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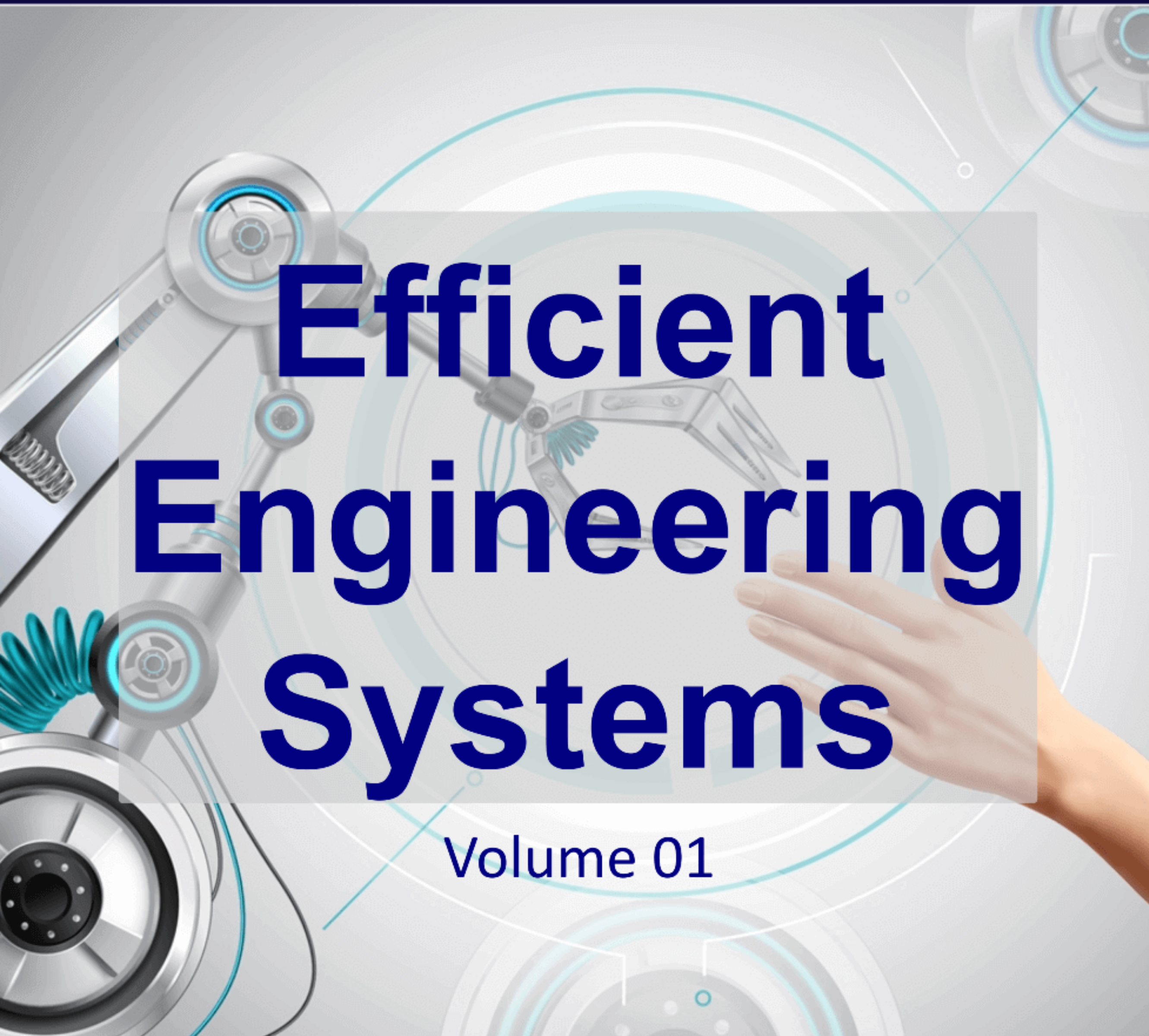

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4 Feasibility of Waste Materials In High Strength Geopolymer Building Blocks

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ABSTRACT

Utilization of waste materials in geopolymerization enhances the sustainability of construction. This chaptr investigates the feasibility of utilizing waste materials in the production of high strength geopolymer building blocks.Suitability of locally available brick waste as a source material for geopolymer binder and the feasibility of ground granulated blast furnace slag in improving the strength characteristics of geopolymer binder was investigated. After optimizing the influencing parameters of geopolymerization, suitability of the proposed geopolymer binder in high strength concrete building blocks was verif ied with respect to strength and durability charecterstics. Results indicate promising outcomes with respect to strength and durability characterstics and suitability for load bearing construction with high strength requirements.

