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Green bricks for masonry structures

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Abstract. Construction industry is now looking for most eco friendly and more sustainable material and technologies. Geopolymer concrete is a new environment friendly material and has reduced environmental impact leading to the concept of sustainable development. This article presents experimental investigation made for developing geopolymer concrete bricks. Effect of particle size and degree of amorphousity of fly ash on compressive strength of bricks is examined in this paper. Present investigation analyse the suitability of geopolymer brick for replacing burnt clay brick and cement concrete block in terms of strength, economy and sustainability.

Keywords: Green; brick; fly ash; geo-polymer; environment

1 Introduction

Burnt clay bricks and cement concrete blocks are being used for masonry construction. India is estimated to have more than 100,000 brick kilns, producing about 150-200 billion bricks annually (Maithel et al. 2007). The brick kilns emit toxic fumes containing suspended particulate matters rich in carbon particles and high concentration of carbon monoxides and oxides of sulphur (SOx) that are harmful to eye, lungs and throat (Joshi and Dudani, 2008). In India, good agriculture soil is preferred as the raw material for making clay bricks. Air pollution and drastic use of large quantity of good quality agriculture soil are the major environmental concerns related with clay brick industry in the country. Large amount of fuel wood also needed for the manufacture of bricks which leads to deforestation and thereby environmental hazards.

Cement is the binding material used for making cement concrete block which is not an environment friendly material. It is estimated that, one ton CO2 (Green house gas) emit to atmosphere during the entire production process of one ton cement (Davidovit 1994). Huge quantity of fly ash are generated around the globe from thermal power plants and generally used for land filling in low level areas which causes ground water contamination. Use of fly ash for making construction material is an added advantage to environment

Geopolymer is more environmentally binding materials that are being developed for using in construction industry. Geopolymers are formed by alkaline activation of an aluminosilicate material. The formation of three dimensional structure of geopolymer involves the basic chemical reactions such as dissolution, hydrolysis and condensation. Depending on the ratio of Silica to Alumina, there could be geopolymer with either Si-O-Al or Si-O-Si bond (Weng and Sageo-Crentsil 2007 part 1&2 , Davidovit 1999). Review of literature shows that fly ash, metakaolin,

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rice husk ash, red mud etc. are the generally used alumino-silicate material and the alkali solutions include sodium hydroxide, potassium hydroxide, sodium silicate, calcium silicate etc (Alonso and Palomo. 2001, Zhihnu et al. 2008, Jae Eun Oh et al 2001, Khale and Chudhary 2007). Only limited study has been reported on bricks made using fly ash based geopolymer. Considering the significance, it is decided to conduct experimental investigation for developing geopolymer concrete brick.

2 Experimental Program

2.1 Materials

2.1.1 Fly ash

Low calcium fly ash (ASTM Class F) collected from Hindustan paper limited,Vellore, Kerala, India, was used as the aluminosilicate source material for making geopolymer binder. The chemical composition of fly ash as determined by XRF analysis is presented in Table 1. The particle size of fly ash obtained from the industry was around 90 micron. Fly ash having maximum particle size around 90 micron named as F90 , fly ash having maximum particle size 40 micron, which are made by mechanical activation of F90 in Ball mill named as F40 and calcined fly ash were used in the study.

Table 1 Chemical Composition of fly ash (% by mass)

Parameter	%
SiO_2	57.4-60
Al_2O_3	27-29.1
Fe_2O_3	3-4.5
CaO	1.4-2.6
SO_3	0.3-0.5
MgO	0.3-1.1
Mn_2O_3	0.027

Parameter	%
Alkalies	0.5
Loss on ignition	3-7.5
Insoluble Residue	75-85
Residue on 90	28-55
Residue on 45	18-30
Fineness(m^2/kg)	470-600

2.1.2 Alkali

A mixture of NaOH and Na2SiO3 solution (SiO_2 = 34.64%, Na_2O= 16.27%, water 49.09%) was used as alkali. NaOH pellets of 98% purity were used to make sodium hydroxide solution of molarity 8.The specific gravity of the made up solution was 1.54

