ISSN (online): 2349-784X

Geopolymer Concrete using GGBS with Partial Replacement of Coarse Aggregate with Manglore Tile

Arya Elizabeth Mathew
Department of Civil Engineering
Amal Jyothi College of Engineering, Kanjirapally

Gopika Rajeev
Department of Civil Engineering
Amal Jyothi College of Engineering, Kanjirapally

Jerin Thomas John
Department of Civil Engineering
Amal Jyothi College of Engineering, Kanjirapally

Jinchu Sabu
Department of Civil Engineering
Amal Jyothi College of Engineering, Kanjirapally

Abstract

Geopolymer concrete is a relatively new form of concrete that is considered "green" and environmentally friendly. The production of Portland cement accounts for five percent of the carbon dioxide emissions today. As abundant as this material is, it should not be one of the top contributors to carbon dioxide emissions and therefore a new form of concrete should be developed. The current goal for scientists and engineers is to formulate a Geopolymer that possesses the most beneficial characteristics of all of these different types while maintaining its environmental integrity. This goal sounds simple but because there are so many different compositions, it is tough to obtain a Geopolymer concrete that adheres to the previously mentioned guidelines. We are doing our project on Geopolymer concrete using GGBS which will react with sodium hydroxide and sodium silicate solutions. GGBS is rich in silica and alumina which will react with alkaline solution to produce alumina silicate gel that acts as the binding material for the concrete. As coarse aggregate we are using a combination of gravels and broken tile (Mangalore tile) pieces and rock sand as fine aggregate.
Keywords: Geopolymer concrete, replacement with Mangalore tile, eco-friendly, alkaline solution, strength

I. INTRODUCTION

Ordinary Portland cement has been used traditionally as a binding material for preparation of concrete. The world-wide consumption of concrete is believed to rise exponentially primarily driven by the infrastructural development taking place in China and India. 1 tone of carbon dioxide is estimated to be released to the atmosphere when 1 ton of ordinary Portland cement is manufactured. Also the emission by cement manufacturing process contributes 7% to the global carbon dioxide emission. It is important to find an alternate binder which has less carbon footprint than cement. The Geopolymer technology is proposed by Davidovits and gives considerable promise for application in concrete industry as an alternative binder to the Portland cement Concrete is the second most used material in the world after water. In this technology, the source material that is rich in silicon (Si) and Aluminium (Al) is reacted with a highly alkaline solution through the process of geopolymerisation to produce the binding material.

The polymerization process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals that result in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. Geopolymer concrete is emerging as a new environmentally friendly construction material for sustainable development, using fly ash and alkali in place of OPC as the binding agent. This attempt results in two benefits. i.e. reducing CO_2 releases from production of OPC and effective utilization of industrial waste by products such as fly ash, slag etc. by decreasing the use of OPC. Geopolymer are a class of largely X-ray amorphous alum inosilicate materials, generally synthesized at ambient or slightly elevated temperature by reaction of a solid alum inosilicate powder with a concentrated alkali metal silicate or hydroxide solution. As a means of converting waste materials to useful products, the value of Geopolymer technology lies primarily in its ability to produce a high performance binder from materials such as fly ash or blast furnace slag. Low calcium (class F) fly ash is currently most commonly used in Geopolymer synthesis, although there seems to be no reason why Class C fly ash could not be used. Brown coal fly ash has also been used in combination with metakaolin (calcined kaolinite clay) to produce geopolymeric materials.

Geopolymer concrete is the result of the reaction of materials containing aluminosilicate with concentrated alkaline solution to produce an inorganic polymer binder. While it has a history starting in the 1940's and has attracted significant academic research, Geopolymer concrete has yet to enter the mainstream of concrete construction. Most applications to date have been in the precast industry using accelerated curing. However, the use of geopolymer concrete in ready mixed applications is increasing; building on the information currently available and motivated by the considerable sustainability benefits of using a binder system composed almost entirely of recycled materials.

The geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. Geopolymer utilize the waste materials as source material and get activated by alkaline activator to act as binder. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80%. Development of geopolymers is a new generation of cementitious materials being an alternative to traditional cement and concretes through alkali activation of industrial waste is a relatively new area and research topic for the scientific community.