Keywords: Brick waste, geopolymerization, geopolymer concrete blocks, masonry unit

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1. INTRODUCTION

Production of ordinary Portland cement (OPC) is highly resource intensive and results in the emission of large amounts of carbon dioxide and greenhouse gases.Geopolymers, an ideal alternative to OPC,can be produced by the chemical action of alumino silicate materials rich in silica and alumina. On interacting with alkaline solution, it produces alumino silicate gel with binding properties [1][2]. In the past years, many research works have been carried out to investigate the suitability of using waste materials as source materials to produce geopolymer cements [3][4].

Burnt clay bricks are extensively used in construction and its wastes are plenty available during the demolition of old structures and also as unburnt / over burnt wastes near the premises of brick industries. It can be used as a raw material for geopolymer binder. Brick waste contains high levels of silica and alumina which are the essential constituents for geopolymerization process. In brick based geopolymer, geopolymerization process continues in much faster rate with finer fractions of brick. [5][6].

Ground granulated blast-furnace slag (GGBS) is a good alumino silicate source as it contains high amounts of alumina and silica which are necessary for the geopolymerisation reaction to take place. The geopolymeric binder produced by the alkali activation of GGBS requires reasonably lower alkali activator concentration than flyash and metakaoline based geopolymer [7]. The inclusion of GGBS in the waste fire clay bricks based geopolymer leads to improvement in the physico-mechanical properties of the geopolymer composite [8][9][10].

Since the production of geopolymeric building components consist of low cost raw materials and consumes less energy, development of which give better performance and environmental friendly materials for construction [11]. Geopolymer building blocks possess easy setting and fast drying, achieve considerable compressive strength gain at early ages which makes easy handling of the blocks and hence the geopolymer technology is feasible for use in construction[12][13]. This chapter investigates the suitability of brick waste and GGBS based geopolymer composite in high strength concrete building blocks.

2. METHODOLOGY

The concept of Hybrid Dynamic Simulation is that it injects the external signals into the simulation process and it allows interacting with the conventional simulation loops, which interact with the external signals. The Term "Hybrid" refers to sagacity of associating the Real Time Measurements with the Simulation Measurements.

The materials used for this study are brick waste, Ground granulated blast furnace slag (GGBS), sodium silicate solution and sodium hydroxide pellets, M sand (zone II) and coarse aggregate of size 12mm. Brick waste was collected from the dismantled waste of a building near Kothamangalam, Kerala. The brick waste was crushed and powdered manually and sieved through 90µm IS sieve. GGBS used in this study was locally purchased. Table1shows the percentage by weight of Silica, Alumina and Calciumin brick powder and GGBS. The properties of the constituent materials used in the study are given in Table 2.

Table 1. % by weight of Silica, Alumina and Calcium

Compound	% by weight	
	Brick powder	GGBS
SiO_2	50.7	13.68
Ca	24.6	23.96
Al_2O_3	15	9.63

Table 2. Properties of the constituent materials

Material	**Property**	**Value**
M sand	Specific Gravity	2.6
	Fineness Modulus	4.05
Coarse aggregate (12mm)	Specific Gravity	2.85
	Fineness Modulus	7.17
Sodium Hydroxide Pellet	Purity	97%
	Grade	Extra pure
Sodium Silicate	Density	1.39g/cm^3
	pH	11.2

