ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC) VOL. 14, NO. 5 (2013)
PAGES 755-763

Technical Note

EFFECTS OF WASTE BRICKS POWDER OF GACHSARAN COMPANY AS A POZZOLANIC MATERIAL IN CONCRETE

A. Heidari[1*] and B. Hasanpour[2]
[1]Department of Civil Engineering, University of Shahrekord, Shahrekord, Iran.
[2]Department of Civil Engineering, Yasouj Branch, Islamic Azad University, Yasouj, Iran.

Received: 5 November 2012; **Accepted:** 2 March 2013

ABSTRACT

The aim of this study is to investigate the feasibility of using waste bricks powder of Gachsaran Company in concrete. Cement is replaced by waste bricks powder in different proportions until 40 percent by weight. pozzolanic properties of bricks powder and compressive strength of concrete were investigated. The results demonstrated that the bricks powder show pozzolanic properties. Results also show that concrete with partial cement replacement by waste bricks powder has minor strength loss. The results of the investigation confirmed the potential use of this bricks powder material to produce pozzolanic concrete.

Keywords: Waste bricks powder; compressive strength; pozzolan; concrete

1. INTRODUCTION

In concrete the economy, technical aspect of concrete, environmental and energy consumption is important. Sometimes additional materials are used to improve the properties of concrete. Reduction of Portland cement without reducing performance of concrete is very important for huge projects that need a lot of cement. Today, pozzolan and cementitious materials plays an important role in concrete. Wastes of industries and constructions which have pozzolanic or cementitious property, not only can reduce environmental pollution and energy consumption of construction industry, but also make it cheap.

According to some authors the best way for the construction industry to become a more sustainable one is by using wastes from other industries as building materials [1-3]. Portland cement clinker production consumes large amounts of energy (850 kcal per kg of clinker) and has a considerable environmental impact. This involves massive quarrying for raw

* E-mail address of the corresponding author: heidari@eng.sku.ac.ir (A. Heidari)

materials (limestone, clay, etc.), as it takes 1.7 tones to produce 1 ton of clinker, as well as the emission of greenhouse and other gases (NOx, SO2, CO2) into the atmosphere. Around 850 kg of CO2 are emitted per ton of clinker produced [4]. Therefore, the replacement concrete by brick wastes represents a tremendous saving of energy and has important environmental benefits. Besides, it will also have a major effect on decreasing concrete costs, since the cost of cement represents more than 45 percent of the concrete cost.

A partial replacement of cement by mineral admixture such as fly ash, silica fume or blast furnace slag in cementing materials (mortar or concrete) in mixtures would help to overcome these problems and lead to improvement in the workability, strength and durability of cementing materials [5]. This would also lead to additional benefits in terms of reduction in costs, energy saving, promoting ecological balance and conservation of natural resources, etc. Portland cement with pozzolanic admixture is low in C3S (tricalcium silicate), low in C3A (tricalcium aluminate) and low heat of hydration and high long term strength. The continuing search for partial cement replacement materials has led the authors to investigate the utilization of waste fired clay bricks as a pozzolan for mortar [6] and concrete [7].

Waste bricks (calcined clay) are an artificial pozzolana which can be hydrated in the presence of Ca (OH) 2. The formation of cementitious material by the reaction of free lime with the pozzolan admixture in the presence of water is known as hydration. The hydrated calcium silicate gel or calcium aluminate gel (cementitious material) can bind inert material together. Since the lime content of calcined clay is relatively low, with the addition of lime it is necessary for a hydration reaction with the pozzolan of the calcined clay to occur [8]. The hydration chemistry of calcined clay is very complex [9]. The strength of concrete that contains recycled brick is independent of the strength of the brick [10-12] stated that including ground brick in concrete increases its long-term strength because of waste brick's pozzolanic nature. Accordingly, this investigation evaluates the effect of waste brick blended cement paste on the pozzolanic reaction of waste brick when the paste is adopted as a partial substitute for cement.

