International Journal on Applications in Civil and Environmental Engineering
Volume 2: Issue 3:March 2016, pp 14-18. www.aetsjournal.com ISSN (Online) : 2395 - 3837

Experimental Investigation on Replacement of GGBS for Fly Ash in Steel Fibre Reinforced Geopolymer Concrete (SFRGPC)

Y.Emilius Sebastina Antony

Abstract— Considering the increasing demand for developing alternative construction materials due to growing environmental concerns. Carbon di oxide has encouraged searching for sustainable building materials. Geopolymer concrete is obtained from the industrial waste fly ash and GGBS which are eco friendly alternative to Ordinary Portland Cement (OPC) based concrete. Here the geopolymer concrete is added with Crimpled Steel Fibres this type of concrete is known as Steel Fibre Reinforced GeoPolymer Concrete (SFRGPC). Fibres are added to the mix in the 1.5% by the volume of concrete. A mix proportion for SFRGPC was designed and carried out test for M_{30} grade of concrete. The compressive strength, tensile , flexural strength of SFRGPC have studied and compared with OPC. Here the SFRGPC is kept under normal water curing and sea water curing the strength is checked in the following investigation .Here the concrete is made of GGBS which results 75% reduction in CO_2 emission compared to OPC although alkaline solution to some extent pollutes the environment.

Keywords: GGBS ,Geopolymer concrete, Crimpled Steel Fibres, alkaline solution.

I. INTRODUCTION

The emission of CO_2 coupled with non absorption of the same on account of deforestation has tremendous environmental pollution leading to global warming and other bad effects. It is estimated that about 7% of green house is being emitted into the atmosphere annually on account of production of OPC alone. Therefore to reduce the emission of the CO_2 into atmosphere by reducing the cement production and consumption.

The demand for Portland cement is increasing day by day and hence, efforts are being made in the construction industry to address this by utilizing supplementary materials and developing alternative binders in concrete; the application of geopolymer technology is one such alternative. The abundant availability of fly ash worldwide creates opportunity to utilize this by product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate.

Y.Emilius Sebastina Antony , M.E.Structural Engineering, Department of Civil Engineering, New Prince Shri Bhavani College of Engineering and Technology.

Palomo et al (1999) suggested that pozzolans 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. Hence, in this paper an effort is made to identify and study the effect of salient parameters that affects the properties of low-calcium fly ash-based geo-polymer concrete and the properties of concrete at varied concentrations of alkali solutions and how the change in temperature affects the strength characteristics.

II. GEOPOLYMER CONCRETE

Geopolymer is a term covering a class of synthetic alumino-silicate materials with potential use in a number of areas, essentially as a replacement for Portland cement and for advanced hightech composites, ceramic applications or as a form of cast stone. The name Geo-polymer was first applied to these materials by Joseph Davidovits in the 1970s, although similar materials had been developed in the former Soviet Union since the 1950s, originally under the name "soil cements". However, this name never found widespread usage in the English language, as it is more often applied to the description of soils which are consolidated with a small amount of Portland cement to enhance strength and stability.

III. GEOPOLYMER CONCRETE PROPERTIES

High early strength gain is a characteristic of geopolymer concrete when dry-heat or steam cured, although ambient temperature curing is possible for geopolymer concrete. It has been used to produce precast railway sleepers and other pre-stressed concrete building components. The early-age strength gain is a characteristic that can best be exploited in the precast industry where steam curing or heated bed curing is common practice and is used to maximize the rate of production of elements.

Recently geopolymer concrete has been tried in the production of precast box culverts with successful production in a commercial precast yard with steam curing. Geopolymer concrete has excellent resistance to chemical attack and shows promise in the use of aggressive environments where the durability of Portland cement concrete may be of concern. This is particularly applicable in aggressive marine environments, environments with high carbon dioxide or sulphate rich soils. Similarly in highly acidic conditions, geopolymer concrete has shown to have superior acid resistance and may be suitable for applications such as mining,

International Journal on Applications in Civil and Environmental Engineering
Volume 2: Issue 3:March 2016, pp 14-18. www.aetsjournal.com ISSN (Online) : 2395 - 3837

some manufacturing industries and sewer systems. Commercial geopolymer sewer pipes are in use today.

IV. PROPERTIES OF GEO-POLYMER CONCRETE

Geopolymer are inorganic binders, which are identified by the following basic properties:

Compressive strength depends on curing time and curing temperature. As the curing time and temperature increases, the compressive strength increases.

Resistance to corrosion since no limestone is used as a material, Geopolymer cement has excellent properties within both acid and salt environments. It is especially suitable for tough environmental conditions. Geopolymer specimens are possessing better durability and thermal stability characteristics.

