ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and :hnology (IJARTET)
Vol. 5, Special Issue 12, April 2018

EXPERIMENTAL STUDY ON GEOPOLYMER CONCRETE WITH GLASS FIBER

M.Tholkapiyan[1], A.Mohan[2]
1 Professor of civil engineering, Vel tech high tech Dr.Rangarajan Dr.Sakunthala engineering college,
2 Assistant professor of civil engineering, Vel tech high tech Dr.Rangarajan Dr.Sakunthala engineering college,
Email: m.tholkapiyan@gmail.com, drtholkapiyan@velhightech.com

Abstract— Geopolymer concrete (GPC) are representing the most promising green and eco-friendly alternative to Ordinary Portland cement (OPC). This paper presents results of an experimental program on the properties of Fibre Reinforced Geopolymer Concrete (FRGPC) such as compressive strength, split tensile strength, flexural strength. FRGPC contains flyash, alkaline liquids, fine aggregate, coarse aggregate and glass fibre. Alkaline liquid to fly ash ratio was fixed as 0.45 with 100% replacement of OPC. For alkaline liquid combination, ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5. The sodium hydroxide with 97-98% purity, in flake or pellet form has to be used. Glass fibre was added to the mix in volume fractions of 0.5%, 1.0%, and 1.5% by volume of concrete. Specimens were subjected to 24 hours of Heat curing at 80°C in heat curing chamber. Based on the test results, optimum % were formulated and compared it with conventional Concrete.

1. Introduction

1.1. general

Concrete is one of the vital materials for infrastructure development due to its versatile application, globally its usage is second to water. For last years, there are many concerns raised for the continuous increase of cement use because of the reasons that the production of cement causes large amount of carbon dioxide (CO_2) emission and it also consume significant amount of natural rock and minerals that may lead to deplete at one point of time.

The choice of source materials for making geopolymers depends on factor such as availability, cost, and type of application and specific demand of end users. Alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquids used in geopolymerisation are combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate

The geopolymer technology may reduce the total energy demand for producing concrete, lower the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80%, there by reducing the global warming. They possess the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and can serve as eco-friendly and sustainable alternative to ordinary Portland cement concretes.

1.2GEOPOLYMER

In 1978, Davidovits proposed that an alkaline liquid could be used to react with the silicon(Si) and the aluminium(Al) in a source material of geological orgin or in byproduct materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, coined the term geopolymer to represents these binders. Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous instead of crystalline. The polymerization process involves a

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 12, April 2018

substantially fast chemical reaction under alkaline condition on Si-Al minerals that result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.

1.3CONSTITUENTS OF GEOPOLYMER

1.3.1 Source Materials

Any material that contain mostly silicon (Si) and Aluminium(Al) in amorphous form is a possible source material for the manufacture of geopolymer. These could be natural minerals such as kaolinite, clays,by-product materials such as fly ash,silicafume,slag,rice-husk ash,redmud,etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability,cost,and type of application and specific demand of the end users.

a)Fly ash: Fly ash is a kind of coal ash produced from the combustion process in a coal power plant. Fly ash is a very fine, light dust which is carried off in the stack gases from a boiler unit and collected by mechanical or electrostatic methods.

According to the American Concrete Institute (ACI) committee 1116R, fly ash is defined as the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the partical removal system. Fly ash particals are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1µm to no more than 150 µm. The chemical composition is mainly composed of oxides of silicon (SiO_2), Aluminium(Al_2O_3), Iron (Fe_2O_3), and calcium (CaO), wheres magnesium, potassium, sodium, titanium, and sulphur are also present in lesser amount. The major influence on the fly ash chemical composition comes from the type of coal. The combustion of sub bituminous coal contains more calcium and less iron than fly ash from bituminous coal.

Fly ash that results from burning sub bituminous coals is referred to as ASTM Class C fly ash or high calcium fly ash as it typically contains more than 20 percent of CaO. On the other hand, fly ash from the bituminous and anthracite coal is referred to as ASTM Class F fly ash or low calcium fly ash. It consists of mainly an alumina-silicate glass, and has less than 10 percent of CaO .

Alkali and sulphate (SO_4) contents are generally higher in Class C fly ash. In the past, fly ash produced from coal combustion was simply entrained in the flue gases and dispersed into the atmosphere. This created environmental and health concerns that prompted laws which have reduced fly ash emission to less than 1 percent of ash produced. Worldwide , more than 65 percent of fly ash produced from coal power stations is disposed of in landfills and ash ponds.

