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Experimental Investigation of Geopolymer Concrete Using Fly Ash and GGBS

Y. Dwaraka[1*], T. Naresh Kumar[2], S. Vinay Babu[3]

[1,2]Department of Civil Engineering, AITS Rajampet, Andhra Pradesh, India
[3]Department of civil Engineering, GPCET-Kurnool, Andhra Pradesh, India

ABSTRACT

This experimental study was undertaken to study the strength characteristics of Geo-polymer concrete. This experiment involves study to reduce the greenhouse gas emissions by implementing use of alternative material to cement. Five to eight percent of the world's man- made greenhouse gas emissions is from the cement industry itself. It is an established fact that the greenhouse gas emissions are reduced by 80% in Geo-polymer concrete compared to conventional Portland cement manufacturing, as it does not involve carbonate burns etc. Thus Geo-polymer based Concrete is highly environment friendly and the same time it can be made a high-performance concrete. In the present study, 100% replacement of conventional ordinary Portland cement is made by using ASTM class F fly ash, Ground granulated blast furnace slag and catalytic liquids (or AAS) to prepare Geo-polymer concrete mixes. In our present study we evaluated strength characteristics of Geo polymer concrete by varying the molar concentration (6M, 8M, and 10M) and varying percentage of binding material. The work has been done to structural specimen like cylinders and cubes and evaluated compressive, split tensile strength for different binding material proportions and solution concentration.

Keywords: Geo-polymer concrete, Fly ash, Ground Granulated Blast Furnace Slag (GGBS), alkaline activator, compressive strength, Split tensile strength.

I. INTRODUCTION

Geo-polymer is used as the binder, instead of cement paste, to produce concrete. The geo-polymer paste binds the loose coarse aggregates, fine aggregates and other un reacted materials together to form the geo-polymer concrete. The manufacture of geo-polymer concrete is carried out using the usual concrete technology methods. As in the Portland cement concrete, the aggregates occupy the largest volume, that is, approximately 75 to 80% by mass, in geo-polymer concrete. The silicon and the aluminium in the fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geo-polymer paste that binds the aggregates and other un-reacted materials synthesis of a geo-polymer usually involves mixing materials containing alumina silicates, such kaolin, fly ash, slag with alkali hydroxide, and alkali silicate solution, sometimes sodium carbonate in slag based systems.

A. Need for Alternate Concretes

Continuous technological upgrading and assimilation of latest technology has been going on in the cement industry. Presently, 93%of the total capacity in the industry in India is based on modern and environment friendly process technology and only 7% of the capacity is based on old wet and semi-dry process technology. There is a scope for waste heat recovery in cement plants and thereby reduction in emission level.

The cement production is highly energy insensitive next only to steel aluminium (also consumes significant amount of non-renewable natural sources such as lime stone deposits, coal, etc.). The EE of P-C being about 1.3Wh/kg is a very high quantity. A tonne of P-C production involves emission of about a tonne of CO_2, which is greenhouse gas causing global warming. More than 7% of the world CO_2 production is attributed towards production of P-C. Moreover, among the greenhouse gases, CO_2 contributes about 65% of global warming [McCaffery, 2002]. Therefore, the Portland cement industry does not fit the contemporary desirable picture of a suitable industry. There is an urgent need to find an alternate to P-C in order to make the construction industry eco-friendly. However, the new binder material should also possess satisfactory strength and durability characteristics which are comparable, preferably superior to those conventional concretes' (CCs) based on P-C.

B. Environmental Issues

Concrete is the most abundant construction material and Portland cement, a major component of concrete, is the largest volume of construction material produced in the world. The increasing demand of cement in the future will create environmental issues not only regarding the availability of the raw material (limestone) but also regarding CO_2 emissions and the need for large input of energy during the manufacture of Portland cement.

