# BOOSTING THE USE OF GGBS GEOPOLYMER CONCRETE AND STEEL FIBERS TO INCREASE THE MECHANICAL QUALITIES OF THE FIBER VOLUME

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**Abstract**
Concrete, a widely common building material, has cement as its primary ingredient. Global warming-causing greenhouse gases are released into the environment as a result of cement manufacture. Current research is thus concentrating on other materials to replace and lessen the requirement for cement. Steel fibers are incorporated to geo-polymer concrete in this study using GGBS. GGBS is a by-product of the steel industry. Concrete has been strengthened by the use of steel fibers. This experiment used geo-polymer concrete with GGBS and steel fiber (0.5%) together with 8 and 10 mol alkaline activators. The ratio of these alkali activators is 1:2.5. The results showed that fiber may significantly enhance mechanical properties. As the fiber volume fraction grows, so does the augmentation.

**Keywords:** Alkaline Activator Solution, Geo-polymer, Ground Granulated Blast Furnace Slag (GGBS), Molarity, and Steel Fibers, split tensile strength (STS), compressive strength (CS), flexural strength (FS), geo-polymer concrete (GPC)

## 1 Introduction

Due to the growth of the infrastructure, cement use has been steadily rising in recent years. Large quantities of natural resources are used in the production of cement, which causes the depletion of natural resources. Hence, finding a substitute for cement to act as the concrete's binding agent is important. According to reports, a tone of cement requires a lot of energy to produce, and as a result, environmental concerns are becoming more severe. One tone of cement is said to emit 75% of its carbon dioxide during manufacture. Yet, a significant quantity of natural resources was used to support the construction of the global infrastructure. So the need of concrete which was a construction material was increasing, due to this reason the need of ordinary Portland cement was utilized as a primary binder in the concrete was increased. In India iron manufacturing industries were in a big scale and from these industries GGBS was produced. The utilization of GGBS in the construction filed was increasing. Prof. Joseph Davidovits (1989) had done a great research in the geo-polymer technology and had given certain promises for the geo-polymer application in concrete as a binder. Extensive research works had shown that GGBS based geo-polymers an alternative in the concrete made with cement.

The geo-polymers are obtained from GGBS (residue from iron production industries) from the geo-polymerization reaction. The geo-polymerization involves a chemical reaction with silicon and aluminum that were existent in source material with alkaline solution. The concrete that was made by the geo-polymers were exhibiting excellent compressive strengths, good durability aspects also. The best and the potential source material of geo-polymer were blast furnace slag and fly ash among by-products and wastes from the industries. The studies carried out in past had shown good utilization of these materials in the preparation of GPC. In this geo-polymer the second main component was alkaline activator solution, this was a mixture of sodium silicate ($Na2SiO3$) & sodium hydroxide (NaOH), and also potassium silicate ($K2O3Si$) with potassium hydroxide (KOH) and it has been stated that the type of alkaline activator solution is a important feature which affects the mechanical strengths. Finally in past experimental studies it has been said that sodium hydroxide with sodium silicate shows high compressive strengths.

MATERIALS GENERALLY USED IN GPC

Most common materials utilized in GPC production are:

1. FlyAsh
2. GGBS
3. AlkalineSolution
4. Aggregates 1.3Flyash

Advantages of Slag Addition in geopolymer Concrete

A great acceptance for the geo-polymer based concrete was increasing daily due to its rapid hardening technique. Since a good acceptance was there lot of research works were carried out to improve mechanical properties. In several experimental studies it has been investigated that alkaline activation with the various by- products or wastes of industries like fly ash, ground granulated blast furnace slag, silica fume metakaolin among all these slag based geo-polymer has attracted the attention because geo-polymerization process is faster than metakaolin & fly ash. The CS of slag based GPC for 28 days was around 60 N/mm2. On the other side blended geo-polymers which were made by GGBS and palm oil fuel ash with alkaline activators has found to form a stable alumino silicate geo-ploymers.

ALKALINE SOLUTION

Alkaline activator solution was second significant component in geopolymer concrete. The role of this alkaline activator is to react with the byproduct material like GGBS to start geopolymerization process. The byproduct material cannot act as a binder without this alkaline activator solution. The generally used alkaline activator solution was organized by a mixture of potassium or sodium &NaOH or potassium silicate. But in this present the solution was prepared by Na2SiO3 &NaOH. Environmental pollution has increased. Sugar cane bagasse ash is an agriculture waste and it has pozzolanic characteristics. In the construction sector instead of cement or instead of fine aggregates, as a base and sub base material in highway construction, as a filling materials in dam ,in retaining walls, and for the light construction material. Sugar cane bagasse ash when used with Portland cement, it contributes to high.

