Production of Cost Effective and High Strength Geopolymer Concrete Masonry Blocks

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RESEARCH ARTICLE

ABSTRACT: Building block represents one of the vital materials in construction industry, the increased demand and requirement of building material has made the industry to grow vertically, the innovation and change in concrete block industry plays important role to produce cost effective, durable and sustainable building block which is the need of hour. The production of large amount of fly-ash requires land in the form of ash ponds. The challenge arises in utilizing this fly-ash in the production of sustainable building materials. The present experimental study involves the production of Geopolymer concrete blocks from fly ash, GGBS (Ground granulated blast furnace slag), slag sand, coarse aggregate, sodium silicate, sodium hydroxide to make the concrete block cost effective, high strength, sustainable and durable. The block is cast with different percentages of fly ash (16.8%), GGBS (5.2%), slag sand (19.2%), manufactures sand (12.8%), coarse Aggregate (35%), Alkaline solution (6%), Water (5%). The tests on specimen conducted are compressive strength, water absorption test, and dimension test on respective ambient/oven curing of 3 and 7 days. The cost estimation is also done for the geopolymer concrete block. The blocks produced are found to be high in strength, cost effective, durable and sustainable as compared to conventional cement concrete blocks and thus it makes them to use commercially in construction industry.

KEYWORDS: Fly-ash, GGBS, slag sand, durable, cost effective, compressive strength

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1. INTRODUCTION

The production of cement releases large amount of carbon dioxide (CO₂) to the atmosphere that significantly contributes to greenhouse gas emissions. It is estimated that one ton of CO₂ is released into the atmosphere for every ton of Ordinary Portland cement (OPC) produced [4]. In view of this, there is a need to develop sustainable alternatives to conventional cement, utilizing the cementitious properties of industrial by-products such as fly ash, GGBS and slag sand in replacement to river sand. A significant quantity of fuel is utilized in making conventional bricks making them non sustainable [11]. In this present work, an attempt is made to make the geopolymer concrete blocks as replacement to the conventional burnt brick with more added benefits. There is strong need to adopt sustainable technologies. Approximately half of the electricity consumed in the world is by burning coal which also has a byproduct fly-ash (a cementitious material) that is left out as waste. Disposal of this waste has become an emerging problem. As of which we are using geopolymer blocks in which cement is been replaced by fly ash which aids in both issues i.e. reducing of environmental problem caused by cement & bricks as well as decreases problem of disposal of fly-ash [3,8,17].

Geo-polymerization is a technology that relies on the chemical reaction of amorphous silica & alumina

rich solids with alkaline solution to form amorphous to semi-crystalline alumino-silicate inorganic polymer or geopolymers [1]. In the construction sector, geopolymers represent an eco friendly, low cost and low power consumption alternative of traditional inorganic matrices & composites due to the use of industrial by-products as solid precursors & low calcinations temperature. Compared to Portland cement, they exhibit superior engineering properties [2, 7].

It is in this context an effort is made to produce GPC block (400 mm X 150 mm X 150 mm) using fly ash and GGBS as binder with compressive strength above 4 MPa. The prime factor or parameter considered in this work is alkaline solution in which the molarity of sodium hydroxide is taken as 6M. The water absorption test is carried out for the specimens. The detailed cost estimation per m³ of the block as well as cost per block is done and it is found that the geopolymer blocks are cheaper than conventional cement concrete blocks in the local market [8, 9].

2. METHODOLOGY

The methodology is explained in the following Figure 1. The nominal dimensions of concrete block as per IS 2185 (part 1): 2005 shall be as follows:

Length: 400, 500 or 600 mm

Height: 200 or 100 mm

Width : 50,75, 100, 150,200, 250 or 300 mm.

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The size of the block adopted is: Length: 400mm, Height: 150 mm and Width: 150 mm as shown in Figure 2 [18].

Figure 1. Methodology of the present research work

Figure 2: Dimensions of the masonry concrete block (all dimensions are in mm)

3. MATERIALS

Fly ash which is obtained from Kudagi Thermal Power Station, India and GGBS obtained from JSW steel, Bellary, India. Locally available slag sand and M-sand were used as fine aggregates, coarse aggregates are

used in this present research work. A combination of 6M sodium hydroxide and sodium silicate in the ratio of 2.0 was used as solution for activation. Sodium hydroxide flakes of commercial grade were used in present work. Sodium silicate also known as water

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glass is of industrial grade with SiO_2 as 34.8% by mass and Na_2O as 16.51% & water as 48.69% [6]. Water used for the mix is of potable quality. The nomenclature KF-60 is Kudagi Fly-ash, used as 60% in volume of total binding agent.