2.1. Optimization of influencing parameters for geopolymer binder

The optimization of the influencing parameters i.e. concentration of NaOH, percentage of GGBS, A/B ratio and SS/SH ratio were done by analyzing the compressive strength of geopolymer binder at different ages of curing under ambient and elevated temperature (60^{0}C for 24 hours). For this geopolymer mortar cube specimens of size 50mm x 50mm x 50mm were prepared. The specimens were prepared by mixing all the materials in the laboratory at room temperature. As a preliminary study, to optimize the molarity, specimens were cast with brick powder alone by varying the molarity from 8 to 14. In the next step geopolymer mortar cube specimen were prepared by replacing brick powder (BP) with various percentages of GGBS (0%, 20%, 40%, 60%, and 80%). The optimum molarity of NaOH for the geopolymer composite with BP and GGBs was then confirmed. Further, optimization of A/B ratio was done by investigating the results varying from 0.3 to 0.9. Finally the SS/SH ratio was optimized by conducting experiment with different ratios varying from 1 to 2.5.

2.2. Application of geopolymer composite in building blocks

Cement concrete blocks (CCB) andgeopolymer concrete blocks (GCB) of size 300mmx200mmx150mmwere cast withmix proportion 1:3:6 using a hydraulic block making machine. The mix proportion for producing one building block is shown in Table 3. Figure 1 shows the geopolymer concrete blocks.

Fig. 1. Geopolymer concrete blocks

2.3. Tests on geopolymer building blocks

The building blocks were tested for strength and durability characteristics in accordance with IS: 2185 (Part I) – 2005 and ASTM C 67 to confirm the suitability as a building material [14],[15].

2.3.1 Strength Characteristics

The block density and compressive strength properties of the building blocks were tested (IS: 2185 (Part I) – 2005) and tabulated in Table 4.For block density average of three blocks were considered and for compressive strength, eight blocks were tested and took the average.

Table 3. Mix proportion of concrete building blocks

Material	Cement	BP	GGBS	CA	FA	SS	SH	Water
Cement Concrete Building	2.18	0	0	13.08	6.54	0	0	1.09
Geopolymer concrete blocks	0	0.85	1.28	12.78	6.39	0.77	0.17	0.35

Table 4. Mechanical properties of Building Blocks

Type of Block	Block Density (Average of 3 blocks in kg/m^3)	Avg. compressive strength (Average of 8 blocks in N/mm^2)	
		7th day	28thday
Cement concrete block	2425.5	6.74	9.3
Geopolymer concrete block	2366.11	10.83	15.16

2.3.2 Durability Characteristics

Durability characteristics were verified bywater absorptiontest (IS: 2185 (Part I) – 2005) and initial rate of absorption (IRA) test(ASTM C 67). Initial rate of absorption (IRA) is considered as the amount of water absorbed in 1minute through the bed face of the block. Average test results of three samples were taken for both the tests and the results obtained are tabulated in Table 5.

Table 5. Durability properties of Building Blocks

Type of Block	% water absorption (Average of 3 blocks)	Initial rate of absorption (Average of 3 blocks in kg/m^2/min)
Cement concrete block	4.4	1.19
Geopolymer concrete block	3.22	1.02

3. RESULTS AND DISCUSSIONS

3.1. Optimization of influencing parameters

The variation in compressive strength of brick powder based geopolymer specimens for various molarities (8 to 14) cured under both elevated and ambient curing conditions are is shown in Figure 2. The compressive strength increases with increase in molarity of NaOH up to 12M and then decreases with further increase in molarity. The maximum compressive strength obtained are 6MPa and 5.1 MPa respectively for elevated and ambiet temperature curing. This shows that the compressive strength values obtained are very less.