2.1.3 Aggregates

Crushed granite aggregate of nominal size 6mm was used as coarse aggregate. Manufactured sand was used as fine aggregate. The specific gravity of course and fine aggregates was 2.72 and 2.59 respectively. The fine aggregate had a fineness modulus of 2.6

2.2 Mechanical activation and calcinations of fly ash

Particle size of fly ash obtained from the source is reduced by mechanical activation in Ball-mill. Fig. 1 shows photograph of Ball- mill. Ball mill was of 60cm internal length and 50cm internal diameter. The grinding medium was alumina balls of 40 kg. Grinding was done for one and half hours and the particle size was reduced to 40 micron and down. Fly ash was heated in Muffle furnace at 800 ˚C for 6 hours and cooled down to room temperature for producing calcined fly ash. Photograph of Muffle furnace is shown in the Fig. 2

	
Fig. 1. Photograph of Ball-mill	Fig. 2. Photograph of Muffle furnace

2.3 Mixture Proportioning

Batching of materials was done as volume batching with a mix proportion of Fa:C:F = 1:1:1, where Fa is the combined volume of fly ash and alkaline solution, C is the volume of coarse aggregate and F is the volume of fine aggregate. The volumes of coarse and fine aggregates are kept constant (=0.35), but the ratio between volume of alkaline solution and fly ash is varied to get different mixes (0.2, 0.3, 0.4, 0.6). Ratio of Na_2SiO_3 to NaOH solution is 2.5 . Using the above proportion two sets of bricks was made – one is using F90 fly ash and other is using F40 fly ash. Three more geopolymer brick were made using calcined fly ash and fly ash to geopolymer ratio was 0.6. Quantity of each material required for producing 1m3 of concrete is given in the table 2.

Table2. Quantity of materials required for making 1m3 of concrete.

Alkali Fly ash ratio by mass	Weight of Fly ash (F90 or F40) (kg)	Weight of alkaline solution (kg)	Weight of NaOH pellets (kg)	Amount of water for NaOH solution (kg)	Weight of Sodium silicate solution (kg)	Weight of 6mm aggregates (kg)	Weight of M-sand (kg)
0.2	507.33	101.46	9.10	19.88	72.47	900.00	863.34
0.3	461.42	138.42	12.41	27.13	98.87	900.00	863.34
0.4	423.14	169.25	15.18	33.17	120.89	900.00	863.34
0.6	362.92	217.75	19.53	42.68	155.53	900.00	863.34

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2.4 Mixing and casting

The prepared solution of NaOH was first mixed with the calculated amount of Na2SiO3. The resulting alkali liquid was stirred well and kept for 24 hours before use. The required quantities of fly ash, coarse and fine aggregates in saturated surface dry conditions were dry mixed in a pan mixture. 200mmx100mmx100mm size brick specimens were cast in steel mould. The concrete, after placing in moulds, were compacted with the help of a table vibrator. The top side of moulds was covered with a steel plate and edges were sealed properly to avoid the loss of moisture from specimens during heat curing. The geopolymer concrete specimens were subjected to heat curing in an electric oven at 100˚C for a period of 24 hours. The curing temperature and period were arrived at based on a preliminary study conducted by the first author (Joseph and Mathew 2013). After the temperature curing, the specimens were demoulded and were kept in room temperature till it was tested (on 28th day). Two sets of specimen were prepared using F90 fly ash and F40 fly ash. Fig. 3 depict geopolymer brick.

