

**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH
TECHNOLOGY****AN EXPERIMENTAL STUDY ON GEO-POLYMER CONCRETE
INCORPORATING GGBS (GROUND GRANULATED BLAST FURNANCE SLAG)
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ABSTRACT

The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and Metakaolin and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃). 10Molar Sodium hydroxide is taken for the preparation of different mixes by varying the percentages of GGBS (Ground granulated blast furnace slag) and Metakaolin. The cube specimens are taken of size 150mm x 150mm x 150mm for compression test. The curing was done directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3, 7 and 28days and compared with conventional concrete. For this study M30 concrete mix was used for experimental work. The result shows that there is an increase in the strength of Geopolymer concrete up to 40%GGBS content and then it is decreasing. Therefore it is preferable to use 40%GGBS with metakaolin to get high strength. Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete.

KEYWORDS: Geopolymer concrete, GGBS, Metakaolin, Alkaline solutions, curing, compressive strength.**INTRODUCTION**

The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. According to one of the studies in the past the worldwide cement production accounts for almost 7% of the total world CO₂ emissions. In addition to this, about three billion tons of the raw materials are needed every year for cement manufacturing, which consumes considerable energy and adversely affect the ecology of the planet. In order to reduce the emissions of carbon dioxide, cement in concrete is replaced by materials like fly ash, GGBS (Ground granulated blast-furnace slag) and Metakaolin is considered as a more eco- friendly alternative to Ordinary Portland Cement (OPC) based concrete. It is termed as Geopolymer concrete. Presently large amounts of Metakaolin, a dehydroxylated form of the clay mineral kaolinite came into existence. This study describes the feasibility of using GGBS (Ground granulated blast-furnace slag) and Metakaolin in concrete production as replacement of cement.

In contrast to the Portland cement, the most Geopolymer systems rely on minimally processed natural materials or industrial byproducts to provide the binding agents. In 1978, Davidovits proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers. Palomo et al suggested that pozzalona such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. The curing of freshly prepared Geopolymer concrete is the most crucial aspect and it plays an important role in the entire geopolymerisation process. The proper curing of concrete has a positive effect on the final properties of the Geopolymer concrete.

The curing of such concrete is mostly carried out at elevated temperatures; however, curing at ambient temperatures is also carried out at times. At ambient temperatures, the reaction of fly ash-based Geopolymeric materials is very slow and usually shows a slower setting and strength development. It is believed that higher temperatures activate alumino-silicate phases in the fly ash; therefore, they are generally cured at elevated temperatures between 60°C- 90°C. As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in Geopolymer concrete. The silicon and the aluminum in the Metakaolin-GGBS react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the Geopolymer paste that binds the aggregates and other un-reacted materials.

MATERIALS AND METHODS

Metakaolin



Figure 1. Metakaolin

Metakaolin is a calcined product of the clay mineral kaolinite. The Particle size of Metakaolin is smaller than cement particles, but not as fine as silica fume. When kaolinite, a layered silicate mineral with a distance of 7,13 Å between the layers of SiO₂ and Al₂O₃ is heated, the water contained between the layers is evaporated and the kaolinite is activated for reaction with cement.

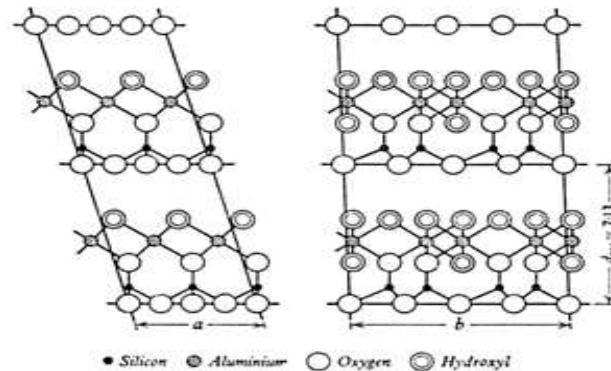


Figure 2. Metakaolin structure

Calcined between 600o and 850o the kaolin transformed to an amorphous phase called metakaolin. This Mineral is activated and Meta stable. Metakaolin can then react with cement and lime. Heating above 900oC produces mullite, a non pozzolanic material.

Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a byproduct of the steel industry. In the production of iron, blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. GGBFS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate (Partha Sarathi Deba,2003). When cement reacts with water, it hydrates and produces calcium silicate hydrate

(CSH), the main component to the cements strength, and calcium hydroxide (Ca(OH)₂). When GGBFS is added to the mixture, it also reacts with water and produces CSH from its available supply of calcium oxide and silica.



Figure 3. Ground granulated blast furnace slag

Typical chemical composition

Calciumoxide: 40%, Silica: 35%, Alumina:13%, Magnesia : 8%

Typical physical properties

GGBS is obtained from jindal steel and power ltd.,Vijayawada office . The specific gravity of GGBS is 2.9. Bulk density is 1200 kg/m³ and Fineness is >350m²/kg. The colour of GGBS is off-white.

Alkaline liquids

The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃). It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO₂-to-Na₂O ratio by mass of approximately 2, i.e., SiO₂ = 29.4%, Na₂O = 14.7%, and water = 55.9% by mass is used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. In this investigation 10M is adopted.



Figure 4. Alkaline Solution

Cement

Ordinary Portland Cement of “BHARATHI” brand 53 GRADE confirming to Indian standards is used in the present investigation. The cement is tested for its various properties as per IS: 4031-1988 and found to be confirming to the requirements as per IS: 8122-1989.

Fine aggregate:

The sand obtained from Krishna River near Vijayawada is used as fine aggregate in this project investigation. The sand is free from clayey matter, silt and organic impurities etc. The sand is tested for specific gravity, in

accordance with IS: 2386-1963 and it is 2.719, where as its fineness modulus is 2.31. The sand confirms to zone-II.

Coarse aggregate

Machine crushed angular Basalt metal used as coarse aggregate. The coarse aggregate is free from clayey matter, silt and organic impurities etc. The coarse aggregate is also tested for specific gravity and it is 2.68. Fineness modulus of coarse aggregate is 4.20. Aggregate of nominal size 20mm and 10mm is used in the experimental work, which is acceptable according to IS: 383-1970.

A concrete mix of M30 grade is designed based on IS:10262-1984 and cubes are casted for the conventional mix. Geopolymer concrete mixes of varying percentages of GGBS and METAKAOLIN are laid with alkaline binders.

The binder is prepared with sodium hydroxide and sodium silicate.

PREPARATION OF ALKALINE SOLUTION

400 g (molarity x molecular weight) of sodium hydroxide flakes dissolved in one litre of water to prepare sodium hydroxide solution of 10M. The mass of NaOH solids in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured as 310 g per kg of NaOH solution of 10M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the Geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds as early as possible as the setting times are very low.

For one litre of water mix:

NaOH = 160gm/lit

Na₂SiO₃ = 370.3gm/lit

MIXING AND CASTING

It was found that the fresh Geopolymer masonry mix was grey in colour and was cohesive. The amount of water in the mix played an important role on the behavior of fresh mix. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃). It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO₂-to-Na₂O ratio by mass of approximately 2, i.e., SiO₂ = 29.4%, Na₂O = 14.7%, and water = 55.9% by mass is used. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 8 Molar and 16 Molar. In this investigation 10M is adopted.

The different percentages of GGBS and Metakaolin based Geopolymer concrete are as follows:

80%MK+ 20% GGBS

70%MK+ 30% GGBS

60%MK+ 40% GGBS

50%MK+ 50% GGBS

100%MK

100% GGBS

For the above percentages cubes of 150mmx150mmx150mm are casted and compressive strength results are compared with the conventional mix

CURING METHOD

Ambient CURING / oven curing:

Curing is not required for these Geopolymer blocks. The heat gets liberated during the preparation of sodium hydroxide which should be kept undisturbed for one day. For the curing geo-polymer concrete cubes, two methods are used, one by placing the cubes in hot air oven and by placing the cubes in direct sun-light. For oven curing, the cubes are placed in an oven at 600 c for an hour. Then the cubes are demoulded and kept in oven at 500 c for 3 days and 7 days. For the sun light curing, the cubes are demoulded after 1 day of casting and they are placed in the direct sun light for 3, 7 and 28 days.