4. EXPERIMENTAL WORK

4.1 Mix Design for Optimum Fly-ash to GGBS Ratio

GPC is produced with many materials like fly-ash, GGBS and binding agents. The intention is to produce the block with optimum fly-ash to GGBS ratio to optimize the cost and environmental impact. Various trials with different ratios of fly-ash to GGBS are cast, if desired

compressive strength is obtained then various tests are carried out. The Water to geo polymer solids ratio is fixed as 0.38 [8]. The Alkaline solution to Binder ratio is fixed as 0.27 [8]. The mixing process of ingredients for concrete is adopted as per the work of [8].

4.2 Mix design

Geo-polymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete and the procedure is as follows:

Table No. 1: Physical properties of Materials

S.No.	Property	Specific gravity
1.	Fly-ash	1.78
2.	GGBS	2.70
3.	M-sand	1.7
4.	Slag-Sand	2.27
5.	Coarse aggregate	2.73

Table 2: Mix design adopted for various trials

Materials	KF60	KF70	KF60	KF70
Fly ash kg/m^3	238=13.2%	302=16.8%	238=13.2%	302=16.8%
GGBS kg/m^3	158=8.8%	94=5.2%	158=8.8%	94=5.2%
Coarse Aggregate kg/m^3	630=35%	630=35%	630=35%	630=35%
M-sand kg/m^3	346=19.2%	346=19.2%	346=19.2%	346=19.2%
Slag sand kg/m^3	230=12.8%	230=12.8%	-	-
NaOH Solution kg/m^3	36=2%	36=2%	36=2%	36=2%
Molarity of NaOH	6M	6M	6M	6M
Na_2SiO_3 Solution kg/m^3	72=4%	72=4%	72=4%	72=4%
Water to geo polymer solids ratio	0.38	0.38	0.38	0.38
Alkaline solution to Binder ratio	0.27	0.27	0.27	0.27
Extra Water kg/m^3	90=5%	90=5%	90=5%	90=5%

Table 3: Adopted mix design KF : GGBS 70:30

Materials	Quantity in Kg/m^3
Fly ash kg/m^3	238
GGBS kg/m^3	158
Coarse Aggregate kg/m^3	630
M-sand kg/m^3	346
Slag sand kg/m^3	230
NaOH Solution kg/m^3	36
Na_2SiO_3 Solution kg/m^3	72

Figure 3 Block Mould

Figure 4 GPC Block

Figure 5: Industrial waste utilization v/s other constituents in GPC blocks

After all trial mix design, the following mix design is adopted because the optimum consumption of fly-ash and GGBS is achieved and hence the cost and sustainable properties are also achieved.

7. RESULTS AND DISCUSSIONS

7.1. Compressive Strength: The test procedure for finding a compressive Strength of geo-polymer block is adopted from IS 3495-1992 Part-I. Here, Figure-2 shows the compressive strength of geo-polymer concrete specimen at ambient temperature at 3 and 7 days of ratio fly-ash: GGBS is 70:30.

Attributes from the graph: CC block: Cement Concrete block, GPC block: Geo-Polymer Concrete block.

From the fig 5, we come to the know that the compressive strength for GPC block is 3 times higher than conventional cement concrete block which makes it high strength.

7.2 Water Absorption: The test procedure is done according to IS 2185 part 1. The test specimens shall be completely immersed in water at room -temperature for 24 h. They shall be removed from the water and visible surface water being removed with a damp cloth and immediately weighed. All specimens shall be dried in a ventilated oven at 100 °C to 115 °C for not less than 24 h [14, 18].

As per IS-2185: 2005 part 1, 24-hour water absorption should be more than 10% for individual blocks. Geo-

polymer paver blocks had an average of 1.531%. Thus all blocks met the specification.

7.3 Density test: The density of concrete block is defined as the ratio of Mass by Volume. The mass of the block is measured at the room temperature of 27 ± 2 °C [18].