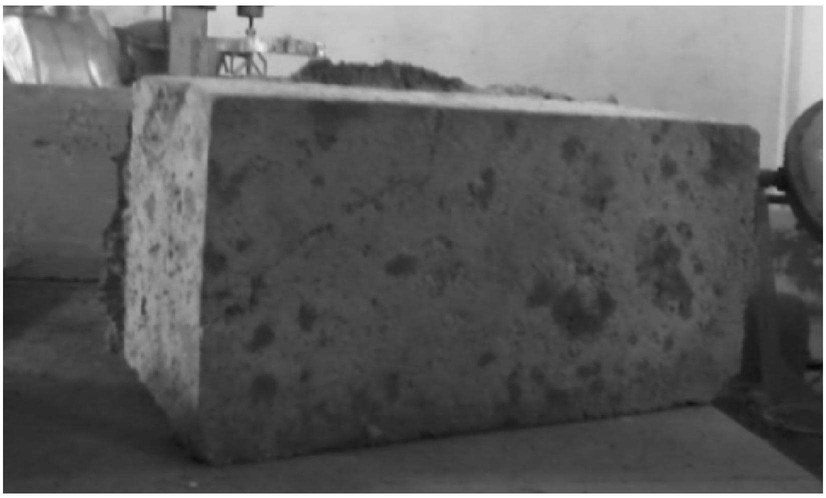

Fig. 3. Geopolymer brick.

3 Test results and discussion

Table 3 shows compressive strength of geopolymer brick made using F90 fly ash. It could be seen that, among four set of bricks (brick with different alkali fly ash ratio) none of the bricks is suitable for masonry construction. Large particle size of fly ash is the reason for low compressive strength (Temuujin et al 2007).

Table 3. Compressive strength of geopolymer brick using F90 fly ash

Alkali-Fly ash ratio	Compressive strength (MPa)
0.2	0.454
0.3	0.736
0.4	0.988
0.6	2.295

Table 4 shows compressive strength and water absorption of geopolymer brick using F40 fly ash. It could be seen that compressive strength of geopolymer increases with alkali fly ash ratio. The gain in compressive strength is almost gradual between alkali-Fly ash ratio 0.2, 0.3 and 0.4, and there is a drastic change in compressive strength between 0.4 and 0.6. The percentage water absorption ranges between 1% and 4.35%. The geopolymer brick made with alkali fly ash ratio 0.6 gives maximum compressive strength and lowest water absorption. Reason is that quantity of alkali content available for complete dissolution of alumino-silicate material is sufficient (Joseph and Mathew 2013). Comparing table 3 and 4 it could be observed that, strength of geopolymer brick increased about 235% after grinding of fly ash. Compressive strength of geopolymer brick made using calcined F40 fly ash is increased by 18%. Increase in amorphousity of fly ash due to calcinations is the reason for the increase of compressive strength

Table 4. Compressive strength and water absorption of geopolymer brick using F40 fly ash.

Alkali fly ash Ratio by mass	Specimen size(in cm)	Dry wt (kg)	Wet wt. (kg)	Water absorption (%)	Breaking load (kN)	Compressive Strength MPa)
0.2	10x10x20	4.6	4.8	4.35	16	0.80
0.3	10x10x20	4.7	4.9	3.16	61	3.05
0.4	10x10x20	4.8	4.9	3.12	78	3.90
0.6	10x10x20	4.9	5.0	1.01	178	8.90

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4 Cost analysis

Table 6 shows economical analysis of geopolymer brick. It is seen from the table that cost of one geopolymer brick having compressive strength 8.7 MPa is Rs.8.5. Comparing with cost of bunt clay brick 10 cm x10cmx20cm (Rs.16/no.) and cement concrete block 10cmx10cmx20cm (Rs.14/no.), geopolymer brick is more economical.

Table 6. Cost analysis for one geopolymer concrete brick.

Sl. No	Item	Quantity for one brick (kg)	Rate (Rs./kg)	Cost
1	Fly ash	0.789	2	1.58
2	NaOH pellets	0.043	38	1.64
3	Sodium silicate solution	0.342	8	2.74
4	M-sand	1.890	0.464	0.88
5	6mm aggregate	1.98	0.44	0.87
			Total cost	7.71
Add 10% extra for transportation charge			Total cost	Rs. 8.5

5. Conclusion

Following conclusion are made from the experimental investigation done to study the suitability of geopolymer concrete brick.

- Fly ash available at Hindustan paper limited as it is not suitable for brick manufacturing.
- Mechanical activation to size down the fly ash particle makes the fly ash suitable for manufacturing brick.
- Calcination of fly ash increases the compressive strength of brick.
- Compressive strength of geopolymer brick increases with increase of alkali fly ash ratio.
- Maximum compressive strength of geopolymer brick made using F40 fly ash is 8.7 MPa.
- Geopolymer concrete brick is more economical than burnt clay brick and cement concrete block.

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