V. MATERIALS AND ITS CHARACTERISATION

1) GGBS (Ground Granulated Blast Furnace Slag):

Ground granulated blast furnace slag is another important mineral admixture like fly ash a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a gassy sand like granulated material. The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 m^2/kg (blaine)

The chemical composition of blast furnace slag (BFS) is similar to that of cement clinker.

GGBS

2) COARSE AGGREGATE:

Machine crushed granite obtained from a Local Quarry was used as coarse aggregate. Its properties are tested as per IS 383:1970

3) FINE AGGREGATE:

Sand confirming to zone III as per IS: 383 were used as fine aggregate for the tests conducted. Locally available river sand having specific gravity of 2.74 was used as fine aggregate for Geopolymer concrete mixes.

4) ALKALINE LIQUID:

The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide. The use of a single alkaline activator has been reported (Palomo et al. 1999; Teixeira-Pinto et al. 2002), Palomo et al (1999) concluded that the type of alkaline liquid plays an important 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. Xu and van Deventer (2000) confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution. Furthermore, after a study of the geo-polymerization of sixteen natural Al-Si minerals, they found that generally the NaOH solution caused a higher extent of dissolution of minerals than the KOH solution.

5) SODIUM HYDROXIDE

Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our Geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used. Whose physical and chemical properties are given by the manufacturer is shown in Table 1 and 2.

Sodium Hydroxide

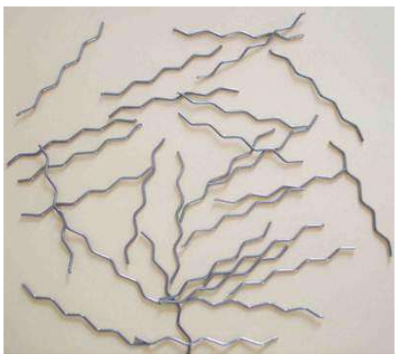
6) SODIUM SILICATE

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na_2O to SiO_2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of Geopolymer concrete.

Sodium Nitrate

7) STEEL FIBRES

Use of crimped steel fibres of aspect ratio (l/d) 50 is used. For the geopolymer mix we have used crimped stainless steel fibers and crimps mild steel fibres. The use of fibres in concrete has the property to resistance against cracking and crack propagation. The fibre composite pronounced post cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied shock or impact loading. These fibres are short, discrete lengths having an aspect ratio in the range of 20-100, with any cross section that are sufficiently small to be randomly dispersed in an unhardened concrete mixture using usual mixing procedures.



Crimpled Steel Fibre

VI. EXPERIMENTAL INVESTIGATION PREPARETION OF ALKALINE LIQUID

1) ALKALINE LIQUID

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react i.e. (polymerization takes place) it liberate large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent.

2) MOLARITY CALCULATION

The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution.

For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 grams of NaOH solids per liter of the water, were 40 is the molecular weight of NaOH.

[Note that the mass of water is the major component in both the alkaline solutions.]

The mass of NaOH solids was measured as 444 grams per kg of NaOH solution with a Concentration of 16 Molar. Similarly, the mass of NaOH solids per kg of the solution for other. A concentration was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, and 14 Molar: 404 grams.

VII. RESULT AND CONCLUSION

1) FRESH CONCRETE PROPERTIES

The fresh geopolymer concrete had a stiff consistency and is glossy in appearance. Workability tests such as slump test were employed for finding the fresh concrete properties. The results of slump test are presented in Table 9. Slump of fresh SFRGPC were measured using slump cone as per IS: 1199-1959(reaffirmed 2004). The slump values were decreased when the value of V_f was increased. It may be noted from Table 9 that as the volume fraction of fibres increases, the workability decreases considerably. Test was conducted as per IS: 1199-1959(reaffirmed 2004) and the results are shown in table.

Slump Cone Test

Slump Test Values

Vf (%)	SLUMP (mm)
0	123
0.25	110
0.5	90
0.75	85
1	77

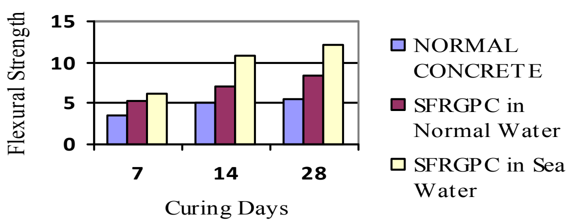
2) COMPRESSIVE STRENGTH

Compressive strength is one of the important properties of concrete. Concrete cubes of size 150mmx150mmx150mm were cast with conventional and SFRGPC. After 24 hours, the specimens were remolded and subjected to water curing. After 7,14,28 days of curing specimens were taken and allowed to dry and tested in compressive strength testing machine.