1.3.2 Alkaline liquids

The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geo-polymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The type of alkaline liquid plays an importand role in the polymerization process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. Generally the NaOH solution caused a higher extent of dissolution of minerals than the KOH solution[9].

a)Sodium hydroxide solution(NaOH):

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate. The type and concentration of alkaline solution affect the dissolution of fly ash. Leaching of Al^{3+} and $Si4+$ ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution. Therefore , alkali concentration is a significant factor in controlling the leaching of alumina and silica from fly ash particles, subsequent geopolymerization and mechanical

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and :hnology (IJARTET)
Vol. 5, Special Issue 12, April 2018

properties of hardened geo-polymer. Sodium hydroxide (commercially grade with 98% purity) pellets, were dissolved in water to make the solution. When the concentration of sodium hydroxide solution was 10 molars. One litre of the solution contained 10x40=400 grams of sodium hydroxide pellets dissolved in one litre of water. Laboratory measurements have shown that the solution comprised 40.4% sodium hydroxide pellets and 59.6% water by mass.

(b) Sodium silicate solution(Na2SiO3):

This type of activator plays an important role in the geopolymerisation process. Reactions occur at a high rate when the alkaline activator contains soluble silicate ,either sodium or potassium silicate, compared to the use of only alkaline hydroxides. The addition of sodium silicate solution to sodium hydroxide solution as the alkaline activator enhanced the reaction between the source material and the solution. The sodium silicate activator dissolves rapidly and begins to bond fly ash particles. Open porosity can be observed and is rapidly filled with gel as soon as the liquid phase is able to reach the ash particles. The liquid phase is important as a fluid transport medium permitting the activator to reach and react with the fly ash particles.

1.4 GEOPOLYMER CONCRETE WITH GLASS FIBER AN OVERVIEW

The extensive research was carried out on the fly ash based geopolymer concrete with glass fiber. Fly ash based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The salient factor that influence the properties of the fresh concrete and the hardened concrete have been identified. The elastic properties of hardened concrete and the behavior and strength of reinforced structural members are similar to those of Portland cement concrete. Therefore , the design provisions contained in the current standards and codes can be used to design reinforced fly ash based geopolymer concrete structural members. The fly ash based geopolymer concrete also shows excellent resistance to sulfate attack, undergoes low creep, and suffers very little drying shrinkage.

Dody M. J.(2004) Sumajouw et al. In geopolymer concrete, a by-product material rich in silicon and aluminum, such as low-calcium (ASTM C 618 Class F) fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates, and other unreacted materials in the mixture.

Wallahet. el,(2006) investigated heat cured fly ash based geopolymer concrete undergoes low creep and very little drying shrinkage and it as excellent resistance to sulfate attack.

Yensheng et al,(2009) a PVA short fiber reinforced fly ash geopolymer composite manufactured by an extrusion technique was developed. This effect of fly ash and fiber on flexural behavior of SFRFGC was also investigated. To elucidate the difference in flexural behaviors of SFRFGC , a scanning electron microscope (SEM) technique was employed to explore the failure mechanism at microscopic scale.

Mazaheripour et al,(2010) found that applying 0.3% volume fractions of polypropylene fiber to the light weight. Self compacting concrete resulted in 40% reduction in the slump flow. They proved that by applying these fibers at their maximum percentage volume determine through this study , increased the tensile strength by 14.4% in the splitting tensile strength test , and 10.7% in the flexural strength.

Songa et al,(2010) investigations showed that at a fiber content of 0.6 kg/m3 Nylon fiber reinforced concrete exhibited higher compressive and splitting tensile strengths and modulus of rupture than of the nylon fiber concrete at a rate of 6.3%,6.7%, and 4.3% respectively over polypropylene fiber reinforced concrete.