This paper presents a preliminary study on the assessment of the pozzolanic activity of waste bricks powder as well as its potential use in concrete as a partial replacement of cement. A series of tests were conducted to study the pozzolanic activity and the compressive strength tests were to monitor the strength development of the concrete at different ages containing from 10 to 40 percent bricks powder as cement replacement.

2. ADVANTAGES RELATED TO BRICKS POWDER

Bricks waste may come from two sources. The first source is the bricks industry, and this waste is classified as non-hazardous industrial waste, the second source of bricks waste is associated with construction and demolition activity, and constitutes a significant fraction of construction and demolition waste. Therefore, the replacement of cement by bricks wastes has the advantage of solving several environmental problems. The use of waste materials with pozzolanic properties in cement achieve as:

1. Conserves the environment by saving large amount of primary raw materials each year.

2. Extends the life of our landfill sites, helping to conserve the countryside.

3. Reduced need for clinker production (lower energy consumption and reduction in the use of raw materials).

4. Long-term mechanical strength, stable resistance to expansion due to the presence of free lime, sulphates and aggregate-alkali reactions, durable resistance to the action of pure and acid water, reduced hydration heat, impermeability, reducing porosity and increasing compactness.

5. Saves a significant amount of energy and reduces the amount of CO2, NOx, and other air pollutants emitted from the manufacturer cement clinker when waste brick powder used as a cement replacement.

6. Offers many alternative uses for recycled brick based products, without compromising on either cost or quality.

If we think of the areas needed for wastes disposal, we clearly understand the importance of avoiding land filled wastes by reusing bricks wastes in concrete.

3. WASTE BRICKS

The waste bricks used in this study were obtained from recycled bricks supplied by Gachsaran Company in Iran. Cracked pieces of bricks were crushed by a jaw crusher. And at laboratory scale the bricks wastes were ground with a air jet mill to obtain bricks powder. The resulting powders were sieved through a 45-µm (325 mesh) sieve. The chemical compositions of brick pastes were analysed and results obtained are reported in Table 1.

Table 1: Chemical analysis of bricks powder

	Materials											
	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na2O	K2O	MgO	TiO2	MnO	P2O5	SO3	LOI
Percent	46.52	10.62	4.29	24.48	1.02	1.84	8.56	0.514	0.079	0.199	0.895	0.66

4. POZZOLANIC PROPERTIES

Pozzolanic properties of bricks powder were measured, and shown in Table 2. Pozzolanic properties conform to ASTM C618 [13]. From this table it is obvious that waste powder can be used as pozzolan.

Table 2: Comparison of pozzolanic properties of waste bricks powder and ASTM C618

Parameter	ASTM in percent	Waste bricks powder in percent
$(SiO_2+Al_2O_3+Fe_2O_3)$	>70	61.43
SO3	<3.0	0.895
L.O.I.	<10	0.66
Autoclave expansion	<0.8	0.1
Moisture content	<3.0	0.5

5. MATERIAL OF CONCRETE

Cement used here is type II Portland. The coarse aggregate and the sand used in the concrete were crushed limestone aggregates. The water absorption, particle size distribution, density and the fineness modulus of the aggregates were determined following tests methods described in ASTM. The physical properties of the aggregates are given in Table 3.

Water used in the concrete was taken from the city of Shahrekord in Iran. In order to obtain a consistency defined by slump values of between 3 and 6 cm a super plasticizer was used, which guarantees compatibility with the cement and the mineral admixture used. The super plasticizer used is based on polymer dispersions. The properties of the super plasticizer used in the study were PH 7, color brown, specific gravity 1.18(kg/Lit).