II. SCOPE AND OBJECTIVE

The main objective is to evaluate the different strength properties of geopolymer concrete mixture with nominal aggregate replaced in percentage to Mangalore tile. This project aims to reduce the usage of ordinary Portland cement and to improve the usage of the other by products like G.G.B.S (Ground Granulated blast furnace Slag). This product helps in reducing the carbon dioxide emissions caused by the conventional concrete. This also produces high strength concretes with the use of nominal mixes when compared to conventional concrete making high strength and durable geopolymer concrete containing G.G.B.S (Slag) without usage of ordinary Portland cement. Here we are testing the compressive strength of cubes, flexural strength of beams and split tensile strength of cylinders. It also involves the Waste Management of old Mangalore tile and slag. The cost of chemical plays an important role. There is a very high increase of 53.16% in the compressive strength, 12.16% in flexural strength and a marginal increase of 6.13% in split tensile strength. Permeability test was not done to find out its water tightness. Modulus of elasticity of cylinders can also be carried out. Skilled labourers are required for handling the chemicals.
The objectives of the project are following:

- To make geopolymer concrete with replacement of coarse aggregate and to compare its strength to geopolymer with normal coarse aggregate
- To compare its strength to geopolymer with normal coarse aggregate.
- To test the compressive strength, flexural strength, split tensile and modulus of elasticity
- To compare the cost of conventional concrete and geopolymer concrete using Mangalore tile and GGBS.

III. METHODOLOGY

A. *Component Materials*

Component materials for concrete mixtures were:

- Ground Granulated Blast furnace Slag (GGBS)
- Fine aggregate (rock sand)
- Coarse aggregate
- Mangalore tile
- Alkaline solution

1) *Specific Gravity of GGBS Using Le Chatlier's Apparatus*

Specific gravity of GGBS was determined using the Le Chatlier's apparatus. The apparatus was made of thin glass having a bulb at the bottom. The capacity of the bulb is nearly 250 ml. The flask was dried carefully and kerosene was filled to a point on the stem between the zero and the 1 ml mark. The level of the liquid in the flask was recorded as initial reading V_1. It is recommended that the flask should be immersed in a constant temperature water bath maintained at about room temperature for a sufficient interval. Weighed quantity of GGBS was poured into the flask in small amounts without splashing. A stopper was placed in the flask after putting all the GGBS to the flask and rolled the flask gently in an inclined position so as to free the GGBS from air. The new liquid level was noted as the final reading V_2. The difference between the first and final readings (V_2-V_1) represents the volume of liquid displaced by the mass of GGBS used in the test.
Specific gravity of GGBS = Density of GGBS/Density of reference substance

2) *Specific Gravity of Coarse Aggregate and Mangalore Tile Using Wire Basket*

Specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are weaker than those with higher specific gravity values. A sample of 2 kg of aggregate with particle size greater than 10 mm was taken. The sample was placed in the wire basket and immersed it in distilled water. The entrapped air was removed from the sample by lifting and dropping the basket 25 times at the rate of about 1 drop per second. The basket and aggregate was kept immersed for a period of 24 hours. After the immersion period, the basket and the sample was jolted and weighed it in water (A_1). The basket and aggregate was removed from the water and drained for few minutes in dry cloths. The empty basket was immersed in the water and weighed it after jolting 25 times (A_2). The aggregate placed on the dry cloth was surface dried and weighed (B). The aggregate was placed in the oven in the shallow tray at a temperature of 100^0C to 110^0C and the temperature was maintained for 24 hours. The aggregate was weighed after the drying period (C).

$$\text{Specific gravity} = \frac{C}{B-A}$$

3) Specific Gravity of Fine Aggregate Using Pycnometer Method

Pycnometer of about 1litre capacity having a metal conical screw top with a 6 mm diameter hole at its apex was used. The screw top shall be water tight when it is screwed on to the jar. A sample of about 500g was taken in a tray and covered with distilled water. Entrapped air was removed by agitating with a rod and kept it for 24 hours. The water was drained from the sample. The aggregate was exposed to evaporate surface moisture and stirred at frequent intervals to ensure uniform drying. The saturated and surface dry sample was weighed (A). Aggregate was placed in the pycnometer and distilled water was filled in it. The pycnometer was dried on the outside and weighed it (B). The contents of the pycnometer was emptied and refilled with distilled water to the same level as before and weighed (C). The sample was placed in the oven in the tray at a temperature of 100-110^{0}C and was weighed (D).

