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Study on Strength Properties of E-Glass Fibre Reinforced Geopolymer Concrete Using Fly Ash and GGBS

P. Sarala¹, M. Vignesh²

Associate Professor, Department of Civil Engineering, Prathyusha Engineering College, Thiruvallur, India¹

M.E (Structural Engineering), Prathyusha Engineering College, Thiruvallur, India²

ABSTRACT: The use of supplementary cementitious materials as partial replacements for the cement in concrete will play a significant role with respect to the environmental control of greenhouse effects and global temperature reduction. The development of geopolymer concrete (GPC), in which all of the Portland cement is replaced with fly ash and ground granulated blast furnace slag (GGBS) in combination with sodium hydroxide and sodium silicate solutions, offers a promising alternative to ordinary Portland cement concrete. The objective of this project is to study the effect of glass fibre, fly ash (FA) and ground granulated blast furnace slag (GGBS) on the mechanical properties of geopolymer concrete (GPC) at different replacement levels of glass fibre (0%, 1%, 1.5% & 2%) fly ash 15% + GGBS 85%. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution have been used as alkaline activators. In the present investigation, it is proposed to study the mechanical properties viz. compressive strength, split tensile strength and flexural strength of fly ash and GGBS based geopolymer concrete. These properties have been determined at different curing periods like 7, 14, and 28 days at ambient room temperature.

KEYWORDS: Glass fibre, Cement, GGBS, Workability, Flexural & Compressive Strength, split tensile strength and deflection.

I. INTRODUCTION

In the today 's world, concrete plays an important role in the construction works like dams, buildings, roads etc. It is made with cement and other additives or aggregates are mixed. These additives are either natural or artificial, but the constant use of natural additives has lead to exhausting of this very important source. Thus, the use of alternative aggregate is a natural step towards solving part of the depletion of natural aggregate and the alternative aggregate processed from waste materials would appear to be a better solution. The search of the alternative material for concrete-making started much before more than half a century. The main objective of the reuse of material is to minimize the impact of human activities on the environment and the planet. Use of inorganic industrial by products in concrete-making will lead to sustainable concrete design. To produce environmentally friendly concrete, it is necessary to replace the cement with the industrial by products such as fly ash, GGBS etc. Disposal of FA is a growing problem, as only 15% of FA is currently used for high value addition applications like concrete and building blocks, the remaining being used for land filling. The SF increases the strength in case of hardened concrete. Another alternative but promising utility of SF in construction industry that has emerged in recent years is in Geopolymer concrete. Geopolymer technology can be appropriate process technology utilize all classes and grades of SF and therefore there is a great potential for reducing stockpiles of waste SF materials. The present study considers SF utilization in production of geopolymer concrete since it can accommodate a major portion of the ash produced.

II. LITERATURE REVIEW

Over the past several decades, extensive researches have been conducted on retrofitting/strengthening of RC structures using various FRP composites. The main purpose of literature review is to give an idea about the research work conducted in the world. This forms the basis on which one can carry out the work and techniques that can be used for conducting experiments. N. Manojkumar et al., (2016) carried out an experimental study on "Geopolymer concrete by using fly ash and ggbbs as a replacement of cement". Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large

infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with FLYASH and GGBS to decrease the usage of cement as well as emission of concrete. Experimental studies were performed on plain cement concrete and replacement of cement with Fly ash is done. In this study the concrete mix were prepared by using fly ash, sodium silicate, sodium hydroxide. A comparative analysis has been carried out for concrete to the Geopolymer concrete in relation to their compressive strength, split tension strength, acid resistance and water absorption. The concrete made with fly ash performed well in terms of compressive strength, split tension strength acid resistance and water absorption showed higher performance at the age of 7,14,28 days than conventional concrete. And also two different types of acid attack is done to determine the and compressive strength both on conventional concrete and geo polymeric concrete. J. Guru Jawaharet al., (2016)² carried out an “ Experimental study on fly ash and ggbs based geopolymer concrete in acid environment”. Geopolymer concrete (GPC) is becoming a sustainable concrete when comparing to ordinary Portland cement (OPC) concrete. This investigation is mainly focused on performance of fly ash (FA) and ground granulated blast furnace slag (GGBS) based GPC in acid environment. The compressive strength, weight and ultrasonic pulse velocity (UPV) values of GPC mixes (FA100-GGBS0; FA50-GGBS50; FA0-GGBS100) were determined after 28 days of immersion in 3% sulphuric acid (H₂SO₄). In this study, sodium silicate (Na₂SiO₃) and sodium hydroxide (NaOH) solution is used as alkaline activator. Specimens were cast and cured for different curing periods at ambient room temperature and then studied the performance of GPC in acid environment. Test results revealed that the increased level of GGBS increased the compressive strength and ultrasonic pulse velocity values of GPC at all curing periods. The percentage of reduction in weight, compressive strength and pulse velocity values is decreased with the increased replacement of GGBS.

