



Technical Note

The use of waste ceramic tile in cement production

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Received 29 August 1999; accepted 3 January 2000

Abstract

In ceramic tile production, because of various reasons, unsold fired products come out. These are waste tiles and only a little part of them are used. Remainings create environmental problems. If these waste tiles are used in cement production, this pollution decreases. In this study, usage of waste tile as pozzolan was studied. Waste tile was added into Portland cement in 25%, 30%, 35%, and 40% weight ratios. Pozzolanic properties of waste tile and setting time, volume stability, particle size, density, specific surface area, and strength of cement including waste tile were investigated. The test results indicated that the waste tiles show pozzolanic properties, and chemical and physical properties of the cement including tile conforms to cement standard up to the addition of 35% waste tile. © 2000 Elsevier Science Inc. All rights reserved.

Keywords: Waste ceramic tile; Physical properties; Pozzolan; Cement

1. Introduction

When they are used alone, pozzolans do not show binding properties. Pozzolans gain binding property as a result of its chemical reaction with water when used with lime or cement [1–6]. Pozzolans are divided into two groups: natural pozzolans and artificial pozzolans. Lime-pozzolans are the oldest construction materials [7–9]. One important artificial pozzolan is fired clay. It was used with lime before cement was invented [2,10]. The clay minerals have a crystal structure. Therefore, clays in raw form do not possess pozzolanic properties. However, by heat treatment, clays become highly pozzolanic. Heat treatment destroys the crystal structure of clays and forms a quasi-amorphous or disordered alumina silicate structure [11]. The reactions occurring between a pozzolanic structure and a cement surface is investigated in various research [12–16]. It is found that silicate hydrates produced in reactions resemble Portland cement hydration product.

Raw materials of ceramic tile are clays, quartz, and feldspar. Tile is fired at 1100–1200°C. Brick and roof tiles are clay products. Brick and roof tile powder can be used

as a pozzolan. Can ground tile be used as a pozzolan? In this study, the answer to this question was investigated.

2. Experimental work

2.1. Materials

In this study, waste glazed ceramic tiles, which are scrap from a ceramic tile plant and Portland cement,

Table 1
Chemical analysis of tile and cement

Materials	Tile (%)	Cement (%)
SiO ₂	63.29	20.52
Al ₂ O ₃	18.29	5.46
Fe ₂ O ₃	4.32	3.64
CaO	4.46	65.04
MgO	0.72	1.35
P ₂ O ₅	0.16	0.04
K ₂ O	2.18	0.68
Na ₂ O	0.75	0.17
SO ₃	0.10	2.18
Cl ⁻	0.005	0.002
TiO ₂	0.61	0.27
SrO ₂	0.02	0.03
Mn ₂ O ₃	0.05	0.07
L.O.I.	1.61	1.16

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Table 2
Particle size analysis of samples

Size (μm)	% Under			
	Tile, 25%	Tile, 30%	Tile, 35%	Tile, 40%
200	—	—	99.91	99.91
90	95.99	94.81	94.69	94.79
45	76.44	75.20	75.38	75.60
32	63.74	62.97	63.43	63.65
3	10.21	10.04	10.51	10.05

were used. Table 1 gives the chemical analysis of tile and cement. Chemical analysis was done by ARL 8680 X-ray spectrophotometre.

2.2. Preparation of test specimens and method

The waste tiles were crushed in a jaw crusher and ground in a ball mill for 55 min. The ground tile was subjected to an activity test. A pozzolanic activity test was done by the Rilem Cembureau method. Portland cement was blended with ground tile by weight ratios 25%, 30%, 35%, and 40% in a ball mill for 30 min. Normal consistency was determined by Vicatring. The initial and final setting times of the specimens were measured in normal laboratory environments. Volume stability was measured by the Le Chateliér method. Particle size analysis of each specimen is given in Table 2. Particle size analysis was done by using a Malvern Mastersizer-E particle sizer. Density was determined by using a Le Chateliér retort and Quanto Chrome multi Picnometre. Specific surface area was measured with TONI Technik Blaine equipment. Four different batches were prepared for the strength test. In each batch, one unit of cement including tiles was mixed with three units of sand and one and a half unit of water. The mortar was placed in prismatic moulds having dimensions of $160 \times 40 \times 40$ mm. Prismatic specimens were subjected to 1, 2, 7, and 28 days compression and bending test by using a test machine (TONI COM, TC III (300 kN)).

3. Results and discussion

Pozzolanic properties of ceramic tiles were measured. Results are in Table 3. Pozzolanic properties conform to

Table 3
Comparison of pozzolanic properties of waste tile and TS 25

	TS 25	Tile
($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$), %	≥ 70.00	86.01
MgO, %	≤ 5.00	0.72
SO_3 , %	≤ 3.00	0.1
L.O.I., %	≤ 10.00	1.61
7 days strength (N/mm^2)		
Bending	≥ 10.00	12.8
Compressive	≥ 40.00	54.8

Table 4
Normal consistency water, initial and final setting time of samples

Tile (%)	Water (ml)	Initial setting time (h)	Final setting time (h)
25	90 + 28	2.50	3.40
30	90 + 27	2.50	3.35
35	90 + 24	3.00	4.00
40	90 + 22	3.00	4.05

Table 5
Volume stability results

Tile (%)	<i>a</i> (mm)	<i>b</i> (mm)	<i>c</i> (mm)	<i>c</i> – <i>a</i> (mm)
25	16	18	19	3
30	14	15	15	1
35	15	16	16	1
40	15	15	15	0

TS 25 [17] and A.S.T.M C 618 [2]. From this table it is obvious that waste tile can be used as pozzolan.

Drinking water was used in the preparation of cement including waste tile (300 g). Initial and final setting time and the amount of needed water are given in Table 4. Results of the volume stability test are given in Table 5. These results conform to TS 26 [18] and TS 12144 [19].

The density of cement including waste tile was measured and it was determined that sample density decreases with increasing tile ratio. As it is seen in Table 6, specific surface area conforms to TS 26. Specific surface area is higher than 2800 g/cm^2 .

The results of the bending and compressive strength tests are given in Table 7. Strength results of samples containing 25%, 30%, and 35% waste tile have enough strength. Samples containing 40% tile have enough 7-day strength but it failed the 28-day strength test. From the test results obtained in this study, it is concluded that up to 35% waste tile can be added to cement.

4. Conclusion

The test results obtained in this study show that:

- Ground waste tile has pozzolanic properties,

Table 6
Density and specific surface area results of samples

Tile %	Density (g/cm^3)	Specific surface area (cm^2/g)
25	3.00	3732
30	2.99	3513
35	2.98	3685
40	2.92	3813

Table 7

Bending and compressive strength test results of samples

Tile (%)	1 day		2 days		7 days		28 days	
	Bending strength (N/mm ²)	Compressive strength (N/mm ²)	Bending strength (N/mm ²)	Compressive strength (N/mm ²)	Bending strength (N/mm ²)	Compressive strength (N/mm ²)	Bending strength (N/mm ²)	Compressive strength (N/mm ²)
25	2.5	8.6	3.4	14.7	5.0	27.8	7.1	38.4
30	2.6	10.2	3.8	15.7	5.3	27.8	6.8	38.0
35	2.1	7.2	2.9	12.0	4.8	26.8	6.1	33.7
40	2.0	6.9	2.9	11.6	4.6	22.2	6.2	32.2

- Waste tile can be added into cement up to 35% weight ratio,
- Adding waste tile into cement reduces cost.

Acknowledgments

The authors would like to thank Eskisehir Cement Factories T.A.S for equipment for this project.

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