Analysis of GGBS GEO-Polymer Concrete by Steel Fibers using Split Cylinder Test

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ABSTRACT

Concrete is the most popular material used in the construction works in which cement is the main composite. The manufacturing of cement involves the emission of greenhouse gases into the atmosphere which are responsible for global warming. Hence the researches are currently focused on various materials to replace and reducing the cement utilization. Moreover, in this contribution the concrete Geo-polymer has been made with GGBS (granulated ground blast furnace) along with steel fibers mixing. GGBS is the by-product produced from steel industry. Steel fibers are added to increase the tensile strength of concrete. In this experimental investigation geo-polymer concrete containing GGBS and steel fiber (0.5%) with 8 Molar and 10 Molar alkaline activators are used. The ratio of these alkali activators is 1:2.5. The results showed that fiber can significantly enhance the Mechanical properties. The enhancement also increases with the increasing fiber volume fraction.

Keywords: Alkaline Activator Solution, Geo-polymer, Ground Granulated Blast Furnace Slag, Molarity, Steel Fibers, tensile strength (TS), flexural strength (FS), Compressive strength (CS)

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INTRODUCTION

Usage of cement from the recent years was increasing in a large scale due to the development of infrastructure. For the manufacturing of cement huge scale of natural resources are utilized due to this reason the natural resources were depleting. So, there is a necessary of identifying an alternative material in the place of cement as a binder in the concrete. Energy consumption in the cement production was in a large scale and due to these environmental problems were rising, it has been stated that for the production of one ton of cement 75% of carbon dioxide was being released in to the environment. However, to fulfill the world infrastructure development huge amount of natural resources were consumed. So, the need of concrete which was a construction material was increasing, due to this reason the need of ordinary Portland cement which was used 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. 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-polymer as 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 the silicon and aluminum that were present in the source material with the 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 the by-products and wastes from the industries. The studies carried out in past had shown good utilization of these materials in the preparation of geo-polymer concrete. In this geo-polymer the second main component was alkaline activator solution, this was a combination of sodium silicate

(Na_2SiO_3) with sodium hydroxide (NaOH) and also potassium silicate (K_2O_3Si) with potassium hydroxide (KOH) and it has been stated that the type of alkaline activator solution is an important factor 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 used in production of GPC are:

1. Fly Ash
2. Ground Granulated Blast Furnace Slag (GGBS)
3. Alkaline Solution
4. Aggregates 1.3Flyash

FLYASH

This term is an outcome from burning of pummeled coal, and is generally utilized as a fixing in water powered concrete. Since it enhances several required solid features. It has been presented either in the form of an independently grouped component or in the form of part of mixed concrete. Fly debris responds with the hydrating water powered concrete to shape an establishing medium. At the point when pounded coal is singed to create heat, the buildup contains 80 percent fly-debris and 20 percent base debris. Coal has been an outcome of huge amount of extensive periods of breaking down vegetable challenge under tension, & its compound structure has been whimsical. Identically, companies related to electric might augment the formation of coal by deploying some of the components, such as conditioners of pipe gas, oil, and many divergent materials have been added for regulating the erosion, fouling & discharges. Moreover, the corresponding debris of fly could possess divergent framework nd comprises some of components from unsuccessful burning

ADVANTAGES OF SLAG ADDITION INGEO-POLYMERCONCRETE

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 such as ground granulated blast furnace slag, fly ash, silica fume metakaolin among all these slags based geo-polymer has attracted the attention because geo-polymerization process is faster than fly ash and metakaolin. The blending of sodium-silicate besides with sodium-hydroxide for frame alumino-silicates & reactivity among aluminates & silicates in slag ascribed to alumino-silicate gel arrangement and upon heat restoring gives a solid polymeric chain. Compressive quality of slag based geo-polymer concrete 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 important component in geo-polymer concrete. The role of this alkaline activator is to react with the byproduct material like GGBS to start geo-polymerization process. But in this present the solution has been made by sodium silicate &hydroxide 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 material 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 the high performance and mechanical properties of the geo-polymer concrete made with GGBS and alkaline activator solution with addition of steel & and without steelfibers.

To study the influence of molarity concentration in the alkaline activator solution.

•To study the flexural concrete geo-polymer conduct made with & without steel-fibers.

•Toidentify the strength characteristics of geo-polymer concrete made of fibers and without fibers at ambient temperatures.

