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Strength and Durability of Mortar Incorporating Roof Tile Powder as Partial Cement Replacement Material

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***Abstract*— The paper discusses the effects of using roof tile powder (RTP) as a partial cement replacement material in mortar mixes. An experimental study of mortar made with Pozzolona Portland cement (PPC) and 15% of PPC replaced by RTP was tested for the strength and durability properties, to determine the effect of RTP on mortar properties and was compared to control mortar mix. An extensive experimental study was carried out including physical property, chemical analyses, X-ray diffraction and scanning electron microscopy (SEM) on RTP and water absorption and sorptivity on mortar containing RTP. Mortar specimens were tested for compressive strength at age of 28 days. To investigate the mortar for its durability, the specimens after initial curing of 28 days in fresh water, were immersed in solutions of 2.5% sodium sulfate (Na_2SO_4), 3% hydrochloric acid (HCl) solution, 3% sulphuric acid (H_2SO_4) solution and 3.5% sodium chloride (NaCl) for another period of 4 months. Through this period, the specimens were tested for change in compressive strength and weight loss at 56, 90, 120 and 150 days to evaluate its durability.**

Keywords*— Cement; Roof Tile Powder; Mechanical Properties; Durability Properties; Mortar.

I. INTRODUCTION

Ordinary Portland Cement (OPC) is a major construction material choice in Civil Engineering construction. Every year more than 10 billion tons of concrete are produced with Portland cement being the key ingredient, but producing the greatest environmental burden. Cement manufacture is highly resource intensive and liable for the emission of green house gases. CO_2 emissions associated with cement manufacture have brought about pressure to reduce cement conception through the use of supplementary materials.

Potential of solid wastes in building industry as alternative materials is already well established. Utilization of pozzolanic materials as supplementary cementing materials has become the leading research interest in recent decades. Considering the properties of ceramics their waste such as broken tiles should be included in concrete as a substitute to conventional construction material. This will help to solve problems like cost, scarcity as well as other environmental issues that may arise due to improper dumping of such waste.

Potential of roof tile construction wastes as a partial cement replacement material in mortar is investigated through this paper. There is often a requirement to test mortar for durability, but satisfactory tests are difficult to develop in practice and most suggested regimes are either too lengthy and complicated or do not relate sufficiently well to site practice.

II. EXPERIMENTAL PROGRAM

A. *Materials*

Materials used for this study include Portland Pozzolona cement (PPC), fine aggregate, roof tile powder (RTP) and water. The details of various materials used in the experimental investigation are presented below.

a. Cement

The cement used in the present investigation is PPC grade cement manufactured by Ramco Ltd. as per IS 1489 (Part 1):1991. The physical properties and chemical compositions of PPC are given in Table 1.

b. Fine aggregate

The fine aggregate used in this experimental investigation is manufactured sand obtained from Chalakkudy, Thrissur district in Kerala. Properties of fine aggregate is given in Table 2.

c. Roof tile powder

Roof tile powder used in the present study was collected from a tile manufacturing industry near Chalakkudy, Thrissur district in Kerala. Roof tile waste obtained was grinded and passed through 90 micron sieve and used for cement replacement. The physical properties and chemical compositions of roof tile powder are given in Table 1.

d. Water

Water used for mixing and curing is fresh potable water, conforming to IS : 3025 – 1964 part 22, part 23 and IS : 456 – 2000.

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III. EXPERIMENTAL PROGRAM AND RESULTS

A. Physical and chemical properties

Physical and chemical properties of various materials used in the experiment is shown in the table below

Table 1 : Physical properties and chemical analysis of PPC and RTP

Physical properties			
Sl No.	Particular	PPC	RTP
1.	Fineness	2.67%	0%
2.	Standard Consistency	29%	-
3.	Initial setting time	86 minutes	45 minutes
4.	Final setting time	300 minutes	220 minutes
5.	Specific gravity	3.05	3.19
Chemical properties			
1.	Silica (SiO_2)	31	62.8
2.	Alumina (Al_2O_3)	10.6	12.9
3.	Ferric oxide (Fe_2O_3)	4.6	4.7
4.	Lime (CaO)	42.5	47.2
5.	Sulphur trioxide (SO_3)	2.1	2.7
6.	Magnesia (MgO)	2.2	4.7
7.	Loss on Ignition, %	5.6	5.4
8.	Free moisture content, %	1.5	-
9.	Insoluble residue, %	2.3	7.3

Table 2 : Properties of fine aggregate

Sl. No	Property	Magnitude and Unit	
		M-sand (Loose)	Compacted
1.	Bulk density (g/L)	1470	1600
2.	Porosity (%)	41.2	36
3.	Void ratio	0.7	0.56
4.	Fineness modulus	3.87	
5.	Specific gravity	2.5	
6.	Bulking	Max bulking at 6% moisture content	

B. Test on pozzolanicity

The following tests were conducted to establish the potential of RTP as pozzolanic material.

a) X-Ray diffraction test

The diffraction pattern of the materials is important in governing its suitability for use as pozzolanic material in mortar.