III.METHODOLOGY

The methodology adopted in this study is discussed in this chapter. To achieve the objective of the study the following methodology has been adopted in this project.

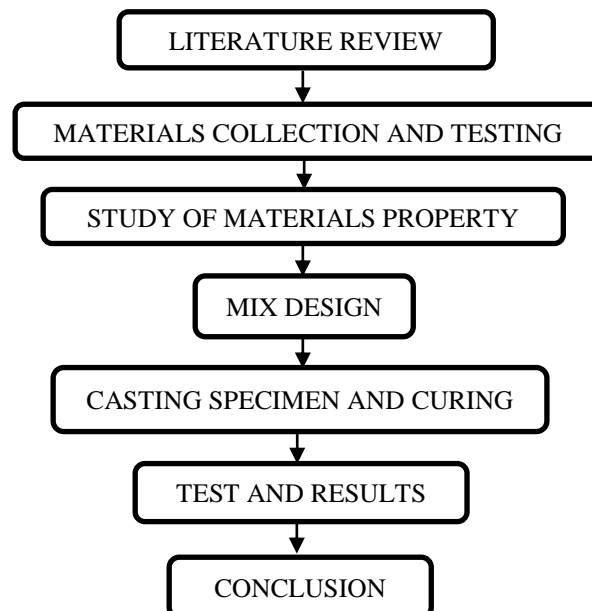


Fig 1.1 Methodology

IV. EXPERIMENTAL PROGRAM

A. Material Properties CEMENT

Cement is the most important ingredient and acts as a binding material (having adhesive and cohesive properties). Cement is obtained by pulverising clinker formed by clamping raw materials primarily comprising of liming (CaO), Silica (SiO_2), Alumina (Al_2O_3) and Ferric Oxide (Fe_2O_3) along with some minor oxides. Joseph Aspdin, a brick layer in England, developed Portland cement in 1824. Further developments lead to the present forms Portland cement exhibiting the variety of properties and suitable for variety of functional requirements of strength, durability, impermeability, and other dimensional constraints, cement when mixed with water forms a paste which sets and hardens under water and binds the aggregate together to produce a continuous compact mass. The characteristic behavior of this concrete mass in a given condition depends on the type, quality and quantity of cement. The Portland cement comprises of four principal compounds such as tri-calcium silicate. The composition of these principal components is affected by the proportions of basic raw material oxides. The actual proportions of these principles compounds affect the behavior of cement to cement and accordingly form the basis of classifying Portland cement into different types. Apart from variety of Portland cements, there are other special cements which are suitable under special conditions and structural requirements.



Fig 1.2 Ordinary Portland cement

Various physical properties of cement

- Fineness
- Setting and Hardening
- Strength
- Soundness
- Heat of Hydration
- The cement shall be used and the selected should be appropriate for the intended use:
- 53 Grade Portland pozzalano Cement confirming to IS: 8112.

FINE AGGREGATE

Fine aggregate is a naturally occurring granular material composed of finely divided rock and mineral particles. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic matter. Sand that have been sorted out and separated from organic materials by the action of currents of water or by winds across arid lands are generally quite uniform in size.

**Fig 1.3 Fine aggregate**

Usually, commercial sand is obtained from river beds or from sand dunes, originally by the action of wind. Fine aggregate are generally composed of quartz and other siliceous materials. Sand is used for making mortar, concrete and for polishing and blasting. Clear sand is employed for filtering water. The fine aggregates obtained from the river beds were used in this experimental program. The fine aggregate passing's through 4.75mm sieve were used.

Physical properties

The particle shape of the river sand used in this research was quite irregular in nature. The fine aggregate was brownish in its appearance for which the sieve analysis, specific gravity, water absorption tests were performed. The purpose of addition of river sand as fine aggregate is chiefly due to its inert nature on its addition to cement in concrete.

