ROOF TILE POWDER AS A PARTIAL REPLACEMENT TO CEMENT IN MASONRY MORTAR

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ABSTRACT

Ordinary Portland cement is an inevitable material for construction. However, it is highly energy intensive and liable for the emission of green house gases. In this context, utilization of pozzolanic materials as supplementary cementing materials has become the leading research interest in recent decades. Roof tile industries generate huge amount of solid waste materials during their manufacturing processes. Disposal of these waste materials is serious environmental concern. This paper presents the results of the study conducted on the potential of roof tile powder (RTP) as a cement replacement material in mortar. The physical, chemical and mineralogical compositions of RTP were investigated. Strength characteristics of masonry mortar with varying proportions of RTP as cement replacement were tested. The test results verify the potential of roof tile powder as partial replacement to cement in masonry mortar upto an extend of 15-20% in 1:3 and 1:5 mortar proportions respectively.

KEYWORDS

Pozzolanic Materials, Supplementary Cementitious Materials, Compressive Strength.

1.INTRODUCTION

Ordinary portland cement (OPC) is an inevitable material for construction. However, it is highly resource intensive and liable for the emission of green house gases. Currently manufacturers find it difficult to locate adequate sources of raw materials due to the excessive exploitation. The raw materials have been produced from the existing natural resources and will have intrinsic damage to the environment due to their continuous exploitation. Affordability of building materials is another major concern of today along with environmental issues. In India, the cost of cement during 1995 was Rs 1.25/ kg. while in 2005, the price was increased to three times and in 2015, it is increased to eight times. Moreover, a huge quantity of solid waste is generated annually during construction, mining, municipal, agricultural and commercial activities contributing to the environmental pollution. It is estimated that about 14.5 MT of solid wastes are generated annually from construction industries alone [1]. 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. Potential of construction wastes as cement replacement is investigated through this research. Igor et.al [2] established the pozzolanic activity of recycled red ceramic bricks through their research. Strength and durability properties of concrete and mortar using waste brick powder as cement replacement was also established by many researchers [3,4,5]. This paper presents the results of the study conducted on the pozzolanic property of roof tile powder (RTP) and its application in masonry mortar.

1.1 Experimental Programme

The experimental programme consists of three stages such as material characterization, test on pozzolanicity and test on mortar.

2.1 Material Characterization

2.1.1 Cement

Cement used was 53 grade ordinary portland cement with commercial name Coromandel conforming to IS: 12269:1986.

2.1.2 Fine aggregate

River sand was used as fine aggregate and its properties are shown in table 1.

Table 1. Properties of fine aggregate

Sl.no	Properties	Magnitude (RiverSand)
1	Specific gravity	2.74
2	Bulk density(kg/cm^3)	1.45
3	Grading zone	Zone II
4	Fineness modulus	3.8
5	Bulking	Max bulking at 6%

2.1.3 Roof Tile Powder

The waste roof tile pieces were collected from a tile manufacturing unit at Chalakkudy, Trichur district of the state of Kerala, India. The cracked pieces of roof tiles were crushed and sieved through 90µ IS sieve to obtain standard fineness.

Figure 1. RTP in powder form

2.1.4 Chemical Analysis of cement and RTP

A comparison of chemical and physical properties of OPC and RTP are shown in table 2.

Table 2. Chemical and physical properties of OPC and RTP

Chemical Analysis	**OPC**	**RTP**
Loss on ignition	5.6%	2%
SiO_2	31%	62.4%
Al_2O_3	10.6%	8.8%
Fe_2O_3	4.6%	9.2%
CaO	42.5%	2%
MgO	2.2%	5.4%
SO_3	2.1%	1.7%
Insoluble residue	23%	2%
Specific gravity	3	3.497
Standard consistency	30%	34%
Initial setting time	115 minutes	420 minutes
Final setting time	195 minutes	210 minutes

2.2 Test on pozzolanicity

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

2.2.1 Specific surface area

The specific surface area was evaluated using BET (Brunauer, Emmett and Teller) method according to IS 1727-1967.

2.2.2 Determination of lime reactivity

Lime reactivity test was conducted as per IS 3812:2003. Cube specimens of size (70 mm x 70 mm x 70 mm) were prepared and tested. The specimens were cured at 90 to 100% relative humidiy at 50°C and tested. The 28 day compressive strength was found to be 6.3 N/mm^2.