OBJECTIVES OF THE RESEARCH STUDY

- To study high performance and mechanical properties of the GPC made with GGBS and alkaline activator solution with addition of steel fibers and without steel fibers.
- To survey effect of molarity concentration in the alkaline activator solution.
- To study flexural behavior of geo-polymer concrete made with steel fibers and without steelfibers.
- To identify the strength characteristics of geo-polymer concrete made of fibers and without fibers at ambient temperatures.

**2 Literature Review**

Dattatreyaetal.(2011) conducted evolutional surveys on flexural behavior of reinforced geopolymer concrete beam .In his study the binder materialchosen was fly ash & GGBS in diverse percentages and these geopolymer concrete beams (GPC)are compared with the conventional OPC beams. The fly ash (FA) and GGBS percentages are 75%FA-25%GGBS, 25% FA- 75% GGBS, 0% FA- 100%GGBS, 50% FA-50% GGBS and the NaOH is taken in 8molarity. The beam size is 1500 mm × 100 mm × 150 mm and reinforcement bars used in this study is 16 mm, 12 mm and 8 mm stirrups, the tension reinforcement is varied with 3 different percentages. And specimens were cured under room temperature, after 28 days those specimens were tested under 2 point loading. The author concluded that load Vs deflection characteristics of the reinforced OPC beams and reinforced geo-polymer concrete beams are almost similar and also the crack patterns were similar with conventional concrete beams.

Duxsonetal.(2006)has presented the history of the geopolymer technology in the form of state of art. In this paper the author has explained about the materials that can be used in the geopolymer concrete preparation. And also the chemical characteristics and the structure of the geopolymer concrete prepared by fly ash, GGBS and metakaolin and the properties of these raw materials were clearly explained. The selection of material and mixing procedure of geopolymer concrete is critical for its setting time, workability and mechanical properties. The author concluded by overview of progress in geopolymer science over last two decades, and the materials that were being used in the geopolymer technology were environmental friendly.

Himath Kumar et al. (2017) presented survey on robustness &strength of GPCwill be formed by 100% GGBS &alkaline solution is taken in 14molarity &12molarity. For this simulation survey, cylinders, cubes standard size, & prisms were casted and these specimens were cured under room temperatures and were tested after 3,7,28 days. The cubes were tested for CS and the cylinders were tested for STS and the prisms were tested for flexural behavior. And durability tests were conducted after 30 days curing in respective chemical solutions. The results have shown, the CS of 14molarity cubes were more than 12molarity cubes, 12molarity specimens have less STS compared to 14 molarityspecimens and FS is good for 14 molarity specimens. And the final conclusion is, as the molarities increase the strength increases.

Keerthyet al. (2017) has performed his experimental work on properties of GPC made with fly ash & GGBS. The NaOH was taken in 8 M and 10 M concentration, and the ratio of NaOH and Na2SiO3 were taken as 1:2. The geopolymer concrete was prepared in dissimilar proportions of GGBS and fly ash like 100% GGBS-0% fly ash, 75% GGBS-25% fly ash, 50% GGBS-50% fly ash and 25% GGBS-75% fly ash. The CS, STS, and FS test on prisms were performed for 7 and 28 days. From outcomes that were attained after tests clearly says that as the molarity increases the strength increases with respect curing period.

Kumaravelet al. (2014) carried out experiment on the reinforced geo-polymer concrete beams (RGPC) of fly ash and GGBS composition; the proportions are FA 75%-GGBS 25%. The alkaline liquid is prepared of 12 molarityNaOH solution. The beam dimensions are 3200 mm × 125 mm × 250 mm and the reinforcement in the beam bottom is 2-16 mm dia bars and in the top 2-12 mm dia bars and shear reinforcement is done by 6 mm dia bars. And these geo-polymer beams are compared with the control mix of M 40 grade with same reinforcement detailing. All the specimens were placed in an autoclave for hot air curing up to 24 hours and then tested. The tests that were carried in this study are compression test on cubes that were casted while beams are casted for M 40 grade beams and geopolymer beams. Two points loading is applied on the beams for the load vs deflection results. And finally the experimental values were compared with numerical values that were obtained by ANSYS software. The RGPC beams show good results when compared to control mix beams.