S. No		Strength Of Conventional Concrete kN/mm^2	Strength of SFRGPC in Normal Water Curing kN/mm^2	Strength of SFRGPC in Sea Water Curing kN/mm
1.	7 DAYS	21.17	32.72	36.56
2.	14 DAYS	26.78	37.54	40.87
3.	28 DAYS	32.24	41.33	43.15

Compressive Strength on Cube

Comparative Compressive Strength



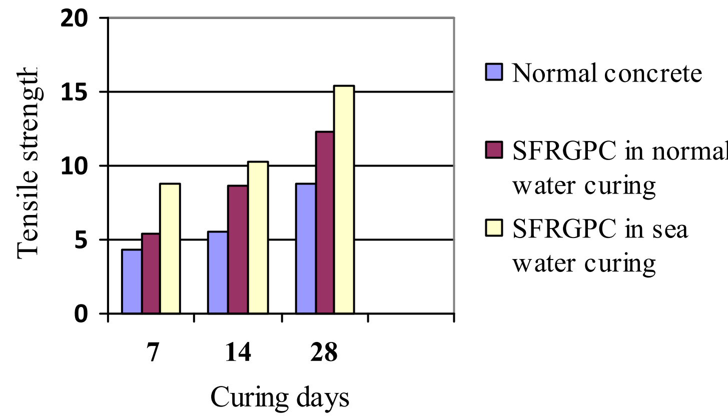
3) SPLIT TENSILE STRENGTH

Split tensile strength is indirect way of finding the tensile strength of concrete by subjecting the cylinder to a lateral compressive force. Cylinders of size 150mm diameter and 300mm long were cast with conventional and SFRGPC. After 24 hours the specimen were remolded and subjected to water curing. After 7,14,28 days of curing of specimens were taken and allowed to dry and tested in universal testing machine by placing the specimen horizontal

Split Tensile Comparative Strength for Conventional to SFRGPC

S.No		Strength Of Conventional Concrete kN/mm^2	Strength of SFRGPC in Normal water curing kN/mm^2	Strength of SFRGPC in sea water curing kN/mm^2
1.	7 DAYS	4.32	5.38	10.52
2.	14 DAYS	5.58	8.63	12.23
3.	28 DAYS	8.74	10.26	15.34

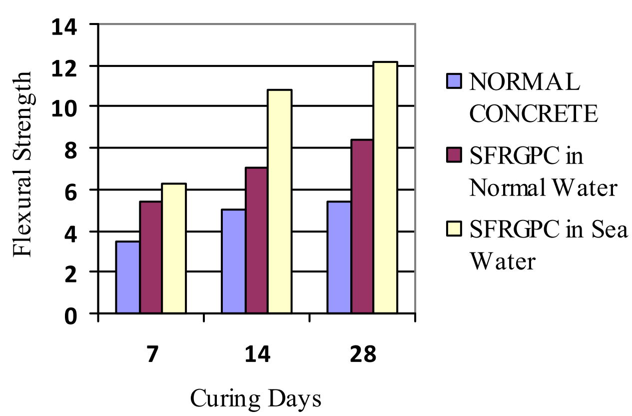
Split Tensile Comparative Strength



4) FLEXURAL STRENGTH

The results of flexural strength of concrete at the age of 28 days are presented . The variations in flexural strength at the age of 28 days.From the test results, it was observed that when the SFRGPC is kept in curing of normal water and sea water the flexural strength of concrete also increases.

S.No.		Strength Of Conventional Concrete kN/mm^2	Strength of SFRGPC in Normal water curing kN/mm^2	Strength of SFRGPC in sea water curing kN/mm^2
1.	7 DAYS	3.51	5.38	6.27
2.	14 DAYS	5.06	7.04	8.44
3.	28 DAYS	5.42	10.85	12.13



VIII. CONCLUSION

Based on the investigation of the engineering properties of steel fibre reinforced geopolymer concrete, following conclusions were arrived at,

- Geopolymer concrete is an excellent alternative to Portland cement concrete.
- Density of Geopolymer concrete is similar to that of ordinary Portland cement concrete.
- Inclusion of steel fibres in Geopolymer concrete shows considerable increase in compressive & flexural strength of GPCC with respect to GPC without fibres.
- Compressive strength & Flexural strength of steel fibre reinforced geopolymer concrete increases with respect to increase in percentage volume fraction of steel fibres.
- The compressive strength of GPC improves slightly with the addition of steel fibres at various volume fractions.
- The strength models developed for SFRGPC predicts the compressive strength, splitting tensile strength, modulus of rupture and modulus of elasticity satisfactorily.
- Geopolymer concrete produces a substance that is comparable to or better than traditional cements with their properties.
- Due to geopolymer concrete the consumption of cement, emission of carbon di -oxide and greenhouse effect are reduced.
- Strength increases when the specimens are kept in sea water curing than the normal water curing and so the concrete which is made up of GGBS is suitable for severe condition.