Table 1.1 physical properties of fine aggregate

PARAMETERS	FINE AGGREGATE
Particle shape	Irregular
Appearance	Brownish yellow
Type	River sand
Specific gravity	2.60
Water absorption %	1.5
Fineness modulus	2.73

COARSE AGGREGATE

As explained aggregate used for concrete production is classified as fine aggregate and coarse aggregate depending on its particle size. Aggregate of size more than 4.75mm, is called as coarse aggregate and is one of the most important ingredient of concrete. It gives strength to the concrete and constitutes about 70 to 75 percent volume of concrete. Crushed stone in general used as coarse aggregate which is black in colour, angular and local name known as black metal or, Gitti. Coarse aggregate is generally derived by crushing natural available. There are three varieties of rocks available.



Fig 1.4 Coarse aggregate

These are igneous rocks are fine grained, strong and dense formed by the cooling of parts of the bodies molten material which is called I general Basalt are more common igneous rocks. Aggregate developed by crushing of these rocks are black in colour and very common used for concrete work also known as black trap. Sedimentary rocks also called derivative rocks were deposited in some geological age mechanically through the agency of water, wind or ice action chemically or organically. These rocks cover about three quarters of the earth's land surface, sandstone is one of its types used in concrete production being hard and durable. Sandstone in the forms of strips is also used in slab construction. Metamorphic rocks are formed from igneous or sedimentary rocks. The igneous crust where they are upon by great heat and pressure because of these agencies rock are also partly or wholly changed and new is formed.

PHYSICAL PROPERTIES OF COARSE AGGREGATE

- Absorption, porosity, and permeability
- Surface texture strength and elasticity
- Density and specific gravity
- Aggregate voids
- Hardness
- Particle shape
- Coatings
- Undesirable physical components

GGBS

GGBFS was collected from Steel Company. Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500OC to 1600OC. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS).

SODIUM HYDROXIDE

Sodium hydroxide(NaOH) was collected from market with purity of 96%-97% The solution of NaOH was formed by dissolving it in water with different molarity. It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state.

SODIUM SILICATE

It is also known as water glass which is available in the market in gel form. The ratio of SiO₂ and Na₂O in sodium silicate gel highly affects the strength of geopolymer concrete. Mainly it is seen that a ratio ranging from 2 to 2.5 gives a satisfactory result. Chemical composition of sodium silicate is: Na₂O-14.7%, SiO₂-29.4% and Water -55.9% by mass.

ALKALINE LIQUID

According to Prof. J. Davidovits, the alkaline liquid should be made prior to one day before mixing because at the time of mixing of Na_2SiO_3 with NaOH solution it generates a huge amount of heat and the polymerization takes place by reacting with one another, which will act as a binder in the geopolymer concrete.

WATER

Although water is an important constituent of concrete, but it does not receive due attention in preparation and quality control of concrete. Strength and other properties of concrete are developed as a result of reaction cement and water (hydration) and thus water plays a critical role. Quality of mixing and curing water sometimes leads to distress and disintegration of concrete reducing the useful life of the concrete structure. Water used for concrete mixture should not contain substances which can have harmful effect of strength (i.e., on hydration process of 11 cement) or durability of the concrete in service. For evaluating the effect of using a water of questionable quality is to make comparative tests for time of set and soundness, and strength with water of doubtful quality and distilled water. Compressive strength test for performance of water in concrete shall be carried out on the 150 mm concrete cubes prepared with water proposed to be used. Average 28 days' compressive strength of 3 similar cubes prepared with distilled water. Initial setting time of test block made with proposed water and cement shall not be less than 30 minutes and not differ by ± 30 minutes from the initial setting time of control test block prepared with the same cement and distilled water.

B. EXPERIMENTAL RESULTS

Compressive strength

- For Glass fibre (0%), the compressive strength has increased to about 35.3 N/mm² from 34.3 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1%), the compressive strength has increased to about 36.2 N/mm² from 34.3 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1.5%), the compressive strength has increased to about 37.5 N/mm² from 34.3 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (2%), the compressive strength has increased to about 38.6 N/mm² from 34.3 N/mm² for M30 when compared to conventional concrete.

