COMPARATIVE STUDY OF CEMENT CONCRETE AND GEOPOLYMER MASONRY BLOCKS

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Abstract

It is well known that the production of cement is extremely resource and energy intensive process producing an equal amount of CO_2 per ton of cement. Hence, due to growing environmental concerns of the cement industry, there is a need to develop alternative materials such as fly ash, Ground granulated blast furnace slag (GGBS). Also there is a need to develop masonry units using these alternative materials for sustainability. Geopolymer technology makes use of fly ash which is a byproduct of thermal power plants. In the present research, cement and geopolymer blocks are produced by the same method. The basic properties of these masonry units such as compressive strength, density, modulus of elasticity, Initial rate of absorption (IRA) and water absorption are determined and compared. The results indicate that Geopolymer blocks posses superior properties compared to traditional cement blocks. Geopolymer blocks can be recommended for the use as masonry units for structural masonry. Thus the use of conventional cement can be eliminated.

Keywords: *Geopolymer, cement, comparative study, compressive strength, water absorption, stress strain relationship.*

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1. INTRODUCTION

Masonry is the building of structures from individual units that are usually bound together by means of mortar [1]. Concrete block masonry is a common construction material in India because of its abundance, low cost and availability of skilled labour [2]. The main drawback of cement concrete blocks is consumption of cement which is a major contributor to the greenhouse effect and the global warming, it is necessary to consider this with very severe regulations and limitations [3]. At the same time the demand for industrial and domestic energy results in the production of a large volume of fly ash from solid coal fuel, which may increase in the world on an unprecedented scale in future [4]. Therefore, fly ash should not only be disposed of safely to prevent environmental pollution, but should be treated as a valuable resource. Production of building materials, particularly bricks/blocks using fly ash is considered to be one of the solutions to the ever increasing fly ash disposal problem in the country [5]. All the three methods of utilizing fly ash are considered in construction in different forms. Cement can be replaced partly with fly ash, Geopolymer and FaL-G can be used in the form of masonry blocks for better and strength and durability [6].

2. EXPERIMENTAL WORK

Cement used for this project is of 53 grade. As per IS: 12269 physical properties of cement are determined. It has an initial setting time of 43 minutes, final setting time of 3hour 38mins and Specific gravity is 3.1. Locally available river Sand is used as fine aggregate in the production of cement and geopolymer blocks. Fine aggregates passing through 4.75 mm sieve were taken for the experiment. The physical and chemical properties of fly ash used in this investigation are shown in Tables 1 and 2. The ratio of SiO2 and Al2O3 of the fly ash is around 2, suitable to use for making low CO2 cements. The physical and chemical properties of GGBS are indicated in Table 3. Since it contains aluminum oxide and silica oxide; it is suitable for making of the Geopolymers.

Table 1 Physical Properties of fly ash

Specific Gravity	Percentage Finer than 45µ	Fineness, m2/Kg	Loss on Ignition	Lime reactivity, MPa
2.40	0.00	1134.1	0.9	7.23

Table 2 Chemical Properties of fly ash

Binder	Chemical Composition in percentage							
	Al2O3	Fe2O3	SiO2	MgO	SO3	Na2O	Total Chlorides	CaO
Fly Ash	31.23	1.5	61.12	0.75	0.53	1.35	0.06	3.20

Table 3 Properties of GGBS

Specific Gravity	Fineness m2/Kg	Insoluble residue	Loss on Ignition	Chemical Composition in percentage							
				Al2O3	Fe2O3	SiO2	MgO	MnO	S	Chlorides	CaO
2.90	370.0	0.05	0.3	13.24	0.65	37.21	8.65	0.325	2.23	0.003	37.23

Alkaline solution was prepared using Sodium hydroxide, Sodium silicate and water. Calculated amount of Sodium hydroxide and Sodium silicate was added to water in a container. This mixture was mixed thoroughly to dissolve all the particles. The solution was stirred once in an hour for five to six times to avoid deposits. This solution was used after 24 hours of its preparation. For the preparation of 1liter of 1M (1 molar) solution, 40g of sodium hydroxide and equal amount of sodium silicate powder were added to 1liter of water.

2.1 Preparation of Blocks

The binder used in the preparation of cement block is 53grade cement and that for geopolymer block, Fly ash and GGBS. Fine aggregate (River sand) passing through 4.75mm sieve was used.

The binder was taken in a pan; the aggregate was added and mixed thoroughly till homogenous colour is obtained. Then water/ alkaline solution was added to the dry mix. It is mixed thoroughly and wet mix is used to prepare the blocks by manual compression. Mardini, a manually operated device is used for this purpose. Tables 4 and 5 give the proportioning of cement and geopolymer mortar respectively.