Mukhalladet al. (2018) performed the experimental investigation on mechanical and microstructural characteristics of geo-polymer mortars made with fly ash and that was reinforced with 3 different fibers. Those three were polypropylene, steel, & polyvinyl alcohol fibers. The addition of those fibers in the geo-polymer composite and the abrasion resistance, strength properties, and drying shrinkage were studied in this experimental investigation and also to understand the geo-polymeric matrix the microstructural analysis was carried out. From the test outcomes the strength properties were increased by the addition of steel fibers, and also FS ofgeo-polymer mix with steel fibers and polyvinyl alcohol fibers were in increasing manner

**Materials and Experimental**

In this chapter a detailed outline was given on the various materials that were utilized for this survey and the properties of those materials was shown. And also the preparation of geo-polymer concrete made with slag were explained, further the experimental work for various tests were also discussed in thissection.

**Materials Utilized**

The materials that were utilized in this simulation study were discussed as below:

**SLAG**

The slag that was utilized in this survey was from Jindal south west steel industries, this company sells GGBS in 50-kilogram sacks that comply with IS 12089-1987. GGBS is made in a blast furnace that was once employed in the iron industry. Iron ore, coke, and limestone are fed into the furnace at around 1500 degrees Celsius. Where the iron ore becomes iron and the remaining materials form molten slag that floats on top of the iron in the furnace, and this slag is taken out of the furnace and rapidly quenched with water, after which it forms granulated slag, which is then ground to form ground granulated blast furnace slag.

| Parameters | GGBS |
|---|---|
| CaO | 37.34% |
| $SiO_2$ | 37.73% |
| $Al_2O_3$ | 14.42% |
| $Fe_2O_3$ | 1.11% |
| Glassy content | 99.90% |
| Loss of ignition | 1.41% |

Table.1. Physical properties of GGBS

Fine Aggregate

The gradation mentions to particle size distribution of aggregates. The grading will be more significant property of aggregate utilized for manufacture concrete, considering its particles packing, resultant in void decrease. This effects the cement content &water demand of concrete. The grading will be based on the total percentage of weights that pass through a given IS sieve.

For fine aggregate grading, IS 383-1970 defines four zones. The percentage range passing for each zone is listed in the table. Zone I sand is the coarsest, and Zone IV sand is the finest, while sand in Zones II and III is fair. Fine aggregates adhering to grading zones II or III may be used in reinforced concrete, according to the recommendations.

| S.No | Property | Result |
|---|---|---|
| 1 | Fineness modulus | 2.7 |
| 2 | Specific Gravity | 2.6 |
| 3 | Diameter | 0.6 mm |
| 4 | Length | 30 mm |
| 5 | Aspect ratio(L/d) | 50 |
| 6 | Type | Hooked End |
| 7 | Tensile strength | 1450 MPa |
| 8 | Yield strength | 1000 MPa |
| 9 | Strain at failure | 4% |

Table.2. Physical properties of fine aggregates

COARSE AGGREGATE

Coarse aggregate is the material that is retained after passing through an IS Sieve of 4.75 mm. Although particle sizes up to 40 mm are used in Self Compacting Concrete, the standard maximum size will be gradually 10-20 mm. When it comes to the characteristics of different types of aggregate, crushed aggregates generate strength as a result of angular particles interlocking, whereas rounded aggregates improved flow due to lower internal friction.This approach used locally available coarse aggregate with a minimum size of 12.5 mm and a maximum size of 20 mm. The aggregates were washed to remove dirt and dust, and then dried to a surface dry condition. IS: 383- 1970 was used to test the aggregates.

| S.No | Property | Result |
|---|---|---|
| 1 | Specific Gravity | 2.74 |
| 2 | Fineness Modulus | 8.0 |
| Bulk Density | | |
| 3 | Loose State | 2.465gm/cc |
| 4 | Compacted State | 2.701 gm/cc |

Table.3. Physical properties of coarse aggregates

STEEL FIBERS

Steel fibers that were utilized in this experimental study wascylindrical in geometry and hooked ends. The properties of the steel fibers that were used were shown in the Table 3.4. Steel fibers addition in concrete will withstand against cracking and extension of cracks. The change of brittle material to ductile material will increase the energy absorption and load carrying capacity and also with stands against repeated or impact loading Physical properties of steel fibers