Though the term, „geopolymer‟ has become now more common to represent the synthetic alkali aluminosilicate material (produced by reaction of a solid aluminosilicate with a

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 12, April 2018

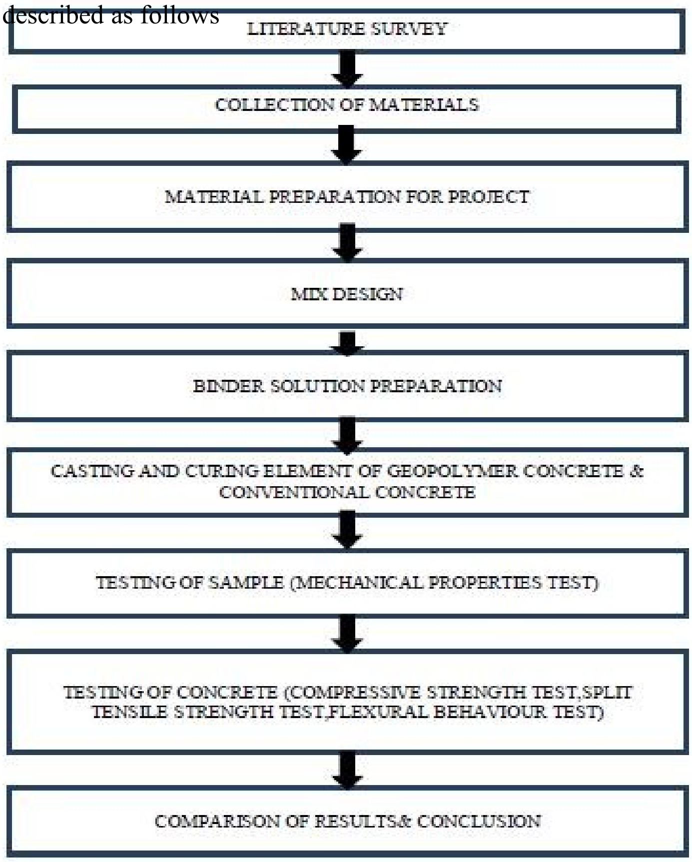
highly concentrated aqueous alkali hydroxide or silicate solution),

It is worthwhile to note that the following nomenclatures are also reported to describe similar materials:

- Inorganic polymer [Van Wazer, 1970]
- Low-temperature aluminosilicate glass[Rahier, 1996]
- Alkali-activated cement [Roy, 1999; Palomo, 2003;]
- Alkali-activated binders [Torgal, Gomes, and Jalali, 2008]
- Geocement [Krivenko, 1994]
- Alkali-bonded ceramic [Mallicoat, 2005]
- Inorganic polymer concrete [Sofi, 2006]
- Hydroceramic [Bao, 2005]
- Mineral Polymers[Davidovits, 1980]
- Inorganic polymer glasses[Rahier, 2003]
- Alkali ash material[Rostami, 2003]
- Soil cements [Glukhovsky, 1965]
- Alkali Activated Binder [Provis and Deventer, 2009],

1.5 METHODOLOGY

The methodology for the casting and testing of cubes are described as follows



MATERIALS AND THEIR PROPERTIES

1.5.1 Fly Ash

The fly ash used in this study was obtained from Neyveli Thermal power plant. It falls in the category of class C grade. Fly ash is one of the important substance which is required for the preparation of GPC. We can get this from the coal mine and from the production of cement. Fly ash can be classified in to two kinds, such as, class F and class C. In this project we use class C fly ash for the preparation of GPC. The physical properties of fly ash are determined as per IS:1727-1967.

1.5.2 Fine Aggregate

Locally available sand passing through 4.75 mm has to be used in this experimental work. The following properties of fine aggregates are determined as per IS:2386-1963.

1.5.3 Coarse Aggregate

The coarse aggregate passing through 20 mm and retaining 4.75 mm has to be used for experimental work. The following properties of coarse aggregate are determined as per IS:2386-1963.

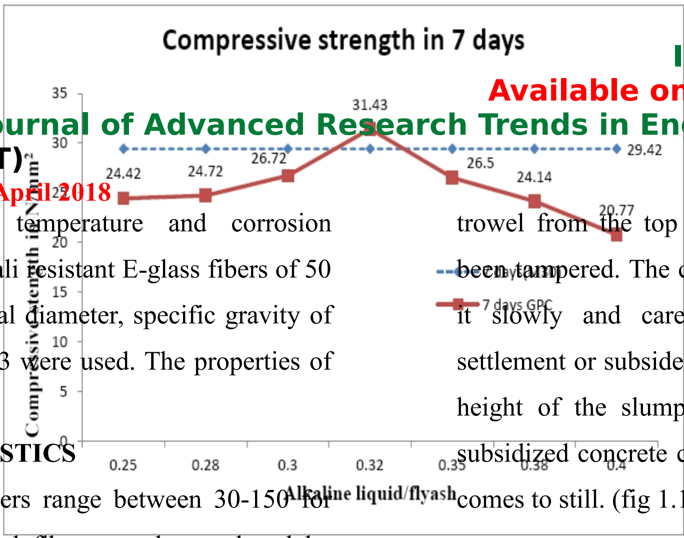
1.5.4 Alkaline Liquids

A combination of sodium silicate solution and sodium hydroxide solution has to be used as alkaline solution. The chemicalcomposition of sodium silicate solution are given in table.3.4. &3.5.The sodium hydroxide with 97-98% purity, in flake or pellet form has to be used. The solids must be dissolved in water to make a solution with required concentration.The concentration ofsodium hydroxide solution in range of 10M concentrations.