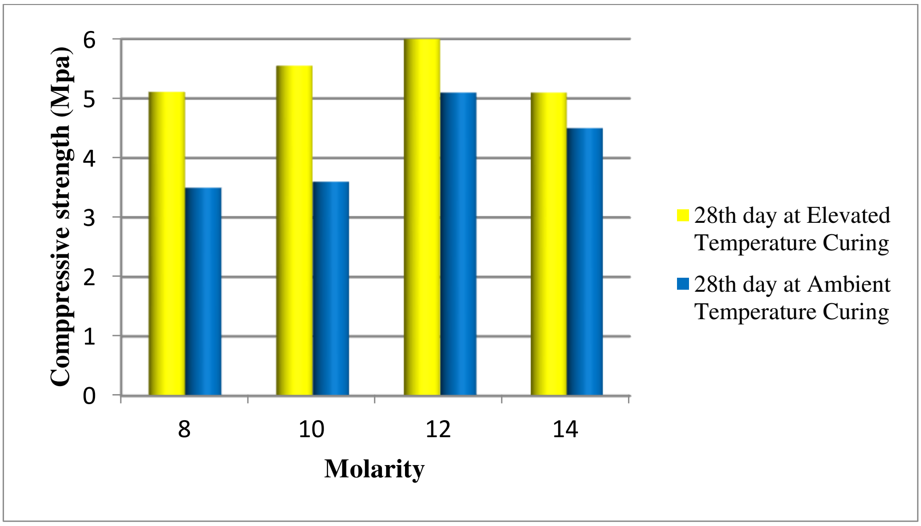

Fig. 2. Influence of molarity on geopolymer binder with brick powder alone

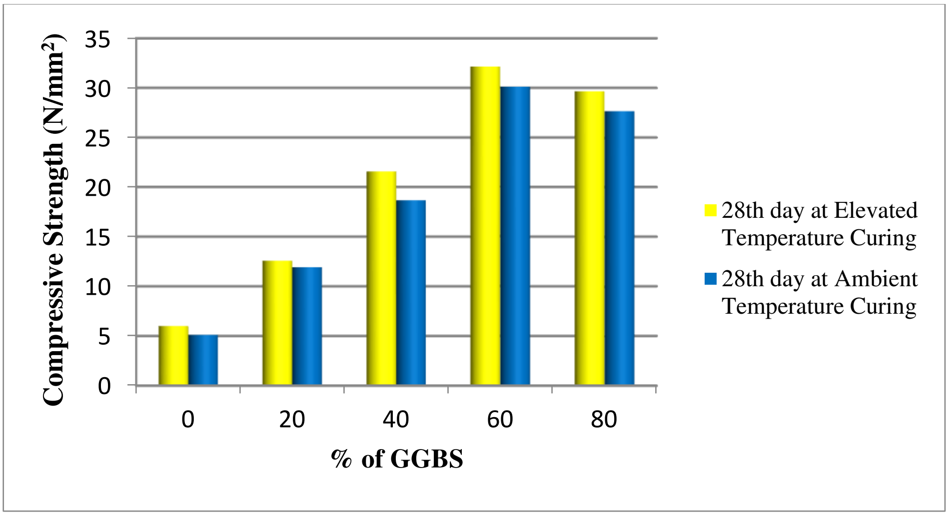

Fig. 3. Influence of GGBS percentage

Figure 3 shows the variations in compressive strength of specimens (with optimized molarity) observed on replacing BP with GGBS. Significant increase in compressive strength was observed with a maximum strength at 60% replacement for both ambient curing and elevated curing .These results are in concurrence with the studies conducted by Zawrah et.al [8].

For reconfirming the optimum molarity, tests were again conducted on specimens (BP -40% & GGBS – 60%)with varying molarities from 8 to 14. Results (Figure 4) shows the variations in compressive strength under the ambient curing and elevated curing confirming the molarity (12M).The highest compressive strengths (32.15MPa and 30.12MPa) were obtained at molarity 12 and the values were found decreasing after that.