2.2.3 X- Ray diffraction test

The diffraction pattern of the materials is important in governing its suitability for use as pozzolanic material in mortar. The X-ray diffraction pattern of RTP was analysed using Joint Committee on Powder Diffraction Standards (JCPDS) database.

2.2.4 Scanning Electron Microscopy Test

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

2.2.5 Electrical conductivity

The variation of electrical conductivity of a saturated solution of calcium hydroxide on dispersing with the RTP samples can be taken as a measure of the pozzolanic activity of the sample (Luxan et.al 1989). Initially the conductivity of calcium hydroxide saturated solution (200 ml, 40^0 C) is measured. To this 5 g of RTP sample is added. The electrical conductivity is measured after two minutes of continuous stirring. The difference between the initial and final conductiveness is calculated as a measure of pozzolanic activity.

2.2.6 Soluble fraction of silica

RTP samples are taken, weighed in an analytical balance and boiled in 100 ml of 2.5 N (10%) NaOH. The solution is then filtered through a filter paper and washed with demineralised water. This filter is dried in an oven at 800 degree Celsius (2 hours), cooled and weighed to get the weight of insoluble silica. Soluble silica remained as dissolved in the solution.

2.3 Tests on Mortar

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

2.3.1 Compressive Strength Test

Mortar cubes were prepared in 1:3 and 1:5 proportions using cement and RTP as binders according to IS 2250:1981. To optimize the replacement of cement with RTP in cement mortar, compressive strength tests were conducted with varying proportions of replacements (5%, 10%, 15% and 20%) . Table 3 and 4 shows the results.

Table 3. Compressive strength of modified mortar

Replacement levels (%)	Mortar Proportions (1:3)	
	Compressive Strength in N/mm^2 (28 days)	Compressive Strength in N/mm^2 (90 days)
0	22.13	26.38
5	19.86	23.55
10	16.14	17.82
15	12.11	14.95
20	5.23	9.33

Table 4. Compressive strength of modified mortar

Replacement levels (%)	Mortar Proportions (1:5)	
	Compressive Strength in N/mm^2 (28 days)	Compressive Strength in N/mm^2 (90 days)
0	20.22	23.98
5	16.37	20.13
10	13.19	15.74
15	7.25	10.62
20	4.35	7.46

2.3.2 Water Absorption Test

Water absorption tests of modified mortar specimen of binder: aggregate ratio 1:3 and 1:5 were carried out according to IS 1237. Table 5 shows the results

Table 5. Water absorption at 28 days curing

Sl.no	% Replacement	% Water Absorption (1:3)	% Water Absorption (1:5)
1	Control Mix	4.10	9.55
2	5	4.45	9.63
3	10	8.81	10.24
4	15	9.33	11.20
5	20	12.96	15.61

3. Results And Discussions

This section presents the discussion of the results of the experimental researches.

3.1. Chemical Analysis

The results of chemical analysis of RTP satisfy the requirements of pozzolanic materials with a higher percentage of silica content. The analysis reveals a predominance of SiO_2, Al_2O_3 and Fe_2O_3 for RTP which satisfies the specifications (min 70%) of class N pozzolana as per ASTM C 618.

3.2 Specific Surface Area

The specific surface area of the OPC sample was 341m²/kg and that of the RTP was 404 m²/kg. The higher surface area is an indication of high reactivity and thus improves the pozzolanic property.

3.3 Lime reactivity

The lime reactivity test confirms the pozzolanic property of RTP i.e 6.30 N/mm^2 at 28 days where as standard value as per IS 3812 is 4.5N/mm^2. The higher value is an indication of high pozzolanicity of RTP and micro-filling effect owing to the higher surface area.

3.4 X- Ray diffraction pattern of roof tile powder

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 Figure 2.

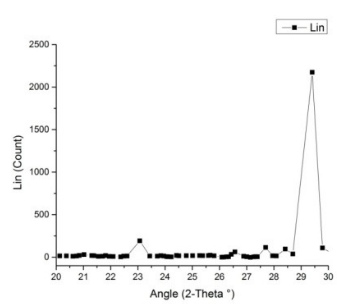

Figure 2. X-Ray diffraction pattern of RTP

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.

3.5 Scanning electron microscopy

The result of scanning electron microscopy is shown in figure 3. From the SEM images, it is clear that pore size of RTP is very minute. The surface texture is homogeneous and spherical. Finer particles are traced which confirms the pozzolanic activity of the material.