2. LITERATUREREVIEW

Dattatreyaet al.(2011)Conducted experimental studies on the flexural behavior of the reinforced geo-polymer concrete beam .In his study the binder materialchosen was fly ash and GGBS in different percentages andthesegeo-polymer concrete beams (GPC)are compared with the conventional OPC beams. The fly ash (FA)and GGBS percentages are 50% FA-50%, - 75% GGBS, 75%FA-25%GGBS, 0% FA- 25%FA, 100%GGBS,,GGBS and the NaOHis taken in 8molarity. The magnitude of the beam is 1500 × 100 × 150 mm & reinforcement bars used in this study is 16 mm, 12 mm and 8 mm stirrups, the tension reinforcement is varied with 3 different percentages. Moreover, under the temperature of room, the specimens have been cured, after 28 days those specimens have been examined under 2 plug loading. Besides, author concluded that load 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 concretebeams [1-2].

Duxsonet al.(2006)has presented the history of the geo-polymer technology in the form ofstate of art. In this paper the author has explained about the materials that can be used in the geo-polymer concrete preparation. And also, the chemical characteristics and the structure of the geo-polymer concrete prepared by metakaolin, GGBS, fly ash, the properties of these raw materials were clearly explained. The selection of material and mixing procedure of geo-polymer concrete is critical for its setting time, workability and mechanical properties. The author concluded by overview of progress in geo-polymer science over last two decades, and the materials that were being used in the geo-polymer technology were environmentalfriendly. [3-4]

Himath Kumar et al. (2017) carried out study on geo-polymer concrete durability and robustness, in which geo-polymer concrete is made by 100% GGBS and the alkaline solution is taken in 12molarity and 14molarity. For this experimental study standard size of prisms, cylinders & cubes have been casted and these specimens were cured under room temperatures and were tested after 3,7,& 28 days. Further, cubes were examinedto identify the compressive robustness and the cylinders were examined for split-tensile-strength (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 compressive strength of 14molarity cubes would be more than 12molarity cubes, 12molarity specimens have less STS compared over 14 molarityspecimen and the flexural strength is good for 14 molarity specimens. And the final conclusion is, as the molarities increase the strength increases. [5-6]

Keerthyet al. (2017) has performed his experimental work on properties of geo-polymer concrete made with GGBS and fly ash. The sodium hydroxide was taken in 8 M and 10 M concentration, and the ratio of sodium silicate &hydroxide were taken as 1:2ratio. The geo-polymer concrete has been prepared in divergent proportions of the GGBS & fly ash like 100% GGBS-0% fly ash, 75% GGBS-25% fly ash, 50% GGBS-50% fly ash and 25% GGBS-75% fly ash. Flexural robustness test, tensile strength split test on prisms were performed for 7 & 28 days. From results that were attained after tests clearly says that as the molarity increases the strength increases with respect curingperiod.[7-8]

Kumaravelet al. (2014) conductedsimulation on the 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 geo-polymer beams. Two point 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. [9-10]

Mahanteshet al. (2017) have described the deformation behavior of the reinforced geo-polymer concrete flexural elements, this research work gives an outline of the reinforced geo-polymer concrete beams and slabs. The binder material is taken in the proportion of FA 70%-GGBS 30%. The specimens were reinforced with steel bars and also steel fibers of two types are used, crimped steel fibers (SF) and polyester fibers (PF). The SF is taken in 1.5% of binder weight and PF is taken in 0.5% of binder weight. In this experimentalinvestigationNaOHistakenin8molaritymoreover, beam magnitudewould be 1750 × 150 × 210 mm with varying reinforcement details and slab dimensions are 1000 mm × 1000 mm × 60 mm, 8 mm bars were used in the slab reinforcement. The specimens were cured under room temperatures and tested after 28 days. The type of load applied on the beam is 2-point loading and on slabs the loading type is UDL. The load vs deflection relations at center bottom of slabs and beams are studied. By this tests the first cracking load, ultimate load and deflections of the specimens areidentified [11-12].

Mukhalladet al. (2018) performed the experimental investigation on microstructural &mechanical geo-polymer mortars characteristics made with fly ash and that was reinforced with 3 different fibers. Those three were polyvinyl alcohol, polypropylene, steel, and fibers. The addition of those fibers in the abrasion resistance, geo-polymer composite and drying shrinkage, strength properties, and were researched in this experimental investigation and also to understand the geo-polymeric matrix the microstructural analysis was carried out. From the test results the strength properties were increased with the combination of geo-polymer along with polyvinyl alcohol & steel fibers it has been in enhancing approach. Further, the microstructural examination of sample has been revealed optimal geo-polymerization among alkaline solutions & fly-ash. Here, both polyvinyl alcohol & steel have generated composites as well as with optimal internal features and suitable interfacial bonding among geo-polymeric matric & fibers. Nevertheless, micrographs of polypropylene fibers exhibited poorer performance while compared with above stated fibers [13].