MIX DESIGN

There was no certain code for mix design of GPC. But for mix design of geo-polymer concrete mix, from the past literature it was noted that the overall density of GPC made with fly ash or GGBS was similar to ordinary Portland cement concrete (2400 kg/m3). From this the total percentage of combined fine and coarse aggregate was 75 % from the total mass of the geo-polymer concrete mixand this was similar to OPC concrete. And the percentage of fine aggregate was 37 % from the total combined percentage of aggregates. By knowing the density of geo-polymer concrete, the GGBS and alkaline liquid combined mass can be determined. The ratio of alkaline liquid to cementitious material was assumed to be 0.45, from this the quantity of GGBS and alkaline liquid were determined. By the addition alkaline liquid the geo-polymerization process will start. Alkaline activator solution was prepared by NaOH and Na2SiO3, NaOH was taken in 8 M and 10 M. the ratio of NaOH to Na2SiO3 was taken as 1:2.5.Steel fibers were taken in 0.5 % to the volume of concrete.

| S.No | Materials | Quality(Kg/m$^3$) |
|---|---|---|
| 1 | GGBS | 414 |
| 2 | Fine aggregate | 660 |
| 3 | Coarse aggregate(20mm) | 681.6 |
| 4 | Coarse aggregate(10mm) | 454.4 |
| 5 | Sodium hydroxide 8M,10M | 53 |
| 6 | Sodium silicate | 133 |
| 7 | Extra water | 10% |

Table.4. Mix Proportion of Geo-polymer Concrete

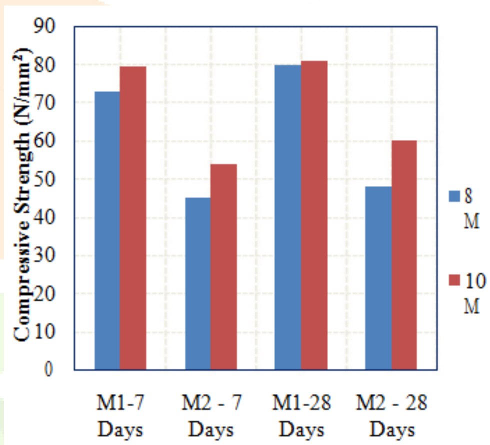
| S.No | Property | Result |
|---|---|---|
| 1 | Fineness modulus | 2.7 |
| 2 | Specific gravity | 2.6 |

Table.5. Mix Identification

**Results and Discussions**

Compression test on concrete cubes

The CS purpose of concrete will be imperative due to CS is standard of its quality. The other strength will be usually arranged in terms of CS. The strength will be stated in in N/mm2. This strategy may be pertinent to making of initial compression tests to determine the suitability of accessible materials. The concrete specimens and cubes have been usually tested at ages 3 days 7 days and 28 days.



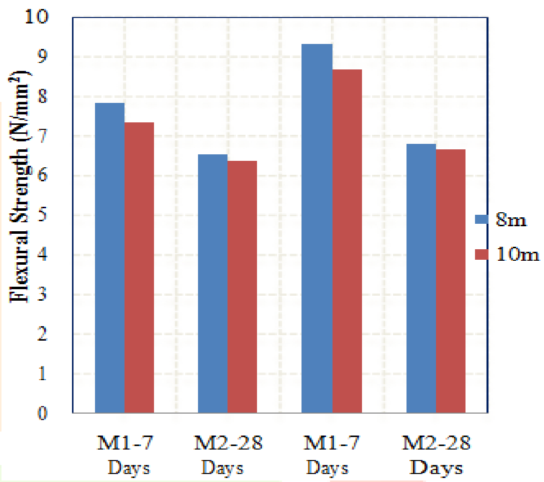

Average CS of GPC cubes with and without steel fibres

SPLIT-CYLINDER TEST

It will be standard test, to describe concrete STS in indirect method. This test might be executed as per IS: 5816-1970. A standard concrete specimen test cylinder (300 mm X 150 mm diameter) is horizontally situated amid the loading surfaces of the Compression Testing Machine. The compression force is delivered equally and diametrically along the length of the cylinder until the cylinder fails vertically. Strips of plywood are put among loading platens and specimens of testing machine to allow uniform distribution of this applied load and to reduce the magnitude of high CS around the points of application of this load. Because of the indirect tensile stress caused by the poison's impact, the concrete cylinders split in half along this vertical plane.