1.5.5 Glass fiber

Glass fibers are made of silicon oxide with addition of small amounts of other oxides. Glass fibers are characteristic for

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 12, April 2018



their high strength, good temperature and corrosion resistance, and low price. Alkali resistant E-glass fibers of 50 mm length, 0.014 mm nominal diameter, specific gravity of 2.6 and density of 2650 kg/m3 were used. The properties of glass fiber.

1.5.6FIBRE CHARACTERISTICS

The aspect ratio for steel fibers range between 30-150 for lengths 6-75 mm. Round steel fibers can be produced by chopping thin wires having dia between 0.25and1.0mm. Steel fibers having rectangular cross section are produced from slitting sheets about 0.25mm thick.

1.5.7 GLASS FIBRES

Glass fibers are available in continuous or chopped lengths. Fiber lengths of up to 3.5mm are used in spray applications and 25mm length in pre-mix applications. Glass fibers have high tensile strength (2-4 GPa) and elastic modulus (70-80 GPa) but have 2.5 - 4.8% elongation at break and low creep at room temperature.

1.5.8 Mixture proportion per m³ of geopolymer concrete with glass fiber

Ingredients	Quantity per m³
Alkaline liquid to fly ash ratio	0.5
Sodium silicate solution	160.72 kg/m³
Sodium hydroxide solution	64.28 kg/m³
Fly ash	450 kg/m³
Fine aggregate	678.84 kg/m³
Coarse aggregate	924.72 kg/m³
Glass fibre	5.02 kg/m³

1.6TEST RESULTS AND DISCUSSION

1.6.1. SLUMP CONE TEST

Concrete is prepared as per designed ratio. The freshly prepared concrete is filled in a clean slump cone in three successive layers. Each layer is tampered with 25 stokes by using a tamping rod. Excessive concrete is stricken off with trowel from the top of the mould after the final layer has been tampered. The cone is removed immediately by raising it slowly and carefully in the vertical direction .The settlement or subsidence (slump) (i.e. difference between the height of the slump mould and the highest point of the subsidized concrete cone). In cone is measured as soon as it comes to still. (fig 1.1)

figure 1.1 slump test value

MIX	W/C	SLUMP VALUE IN mm
M_{30}	0.375	0

MIX	ALKALINE LIQUID/FLY-ASH	SLUMP VALUE IN mm
1	0.25	4
2	0.28	7
3	0.3	9
4	0.32	10
5	0.35	13
6	0.38	15
7	0.4	18

1.6.2. COMPRESSION STRENGTH TEST

The size of steel mould 70.6 x 70.6 x 70.6 mm is well tightened and oiled thoroughly. The fresh mixed concrete is placed and well compacted. For 24 hours they were allowed for curing in Oven at 600C. The Nominal concrete mix is cured in water for different curing periods. The compression strength of concrete is determined at the age of 3, 7, 14, 28 days. After the curing period the specimen is taken out from the oven and then brought to room temperature in one hour. The specimen is placed vertically between the loading surface of the CTM and the load is applied till the specimen fails. The ultimate load at the time of failure is noted down. The load was applied at the rate of 140kg/cm2/min till the cube breaks.

Compression strength = Crushing load/Area in N/mm

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 12, April 2018

MIX	COMPRESSIVE STRENGTH IN N/mm^2			
	Specimen 1	Specimen 2	Specimen 3	Average
M_{30}	26.08	22.07	28.09	25.41
Al/F=0.25	12.07	8.05	12.07	10.73
Al/F=0.28	16.05	14.05	18.04	16.04
Al/F=0.30	20.06	20.06	18.06	19.40
Al/F=0.32	26.08	24.08	32.1	27.42
Al/F=0.35	16.05	18.06	20.06	18.06
Al/F=0.38	14.04	20.06	18.07	17.39
Al/F=0.40	16.06	14.04	18.07	16.06

figure 1.2 compression test value

1.7CONCLUSION

1.7.1 COMPRESSIVE STRENGTH

The compressive strength of geopolymer concrete with glass fiber cubes was tested at 7, 28 days of age after casting on standard compression testing machine as per IS: 516-1959. Each of the compressive strength test data corresponds to the mean value of the compressive strength of three test concrete cubes..