TESTING

The specimens were tested as per IS 516:1959 and strengths were calculated for 3, 7, 14 and 28 days and the results were tabled.

RESULTS AND DISCUSSION

Fineness of the given cement: 2.6 %

As per IS: 269 the residue of cement sampled on the sieve 90 micron after sieving should not exceed 10% and hence it is within its limit.

Standard consistency of cement:

$$(135/400) \times 100 = 28\%$$

As the consistency value of ordinary portland cement need to be varies from 26 to 35%. Consistency is in permissible limits.

Soundness of the cement = 1.2 mm

As per IS:269, when tested by Le Chatelier method, un-aerated ordinary Portland cement shall not have an expansion of more than 10 mm. hence it is in limits.

Specific Gravity :

Specific Gravity of the given Cement at the room temperature = 3.01

The specific gravity of GGBS = 2.85

The specific gravity of Metakaolin = 2.6

Compressive strength for conventional and geopolymer concrete mixes

The following are the various results obtained for concrete and the values are tabulated as below

Table 1: Compressive strength of concrete for M30 control mix for 3,7, and 28 days

No	Time(days)	Compressive load KN	COMPRESSIVE STRENGTH N/mm ²	Average strength N/mm ²
1	3	345	15.1	15.11
		350	15.2	
		355	15.26	
2	7	470	20.81	20.87
		480	21.11	
		475	21.1	
3	28	870	38.28	38.28
		870	38.28	
		860	38.22	

Table 2: Compressive strength of concrete for different % of GGBS and METAKAOLIN for 3,7, and 28 days

S.NO	Percentage of Metakaolin and GGBS in mixture	3DAYS N/mm ²	7DAYS N/mm ²	28DAYS N/mm ²
1	100% GGBS	11.24	14.33	22.13
2	100% MK	45.12	48.56	49.87
3	80%MK+20%GGBS	41.6	43.82	45.14
4	70%MK+30%GGBS	44.37	48.56	50.39
5	60%MK+40%GGBS	47.65	50.72	53.26
6	50%MK+50%GGBS	40.32	42.86	44.32