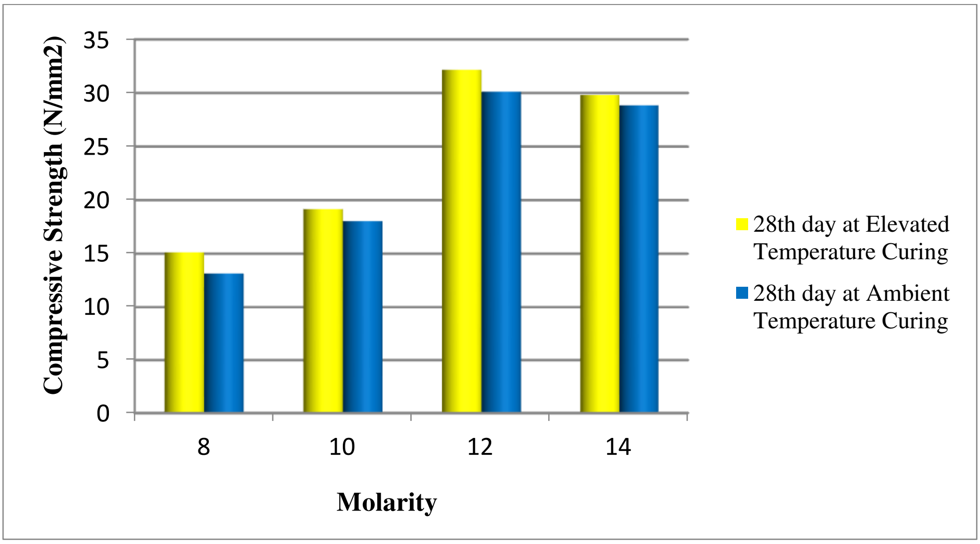

Fig. 4. Confirmation of optimum molarity of geopolymer binder with BP and GGBS

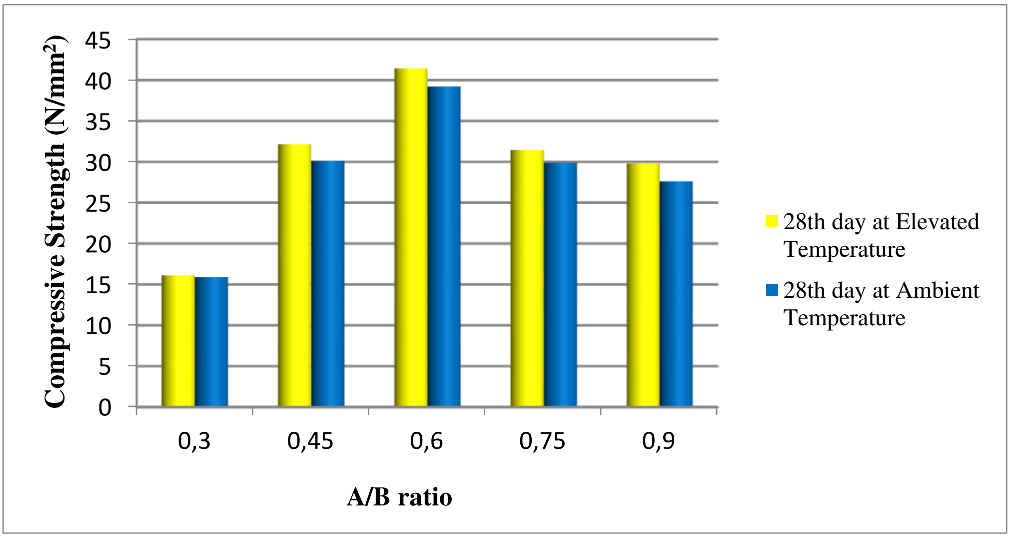

Fig. 5. Influence of alkali activator to binder ratio

The influence of activator to binder (A/B) ratio was evaluated by testing samples with varying A/B ratios (0.30, 0.45, 0.60, 0.75 and 0.90). Figure 5 shows the variations. The highest values (41.42MPa and 39.2MPa) were observedwiththe A/B ratio 0.6 for both the curing conditions.

The influence of sodium silicate to sodium hydroxide (SS/SH) ratio was evaluated with the optimized values of molarity and A/ B ratio by varying SS/SH ratios (1, 1.5, 2, and 2.5). Compressive strength was (Figure 6)found increasing up to SS/SH ratio of 1.5 and then decreasing in both the curing conditions.

