28 days compressive strength: It is observed that after addition of 10% rice husk ash to normal concrete there is about 36% increase in strength as compared to normal concrete, it is again increased about 49% when 20% rice husk ash is added to normal concrete and it is a loss of about -1% of strength after addition of 30% rice husk ash to normal concrete. Therefore the 30% rice husk ash is the optimum content at which it is showing same result as compared to normal concrete, whereas 20% RHA depicts the higher percentage of comprehensive strength (Table 6).

4. Conclusion

The before given analysis point towards some significant and very interesting specifics. The 10% RHA Sample, initially, was found to be exhibiting comprehensive strength qualitatively similar to that of control mix with Hedge's G as small as 1.30. However, at later curing age, the sample exhibits a significant increase in its comprehensive strength with effect Size (Hedge's G) value at 18.66 [9, 10].

Table 4: Comprehensive strength after 7 days

	Comprehensive strength after 7 days			
	RHA 0%	RHA 10%	RHA 20%	RHA 30%
Cube 1	11.9	14.7	16.3	13.1
Cube 2	12.3	14.9	15.9	12.4
Cube 3	12.1	14.6	16.4	11.8
X2-Statistic		1.72495	4.67311	0.14286
P-Value		0.422127	0.096661	0.931043
Interpretation:- Whether the comprehensive strength vary significantly?		Difference not significant	Difference significant	Difference not significant
Hedge's G (Effect Size)		1.30	16.08	0.58

Table 5: Comprehensive strength after 21 days

	Comprehensive strength after 21 days			
	RHA 0%	RHA 10%	RHA 20%	RHA 30%
Cube 1	13.6	18.4	20.1	13.8
Cube 2	13.9	18.8	20.3	13.4
Cube 3	13.7	18.6	19.8	13.6
X2-Statistic		5.17401	9.23382	0.00588
P-Value		0.075245	0.009883	0.997054
Interpretation: Whether the comprehensive strength vary significantly?		Difference significant	Difference significant	Difference not significant
Hedge's G (Effect Size)		24.5	25.1	0.51

Table 6: Comprehensive strength after 28 days

	Comprehensive strength after 28 days			
	RHA 0%	RHA 10%	RHA 20%	RHA 30%
Cube 1	15.9	21.3	23.8	15.4
Cube 2	15.6	21.4	23.1	15.8
Cube 3	16.1	21.9	23.9	15.9
X^2-Statistic		6.07981	11.21069	0.01635
P-Value		0.04784	0.003678	0.991883
Interpretation:- Whether the comprehensive strength vary significantly?		Difference significant	Difference significant	Difference not significant
Hedge's G (Effect Size)		18.66	21.78	0.666

Likewise, The 20% RHA Sample was found to be exhibiting enhanced comprehensive strength as compared to that of control mix right from 7 days curing period with Hedge's G value as high as 16.08 and more interestingly, at later curing age, the sample exhibits highly significant increase in its comprehensive strength with effect Size (Hedge's G) value touching 21.78 threshold.

The statistical analysis, however, further reveals that the 30% RHA sample is not able to maintain the tempo and in fact only tends to show a promise of attaining similar strength as the control mix with curing age with insignificant Effect Size of 0.58 to 0.66 over the curing period of 7 days to 28 days.

Thus, it can be safely concluded that the introduction of the rice husk ash (RHA) presents a good tendency of pozzolanic the RHA/ OPC concrete and can at the moment be adopted for construction of masonry walls and simple foundations activity with RHA level at 20%. Meanwhile research studies towards boosting the property of the rice husk ash will be a welcome development not only because it boosts comprehensive strength of concrete but more significantly it will provide an environmental affable alternative to eco-carnage cement industry.

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