The production of Portland cement requires a large input of energy and at the same time produces a large quantity of CO_2 as a result of the calcinations reaction during the manufacturing process. calcinations of $CaCO_2$ to produce one tonne of Portland cement releases 0.53 tons of CO_2 into the atmosphere, and if the energy used in the production of Portland cement is carbon fuel then an additional 0.45 tons of CO_2 is produced. Therefore the production of one tonne of Portland cement produces approximately one tonne of CO_2 to atmosphere. On the other hand, the production of slag has been shown to release up to 80% less greenhouse emissions than the production of conventional Portland. While there are 80% to 90% less greenhouse gas emissions released in the production of fly ash. Therefore a 100% replacement of OPC with GGBS & fly ash would have a significant impact on the environment. However, from an environmental point of view: OPC contributes 5-8% of global CO_2 emissions

Necessity of geopolymer concrete:

Construction is one of the fast growing fields worldwide. As per the present world statistics, every year around 2600,000,000 Tons of Cement is required. This quantity will be increased by 25% within a span of another 10 years. Since the Lime stone is the main source material for the ordinary Portland cement an acute shortage of limestone may come after 25 to 50 years. More over while producing one ton of cement, approximately one ton of carbon di-oxide will be emitted to the atmosphere, which is a major threat for the environment. In addition to the above huge quantity of energy is also required for the production of cement. Hence it is most essential to find an alternative binder.

II. METHODS AND MATERIAL

Statement

Behavior of Geo-Polymer concrete Using Fly ash and GGBS M_{25} grade. The SCM's as fly ash & GGBS Complete replacement of cement for **7,** 14**,** 28 days water curing.

Fly Ash

Class F fly ash collected by electrostatic precipitator, obtained from thermal power corporation at RTPP muddanur kadapa district fly ash was used in the present study.. It may be observed that they appear as plain spherical particles of varying diameters. The surface of fly ash particles appears smooth and clean. Specific gravity= 2.21 India at present produces around 120 million tonnes of ash per annum. The power requirement of the country is rapidly increasing with increase in growth of the industrial sectors. India depend on thermal power as its main source (around 80% of power produced is thermal power), as a result the quantity of ash produced shall also increase. Indian coal on an average has 35% ash and this is one of the prime factors which shall lead to increased ash production and hence, ash utilization problems for the country. Out of the total ash produced, fly ash contributes to a small percent, majority being pond ash & bottom ash

GGBS (Ground granulated blast furnace slag):

Many researchers confirmed that GGBS had the ability to reduce the deleterious expansion caused by alkali aggregate reaction (AAR), especially when GGBS was used to replace Portland cement of high alkali content. Specific gravity = 2.20. Ground granulated blast furnace slag has been dried and ground to a fine powder. Iron ore, limestone, and coke are fed into the blast furnace where they reach a temperature of 1500 °C and the raw material reduced to molten iron and blast furnace slag. These are tapped off from the blast furnace and separated for processing. Molten iron is sent to the steel producing facility and slag (GGBS) is used to make concrete in combination with Portland cement. It is the glassy granular material formed when molten blast furnace slag is rapidly chilled as by immersion in water. The cementations action of a granulated blast furnace slag is dependent to large extent on the glass content. GGBS hydrates are generally found to be more gel like than the products of hydration of Portland cement, so it denses the cement paste.

Fine Aggregate:

The sand used in this investigation is ordinary river sand. The sand passing through 4.75 mm size sieve is used in the preparation of specimens. The sand conforms to grading Zone II as per IS: 383-1970. The properties of sand such as fineness modulus, water absorption and specific gravity were determined as per IS: 2386-1963. The sand used for the experimental program is locally procured and confirming to zone- The specific gravity of fine aggregate is found to be 2.60.The water absorption test on coarse aggregate is found to be 0.45%.

Natural Coarse Aggregate:

The coarse aggregate used in the investigation is 20 mm down size locally available crushed stone obtained from quarries. Specifications for coarse aggregate are included in IS: 383-1970. The physical properties have been determined as per IS: 2386-1963.The specific gravity of coarse aggregate is found to be 2.65. The water absorption test on coarse aggregate is found to be 0.29%.

Alkali Solution:

Sodium Hydroxide (NaOH) Molecular weight: 40.
Sodium Silicate (Na_2SiO_3) Molecular weight: 122.