3. MATERIALS AND EXPERIMENTAL METHODOLOGY

MATERIALS

In this chapter a detailed outline was given on the various materials that were utilized for this contribution and those materials characteristics 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 this chapter.

MATERIALS USED

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

SLAG

The slag that was utilized in this study was from Jindal south west steel industries, this company commercially distributes GGBS in the form 50 Kg bags which will conforms to IS 12089-1987.GGBS is produced from the blast furnace that was used in the iron industries, about 1500 degrees centigrade iron ore, coke and limestone is fed into the furnace. Where the iron ore becomes iron and the remaining materials forms like molten slag and floats on the top surface of the iron in the furnace and this slag is taken out from the furnace and rapid quenching with water after that it forms like granulated slag and this slag is grinded after this process GGBFS is formed

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%

Physical properties of ggbs

FINE AGGREGATE

The term gradation is signified with distribution of particle magnitude. This term is more prominent aggregate property utilized to prepare concrete, in respect to particles packing, leading to lessen voids. Moreover, it inturn impacts the demand of water and concrete cement amount. Moreover, this term has also been explained in respect to sum of weights % passing the specified sieve IS. The IS 383-1970 provides 4 zones for grading fine aggregate. Percentages range has been specified in table

by passing in every region. The sand of primary zone is coarse and fourth zone is the optimal while sand in second and 3rd zones were moderate. Furthermore, it has been suggested that optimal Aggregates conforming for zone 2, 3 grading could be utilized in Concrete that is reinforced.

S.No	Property	Outcome
1	Specific-Gravity	2.6
2	Fitness-modulus	2.7

Physical properties of fine aggregates

COARSE AGGREGATE

The total which is held over IS Sieve 4.75 mm is named as coarse aggregate. The typical most extreme size is step by step 10-20 mm; anyway, molecule evaluates to 40 mm or more have been utilized in Self Compacting Concrete. Hole reviewed totals are oftentimes better than those persistently evaluated, which may costly grader inward grinding and give diminished stream. Concerning qualities of various kinds of total, squashed totals will in general improve the quality in light of interlocking of precise particles, while adjusted totals improved the stream due to bring down inside contact.

Locally accessible coarse total having the greatest magnitude of 20 mm and least 12.5 mm size was utilized in this work. The totals were washed to eliminate residue and earth and were dried to surface dry condition. The totals were tried according to Seems to be: 383-1970.

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

Physical properties of coarse aggregates

STEEL-FIBERS

Steel-fibers that were utilized in this simulation 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.

Diameter	0.6 mm
Length	30 mm
Aspect ratio(L/d)	50
Type	Hooked End
Tensile strength	1450 MPa
Yield strength	1000 MPa
Strain at failure	4%

Physical properties of steel fibers

4.0 MIX DESIGN

There was no certain code for mix design of geo-polymer concrete. But for the mix design of geo-polymer concrete mix, from former literature it was noted that overall geo-polymer concrete density made with fly ash. 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 percentage of fine aggregate was 37 % from the entire combined percentage of aggregates. By knowing the density of the 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 sodium hydroxide and sodium silicate, sodium hydroxide was taken in 8 M and 10 M. the ratio of sodium-hydroxide over sodium-silicate was taken to be 1:2.5. Steel fibers have been taken in 0.5 % to the volume ofconcrete**.**

Materials	Quantity(Kg/m^3)
GGBS	414
Fine Aggregate	660
Coarse Aggregate(20mm)	681.6
Coarse aggregate(10mm)	454.4
Sodium Hydroxide 8M,10M	53
Sodium Silicate	133
Extra water	10%