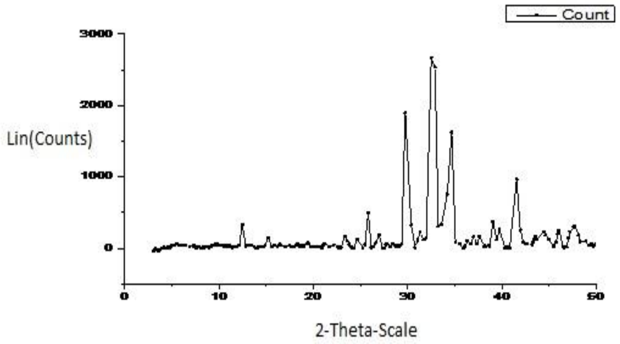

Fig 1 X-Ray diffraction pattern of RTP

The diffraction pattern of the materials is important in governing its suitability as a pozzolanic material. The comparison of X-ray diffraction pattern of RTP with reference database is shown in Fig 1.Absence of sharp peak at 2 theta equals to 22 degrees is an indication of the amorphousness of the sample and shows the pozzolanic property of RTP.

b) Scanning Electron Microscopy Test

A scanning electron microscope (SEM) analysis was conducted on RTP to obtain information about the surface topography and composition.

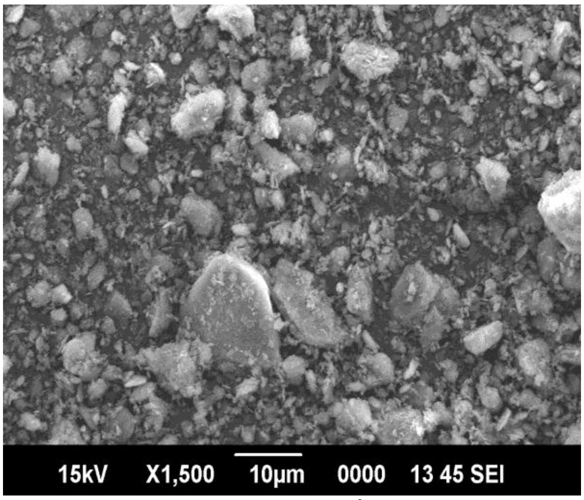

Fig 2 : SEM image of RTP

The result of scanning electron microscopy is shown in Fig 2. From the SEM images, it is clear that pore size of RTP is very minute. The surface texture is homogeneous and spherical. Finer particles ate traced and are uniformly distributed which confirms the pozzolanic activity of the material.

C. Tests on mortar

Compressive strength, water absorption and water soprtivity tests were conducted to determine the strength and durability characteristics of modified mortar.

a) Compressive Strength Test

Mortar cubes were prepared in 1:3 proportion using cement and RTP as binders according to IS 2250:1981. The cement was replaced with 15% roof tile powder to prepare the modified mortar. Water cement ratio of 0.45 was used. Table 3 shows the result.

Table 3 : Results of Compressive strength of mortar

Water content	Binder sand ratio	% of replacement	Compressive strength at 28 day (MPa)
0.45	1 : 3	0%	19.63
		15%	20.71

From the table we can observe that, 28 day compressive strength of modified mortar cubes was higher than traditional mortar cubes.

b) Water absorption Test

Water absorption tests of modified mortar specimen of binder: aggregate ratio 1:3 was carried out according to IS 1237. Table 4 shows the results.

Table 4 : Results of Water absorption Test

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Water content	Binder sand ratio	% of Replacement	Water Absorption (%)
0.45	1 : 3	0%	0.939
		15%	1.259

From the results obtained it is noted that the water absorption is more in roof tile powder incorporated mortar cubes than reference cubes. This is because roof tile powder has very high water absorption due its increase in fineness comparing to cement.

c) Water sorptivity test

Water sorptivity tests of modified mortar specimen of binder: aggregate ratio 1:3 was carried out and Table 5 shows the results.

Table 5 : Results of Water sorptivity Test

Water content	Binder sand ratio	% of Replacement	Water Sorptivity (%)
0.45	1 : 3	0%	2.19
		15%	0.732

Water sorptivity of mortar cubes incorporated with RTP is less than OPC mortar cubes. Water sorptivity depends on the pore size. Capillary pore available in mortar cubes incorporated with roof tile powder is less than OPC mortar cubes.

d) Change in compressive strength and percentage weight change

After 28 days of curing in water, each mortar cubes were tested for weight. Mortar cube specimens of Portland pozzolanic cement and roof tile incorporated cement were subjected to 3% concentrated H_2SO_4 solution and 2.5% sodium sulphate solution individually. Cubes were continuously immersed in solution. The percentage change in weight and percentage change in compressive strength were taken for a set of cubes at 28 days, 56 days, 90 days and 120 days. Fig 3 and Fig 4 gives the compressive strength test results of mortar cube specimens when immersed in Na_2SO_4 solution and H_2SO_4 solution after 28 days water curing.