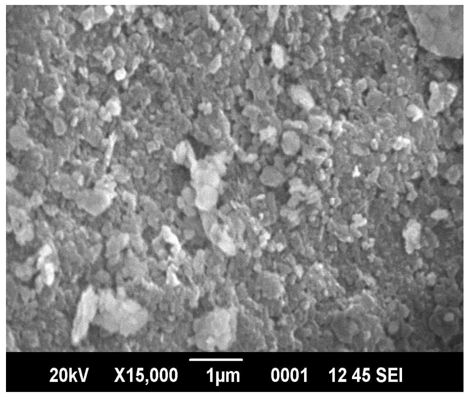

Figure 3. SEM image of RTP

3.6 Electrical Conductivity

The results of electrical conductivity showed that RTP samples have large conductivity charges (1.291ms/cm) which can be interpreted as good value for pozzolanic activity. According to Luxan et.al;(1989) variation in electrical conductivity more than 1.2 is referred as good pozzolana.

3.7 Soluble fraction of Silica

RTP samples were subjected to chemical analysis for amorphous silica. The results shows highest soluble silica fraction (73.05%) which is considered as the reactivity of the RTP samples.

3.8 Compressive Strength

Figure 4 shows the results of 1:3 and 1:5 combinations of mortar with different replacement levels of cement with RTP varying from 0 - 20%. A reduction in compressive strength was observed in both the cases as the replacement level increases. The reduction in strength of the mortars may be attributed to the higher water requirement of RTP owing to the higher specific surface area. This results in incomplete reaction during the hydration process and causes a reduction in compressive strength at a water-binder ratio of 0.45. However, a replacement of cement up to 20% for 1:3 and 15% for 1:5 are possible since the values are above $5N/mm^2$, the minimum specified compressive strength of masonry mortar according to Indian Standards.

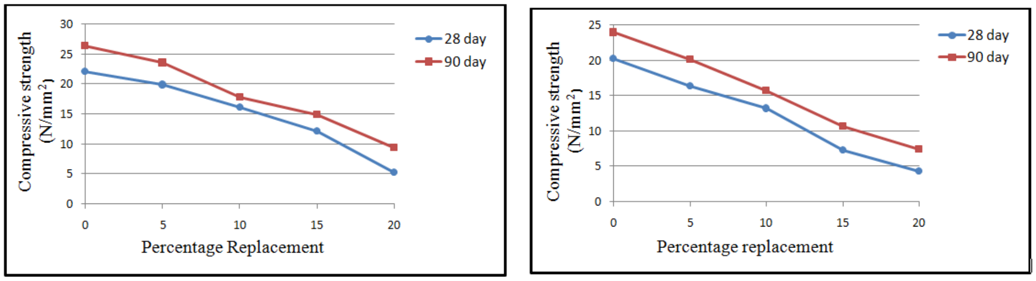

Figure 4. Compressive strength development of 1:3 and 1:5 mortar

3.7 Water Absorption of Mortars

Figure 5 represents water absorption of control mix and modified mortar at 28 days of curing age. It was found that water absorption is higher as the amount of RTP increases. This is due to the fact that the roof tile powder has finer particles than those of OPC; consequently, they absorb more water which can be observed from normal consistency data (Table 3). As per IS 1237, the average % water absorption should not exceed 10%. Hence a replacement of cement up to 15% for 1:3 and 10% for 1:5 is recommended.

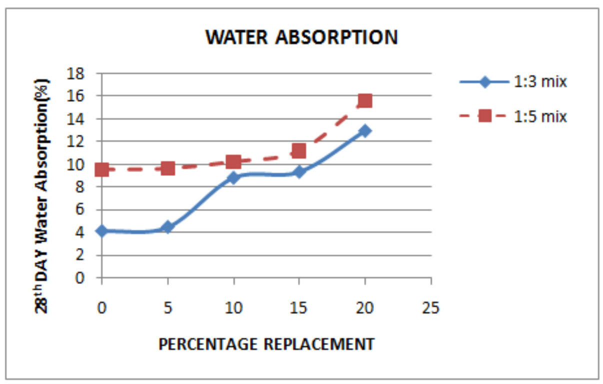

Figure 5. Water absorption of 1:3 and 1:5 mortar at 28 days of curing age.

4. CONCLUSIONS

In this study, potential of roof tile powder was investigated as a pozzolanic material in masonry mortar. The test results confirm its:-

- Pozzolanic property and categorizes it under class N pozzolana.
- Potential as partial replacement to cement in masonry mortar to an extent of 10 to15% for 1:3 and 1:5 mortar proportions respectively.

5.REFERENCES

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