Table 4 Proportioning of cement mortar

Size of the block	Mortar proportion	W/C Ratio
190mmx230mmx100mm	1:6	0.2

Table 5 Proportioning of Geopolymer mortar

Size of the block	Mortar proportion	Flyash: GGBS	F/B Ratio	Molarity
190mmx230mmx100mm	1:1	80:20	0.2	14

Cement blocks are cured by placing in water for 28days. Geopolymer blocks are cured in open air. After 28 days, various tests were carried out to obtain the properties of blocks such as Dimensionality Test, Dry density, Water absorption Test, Initial rate of absorption (IRA), Compressive strength and Modulus of elasticity. Dimensionality test is done according to the IS: 1077-1992. Dry density test is performed to find the brick in dry state. The weight of oven dry brick specimen was measured and the average dimension (i.e.) length, breadth and thickness of block were measured. Initial rate of absorption test was conducted as per the guidance given in ASTM C67. Initial rate of absorption is the measure of block suction and represents the weight of water absorbed in 1 minute by the bed face of the block when immersed to a depth of 3mm in water. Water absorption test is performed as per IS: 3495-1976 part 2. Compressive strength test was conducted as per the guidance given in IS: 1077-1992. To determine the stress-strain behaviour, the specimen was placed along with 100mm demec gauge in CTM. Deformation was measured using Demec gauge at suitable load intervals.

3. RESULTS AND DISCUSSION

Dimensionality test is done according to the IS: 1077-1992. The average dimensions of the cement and geopolymer blocks obtained are given in Table 6. The dimensions of the blocks are within the limits of non modular size specified by IS: 1077-1992. Different tests on masonry blocks were conducted at the age of 7, 14, and 28 day to determine their basic properties as indicated in Table 7. The results indicate that geopolymer blocks have lower dry density compared to cement blocks which is represented in Fig 1. As per Sarangpani [1], the IRA values for masonry units should be in the range 1.31- 3.53kg/m2/min. The IRA values of geopolymer blocks were less compared to cement blocks which are represented in Fig 2. The percentage water absorption for all the blocks ranges from 6.5 – 10% which satisfies the limit of maximum 20 % as per IS 3495-1976 PART 2. From Fig 3 it can be observed that Water absorption of geopolymer blocks have been decreased at the later age and lesser compared to cement blocks. Strengths developed were in the range of 3.5- 10MPa in cement blocks and 8.7- 25MPa in geopolymer blocks. It can be seen that geopolymer blocks have excellent strength as compared to cement blocks. Compressive strength development of two different blocks with the age is indicated in the graph as shown in Fig 4. The test results of modulus of elasticity are indicated in the graph shown in Fig 5 and 6 respectively. The important results from the graphs are given in Table 8. It can be seen that initial tangent modulus of geopolymer block was higher than cement block. Maximum strain was taken by geopolymer block as compared to cement block.

Table 6 Results of Dimensionality test

Type of block	Sides	No of Units	Dimension (mm)	Average Dim(mm)
Cement blocks	L	20	4620	231
	W		3840	192
	H		2040	102
Geopolymer blocks	L	20	4600	230
	W		3820	191
	H		2040	102

Table 7 Results of Basic Properties of blocks

Type of block`	No of days	Dry density Kg/m3	IRA Kg/m2/min	Water absorption %	Compressive strength MPa
Cement block	7	1856.98	1.63	7.47	5.4
	14	1879.86	1.76	7.40	6.4
	28	1891.30	1.95	7.55	7.4
Geopolymer block	7	1836.38	1.68	7.81	8.7
	14	1847.44	1.98	7.74	19.53
	28	1870.7	1.53	6.64	24.56

Table 8 Test details of modulus of elasticity

Specimen	Regression coefficient (R)	Initial Tangent Modulus (MPa)	Maximum strain
Cement block	0.974	5426	0.00215
Geopolymer block	0.912	6721	0.00359