Table 3: Physical and mechanical properties of aggregates

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.6	2.55
Fineness modules	3.1	-
Water absorption in percent	2	0.2
Maximum size in millimeter	-	25
Bulk density (kg/m^3)	1750	1597
Abrasion value in percent	-	26.43

6. MIX DESIGN

The mixture is designed according to ACI-211-89. A concrete without brick powder material, with a resistance f_{ck} of 33MPa and maximum aggregate size of 25 mm, was used as a control. At the beginning of the mixture design, binder content 320 kg/m^3, and water–cement ratio 0.5 were chosen as constant. Concrete mixes were made with waste bricks powder replacing 10, 15, 20, 25, 30 and 40 percent by weight of the cement as pozzolan and with the same amount of aggregates and water as in the reference. The value of cement and waste bricks powder is shown in Table 4.

Table 4: Samples name and composition

Abbreviation	Cementitious materials percent		Cementitious materials weight (kg/m^3)	
	Cement	Pozzolan	Cement	Pozzolan
C	100	0	320	0
CB10	90	10	288	32
CB15	85	15	272	48
CB20	80	20	256	64
CB25	75	35	240	80
CB30	70	30	224	96
CB40	60	40	192	128

The concrete mixtures were mixed in accordance with ASTM C192, in a 120 liter drum mixer. And workability of the fresh concrete was measured with a standard slump cone, slump test fulfilled according to ASTM C143-90. The interior of the drum was initially washed with water to prevent absorption. The coarse and fine aggregate were mixed first, followed by addition of the cement and pozzolan, and water containing required amount of superplasticizer. One-fifth of the superplasticizer was always retained to be added during the last 1 minute of the mixing period. Immediately after mixing and a slump of between 35 and 55 cm was obtained. Super plasticizer admixture was used at various amounts to maintain the workability of fresh concrete. The amount of concrete mixture is shown in Table 5.

Table 5: Concrete mixture proportions

Properties	**Mixture Name**						
	C	CB10	CB15	CB20	CB25	CB30	CB40
Cement (kg/m^3)	320	288	272	256	240	224	192
Waste brick powder (kg/m^3)	0	32	48	64	80	96	128
Water (kg/m^3)	160	160	160	160	160	160	160
W/C	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sand (kg/m^3)	840	840	840	840	840	840	840
Coarse aggregate (kg/m^3)	1040	1040	1040	1040	1040	1040	1040
Superplasticizer (%)	0.125	0.125	0.125	0.125	0.125	0.125	0.125

7. RESULTS AND DISCUSSIONS

The test specimens were cast in steel cubic moulds 15×15×15 (cm) and compacted on a vibrating table. After about 24 hour, the specimens were removed from moulds. Each specimen was labeled as to the date of casting, mix used and serial number. Concrete specimens were cured in lime-saturated water at 21 ºC in cure tanks until the time of testing.

Twelve cubic specimens were made from each mixture. Three cubes were tested at the 7, 28, 56 and 90 days to observe the influence of different age strengths of concrete with bricks powder. Casting, compaction and curing accomplished according to ASTM C192-81.

For each mix, cubic samples were tested to determine compressive strengths, respectively, at 7, 28, 56 and 90 days of curing. Compressive strength for each mixture was obtained from an average of three cubic specimens determined. A 2000kN capacity uniaxial compressive testing machine was used to test the specimens. The average results obtained from the sample compression tests, broken at 7, 28, 56 and 90 days, are shown in Table 6. In the same table is given the settling of Abrams' cone. All samples had a plastic consistency.

The results obtained indicate, as expected, large differences in early curing ages and smaller differences at long curing ages. The 7 day compressive strength varied between

11.15 and 21.79 MPa, and the 90 days strength varied between 31.97 and about 40.62 MPa. Compressive strength was observed to decrease, as the proportion of waste brick powder in concrete produced increased. In sample CB10, there was a decrease of 1.4 percent in compressive strength. In sample CB15, there was a decrease of 2.67 percent in the compressive strength of concrete with 15 percent of waste brick powder. In sample CB20, there was a decrease of 3.23 percent in the compressive strength of concrete. That was used 25 percent waste brick powder; there was a decrease of 7.89 percent in compressive strength. When the proportion of waste brick powder was 30 percent, a decrease of 10.34 percent was determined. However, in sample CB40, this proportion increased to 40 percent, 22.4 percent of decrease in compressive strength was determined. The CB40 had the lowest strength which arose because it contained 40 percent waste brick as cement replacement. The decreases of strengths at 7, 28, 56 and 90 days curing are shown in Table 7. For long curing age concrete mixtures with 10, 15 and 20 percent cement replacement has minor the strength loss.