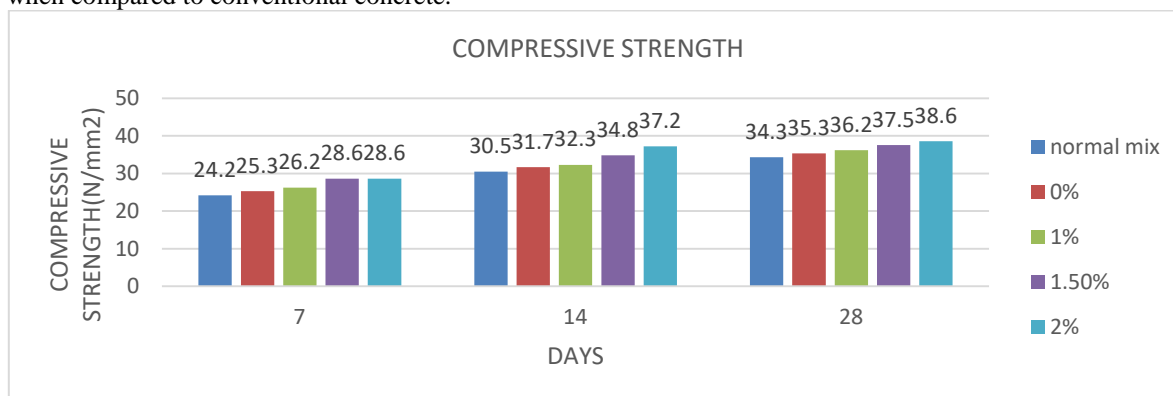


Fig 1.5 Chart for Compression strength test

Split tensile strength

- For Glass fibre (0%), the Split tensile strength has increased to about 4.10 N/mm² from 3.92 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1%), the Split tensile strength has increased to about 4.15 N/mm² from 3.92 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1.5%), the Split tensile strength has increased to about 4.23 N/mm² from 3.92 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (2%), the Split tensile strength has increased to about 4.45 N/mm² from 3.92 N/mm² for M30 when compared to conventional concrete.

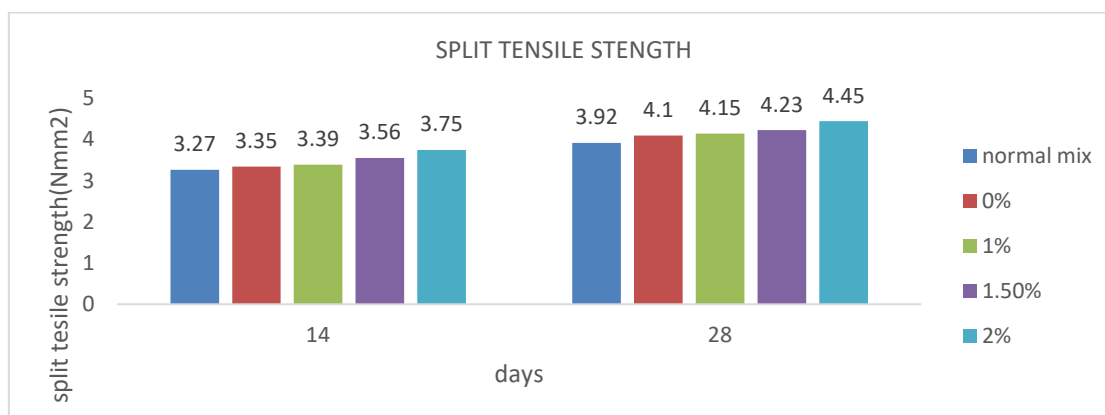


Fig 1.6 Chart for Split tensile strength

Flexural strength

- For Glass fibre (0%), the Flexural strength has increased to about 3.59 N/mm² from 3.53 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1%), the Flexural strength has increased to about 3.69 N/mm² from 3.53 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (1.5%), the Flexural strength has increased to about 3.85 N/mm² from 3.53 N/mm² for M30 when compared to conventional concrete.
- For Glass fibre (2%), the Flexural strength has increased to about 3.98 N/mm² from 3.53 N/mm² for M30 when compared to conventional concrete.