Alkaline Activators : A mixture of sodium hydroxide and sodium silicate solution was chosen in the present study as alkali activators. Commercial grade sodium hydroxide in pallets (purity 97%; specific gravity 2.13) and sodium silicate solution (Na_2O = 18.2%, SiO_2 = 36.7%, water = 45.1%; specific gravity=1.53) were used to prepare the solution. The mass of NaOH pallets in a solution varied according to molar strength M.

Super-Plasticizer

Conplast SP-430 is a superplasticizing admixture. Conplast SP-430 is a based on sulphonated naphthalene polymers and is supplied as a brown liquid instantly dispersible in water. Conplast SP-430 has been specially formulated to give high water reductions unto 25% without loss of workability and produce high quality concrete of reduced permeability. The mix design procedure adopted to obtain a M25 grade concrete is in accordance with IS 10262- 2009. The specific gravities of the materials used are as tabulated in the table.

TABLE I
Specific gravities of materials used

Material	Specific gravity
Flyash	2.29
GGBS	2.95
Fine aggregate	2.60
Coarse aggregate	2.65

As in the Portland cement concrete, the aggregates occupy the largest volume (about 75-80% by mass) in GPCs. The silicon and aluminum in the fly ash and GGBS are activated by the combination of sodium hydroxide and sodium silicate. The strength of cement concrete is known to be well related to its water cement ratio, such as simplistic formulation may not holds good for GPCs. Therefore the formulation of GPCs has to be done by trial and error basis.

TABLE II
Mix proportion with molarities

Molarity	6M	8M	10M
Fly ash + GGBS kg/m^3	466	466	466
Alkali solution / binder ratio	0.5	0.5	0.5
Alkali solution kg/m^3	233	233	233
Fine aggregate kg/m^3	805.16	805.16	805.16
Coarse aggregate kg/m^3	805.16	805.16	805.16
Super plasticizer %	0.4	0.4	0.4

TABLE III

The mix proportion obtained is as shown in the table.

Alkali solution binder ratio	FA+GGBS	Fine aggregate	Coarse aggregate	Super plasticizer
0.5	466	805.16kg/m^3	805.16kg/m^3	0.4%
	1	1.72	1.72	

III. RESULTS AND DISCUSSION

Comparision Between 6M, 8M, 10M Compressive Strength For 50-50% Fly Ash & GGBS ratio

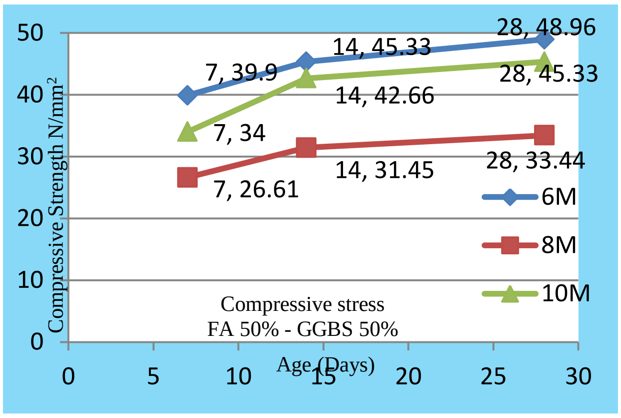

Figure 1: Compressive strength graphs for 50% Flyash-50% GGBS

The comparison graph shows in above Fig the compressive strength of cubes shows for different molarities. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing.

Comparision between 6M, 8M,10M compressive strength for 20-80% fly ash & GGBS ratio

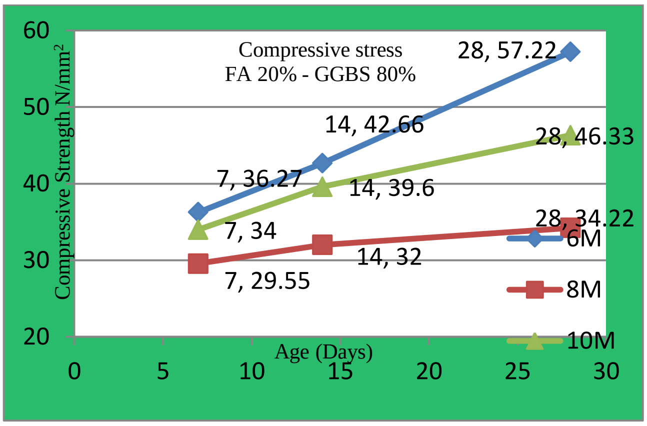

Figure 2 : Compressive strength graphs for 20% Flyash-80% GGBS

The comparison graph shows in above the Fig compressive strength of cubes shows for different molarities for 20-80% FA and GGBS. By increasing GGBS quantity we can achieve more strength. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing.