Mix Proportion of Geo-polymer Concrete

S.No	Property	Outcome
1	Specific-Gravity	2.6
2	Finenes s-Modulus	2.7

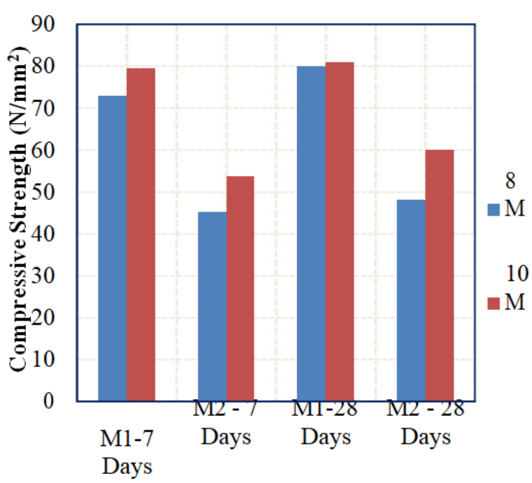
Mix Identification

4. RESULTS & DISCUSSIONS

COMPRESSION TEST ON CONCRETE CUBES

Concrete CS has been determined is significant due to compressive strength has its major part in terms of quality. The robustness is prescribed usually in words of compressed strength. And moreover, it has been denoted in N/mm2. Here, model is applicable in forming preliminary tests of compression for ascertaining the available materials suitability or defining the appropriate proportions of combination. Here, concrete for testing should not possess optimal highest size of cumulative greater than test specimens of 20mm were either 15cm of diameter and cubes have been utilized. Minimum 3 specimens have to be made accessible to test. Each cylinder has been utilized to compressive strength outcomes the strength of cube could be computed beneath. Generally, cubes were usually tested at 28, 3 and 7 days. Moreover, cubes were eradicated from dried, grid and curing tank eradicated. Here, cubes have been tested by utilizing calibrated machine. Here, this could be conducted internally through personnel competent or through certified house test. Furthermore, these cubes have been tested on perpendicular face to casting face. Also, exerts compression machine a stable enhancing the force on cubes until they are unsuccessful, the loading rate has been is 0.6 ± 0.2 M/Pas (N/mm²/s). Here, minimum concrete compressive strength could be specified by designer or client in provided format. BS EN 12390-2: 2009 / BS EN 12390-3:2009

CTM

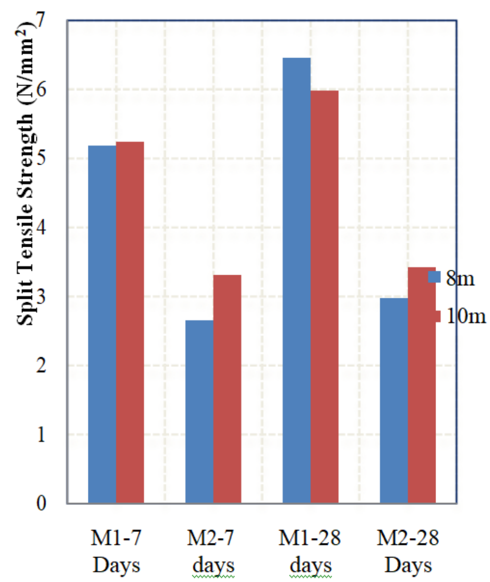


MIX ID

Average CS of GPC cubes with & without steel fibers

SPLIT-CYLINDER TEST

This has been benchmark test for determining concrete tensile strength in an ascertain approach. Here, this test might be executing according to IS: 5816-1970. Moreover, standard concrete specimen standard cylinder test has been horizontally placed among compression testing loading surfaces. The load of compression has been applied uniformly & diametrically along cylinder length until cylinder is failed along diameter that is vertical. For enabling Uniform applied load distribution and for lessening maximum compressive stresses magnitude near the load application, plywood strips have been kept among loading platens and specimen of machine testing. The cylinders made of concrete has been segmented into 2 halves besides with vertical plane because of tensile stress produced by the technology called poison's impact



Mix ID

Average split TS of GPC cubes with & without steel fibers

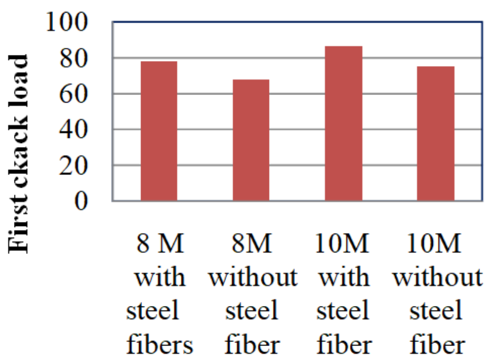
FS OF CONCRETE

The flexural robustness has been similar as tensile when the material has been termed to be homogeneous. Usually, many of the materials were large or small bugs that act for focusing the locally stresses, productively by causing weakness localized. Further, if material has been bending only large fibers at highest stress, then such fibers would be defect or bug free, and moreover, the flexural robustness has been regulated by intact fibers strength. Nevertheless, when similar material has been subjected to forces called tensile, then such entire fibers in material were at identical stress and unsuccessful would start when poorest fiber attains tensile stress at limited. Hence, it is more prominent and common to know that flexural robustness would be more than the tensile robustness