$$\text{Specific gravity} = \frac{D}{A-(B-C)}$$

$$\text{Water absorption} = \frac{100*(A-D)}{D}$$

4) Strength Determination of Cubes, Cylinders and Beams

Materials were weighed as per the mix design and mixed in the batch mixer. The drum was loaded with one half of the coarse aggregate and then with the fine aggregate. It was then rotated to get a uniform mixture after which GGBS and the remaining coarse aggregate were added. The binder solution of sodium hydroxide and sodium silicate was added to the mixer and was thoroughly mixed until a uniform homogeneous mixture of desired consistency was obtained. The moulds were cleaned and oil was applied to the inner surface, joints and base plate. Mould was filled with concrete in three layers and each layer was subjected to a compaction of 25 strokes with a standard tamping rod. The top surface was finished using a trowel. Next day, the specimens were removed from the mould and subjected to air curing for 14 days.

The cubes were tested for compressive strength in the compression testing machine. Bearing surface of the testing machine was cleaned and dried. Cubes were placed such that the load was applied to the opposite side of the cube. Axis of the specimen was carefully aligned. Then the load was applied till the specimen was broken. Compressive strength was calculated. Similarly all the 5 cubes were tested for the same and the average compressive strength of the above 5 cubes were determined.

$$\text{Compressive strength of cube} = \frac{\text{maximum load}}{\text{area}}$$

The cylinders were tested for splitting tensile strength in the compression testing machine. Bearing surface of the testing machine was cleaned and dried. Central line was marked on the two opposite faces. Cylinder was placed positioning along the top and bottom of the plane of loading of the specimen Axis of the specimen was carefully aligned. Then the load was applied till the specimen was broken. Splitting tensile strength was calculated. Similarly all the 4 cylinders were tested for the same and the average splitting tensile strength was determined.

$$\text{Splitting tensile strength of cylinders} = \frac{2P}{\pi LD}$$

The beams were tested for flexural strength in the universal testing machine. Bearing surface of the testing machine was cleaned and dried. Axis of the specimen was carefully aligned with the axis of the loading device. Then the load was applied till the specimen brakes. Appearance of the fractured faces of concrete was noted. The distance between the line of fracture and the nearer support measured on the center line of the tensile side of the specimen was also calculated. Flexural strength was calculated. Similarly all the 4 beams were tested for the same and the average flexural strength was determined.

$$\text{Flexural strength of beam} = \frac{\text{Pl}}{\text{bdd}}$$

Table - 3.1
Physical Properties of Mangalore tile

Sl. No	*Property*	*Mangalore tile*
1	*Specific gravity*	*2.05*
2	*Water absorption*	*3.5%*

IV. RESULTS

A. *Compressive Strength of Cubes:*

Table - 4.1
Avg, compressive strength of cubes

– *Title*	– *% of replacement*	– *Avg compressive strength (N/mm^2)*
– – – – *Compressive strength of cubes*	– *0*	– *51.82*
	– *12.5*	– *75.20*
	– *25*	– *79.37*
	– *37.5*	– *63.55*
	– *50*	– *54.04*

Compressive strength of cubes was tested using compression testing machine. Five cubes were casted for each % replacement of coarse aggregate with Mangalore tile as per the procedure explained in IS: 516-1959. The mould shall be of 150 mm x 150 mms ize confirming to IS: 10086-1982.