Comparison between 6M, 8M, tensile strength For 50-50% Fly Ash & GGBS ratio

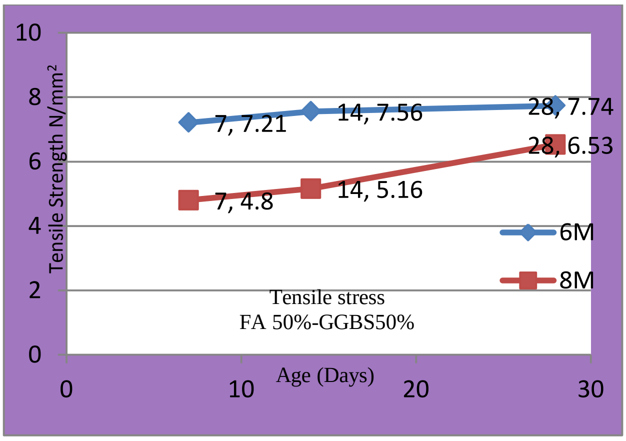

Figure 3: Tensile strength graphs for 50% Flyash-50% GGBS

The comparison graph shows in above Fig the tensile strength of cylinder shows for different molarities. For water curing of specimens 6M which gives less strength compare to the other 8M solutions. The maximum strength achieve within 7 days curing.

Comparision between 6M, 8M, Tensile Strength For 20-80% Fly Ash & GGBS ratio

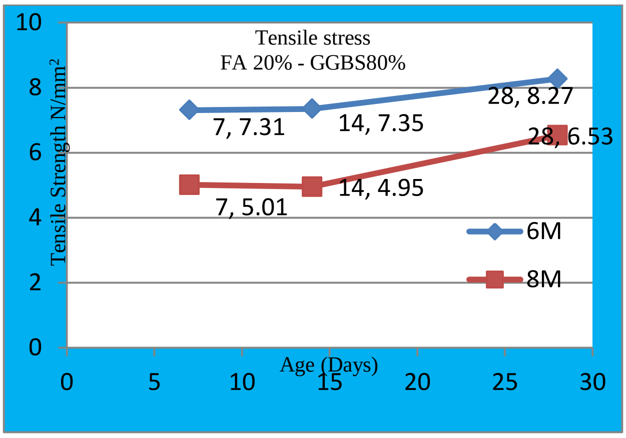

Figure 4 : Tensile strength graphs for 20% Flyash-80% GGBS

The comparison graph shows in above Fig 4 tensile strength of cylinders shows for different molarities for 20-80% FA and GGBS . By increasing GGBS quantity we can achieve more strength. For water curing of specimens 8M which gives more strength compare to the other 6M solutions. The maximum strength achieve within 7 days curing. On Geo-polymers, a rigorous trial-and-error method was adopted to develop a process of manufacturing fly ash-based geo-polymer concrete following the technology currently used to manufacture Ordinary Portland Cement concrete. After some failures in the beginning, the trail-and-error method yielded successful results with regard to manufacture of low-calcium (ASTM Class F) fly ash and GGBS- based geo polymer concrete. The comparison graph shows in Fig 1 and 2 the compressive strength of cubes shows for different molarities. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing.

The comparison graph shows the Fig 2 compressive strength of cubes shows for different molarities for 20-80% FA and GGBS. By increasing GGBS quantity we can achieve more strength. For water curing of specimens 6M which gives more strength compare to the other 8M and 10M solutions. The maximum strength achieve within 7 days curing.