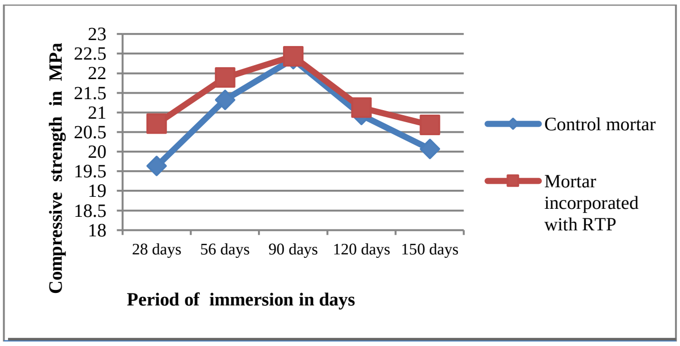

Fig 3 : Compressive strength of mortar cubes cured in Na_2SO_4 solution

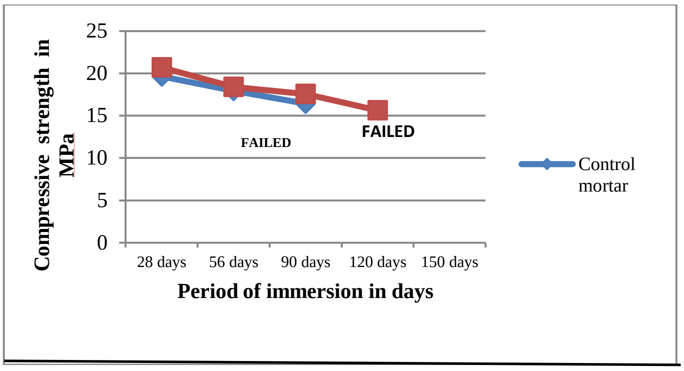

Fig 4 : Compressive strength of mortar cubes cured in H_2SO_4 solution

From the Fig 3 it was noted that compressive strength of mortar cubes reduced with time in H_2SO_4 solution. It can be noted from Fig 4, compressive strength of mortar cubes in Na_2SO_4 solution increased upto 60 days after the immersion and with further increase in days of immersion compressive strength gradually reduced. Compressive strength of partially replaced mortar cubes was higher than control mortar in all mediums of exposure.

Fig 5 and Fig 6 gives the percentage change in weight test results of mortar cube specimens when immersed in H_2SO_4 solution and Na_2SO_4 solution after 28 days water curing.

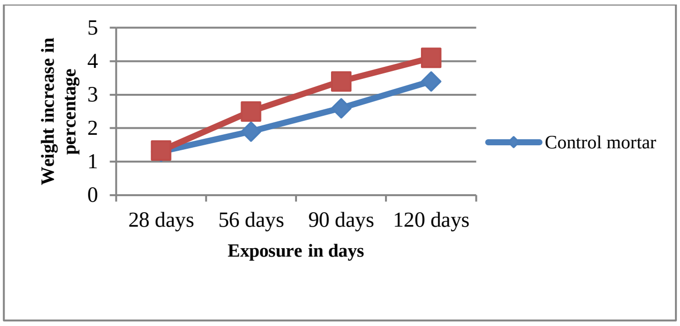

Fig 5: Percentage change of weight of mortar cubes cured in H_2SO_4 solution

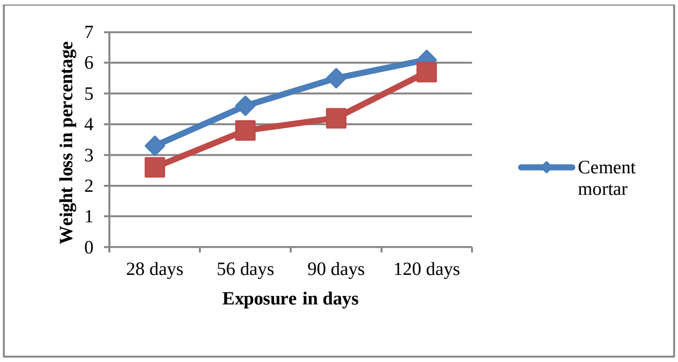

Fig 6 : Percentage change of weight of mortar cubes cured in Na_2SO_4 solution

The Fig 6 shows that the percentage weight increase of modified mortar is higher than control mortar in Na_2SO_4 solution. From the Fig 5, it is evident that the percentage weight loss of modified mortar is less than control mortar in H_2SO_4 solution.

IV. CONCLUSION

From the experimental investigation, following inferences are made :

- The results confirm the pozzolanic activity of the fine roof tile waste, collected from the roof tile industry, making feasible their incorporation as cement mortars.
- Mechanical property tested by compressive strength of modified mortar was higher than traditional mortar.
- Mortar without roof tile powder has suffered the most deterioration in both chemical solutions.
- One possible reason for improved behavior of RTP mortars is due to the presence of C-S-H gel obtained from pozzolanic reaction. The low permeability of these mortars prevents the sulphates from entering into the cementitious matrix.
- The test on sulphuric acid solution further showed the superiority of modified mortar by staying intact in the solution for 120 days while the traditional mortar completely deteriorated.

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