Fig no . 5. – flexural setup

FLEXURAL BEHAVIOR OF REINFORCED GEO-POLYMER CONCRETE WITH STEEL FIBERS AND GEO-POLYMER CONCRETE WITHOUT STEEL FIBERS BEAMS

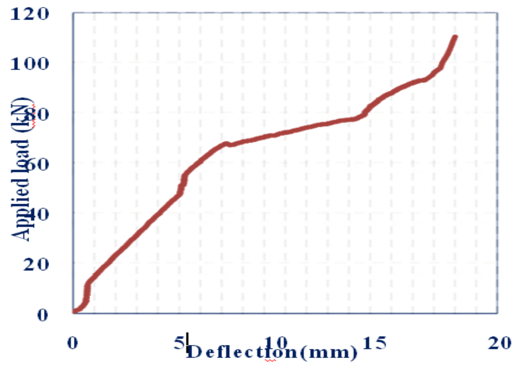
The results for flexural behavior of reinforced geo-polymer concrete made with 100 % GGBS with steel fibers and geopolymers concrete with 100 % GGBS without steel fibers. And all the beams were cast with same reinforcement but made with different molarities were shown below.



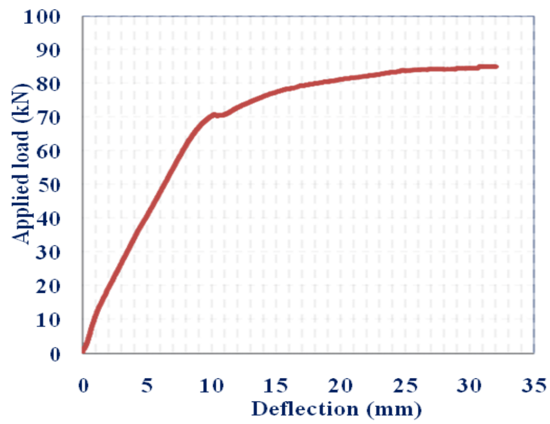
Mix Id Cracking Loads

LOAD – DEFLECTION BEHAVIOR

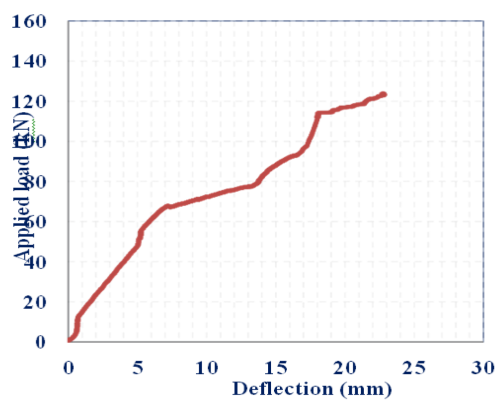
the load Vs deflection behavior of all reinforced geo-polymer concrete beam. The experimental values or outputs were higher for geo-polymer concrete mix with steel fibers than the geo-polymer concrete mix without steel fibers.



Load vs. deflection curve with steel fibers 8M



Load vs. deflection curve with steel fibers10M



Load vs. deflection curve without steel fibers10

Conclusion

Empirical investigations have been performed to Understand the effect of sodium hydroxide in 8M,10M concentration with GGBS and addition of steel fibers with comparison of those results with the effect of sodium hydroxide in 8M,10M concentrations with GGBS and without adding of steel fibers cement. The strength and flexural characteristics behavior of geo-polymer concrete made with 100 % of GGBS with steel fibers and 100% of GGBS without steel fibers. Based on this experimental work certain conclusions were listed below.

Material Characteristics of Geo-polymer Concrete with Steel Fibers and Geo-polymer Concrete without Steel Fibers

The conclusions that can be given by this experimental study are listed below:

The compressive strength of the steel fiber based geo-polymer concrete is higher when compared with the geo-polymer concrete made without steel fibers. It was clear that due to involvement of the NaOH concentration increases the compressive strength also increases. The tensile strength produced by steel fibers of the geo-polymer concrete shows good results. Flexural test on prisms with steel fibers under two-point loading had shown higher values than geo-polymer made without steel fibers. It was clear in all tests, as the age of curing increases the strength of the GPC increases. The load vs deflection on 8 M and 10 M beam with steel fiber are more than the beam without steel fibers. The load carrying capacity of the beams made with steel fibers is higher. The percentage increase difference between each geo-polymer concrete mix with various sodium hydroxide solution concentrations was around 4% to 5 % for 7 days and 28 days.

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