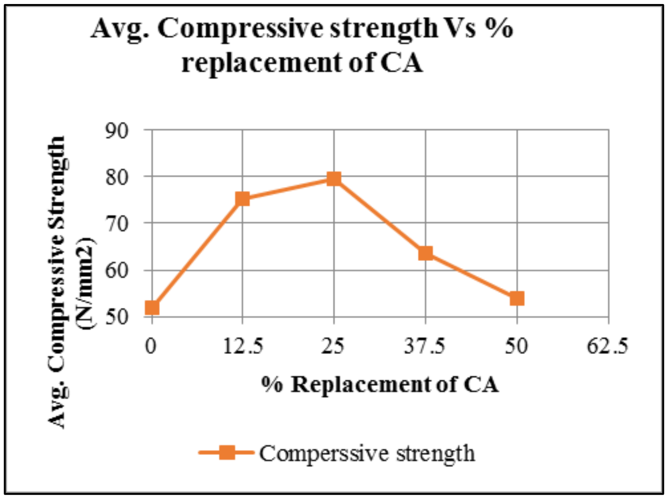

Fig. 4.1: Average Compressive strength Vs % replacement of CA

The compressive strength of each percentage replacement was determined. Replacement of coarse aggregate with Mangalore tile also showed significant increase in compressive strength compared to normal coarse aggregate with maximum value at 25%. The compressive strength at 25% replacement is increased by 53.16% than initial strength with 0% replacement. The strength at 50% replacement and 0% replacement are almost constant.

B. Split Tensile Strength of Cylinders:

Table - 4.2
Avg. split tensile strength of cylinders

Title	% of replacement	Avg split tensile strength (N/mm^2)
Split tensile strength of cylinders	0	3.22
	12.5	3.25
	25	3.43
	37.5	3.00
	50	2.90

Splitting tensile strength of cylinders was tested using compression testing machine. The bearing faces of both platens of the compression testing machine shall provide a minimum loading area of (12 mm x length of cylinder), so that the load is applied over the entire length of the specimen. The cylindrical mould shall be of 150 mm diameter and 300 mm height confirming to IS: 5816-1999.

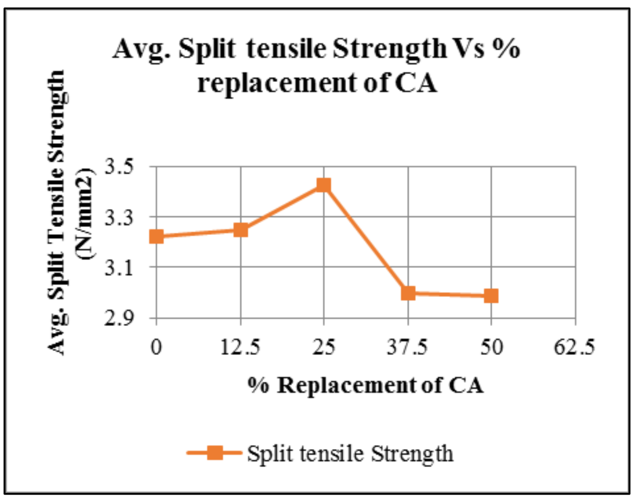

Fig. 4.2: Average split tensile strength Vs % replacement of CA

The Split tensile of each percentage replacement was determined. Replacement of coarse aggregate with Mangalore tile also showed increase in split tensile strength compared to normal coarse aggregate with maximum value at 25% .The compressive strength at 25% replacement is increased by 6.5% than initial strength with 0% replacement. The strength at 37.5% and 50% remains almost constant.

C. *Flexural Strength of Beams*

Table - 4.3
Avg. flexural strength of beams

Title	% of replacement	Avg flexural strength (N/mm^2)
flexural strength of beams	0	3.90
	12.5	4.00
	25	4.40
	37.5	4.20
	50	3.70

Flexural strength test was conducted on four beams for each replacement of coarse aggregate with Mangalore tile. Flexural strength is considered as an index of tensile strength of concrete. Beam tests are found to be dependable to measure flexural strength property of concrete. In a flexure test on a beam the theoretical maximum tensile stress reached in the bottom fibre of the test beam is known as Modulus of Rupture.