Rheological properties of the fresh GPC are dependent on the type and the contents of the materials used in the mixture. As compared with the conventional Portland cement concrete mixes, GPC mixtures exhibit a different rheological behavior. The geo-polymer concrete gains about 60-70% of the total compressive strength within 7 days.

The Geo-polymer concrete showed high performance with respect to the strength. The Geo-polymer concrete was a good workable mix. High early strength was obtained in the Geo-polymer concrete mix. The increase in percentage of GGBS increased the compressive strength up to the optimum level. This may be due to the high bonding between the aggregates and alkaline solution. The compressive strength was found reduced beyond the optimum mix. This may be due to the increase in volume of voids between the aggregates.

Geo-polymer concrete is an excellent alternative solution to the CO_2 producing port land cement concrete. Low-calcium fly ash-based geo-polymer concrete has excellent compressive strength within a day and is suitable for structural applications. The price of fly ash-based geo-polymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete.

IV. CONCLUSION

User-friendly geo-polymer concrete can be used under conditions similar to those suitable for ordinary Portland cement concrete. These constituents of Geo-polymer Concrete shall be capable of being mixed with a relatively low-alkali activating solution and must be curable in a reasonable time under ambient conditions. The production of versatile, cost-effective geo-polymer concrete can be mixed and hardened essentially like Portland cement. Geo-polymer Concrete shall be used in repairs and rehabilitation works. As the GPCs do not contain any Portland cement, they can be considered as less energy intensive (i.e., low Embodied energy') apart from less energy intensiveness the GPCs Utilize the industrial waste for producing the binding system in concrete. Compressive strength for 6M is more, compared to 8M and 10M. While Morality of solution decreases the strength is increases for water curing 70 to 80% of the strength are gain with in 7days. The increase in GGBS quantity increases the strength. The split tensile strength is more in 8M compared to 6M. User-friendly geo-polymer concrete can be used under conditions similar to those suitable for ordinary Portland cement concrete. These constituents of Geo-polymer Concrete shall be capable of being mixed with a relatively low-alkali activating solution and must be curable in a reasonable time under ambient conditions. The production of versatile, cost-effective geo-polymer concrete can be mixed and hardened essentially like Portland cement.

V. REFERENCES

[1]. M. I. Abdul Aleem P. D. Arumairaj : GEOPOLYMER CONCRETE- A REVIEW (page no 118-122 International Journal of Engineering Sciences & Emerging Technologies 2012)

[2]. R. Anuradha, V.Sreevidya, R Venkatasubramani & B V Rangan: Relationship between compressive and tensile strength of geopolymer concrete. (Page no 18-23 The Indian concrete journal 2011).

[3]. B.V Rangan, Djwantoro Hardjito, Steenie E.: Studies on of fly ash based geopolymer concrete.(Page 133-137 Curtain University of technology).

[4]. Pratap Kishanrao: Design of Geopolymer concrete (Page no 1841-1844 international journal of innovative research in science. 2013).

[5]. Ganapati Naidu. P, A. S. S. N.Prasad, S. Adiseshu, P. V. V.Satayanarayana: A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S (page no 19-28 International Journal of Engineering Research and Development 2012).

[6]. K. Vijai, R. Kumutha and B. G. Vishnuram: Effect of types of curing on strength of geopolymer Concrete(page no 1419-1423 International Journal of the Physical Sciences, 2010).

[7]. Collins (1988) & James Aldred and John Day : IS Geopolymer concrete a suitable alternative to traditional concrete? (37th Conference on Our World in Concrete & Structures 29-31 August 2012, Singapore.

[8]. Shankar H. Sanni1, Khadiranaikar, R. B: Performance of geopolymer concrete under severe environmental conditions (page no 396 – 407 International journal of civil and structural engineering Volume 3, No 2, 2012).

[9]. Djwantoro Hardjito, Steenie E. Wallah, Dody M. J. Sumajouw, and B.Vijaya Rangan : On the Development of Fly Ash-Based Geo-polymer Concrete (Page no 467 – 472, ACI Materials Journal/November-December 2004).