1.7.2 EFFECT OF SALIENT PARAMETERS

The following parameters which affect the compressive strength of geopolymer concrete were considered in this project:

a. Concentration of sodium hydroxide solution, in molar
b. Ratio of alkaline solution to fly ash, by mass.
c. Curing condition.

1.7.3 Concentration of sodium hydroxide(NaOH) solution

Various researchers revealed that the concentration of sodium hydroxide solution was one of the parameter which altered the compressive strength of concrete. Lower concentration of the activator was found to create a microstructure that was more porous than that in a paste using concentration of the activator. This shows that the use of more concentrated alkali increases the amount of reaction Product formation, consequently reduces the porosities and increases the compressive strength. Based on these facts, the concentration of sodium hydroxide solution was fixed as 10M in this project work.

1.7.4 Ratio of alkaline solution to fly ash

The alkaline solution to fly ash ratio mass as 0.5. The alkaline solution to fly ash ratio has considerable effect on the compressive strength of geopolymer concrete. The reason for increase in compressive strength was concluded by previous researchers as, in lower alkaline solution to fly ash ratios, only the glassy phases in fly ash were the source of Al and si to form alumino- silicate gel and also the reaction product was quickly formed that engulfs the fly ash particle and slowing down the further activation of the fly ash particles, thus resulting in only low to moderate degrees of reaction. However, in a higher alkaline solution to fly ash ratios the quartz and mullitephases in fly ash were completely dissolve and increases the amounts of reaction product formation thereby increases the compressive strength.

REFERENCES

[1]T. Alomayri.; I.M. Low.; "Synthesis and characterization of mechanical properties in cotton fiber-reinforced geopolymer composites," Journal of Asian Ceramic Societies (JAsCerS),science direct journal, Jan.-Feb. 2013, pp. 30-34.

[2]Zhang Yunsheng; Sun Wei; Zongjin Li; and Zhou Xiangming, "Geopolymer Extruded Composites with Incorporated Fly Ash and Polyvinyl Alcohol Short Fiber", ACI Material journal, V.106,No.1,Jan-Feb.2009.

ISSN2394-3777 (Print)
ISSN2394-3785 (Online)
Available online atwww.ijartet.com
International Journal of Advanced Research Trends in Engineering and
:hnology (IJARTET)
Vol. 5, Special Issue 12, April 2018

tali ;S. Manzia; M. C. Bignozzia;"Novel fiber-reinforced composite materials based on sustainable geopolymer matrix,", (JAsCerS), 2011, pp. 1124 – 1131.

[4] Benny Joseph ;George Mathew;"Influence of aggregate content on the behavior of fly ash based geopolymer concrete", (JAsCerS), (2012)V. 19 (5),PP. 1188–1194.

[5] Aaron Richard Sakulich; "Reinforced geopolymer composites for enhanced material greenness and durability," Sustainable Cities and Society ,science direct Journal, (2011),pp. 195– 210.

[6] Aminul Islam Laskar and RajanBhattacharjee; "Effect of Plasticizer and Super plasticizer on Rheology of Fly-Ash-Based Geopolymer Concrete," ACI Materials Journal, V. 110, No. 5, September-October 2013.

[7]BlessenSkariaThomas; Alexchristopher;"An experimental study on the properties of glass fiber reinforced geopolymer concrete", IJESRT Journal, (2012)V. 6 (5),PP. 1188–1194.

[8]A.Vignesh,A.R.Krishnaraj; "Study on Mechanical properties of Geo Polymer Concrete Using M-Sand and Glass Fibers," IJIRSET journal ,V.3,issue 6,(2014).

[9]A.R.Southararajan; "Reinforcing efficiency of glass fibres in low volume class F fly ash concrete,"JCECT Journal, V. 4, pp.184-191 june 2013.

[10] srinivasarao k. " comparative study on mechanical properties of geopolymers and their composites", APRN journal,V.8,issue 10,2013.

[11] Djwantorohardjito, Steenie E wallah, Dody M J sumajouw&vijayaRangan B –(2005) "Fly ash-based geopolymer concrete "-Australian journal of structural Engineering.vol 6 No.1 Page1-9.