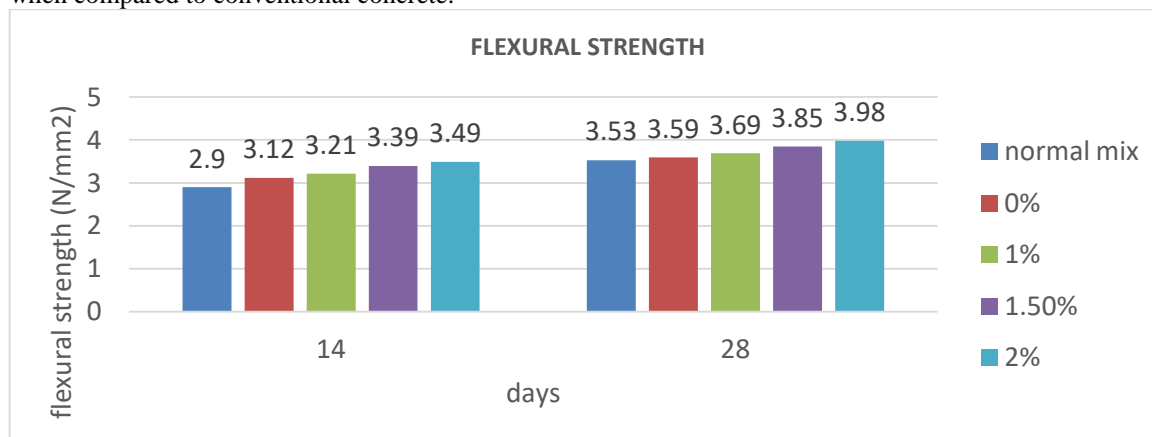


Fig 1.7 Chart for Flexural strength test

Deflection of beams

The gradient of the load-deflection relationship is an indication of beam stiffness. It may be seen in Figure that prior to cracking, the stiffness of the beams remained practically the same for the entire set of parameters and their ranges considered in this study. 2% glass fibre beams, demonstrated slightly smaller load is increased than the corresponding normal beam. The post cracking stiffness has been found to decreases in FAC beam specimens and with an increase in the amount of tension reinforcement with Bagasse ash beam. The effect of the amount of compression reinforcement or the spacing of stirrups in the flexural zone has practically no influence on beam stiffness. The maximum (mid span) deflection, (δ_s) obtained experimentally at the maximum load.

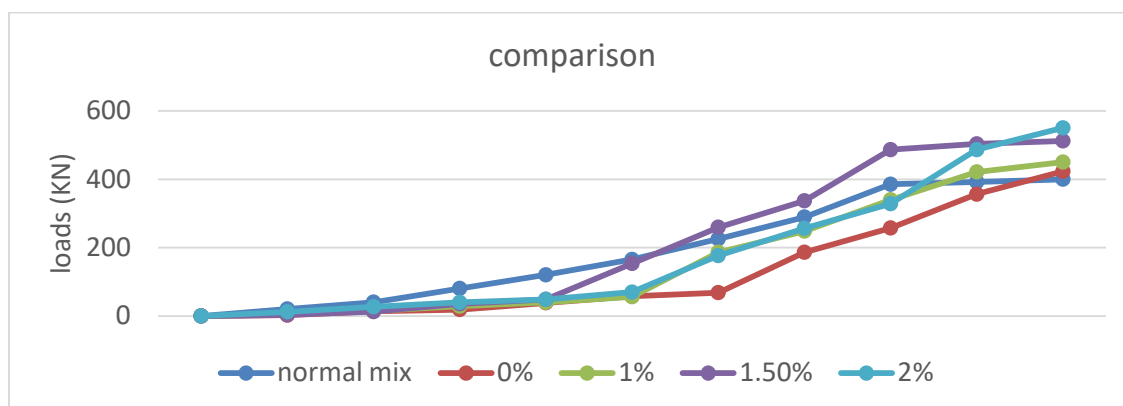


Fig 1.8 Comparison of load values of conventional beam & glass fibre beams

V. CONCLUSION

Based on the results obtained in the experimental investigation, the following conclusions are drawn. The geopolymer concrete gained strength within 24 hours at ambient temperature without water curing. The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix. The strength of geo polymer concrete was increased with increase in percentage of GGBS in a mix. Low-calcium fly ash-based geo polymer with glass fibre concrete has excellent compressive strength and is suitable for structural applications. Geo polymer concrete structural members are similar to those observed in the case of Portland cement concrete. The paper has identified several economic benefits of using geo polymer concrete. Based on the results reported in this investigation, the following conclusions are drawn. The compressive strength and split tensile strength of geopolymer concrete decrease with increasing FA content in the mix irrespective of curing periods. For a given proportion of a mix, the compressive strength and split tensile strength increase with age. The compressive strength and split tensile strength of geopolymer concrete is maximum for the 2.0% of E-Glass fibre (FA15-GGBS85) irrespective of curing period. The rate of gain in compressive strength and split tensile strength of geopolymer concrete is very fast at 7 days curing period and the rate gets reduces with age. Geopolymer concrete can be recommended as an innovative construction material for the use of construction.

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