

Effect of Gradation of Coarse Aggregate on Strength Properties of Geopolymer Concrete

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ABSTRACT: Geopolymer concrete is emerging as an alternate green material in the construction industry. It is produced from the reaction of silica and alumina rich materials with alkaline liquid. Reviews of literatures have indicated that geopolymer concrete (GPC) gets target compressive strength at 14days of curing compared to conventional concrete and hence can be used in many applications. However, very few studies have comparatively assessed performance of GPC on different gradations of coarse aggregates when compared with conventional concrete. The experimental investigation done on compressive strength and split tensile strength of geopolymer concrete of finely graded aggregates and compared with conventional concrete of finely graded aggregates. The grades chosen for the investigation is M-40&G40, the mixes were designed for molarity of 8M, 10M & 12M, with Flyash replacement for 30% and 50%. Geopolymer concrete were kept for ambient curing and Conventional concrete were kept for water curing cured for a period of 7, 14, & 28days and 28 days respectively. The compressive strength and split tensile strength reductions were determined. The present investigation confirmed that the use of GPC for the production of thin precast elements using finely graded aggregate having more compressive strength and split tensile strength compared to conventional concrete.

KEYWORDS: Geopolymer concrete, Alkaline liquids, Flyash, Compressive strength, Split tensile strength.

I. INTRODUCTION

Geopolymer concrete is a concrete consisting of materials like fly ash or ground granulated blast furnace slag (GGBS) instead of cement, Aggregate and Alkaline liquids (Sodium hydroxide and Sodium silicate or Potassium hydroxide and Potassium silicate solutions) instead of water. Studies carried out on development of strength for various grades of geopolymer concrete with varying molarity of alkaline liquids. Effect of molarity of alkaline liquids on Compressive strength of GPC was tested at the age of 7, 14 and 28 days. In this content the present study aims to investigate the effect of gradation of coarse aggregate in the production of GPC mixes with different proportions of fly ash and GGBS at various curing period at ambient room temperature. Two types of coarse aggregate one passing 12.5mm & down size aggregates and the other 20mm & down size aggregates are proposed to be used for the production of GPC to achieve target compressive strength and verify their strength characteristics. Though many investigations are studies GPC as a viable material for beams and slabs it can be used for thin precast elements like Ferro cement based concrete. Very few studies are available in literature regarding effect of gradation of the coarse aggregate on strength of GPC.

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II. RELATED WORK

a. MATERIALS USED

1.1 Flyash and GGBS

Class F Flyash was used which was obtained from RDC Concrete Plant Yelahanka, Bangalore. Flyash is finely grained residue resulting from the combustion of ground or powdered coal. Mean particle size is about 0.1 to 0.2 μm and finer than cement. The specific gravity, fineness modulus of Flyash are 2.82, 1.375, respectively.

Ground granulated blast furnace slag that was obtained from Surya Concrete Plant Yelahanka, Bangalore. The specific gravity, fineness modulus of Flyash are 2.90, 0.16, respectively.

1.2 Alkaline liquid

The alkaline liquid is prepared by mixing sodium hydroxide pellets mixed with water and sodium silicate solution together at least 24 hours prior to use for thorough mixing and reaction. Ratio of these solutions is 2.5. The solids are dissolved in water to prepare the NaOH solution of required concentration of 8M, 10M and 12M. After the pellets dissolved fully in the water, then sodium silicate was added to make alkaline solution.

1.3 Fine aggregate

Natural river sand is used as fine aggregate conforming to grading zone-II of table 4 of IS: 383-1970. The specific gravity and fineness of the fine aggregates are 2.62 and 2.3% respectively.

1.4 Coarse aggregate

The crushed coarse aggregate of two differently graded aggregates of 12.5mm down size and 20mm down size is used in the present study. The specific gravity of the coarse aggregate was 2.67.

1.5 Cement

Ordinary Portland cement conforming to grade 53 with specific gravity of 3.15 was used.

b. MIX-DESIGN FOR GPC (G40 GRADE)

The mix design proposed by Madheswaran et al (2013) was used for design GPC of grade G40 [5].