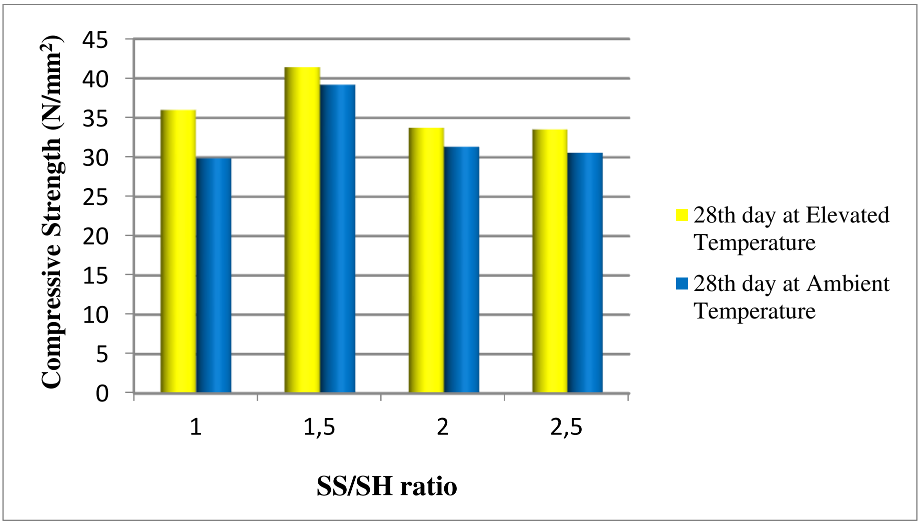

Fig. 6. Influence sodium silicate to sodium hydroxide ratio

Even though, higher strength values were obtained for specimens cured at elevated temperature (60^0C for 24 hours) than that under ambient curing condition , ambient cured samples can be suggested for practical applications as the results are comparable. 28th day strength of the geopolymer composite with ambient curing was even better (39.2MPa) than that of OPC 33 grade cement.

3.2. Application of geopolymer composite in building blocks

3.2.1. Strength and Durability

Figure 7 shows the comparison of compressive strength results for cement concentrate blocks and geopolymer blocks. Higher compressive strength of the proposed geopolymer blocks (15.16MPa) indicate its suitability for load bearing masonry with high strength requirements over cement concrete blocks (9.3 MPa) . Early strength of proposed geopolymer blocks (7th day compressive strength - 10.83MPa) can be considered as a positive feature in practical applications

Block density of geopolymer blocks (2366.11 kg/m^3) and cement concrete blocks (2425.5 kg/m^3) were found satisfying the IS code requirements. Comparing the block densities, geopolymer blocks were lighter than the corresponding cement concrete block.

The durability properties of geopolymer blocks and cement concrete blocks with respect to water absorption and initial rate of absorption were found satisfying the standards and verifying the better performance of proposed geopolymer blocks .

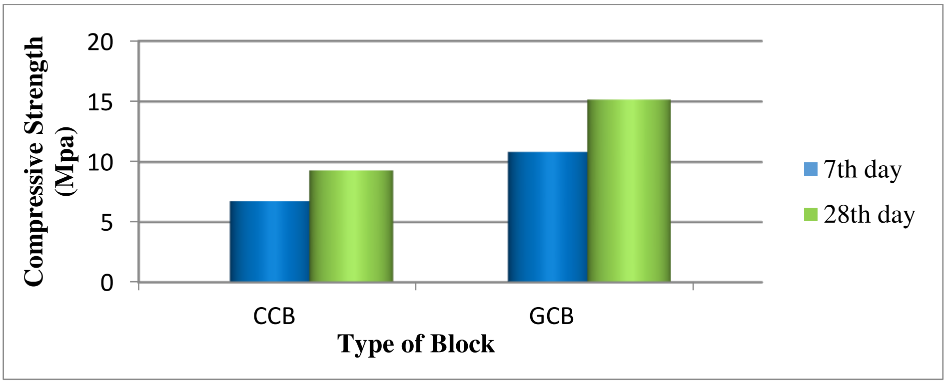

Fig. 7. Compressive Strength of Building Blocks

4. CONCLUSION

This research has confirmed the potential of using a combination of brick waste and GGBS (40 :60) in high strength geopolymer building blocks. The optimized condition for this combination was arrived as, molarity of NaOH - 12M, alkali activator to binder ratio - 0.60, sodium silicate to sodium hydroxide solution ratio - 1.5, curing condition- ambient temperature. The proposed geopolymer blocks exhibited superior strength and durability over cement concrete blocks and proved its suitability for load bearing masonry with high strength requirements. Utilization of waste brick powder and GGBS as source materials in geopolymer building blocks also established the environmental sustainability of the proposed blocks. Comparatively lower block density, better dimensional qualities and surface finishes over cement concrete blocks add to its sustainability characteristics.

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