Research Article

Journal of Environmental Nanotechnology

An Endeavour to decrease CO_2 Outflow through efficient use of Supplementary Cementitious Materials in Construction

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Received: 30.08.2020 Accepted: 25.10.2020 Published: 30-09-2020
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ABSTRACT

Massive construction demand in today's world poses a significant threat to the environment owing to the bulk utilization of cement (as a binder material). Cement tends to be an important ingredient for producing qualitative concrete; on the contrary, higher production of cement may lead to high emission of CO_2 gas, which itself is a great concern for the environment as well as society. In order to overcome this issue, several researches have been carried out to reduce the percentage usage of cement in concrete through partial replacement using supplementary cementitious materials, like fly ash, rice husk ash, GGBS, silica fume, metakaolin, etc. The utilization of such materials not only enhances the mechanical properties of the cement matrix but also decreases the burden on the environment. In this article, an attempt has been made to identify the feasible use of different binding materials as a partial replacement of cement in producing concrete.

Keywords: Ash; Durability; Mechanical Property; Metakaolin; Silica fume; Supplementary Cementitious materials.

1. INTRODUCTION

The supplementary cementitious materials (SMCs) are the materials that shows either pressure-driven (hydraulic) or pozzolanic behavior. The material, which can set and solidify when it is submerged in water by forming cementitious items in a hydration response, is known as a hydraulic binder. Today, SCMs are broadly utilized as a part in blending of cement or added separately in the mixer of concrete. The utilization of SCMs, for example, blast furnace slag, fly ash, silica fume, rice husk ash, marble dust, ceramic waste, waste paper sludge ash, waste glass powder, etc., represent a valuable solution to partially substitute Portland cement. With no extra clinker process included, the utilization of these materials resulted in a noteworthy decrease in CO_2 emissions per ton of cementitious materials; additionally, it a method for usage of waste material. Usage of industrial waste products save the environment and conserve natural resources (Lothenbach *et al.* 2011).

2. NECESSITY OF SUPPLEMENTARY CEMENTITIOUS MATERIALS

All through, the overall yearly generation of cement is around 12 billion tons; it consumes roughly 1.6 billion tons of Portland cement, around 10 billion tons of sand and rock and approximately 1 billion tons of water. In making one ton of Portland cement, it produces approximately one ton of carbon dioxide, and it requires up to 7000 MJ of power and fuel vitality. On the other hand, substantial amounts of waste materials and side-effects are produced from manufacturing processes, industries and municipal solid wastes, etc.; therefore, the administration of solid waste has turned out to be one of the major concerns in the planet. Because of ecological mindfulness, shortage of landfill space and its expanding cost, waste material usage have turned into a viable and appealing alternative. High utilization of common sources and high measure of generation of mechanical waste and natural contamination require another answer for a feasible advancement. The usage of waste materials as development materials is a fractional answer for natural and biological issues from late years. The use of these waste materials helps in the bonding of concrete; yet, it helps in decreasing the cost of cement and solid assembling and furthermore has diminishment in landfill cost, sparing in vitality and shielding the earth from contamination impacts. The mechanical and strength properties of mortar and cement may enhance by the use of these materials, which are hard to accomplish by the utilization of Ordinary Portland Cement (Siddique *et al.* 2011). Hence, there is a need to search for supplementary cementitious material for utilization of these waste materials and a by-product as a partial substitute for cement.

3. MATERIALS AND 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, confirming 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. Properties of cement.

Properties	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 Silica Fume

Silica fume (SF) is a mineral admixture obtained from clay. The clay contains the mineral kaolin. It ought to be consistently calcinated at a tolerable high temperature (650-800 °C). One of the conspicuous utilization of SF is blending with concrete since it is an exceptionally receptive pozzolanic material and compound. Physical properties are like the bond. It is in the control frame and fineness of SF 700 to 800 m^2/kg. SF is principally comprised of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), ferric oxide (Fe_2O_3), calcium oxide (CaO) and potassium oxide (K_2O).

SF is a de-hydroxylated form of the clay mineral kaolinite with 4-, 5- and 6- coordinated aluminium ions in alumina polyhedron sheet structures (Duxson *et al.* 2007). It is a significant admixture with numerous astounding favorable characteristics, including porosity, high specific area, great absorbability and solid coordinative bonds when fortified. The underlying response process and execution of soluble base actuated Silica Fume-based geopolymer isn't just impacted by the nano substance creation, measurement and centralization of crude materials (Duxson *et al.* 2005; Roviello *et al.* 2015); it is additionally influenced by the curing conditions amid the early-age polymerization process (Muñiz-Villarreal *et al.* 2011; Rieger *et al.* 2015).