REFERENCES

[1] ACI Committee 318 (2008), Building Code Requirements for Structural Concrete, American Concrete Institute, Farmington Hills, MI.
[2] ACI Committee 363 (1992), State of the Art Report on High-Strength Concrete, American Concrete Institute, Detroit, USA.
[3] P. C. and P. K. Mehta (1990), "Effect of Coarse-Aggregate Characteristics on Mechanical Properties of High-Strength Concrete", ACI Materials Journal 87(2): 103-107.
[4] Barber, S. (2010), Final Year Project Report, Curtin University (private communication).
[5] Chang, E. H. , Sarker, P, Lloyd, N and Rangan, B.V. (2007), "Shear behavior of reinforced fly ash based Geopolymer concrete beams", Proceedings of the23rd Biennial Conference of the Concrete Institute of Australia, Adelaide, Australia, pp 679 – 688.
[6] Cheema, D.S., Lloyd, N.A., Rangan, B.V. (2009), "Durability of Geopolymer A Green Alternative", Proceedings of the 34th Conference on Our World in Concrete and Structures, Singapore.
[7] Collins, M. P., D. Mitchell, J.G MacGregor (1993), "Structural Design Considerations Hfor High Strength Concrete", ACI Concrete International 15(5): 27-34. Committee BD-002 Standards Australia (2009), Concrete Structures: Australian Standard AS3600- 2009, Standards Australia.
[8] Davidovits, J (1988) "Soft Mineralogy and Geopolymers", Proceedings of the of Geopolymer 88 International Conference, the Université de Technologie, Compiègne, France.
[9] Davidovits, J (1994) "High-Alkali Cements for 21st Century Concretes. in Concrete Technology, Past, Present and Future", Proceedings of V. Mohan Malhotra Symposium, Editor: P. Kumar Metha, ACI SP- 144, 383-397.
[10] Duxson P, Provis J L, Lukey G C and van Deventer J S J (2007), "The Role of Inorganic Polymer Technology in the Development of Green Concrete", Cement and Concrete Research, 37(12), 1590-1597.
[11] Fernández-Jiménez A M, Palomo A, and López-Hombrados C (2006a), "Engineering Properties of Alkali-activated Fly Ash Concrete", ACI Materials Journal, 103(2), 106-112.
[12] Fernández-Jiménez A M, de la Torre A G, Palomo A, López-Olmo G, Alonso M M, and Aranda M A G (2006b), "Quantitative Determination of Phases in the Alkali Activation of Fly Ash, Part I, Potential Ash Reactivity", Fuel, 85(5-6), 625-634.
[13] Gartner E (2004), "Industrially Interesting Approaches to 'Low-CO2' Cements", Cement and Concrete Research, 34(9), 1489-1498.
[14] Gourley, J. T., & Johnson, G. B. (2005), "Developments in Geopolymer Precast Concrete", Paper presented at the International Workshop on Geopolymers and Geopolymer Concrete, Perth, Australia.
[15] Hardjito, D. and Rangan, B. V. (2005), Development and Properties of Low-Calcium Fly Ash-based Geopolymer Concrete, Research Report GC1, Faculty of Engineering, Curtin University of Technology, Perth, available at espace@curtin or www.geopolymer.org.
[16] Lee W K W and van Deventer J S J (2004), "The Interface between Natural Siliceous Aggregates and Geopolymers", Cement and Concrete Research, 34(2) 195-206.
[17] Malhotra, V. M. (1999), "Making concrete 'greener' with fly ash", ACI Concrete International, 21, 61-66.
[18] Malhotra, V.M. (2006), "Reducing CO2 Emissions", ACI Concrete International, 28, 42-45. McCaffrey, R. (2002), "Climate Change and the Cement Industry", Global Cement and Lime Magazine (Environmental Special Issue), 15-19.
[19] Neville, A. M. (2000), Properties of Concrete, Prentice Hall.
[20] Nuruddin M.F., Qazi S.A., Kusbiantoro A., and Shafiq N (2010), "Utilization of Waste Material in Geopolymeric Concrete", ICE Journal of Construction Materials (in Press).
[21] Provis J L, Muntingh Y, Lloyd R R, Xu H, Keyte L M, Lorenzen L, Krivenko P V and J.S.J. van Rangan, B.V. (1990), "Strength of Reinforced Concrete Slender Columns", ACI Structural Journal, 87(1) 32-38.