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Rice Husk Ash as a Supplementary Cementitious Material in Rigid Pavement - an Attempt to Reduce Carbon Footprint

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ABSTRACT

Owing to the growing road network needed for increasing developmental activities, massive burden is being posed to the environment in terms of direct products and by-products. Cement is the prime construction material for rigid pavement, and its huge production to meet out the demand is of great concern for environmentalists. During the production of cement, various harmful gases are emitted, out of which CO_2 is of prime concern. Several materials, viz., fly ash, rice husk ash, GGBS, silica fume and metakaolin can be used as partial replacement of cement in construction. The use of supplementary cementitious materials in construction not only improves the mechanical property of the cement matrix but also reduce the burden of the environment. In this paper, an attempt has been made to explore the possibility of using rice husk ash as a partial replacement of cement in the rigid pavement to lower down the carbon footprint.

Keywords: Rice husk ash; Rigid pavement; Supplementary cementitious material.

1. INTRODUCTION

In the rice-growing region, one of the waste material is rice husk. The utilization of this agricultural waste is purposeful, but it will also reduce the energy consumption, which is used in the production of cement. Therefore, it is an agro-based product that can produce cement without affecting the durability and strength of concrete. Rice husk ash is made by burning rice husk, a by-product of the rice milling process. When the rice husk is burned, about 20% (40 kg) of the rice husk collected is estimated to yield 200 kg of rice husk. RHA contains 80 to 85% silica, which is highly reactive and varies depending on the burn temperature (Kishore *et al.* 2011). The mechanical and strength properties of mortar and cement may enhance by using these materials, which are hard to accomplish by the utilization of just Ordinary Portland Cement (Siddique, 2011). Approximately seven per cent of the world's carbon dioxide emissions are attributed to Portland cement. Carbon dioxide belongs to the greenhouse gases which contribute to global warming. To meet sustainable development and environmental goals, responsiveness to environmental regulations and waste management should be part of daily operations in the concrete industry. The annual worldwide production of Rice Husk Ash is nearly about 20% of the 649.7 million tons of rice produced. Because of variations in paddy type, crop year, climate and geographical conditions, the chemical composition of rice husk ash varies from place to place. Rice husk ash, often in amorphous form of silica, can be produced by burning the rice husk at a regulated temperature below 800 °C (Habeeb, 2010).

The cement industry contributes about 5% to global anthropogenic CO_2 emissions, making the cement industry an important sector for CO_2 emission mitigation strategies (Ernst Worrell, 2001).

2. MATERIALS & METHODOLOGY

2.1. Synthesis of Activated Porous Carbon

Kishore *et al.* (2011) conducted a study on strength characteristics of high strength rice husk ash concrete. This study investigated the mechanical properties of high strength concrete with the replacement of cement by rice husk ash. In this study, M40 and M50 grades of concrete were cast and the replacement level of rice husk ash varied from 0%, 5%, 10% and 15% with cement. He reported that the workability of concrete decreases with an increase in rice husk ash replacement; the slump of concrete decreases by 27%. The mechanical properties of concrete obtained were maximum at 10% replacement of RHA for both M40 & M50 grades of concrete subjected to 28 days of curing.

Krishna (2016), performed a study on concrete with partial replacement of cement by rice husk ash. In this study, cement is partially replaced by RHA, and the replacement percentage of RHA varied from 0-20%. The concrete mix was designed at a fixed W/C ratio of 0.55

for 7, 14 and 28 days of curing. The experimental investigation found that the optimum replacement of RHA in cement is 10% in terms of workability and strength; beyond this, there is a decreasing trend in the strength of concrete. Thus, the RHA replacement in concrete can decrease the emissions of greenhouse gases.

3. MATERIALS & METHODOLOGY

3.1 Materials Used

3.1.1 Cement

The cement used in this experimental study was Ordinary Portland Cement (OPC) of 43 grade from Birla Corporation Limited, conforming to Indian Standard $IS: 8112 - 1989$. The values obtained by laboratory testing appeared to be almost similar to values provided by the manufacturer (Table 1).

Table 1. Properties of cement.

Property	Observed value
Fineness modulus	2.73
Normal Consistency	28%
Specific Gravity	3.14
Initial setting time	95 minutes
Final setting time	225 minutes

3.1.2 Aggregate

The Fine Aggregate used for the experimental work was locally available Yamuna River Sand; the coarse aggregate used in this experimental work was locally available from Banda, U.P. (Table 2 and Table 3).

Table 2. Properties of fine aggregates.

Fineness Modulus	2.75
Specific Gravity	2.61
Grading Zone	Zone-II
Water absorption	1.4%

Table 3. Properties of coarse aggregates.

S. No.	Property	Coarse Aggregate	
		12.5 mm	20 mm
1	Fineness Modulus	7.80%	8.21%
2	Specific Gravity	2.74	2.61
3	Water Absorption	0.56%	0.40%

3.1.3 Rice Husk Ash

The Rice Husk Ash (RHA) was collected from Astra Chemicals, Chennai, India. The physical and chemical properties of RHA provided by the manufacturer are illustrated in Tables 4 & 5.

Table 4. Physical properties of Rice Husk Ash (RHA).