flexural strength of concrete

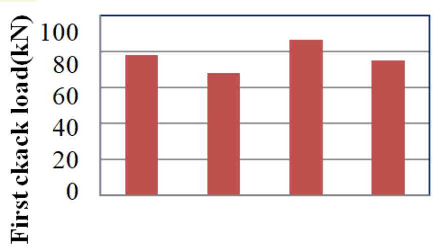
The FS is the similar as STS, if material is homogeneous. In reality, many materials have big or small faults in them. The FS is handled by intact 'fibers' strength



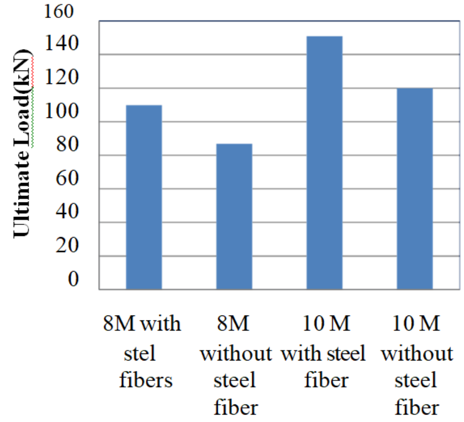

Average flexural strength of GPC cubes with and without steel fiber

FLEXURAL BEHAVIOR OF REINFORCED GPC WITH STEEL FIBERS AND GEOPOLYMER CONCRETE WITHOUT STEEL FIBERS BEAMS

The results for flexural behavior of reinforced geo-polymer concrete made with 100 % GGBS with steel fibers and geo-polyemer concrete with 100 % GGBS without steel fibers. And all the beams were cast with same reinforcement but made with different molarities were shown below



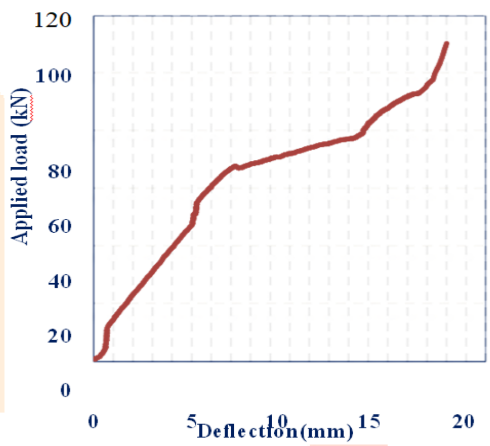

Cracking Loads



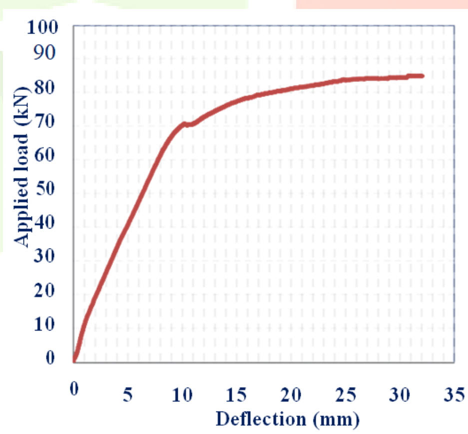

Ultimate Loads

LOAD – DEFLECTION BEHAVIOR

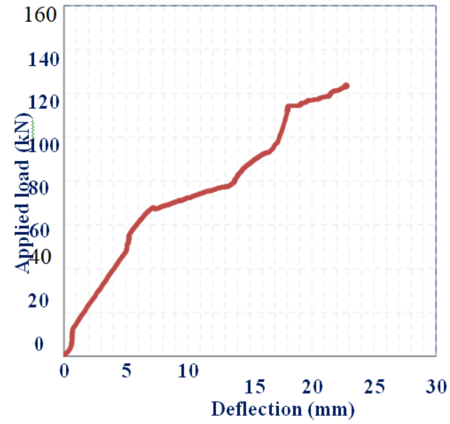
The load Vs deflection behavior of all reinforced GPC beam. The experimental values or outputs were higher for geo-polymer concrete mixwith steel fibers than the geo-polymer concrete mix without steel fibers.




Load vs. deflection curve with steel fibres 8M




Load vs. deflection curve with steel fibres10M




Load vs. deflection curve without steel fibres10

**Conclusion**

To compare the results with the impact of NaOH in 8M and 10M concentrations with GGBS and without adding steel fibers cement, experimental studies were conducted to understand the effect of NaOH in these concentrations. The flexural behavior and strength of GPC produced with 100% GGBS with steel fibers and 100% GGBS without steel fibers were compared..

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