3.1.3 Fly Ash

Fly ash remains is especially like volcanic powder utilized as a part of the creation of the earliest known hydraulic cements around 2,300 years ago. These cements were made close to the little Italian town of Pozzuoli - which later gave its name to the expression "pozzolan". A pozzolan is a siliceous or siliceous/aluminous material which when blended with lime and water, forms a cementitious compound. Fly ash is the best known and a standout amongst the most generally utilized pozzolans on the planet. Fly ash remains is the infamous waste result of coal-based power-creating power plants, known for its ill consequences in rural land, surface and sub-surface water contamination, soil and air contamination and ailments to humankind.

Fly ash is the material gathered in the dust accumulation frameworks that expel particles from the fumes of energy plants that consume pulverized coal. It is generally finer than Portland cement and comprises little circles of a glass of complex arrangement, including silica, ferric oxide and alumina. Two noteworthy classes of fly ash remains are identified with the kind of coal consumed. The American Society for Testing and Materials (ASTM) assigns Class F and Class C, and this separation is mainly utilized as a part of the vast majority of the current literature.

3.1.4 Rice Husk Ash

In the rice-growing region, one of the waste materials is rice husk. The utilization of these agricultural wastes is not only purposeful, but it will also reduce the energy consumption, which is used in the production of cement. Therefore, it is an agro-based product, which can be used as a substitute for cement without affecting the strength and durability of concrete. The use of rice husk is generally in burning the raw clay bricks in the kilns. Now, recently it is used for cooking purposes in hotels, but now it is replaced by LPG gas. Rice husk is not useful for animal feeding because it has negligible protein content.

Rice husk ash is obtained by the burning of rice husk, which is a by-product of rice milling. It is calculated that 1000 kg of rice grain produce 200 kg of rice husk; when the rice husk burnt about 20%, 40 kg of rice husk ash was obtained. RHA contains as much as 80-85% silica, which is highly reactive, and it depends upon the temperature of the burn (Kishore *et al.* 2011).

The annual worldwide production of Rice Husk Ash is near about 20% of the 649.7 million tons of rice produced. The chemical composition of rice husk ash is varying from place to place or one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions. Burning of the rice husk is under controlled temperature below 800 °C can produce rice husk ash mainly in amorphous form with silica (Habeeb *et al.* 2010).

3.1.5 Aggregate

The fine aggregate used for the experimental work was locally available Yamuna River Sand; the coarse aggregate used was from Banda, U.P., India.

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.	Properties	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%

3.1.6 Rice Husk Ash

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

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

Physical Properties	Results
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 Properties	Results
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%

3.1.7 Superplasticizer

Auramix 400 of FOSROC brand was used in this experimental study, which complies 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. RESULTS AND DISCUSSION

4.1 Workability

The results for Supplementary Cementitious Concrete have shown a different variation of workability for the mixes. The maximum value of slump was achieved at 6% SF + 15% FA + 20% RHA.

4.2 Density

The maximum value of density was achieved at 6% SF + 15% FA + 20% RHA, irrespective of other mixes in the same group. It has been discovered that the action of Fly Ash is best ascertained at 15% content rather than its usage in cement on the lower side.

4.3 Compressive Strength

The results for supplementary cementitious concrete have shown a different variation of compressive strength for mixes. The final combination of blending, which gives an optimum value of compressive strength for all mixes, is found to be 8% SF + 10% FA + 10% RHA.

4.4 Flexure & Tensile Strength

The final combination of blending which gives an optimum value of split tensile strength for all mixes is found to be like 8% SF + 10% FA + 10% RHA for ternary blending and for single blending it is 8% SF.

5. CONCLUSION

Based on the investigation, it is quite clear that supplementary cementitious material has proved to be the most promising blending material to provide good quality concrete. The following generalized conclusion can be drawn on the mechanical properties of concrete:

1. Final combination of blending which gives a maximum value of slump for all mixes is found to be 100% OPC + 0% SF + 0% FA + 0% RHA.

2. Final combination of blending which gives an optimum value of compressive strength for all mixes is found to be 8% SF + 10% FA + 10% RHA.

3. Final combination of blending which gives an optimum value of flexure strength for all mixes is found to be 8% SF + 10% FA + 10% RHA for ternary blending, and for single blending it is 8% SF.

4. Final combination of blending which gives an optimum value of split tensile strength for all mixes is found to be 8% SF + 10% FA + 10% RHA for ternary blending, and for single blending it is 8% SF.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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