Physical Property	Result
Colour	Off-white
Specific Gravity	2.25
Bulk Density (loose)	0.39 gm/cc
Bulk Density (tamped)	9.98 gm/cc
pH of 10% slurry	7.7
pH of 4% slurry	7.4
Rate of filtration per minute	5.55 ltrs.
Material passing through 100 mesh	77.55%
Material passing through 300 mesh	38.52%
Moisture	0.11%
Oil absorption	97.85%

Table 5. Chemical properties of Rice Husk Ash (RHA)

Chemical Property	Result
Silica (SiO_2)	88.90%
Alumina (Al_2O)	2.50%
Ferric Oxide (Fe_2O_3)	2.19%
Calcium Oxide (CaO)	0.22%
Total Alkalies (Na_2O+K_2O)	0.69%
Loss on drying at 100°C	4.01%
Specific Gravity	2.25%
Bulk Density	0.2-0.3 gm%
Free silica sand	Max. 3%

3.1.4 Superplasticizer

Auramix 400 of FOSROC brand was used in this experimental study, which compiles with IS: 9103– 1999(2007) and ASTM C494 type G, as a high range water-reducing admixture. Auramix 400 is a unique combination of the latest generation superplasticizers, based on poly-carboxylic ether polymer with long lateral chains.

4. EXPERIMENTAL METHODOLOGY

The concrete mix was designed according to the absolute volume method for M25 grade of concrete confirming to IS: $10262 - 2009$, and the proportioning of materials was carried out on a weight basis. All the concrete mixtures were prepared with cementitious materials of 370 kg/m^3, effective water to cementitious materials ratio of 0.4, and coarse to total aggregate ratio of 0.60. A superplasticizer was added to the concrete mixtures with a fixed amount of 0.7% by weight of cement to obtain a slump of 100 ±25 mm (Table 6).

Table 6. Quantities of Different Ingredients for Different Mixes

Mix [M]	OPC	Materials (kg)				
		RHA	CA		Water	SP
			12.5 mm	20 mm		
M0 (0 % RHA)	370.0	0	480.2	682.7	148	2.59
M1 (5% RHA)	351.5	18.5	476.7	681.0	148	2.59
M2 (10%RHA)	333.0	37.0	475.6	679.4	148	2.59
M3 (15%RHA)	314.5	55.5	473.7	676.8	148	2.59
M4 (20%RHA)	296.0	74.0	472.6	674.0	148	2.59

5. RESULT AND DISCUSSION

5.1 Effect of RHA on Workability

The workability decreased with increase in blending of RHA. Moreover, when the concrete is produced by mixing different percentage of RHA, a considerable decrease in workability has been observed.

5.2 Effect of RHA on Compressive Strength

When the concrete is produced by mixing different percentage of RHA, a substantial increase in compressive strength has been observed for 10% RHA. The compressive strength increased with age in all the mixes, but the increasing value tends to disappear as the content of RHA is increased beyond 10%. Hence, the optimum value for compressive strength was attained at 10% RHA.

5.3 Effect of RHA on Flexure Strength & Split Tensile

It is observed that when the concrete is produced by the mixing of different percentage of RHA, a substantial increase in flexure strength has been discovered for 10% RHA blending. The flexure strength increased with age in all the mixes, but the increasing value tends to disappear as the content of RHA is increased beyond 10%. Hence, the optimum value for flexure strength was attained at 10% RHA.

The split tensile strength increased with age in all the mixes. A considerable increase in split tensile strength has been discovered for 10% RHA blending.

6. CONCLUSION

According to the findings, mineral admixtures such as Rice husk ash had proven to be the most promising blending materials for producing high-quality concrete. Regarding the mechanical properties of concrete, the following generalized conclusion can be drawn:

1. The workability decreased with increase in blending of RHA.
2. Substantial increase in compressive strength has been observed for 10% RHA.
3. Substantial increase in split tensile strength has been observed for 10% RHA blending.
4. To meet sustainable development and environmental goals, RHA can be used as Supplementary nano-level material to reduce CO_2 emission.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Ernst Worrell, Lynn Price, Nathan Martin, Chris Hendriks and Leticia Ozawa Meida, Carbon dioxide emission from the global cement industry, *Annu. Rev. Environ. Resour.*, 26, 303-329 (2001). https://dx.doi.org/10.1146/annurev.energy.26.1.303

Habeeb, G. A. and Hilmi Bin Mahmud, Study on properties of rice husk and its use as cement replacement material, *Mat. Res.*, 13(2), 55039457 (2010).
https://dx.doi.org/10.1590/S1516-14392010000200011

Kishore, R., Bhikshma, V. and Jeevana Prakash, P., Study on strength characteristics of high strength rice husk ash concrete, *Procedia Eng.*, (14), 2666 – 2672 (2011).
https://dx.doi.org/10.1016/j.proeng.2011.07.335

Krishna, N. S. *Mater. Sci. Eng.*, 01-11 (2016).

Siddique, R. and Mohammed Iqbal Khan, Supplementary Cementing Material, *Springer Science and Business Media*, 1, 01-288 (2011).
https://dx.doi.org/10.1007/978-3-642-17866-5