Three blocks taken at random from the samples selected, shall be dried to constant mass in a suitable oven heated to approximately 100 °C. After cooling the

blocks to room temperature, the dimensions of each block shall be measured in centimeters (to the nearest millimeter) and the overall volume computed in cubic centimeters [12]. The block shall then be weighed in kg (to the nearest 10 g) and the density of each block calculated as follows:

The average density of the geo-polymer concrete block obtained is 1965 kg/m^3 . This density is comparable to the low density blocks available in market.

Fig 6: Graph showing compressive strength of GPC block of ratio 70:30

Table 4: Water absorption of Geo-Polymer blocks

Mould no.	Grade	Dry weight(Kg)	Wet weight(Kg)	Oven Dry weight(Kg)	Water absorption (%)
1	KF70	20.71	20.94	20.63	1.503
2	KF70	20.84	21.08	20.76	1.541
3	KF70	20.81	20.98	21.31	1.549
				Average	1.531

Table 5: Density of Geo-polymer Blocks

Block no.	Weight (kg)	Volume (m^3)	Density (kg/m^3)
1	17.65	9.00×10^{-3}	1961.11
2	17.75	9.00×10^{-3}	1972.22
3	17.68	9.00×10^{-3}	1964.44
Average			1965.92

Table 6: Cost analysis

Sl.No	Particulars	Volume in kg/m^3	Rate in rupees	Rate in rupees/ m^3
1	Fly-ash	302	350/tonne	105.7
2	GGBS	94	2500/tonne	235
3	M-sand	356	700/tonne	249
4	Slag sand	238	150/tonne	35.7
5	Coarse aggregate	630	650/tonne	409.5
6	NaOH	36	12.2/kg	439.2
7	Na ₂ SiO ₃	72	21/kg	1512
			Total cost =	2986/-

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Fig 7: Graph showing Cost break-up of GPC block

7.4 Cost analysis of the block

The total cost of GPC block per m³ is Rs. 2986/-. Hence, the cost of 1 block is Rs.26 approx.

The cost estimated for conventional cement concrete blocks manufactured locally cost Rs 3219/- per m³. The cost of 1 block is Rs 29 approximately. Therefore, the GPC block cast is cheaper than CC block. Thus the blocks are cost effective.

6. How GPC block is different from cement concrete block?

6.1. Compressive Strength: The Compressive strength of geo-polymer concrete block after 7 days is 15.5 MPa whereas the compressive strength for cement concrete block after 7 days varies from 7-8 MPa. This shows that geo-polymer concrete blocks are 2 times stronger than cement concrete blocks.

6.2. Water absorption: Water absorption for geo-polymer concrete blocks for 1 day varies from 1.5-1.8%. For cement concrete blocks it varies from 8-8.5% [8]. This shows that geo-polymer concrete blocks prevents the absorption of water and protects from increase in weight and collapse.

6.3. Surface finish and sharp edges: Geo-polymer concrete block possesses smooth surface finish and sharp edges which reduces the consumption of plaster and reduces cost, whereas cement concrete blocks possess rough surface finish and rounded edges making it less efficient in application.

6.4. Cost effective: The cost for 1 geo-polymer concrete block on site is Rs 22-23.5/- and cost of 1 cement concrete block is Rs 28-28.5/-. Thus geo-polymer concrete blocks are cost effective and give both tangible and intangible benefits.

6.5. Sustainability: Geo-polymer concrete blocks use 35-40% of industrial waste materials like fly-ash, GGBS and slag sand thus making them more sustainable than cement concrete block which use 15-18% [16].

8. CONCLUSION

The average compressive strength of Geo-polymer concrete block for 7-day ambient curing is 13.89 MPa which complies with IS 2185 (part1):2005. The cost of the block varies from Rs 25-26/-, which is cheaper than cement concrete block, thus GPC blocks have both tangible and intangible benefits. Geo-polymer concrete block has an average water absorption of 1.53% which is better than that of conventional cement concrete block. The average density of Geo-polymer block is 1965 kg/m³. The block has good surface finish and sharp edges, which saves the plaster and other additives applied to walls. There is no requirement of water for curing of geo-polymer concrete block, thus it saves water as well as curing time. Due to utilization of large quantity of industrial waste materials to manufacture this block, makes it more sustainable and commercially viable. The block has good surface finish and sharp edges, which saves the plaster and other additives applied to walls. There is no requirement of water for curing of geo-polymer concrete block, thus it saves water as well as curing time. Due to utilization of large quantity of industrial waste materials to manufacture this block, makes it more sustainable and commercially viable.

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