Take a Density of concrete = 2400 kg/m^3

Take mass of combined aggregate = 75% to 80%

$$= 0.77 * 2400$$

$$= 1848 \text{ kg/m}^3$$

Take = 77%

Take fine aggregate to total aggregate ratio = 0.45 (from least void ratio graph)

Weight of fine aggregate = $0.45 * 1848 = 831.6 \text{ kg/m}^3$

Weight of coarse aggregate = $1848 - 831.6$

$$= 1016.4 \text{ kg/m}^3$$

Take fluid/ binder ratio = 0.6

Weight of binder + solution = $2400 - 1848$

$$= 552 \text{ kg/m}^3$$

Weight of binder only = $(551 * 1) / (1 + 0.6)$

$$= 345 \text{ kg/m}^3$$

Weight of fluid = $552 - 345$

$$= 207 \text{ kg/m}^3$$

The ratio of NaOH and Na_2SiO_3 is 1: 2.5

So, NaOH = $(207 * 1) / (1 + 2.5)$

$$= 59.14 \text{ kg/m}^3$$

$\text{Na}_2\text{SiO}_3 = 59.14 * 2.5 = 147.85 \text{ kg/m}^3$

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The total quantities of materials for 1 m³

Mass of binder = 345kg/m³

Mass of fluid = NaOH = 59.14 kg/m³

Na₂SiO₃ = 147.85 kg/m³

Mass of fine aggregate = 831.6 kg/m³

Mass of coarse aggregate = 1016.4 kg/m³

For cube size (150*150*150)mm

Volume of cube size (150*150*150)mm = 0.003375 m³

Mass of binder = 345*0.003375

= 1.164 kg/m³

Mass of fluid = NaOH = 59.14*0.003375 = 0.200 kg

Na₂SiO₃ = 147.85*0.003375 = 0.500 kg

Mass of fine aggregate = 831.6*0.003375 = 2.806 kg

Mass of coarse aggregate = 1016.4*0.003375 = 3.430 kg

Extra water added = 20% of binder taken

c. MIX DESIGN FOR CONVENTIONAL CONCRETE (M40 GRADE)

Mix design conforming to IS: 10262-2009 was done and the following were the materials obtained per cubic meter of concrete.

Cement content = 350 kg/m³

Water content = 178.86 kg/m³

Fine aggregate = 708.9 kg/m³

Coarse aggregate = 1225.40 kg/m³

Chemical admixture = 3.5kg/m³

Water cement ratio = 0.45

III. EXPERIMENTAL RESULTS

In the present experimental work, properties of materials used in the experimental work were determined. Then Flyash and GGBS based Geopolymer concrete (G40) cubes of 30% & 50% flyash replacement and conventional concrete (M40) cubes of size 150mm×150mm×150mm were cast for both finely graded (12.5mm down) and coarsely graded (20mm down) coarse aggregates. The sun dried Geopolymer concrete cubes attained target strength of the mix design when exposed under sun light for a period of 7 to 14 days where as conventional concrete cubes has to be cured for a period of 28 days by immersion in water. After completion of curing process, the compressive strength and split tensile strength of concrete cubes was determined and the obtained results are compared. Average of three specimens for the same configuration was considered.

1. COMPRESSIVE STRENGTH

Table 1 and Table 2 summarized values of compressive strength of both GPC and CC of 12.5mm graded aggregate and 20mm graded aggregate with 30% and 50 % flyash replacement. Chart 1 and Chart 2 shows comparative variation of compressive strength of both GPC and conventional concrete (CC) of 12.5mm graded aggregate and 20mm graded aggregate with 30% and 50% flyash replacement.

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Table 1: Compressive strength of C.C & GPC

| Mechanical property | Age | Finely graded coarse aggregate (12.5mm down) | | | | | | |
|----------------------|-----|---|-------------|-------------|-------------|-------------|-------------|-------------|
| | | CC (28days) | 8M | | 10M | | 12M | |
| | | | FA30-GGBS70 | FA50-GGBS50 | FA30-GGBS70 | FA50-GGBS50 | FA30-GGBS70 | FA50-GGBS50 |
| Compressive strength | 7 | | 41.19 | 38.96 | 47.33 | 44.89 | 52.89 | 50.96 |
| | 14 | | 42.44 | 40.89 | 48.22 | 46.89 | 55.19 | 53.78 |
| | 28 | 40.15 | 46.44 | 45.56 | 53.11 | 50.96 | 59.19 | 57.63 |