GRAPHICAL REPRESENTATION OF RESULTS

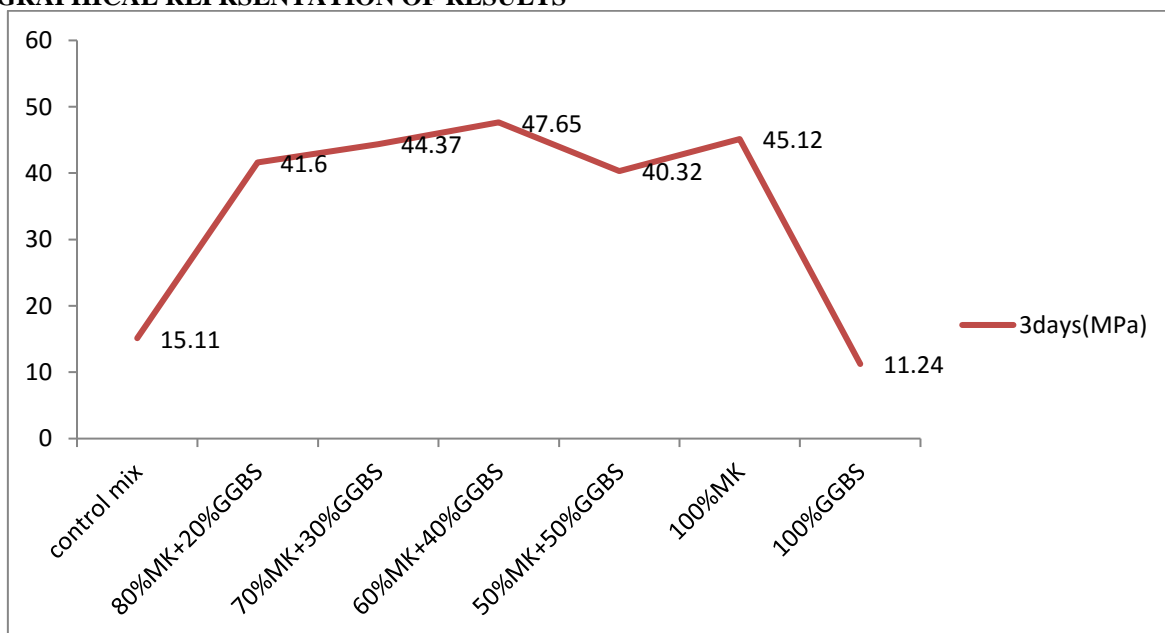


Figure 6 Compressive strength of Geopolymer concrete for 3days

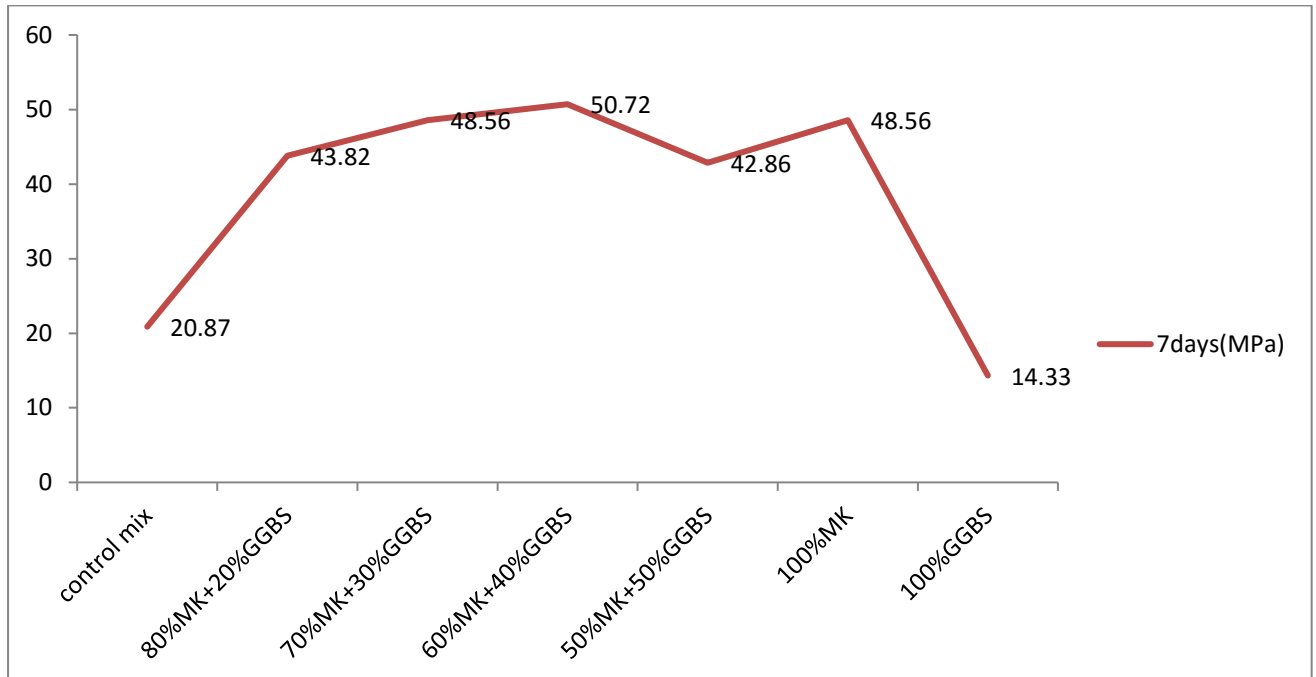


Figure 7 Compressive strength of Geopolymer concrete for 7days



Figure 8 Compressive strength of Geopolymer concrete for 28days

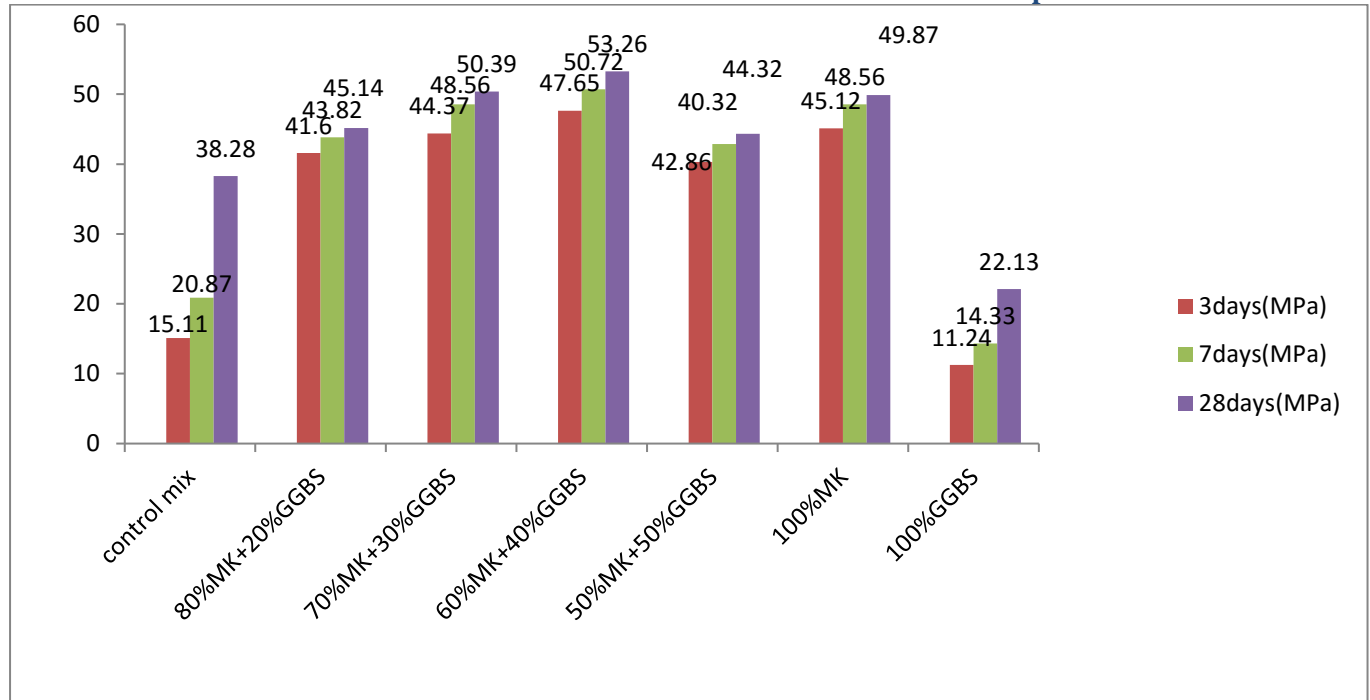


Figure 9 Compressive strength of Geopolymer concrete for different mixes

CONCLUSION

From the above results it is apparent that Geopolymer concrete based on GGBS and metakaolin has got more compressive strength than conventional concrete. The strength of the Geopolymer concrete increases with the increase in GGBS content upto 50% and then reduces, so it is preferable to use GGBS upto 50% in the mixes. The strength of the Geopolymer concrete increases with 2% -4% from 7 to 28 days that means there is no much increase in the strength after 7 days. Alone Metakaolin can perform well but GGBS cannot be 100% replaced. The results showed that the substitution of 60% Metakaolin and 40% GGBS content induced higher compressive strength. From the above all tests, it is concluded that the Metakaolin and GGBS can be used as a replacement material for cement gives an excellent result in strength aspect and quality aspect since it is better than the control concrete. By using the Metakaolin and GGBS as a filler or replacement in cement will reduce environmental pollution.

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