Table 6: Results of compressive strength

Samples	**Settling (mm)**	**Average resistance in MPa**			
		7 days	28 days	56 days	90 days
C	55	25.15	35.8	39.75	41.2
CB10	50	21.79	33.12	37.93	40.62
CB15	50	20.83	31.57	37.21	40.1
CB20	45	19.25	29.05	35.91	39.87
CB25	45	17.15	25.93	32.76	37.95
CB30	40	16.03	23.39	30.92	36.94
CB40	38	11.15	20.12	26.71	31.97

Table 7: Decrease of compressive strength

Curing day	**Decrease of compressive strength in percent**						**Average of decrease**
	CB10	CB15	CB20	CB25	CB30	CB40	
7	13.36	17.18	23.46	31.81	36.26	55.67	29.62
28	7.49	11.82	18.85	27.57	34.66	43.79	24.03
56	4.57	6.39	9.66	17.58	22.21	32.81	15.54
90	1.4	2.67	3.23	7.89	10.34	22.4	7.99

Relative strength of tested concrete specimens was given in Figure 1. In this Figure, illustrates the compressive strength development for all the concrete mixtures used in this study. The compressive strength of the control concrete is seen to be greater than those of modified concretes at all ages, it can be seen that the compressive strength was developed in samples containing brick powder in every case higher than that of control cement sample. The difference in the strength development of the samples can be attributed to pozzolanic reaction.