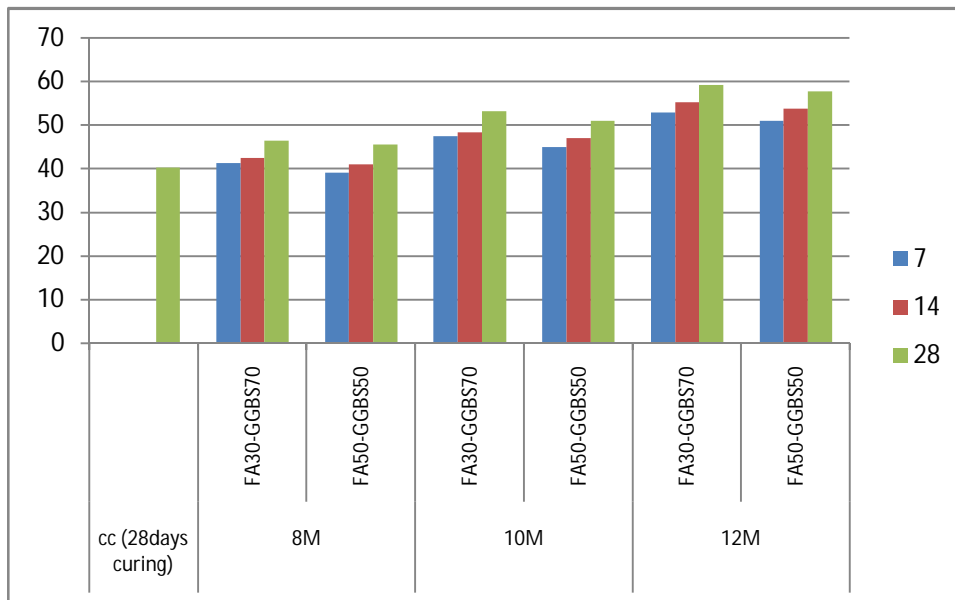


Chart 1: Compressive strength of both GPC and conventional concrete (CC) of finely graded coarse (12.5mm down) aggregate with FA30-GGBS70 and FA50-GGBS50.

Geopolymer concrete after 14 days of curing was 42.44 MPa and Compressive strength of Conventional concrete after 28 days of curing was 40.15 MPa. 12M geopolymer concrete has higher compressive strength when compare to conventional concrete. It was observed that shows that increasing the molarity of NaOH causes increase in the compressive strength of GPC. The compressive strength of GPC cubes increases with increasing the curing period.

Table 2: Compressive strength of C.C & GPC

| Mechanical property | Age | Coarsely graded coarse aggregate (20mm down) | | | | | | |
|----------------------|-----|---|-------------|-------------|-------------|-------------|-------------|-------------|
| | | CC (28days) | 8M | | 10M | | 12M | |
| | | | FA30-GGBS70 | FA50-GGBS50 | FA30-GGBS70 | FA50-GGBS50 | FA30-GGBS70 | FA50-GGBS50 |
| Compressive strength | 7 | | 42.67 | 40.52 | 48.52 | 46.22 | 54.00 | 52.22 |
| | 14 | | 45.19 | 43.63 | 50.37 | 48.67 | 56.96 | 55.33 |
| | 28 | 42.22 | 49.70 | 47.63 | 55.11 | 52.81 | 61.33 | 59.11 |

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From table 1 for flyash ratio of FA50-GGBS50 GPC of finely graded aggregate gets lesser the target strength at 7days of ambient curing but in table 2 for same fly ash replacement of GPC coarsely graded aggregate gets its target strength this indicates that compressive strength of GPC increases with increases the size of coarse aggregate. From table 1 & 2 we can conclude that GPC cubes gains the compressive strength increases with increasing the curing period.