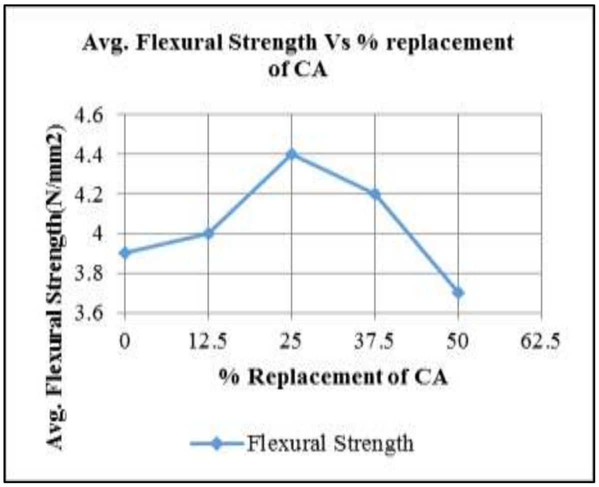

Fig. 4.3: Average flexural strength Vs % replacement of CA

The flexural strength of each percentage replacement was determined. Replacement of coarse aggregate with Mangalore tile also showed increase in flexural strength compared to normal coarse aggregate with maximum value at 25%. The compressive strength at 25% replacement is increased by 12.82% than initial strength with 0% replacement. There is a decremented decrease in strength from 37.5% to 50%.

V. CONCLUSION

The complete replacement of cement with GGBS was a success as the design mix of concrete is in between the range of M20 and M25 and the strength obtain was clearly greater than expected i.e. 50.78 N/mm2. The strength of concrete using GGBS shows significant increase when compared to conventional concrete. The maximum value of strength was obtained at 25% and this increase in strength can be due to the chemical reaction between the Mangalore tile and chemicals. The decrease in strength after 25% can be due to the lower specific gravity and higher water absorption of Mangalore tile compared to normal coarse aggregate. The compressive strength of proposed concrete was found to increase by about 50% when 25% replacement of coarse aggregate with Mangalore tile was done. Similarly the flexural strength and split tensile strength of concrete increased by 13% and 7% respectively. Further tests like permeability test, modulus of elasticity, NDT etc. can be done.
Some of the limitations observed during the project were:

- Rapid setting of concrete mix.
- Difficulty to handle chemical.
- High cost for the alkaline solution
- Safety risk associated with the high alkalinity of the activating solution.

Cost analysis of conventional concrete and proposed concrete was done. From the studies, the cost of proposed concrete with 25% replacement without considering chemicals is 53.67% less than that of the conventional concrete. Thus it is understood that the rate per cubic metre of Geopolymer concrete without using the chemicals is economical when compared with that of the conventional concrete. But because of the high cost of chemicals used there is an overall increase in the cost. The cost of proposed concrete with 25% replacement considering chemicals is 56.79% more than that of the conventional concrete. So in the future if we can produce the chemicals at a cheaper rate then we can make use of the concept of Geopolymer concrete, which will be economical and environmental friendly than the conventional concrete.

User-friendly Geopolymer concrete can be used due to the high early strength. Geopolymer Concrete shall be effectively used in the precast industries, so that huge production is possible in short duration and the breakage during transportation shall also be minimized. The Geopolymer Concrete shall be effectively used for the beam column junction of a reinforced concrete structure. Geopolymer Concrete shall also be used in the Infrastructure like pavement, retaining wall etc. In addition to that the GGBS can be effectively used and hence no landfills are required to dump the GGBS.

REFERENCES

[1] ParasS.Pithadiya and Abhay V. Nakum (2015) "Experimental study on geopolymer concrete by using ggbs" IRJET April-2015
[2] P.Vignesh and K.Vivek (2015) "An experimental investigation on strength parameters of flyash based geopolymer concrete with GGBS" IRJET May-2015
[3] Ganapati Naidu et Al.(2012) "A study on strength properties of geopolymer concrete with addition of G.G.B.S July 2012
[4] Shankar H. Sanni1 and R. B. Khadiranaika (2013) "performance of alkaline solutions on grades of geopolymer concrete "IRJET Nov-2013
[5] V. Supraja, M. KantaRao "Experimental study on Geo-Polymer concrete incorporating GGBS", International Journal of Electronics, Communication & Soft Computing Science and Engineering, Volume2, Issue 2.
[6] Madheswaran C, Gnanasundar Gopalakrishnan ,"Effect of molarity in geopolymer concrete", international journal of civil and structural engineering Volume 4, 2013.
[7] Kotresh K M, Anup D P, MesfinGetahunBelachew "Cost effective concrete by using mangalore tile wastages and iron ore slag".
[8] Material testing lab manual.
[9] IS 456:2000, IS 10262:2009