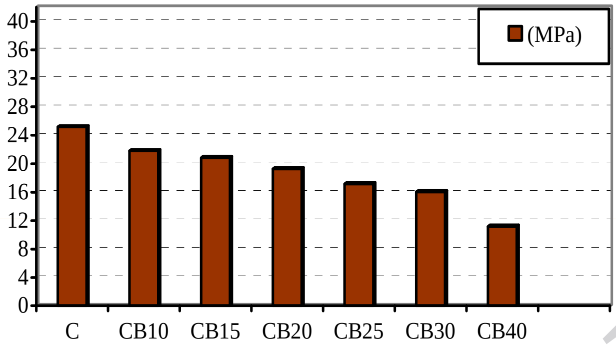

Figure 1. (a) Compressive strength in 7 days

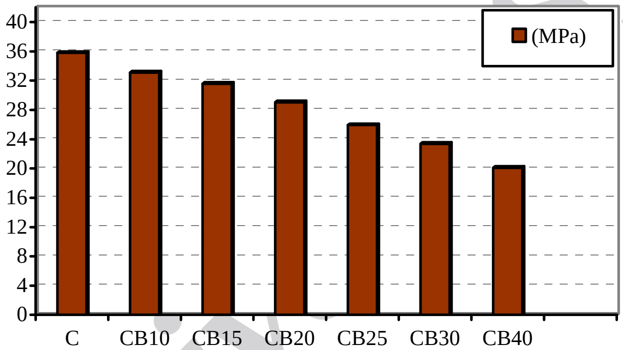

Figure 1. (b) Compressive strength in 28 days

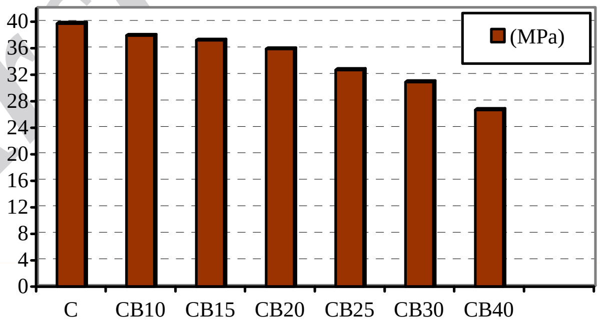

Figure 1. (c) Compressive strength in 56 days

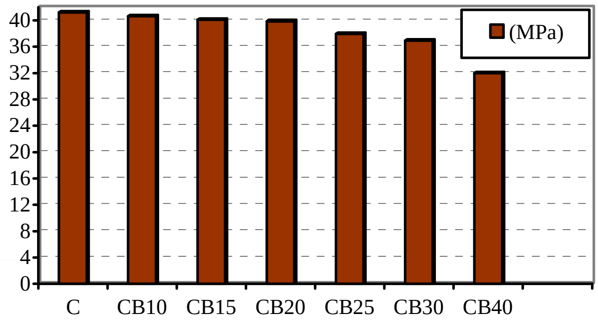

Figure 1. (d) Compressive strength in 90 days

8. CONCLUSIONS

The possibility of using waste bricks powder as a replacement of cement has been investigated in this study, in this paper that waste bricks can be used until 40 percent as a replacement of cement in concrete. The following conclusions can be drived from the present study:

1. The chemical analysis of bricks is shown the sum of SiO_2, Al_2O_3 and Fe_2O_3 is 61.43% for the waste bricks.
2. Compressive strengths of samples decrease with increasing the bricks content, especially at early ages. But results show that concrete with bricks waste powder has minor strength loss and brick waste powder exhibit very good pozzolanic reactivity and can be used as cement replacement.
3. The results show, that the average of resistance decrease 29.62 percent in 7 days curing, but this rate has drop 7.99 percent in 90 days.
4. For less than 20 percent use of the pozzolan (CB10, CB15 and CB20), the average use of pozzolan is 15 percent, although the average decrease in resistance in 7 and 90 day curing is 18 and 2.43 percent in order. This results show, less than 20 percent use of pozzolan, has no considerable effect on resistance

REFERENCES

1. Tavakolia D, Heidari A, Karimian M. Properties of concretes produced with waste ceramic tile aggregate. *Asian Journal of Civil Engineering*, **14**(2013) 369-82.
2. Mehta PK. Reducing the environment impact of concrete. Concrete Can be Durable and Environmentally Friendly, *Concrete International*, **10**(2001) 61–6.
3. Meyer C. The greening of the concrete industry. *Cement and Concrete Composites*, **31**(2009) 601–5.
4. Gartner E. Industrially interesting approaches to low-CO2 cements. *Cement and Concrete Research*, **34**(2004) 1489–98.

5. Schindler AK, Folliard KG. Influence of supplementary cementing materials on the heat of hydration of concrete. *Advanced in Cement and Concrete IX Conference*, Colorado, USA, 2003, pp. 10-14.
6. Naceri A, Chikouche Hamina M. Effects of Pozzolanic admixture (waste bricks) on mechanical response of mortar. *IJE Transactions B: Applications*, **21**(2008) 1-8.
7. Kae LL, Hsiu HW, Je LS, Chao LH, An C. Recycling waste brick from construction and demolition of buildings as pozzolanic materials. *Waste Management and Research*, **7**(2010) 653-9
8. Wild GA, Hansen H, Pederson L, Swabowski J. Pozzolanic properties of a variety of European clay bricks. *Building Research and Information*, **25**(1997) 170-5.
9. He C, Makovicky E, Osaeck B. Thermal stability and pozzolanic activity of calcined Kaolin, *Applied Clay Science*, **9**(1994) 165-87.
10. O'Farrell M, Wild S, Sabir BB. Pore size distribution and compressive strength of waste clay brick mortar. *Cement and Concrete Composites*, **23**(2001) 81–91.
11. Padmini AK, Ramamurthy K, Matthews MS. Relative moisture movement through recycled aggregate concrete. *Cement and Concrete Research*, **54**(2002) 377–84.
12. Khatib JM. Properties of concrete incorporating fine recycled aggregate. C*ement and Concrete Research*, **35**(2005) 763–9.
13. ASTM C618. Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use a Mineral Admixture in Concrete, 2003.