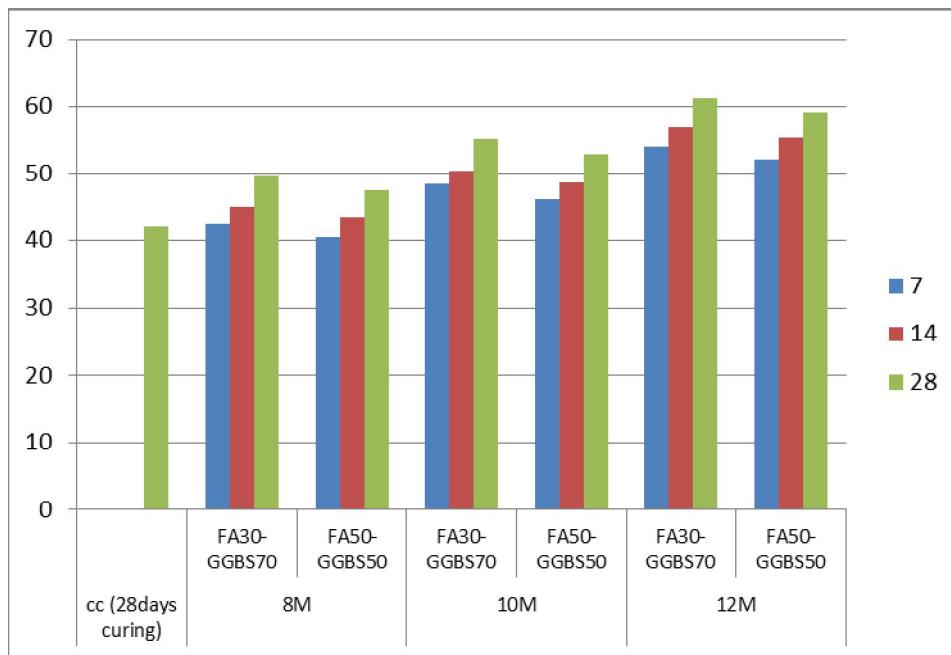


Chart 2: Compressive strength of both GPC and conventional concrete (CC) of coarsely graded coarse (20mm down) aggregate with FA30-GGBS70 and FA50-GGBS50 replacement.

2. SPLIT TENSILE STRENGTH

Table 3 and Table 4 summarized values of Split tensile strength of both GPC and CC of finely graded coarse aggregate and coarsely graded coarse aggregate with 50 % flyash replacement.

Table 3: Split tensile strength of C.C & GPC of Finely graded coarse aggregate (12.5mm down)

| Mechanical property | Age | Finely graded coarse aggregate (12.5mm down) | | | |
|------------------------|-----|---|-------------|------|------|
| | | CC (28days) | FA50-GGBS50 | | |
| | | | 8M | 10M | 12M |
| Split tensile strength | 7 | | 2.85 | 3.25 | 3.73 |
| | 14 | | 2.97 | 3.40 | 3.87 |
| | 28 | 2.92 | 3.30 | 3.70 | 4.22 |

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| Mechanical property | Age | Coarsely graded coarse aggregate (20mm down) | | | |
|------------------------|-----|---|-------------|------|------|
| | | CC (28days) | FA50-GGBS50 | | |
| | | | 8M | 10M | 12M |
| Split tensile strength | 7 | | 2.95 | 3.37 | 3.77 |
| | 14 | | 3.16 | 3.51 | 4.01 |
| | 28 | 3.07 | 3.44 | 3.87 | 4.34 |

Table 4: Split tensile strength of C.C & GPC of coarsely graded coarse aggregate (20mm down)

Chart 3 and Chart 4 shows comparative variation of Split tensile strength of both GPC and conventional concrete (CC) of finely graded and coarsely graded coarse aggregate with FA50-GGBS50 replacement.