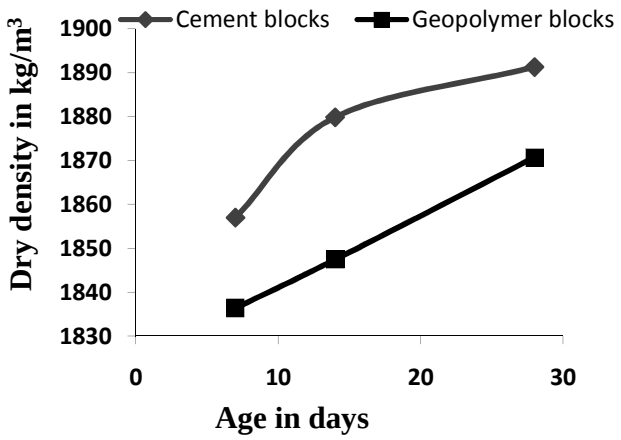

Fig 1 Dry density of blocks

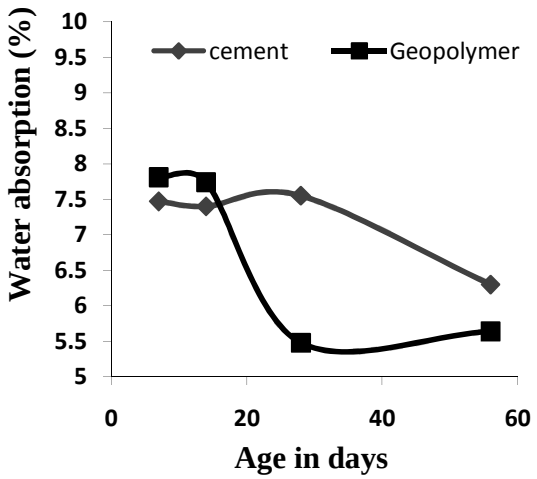

Fig 2 Initial rate of absorption (IRA) of blocks

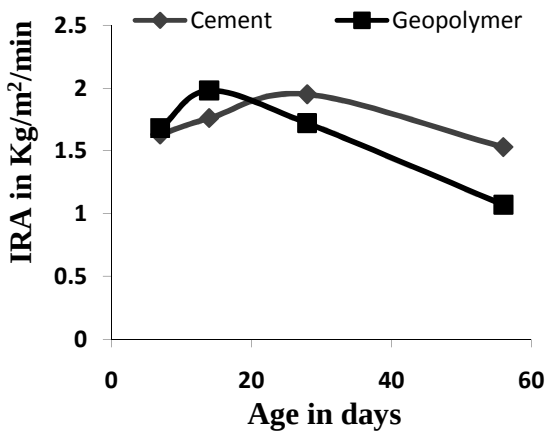

Fig 3 Water absorption of blocks

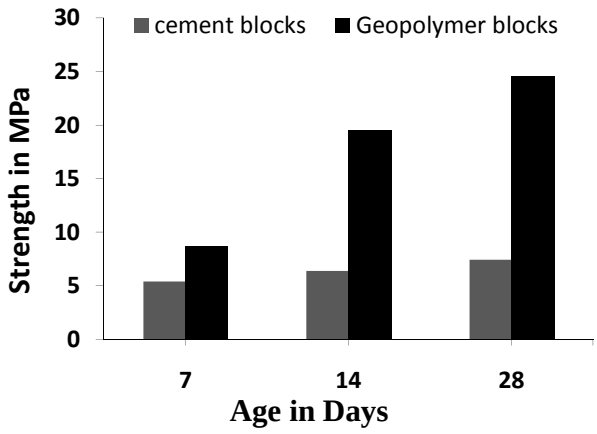

Fig 4 Compressive Strength of blocks

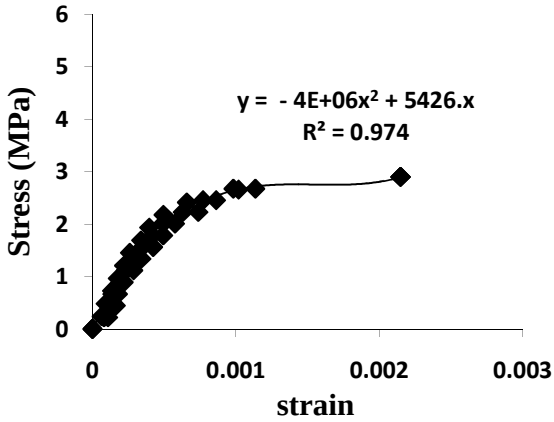

Fig 5 Stress Strain curve – Cement blocks

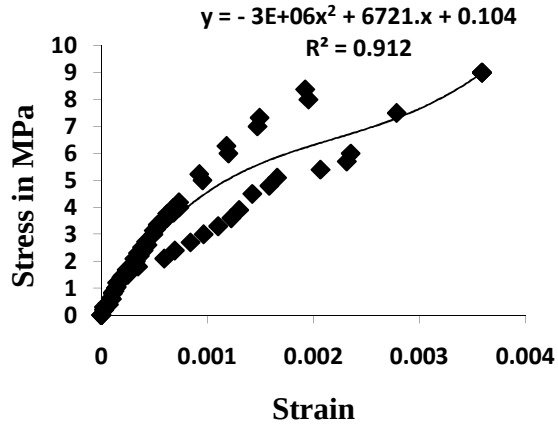

Fig 6 Stress Strain curve – Geopolymer blocks

CONCLUSIONS

The following broad conclusions can be drawn with the limited study.

- Geopolymer blocks have low dry density and excellent strength compared to cement blocks.
- The compressive strength of geopolymer masonry block is as high as 25MPa at 28 days, which is much above the compressive strength of cement block.
- Water absorption and IRA of geopolymer blocks were less at the later age as compared to cement blocks.
- The modulus of elasticity of Geopolymer block is high as compared to cement block.
- Open air curing can be adopted for Geopolymer blocks no water is required.
- It is possible to manufacture masonry block without use of cement.
- Geopolymer blocks can be recommended for the use as masonry units for structural masonry.

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