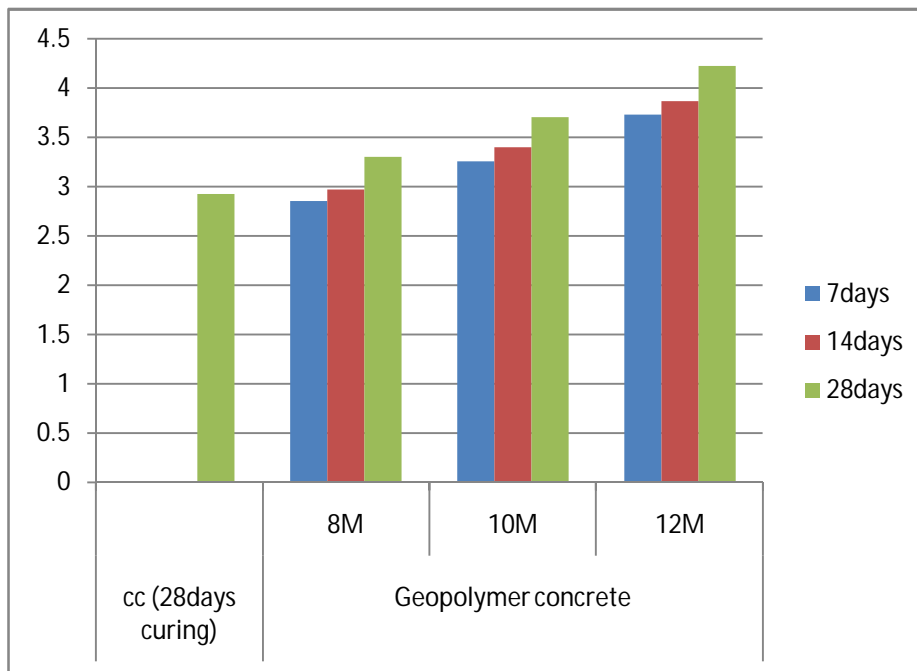


Chart 3: Split tensile strength of both GPC and conventional concrete (CC) of finely graded coarse (12.5mm down) aggregate with FA50-GGBS50 replacement.

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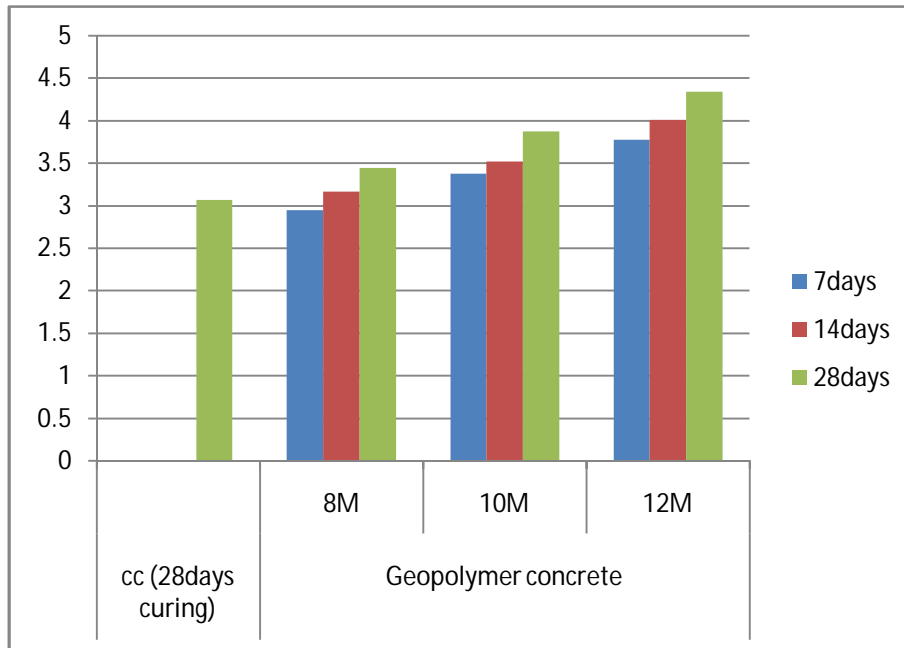


Chart 4: Split tensile strength of both GPC and conventional concrete (CC) of coarsely graded coarse (20mm down) aggregate with FA50-GGBS50 replacement.

From the bar diagram it clearly shows that Geopolymer with FA50-GGBS50 replacement of finely graded coarse aggregate have more split tensile strength value at all curing periods and greater than that of conventional concrete. The Split tensile strength Geopolymer concrete is compare with the CC cubes. The % increase in split tensile strength values of GPC 12M of finely graded coarse aggregate at 7,14 and 28days in ambient curing are 27%, 32% and 44% respectively. For GPC 12M of Coarsely graded coarse aggregate are 23%, 30%, and 41%. This shows that split tensile strength of GPC decreases with increase in the grades of coarse aggregate in the mix

IV. CONCLUSION

Based on present experimental investigation, the following conclusions are drawn:

- The GPC attains target compressive strength at much less curing period of 7 to 14 days under sun light curing when compared with conventional concrete which is to be cured for a minimum period of 28 days immersed in clean water.
- The compressive strength of geopolymer concrete with finely graded (12.5mm down) coarse aggregate of FA30-GGBS70 shows more compressive strength than the FA50-GGBS50 replacement cubes.
- The GPC with finely graded (12.5mm down) coarse aggregate have higher tensile strength. And there is a fall in strength on further increased size of aggregate i.e, for GPC with coarsely graded (20mm down) coarse aggregate.
- The results of the present investigation helps to recommend the use of GPC for the production of thin precast elements using finely graded coarse aggregate (12.5mm down size).

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