Conventional Concrete Over Geo Polymer Concrete Using GGBS

A.Pavani, J.Rakesh, P.Gopichand, P.Suvarnaraju

Abstract— **Portland cement production is under critical review due to the high amount of carbon dioxide gas released to the atmosphere. But at the same time, disposal of huge quantity of fly ash generated from the power plants is also becoming a big burning problem. This is detrimental to animal and plant life, since it pollutes the environment as well as it requires large area for its disposal, when availability of land get scarce day by day. Most of the plants now are facing shortage of dumping space of these waste materials. Most of this by product material is a currently dumped inland fill, thus creating a threat to the environment. In recent years attempts to increase the utilization of fly ash to partially replace the use of Portland cement in concrete are gathering momentum.**

Efforts are urgently underway all over the world to develop environmentally friendly construction materials, which make minimum utility of fast dwindling natural resources and help to reduce greenhouse gas emissions. In this connection, Geopolymers are showing great potential and several researchers have critically examined the various aspects of their viability as binder system. Geopolymer concretes (GPCs) are new class of building materials that have emerged as an alternative to Ordinary Portland cement concrete (OPCC) and possess the potential to revolutionize the building construction industry. Considerable research has been carried out on development of Geopolymer concretes (GPCs), which involve heat curing. A few studies have been reported on the use of such GPCs f or structural applications.

An experimental investigation was carried out to study the material and mixture proportions; the manufacturing processes, the fresh and hardened state characteristics of fly ash based geo polymer concrete are evaluated. In the present study the compression behaviour of geo polymer concrete was assessed and the behaviour was found to be considerably more than that of conventional concrete.

Index Terms— **Geopolymer concrete, Alkaline Solutions, Portland cement, Fly ash.**

I. INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete due to its availability of the raw materials over the world, its ease for preparing and fabricating in all sorts of conceivable shapes. The application of concrete in the realms of infrastructure, habitation, and transportation has greatly promoted the development of civilization, economic progress, and stability and of quality of life. Nowadays with the occurrence of high performance concrete (HPC); the durability and strength of concrete have been improved largely. However, due to the restriction of the manufacturing process and the raw materials, some inherent disadvantages of Portland cement are still difficult to overcome.

The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum.

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 (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass is a significant development.

On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture cement products.

The geopolymer technology is proposed by Davidovits and gives considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission in to the atmosphere, caused by cement and aggregate industries about 80%. In this technology, the source material that is rich in silicon (Si) and Aluminum (Al) is reacted with a highly alkaline solution through the process of geopolymerisation to produce the binding material.

The term "geopolymer‟ describes a family of mineral binders that have a polymeric silicon-oxygen-aluminum framework structure, similar to that found in zeolites, but without the crystal structure. 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 flash and alkali in place of OPC as the binding agent. This attempt results in two benefits. I.e. reducing CO2releases from production of OPC and effective utilization of industrial waste by products such as flash, slag etc. by decreasing the use of OPC.

II. EXPERIMENTAL STUDY

Based on the extensive literature review an attempt has been

A Pavani , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9553115362.,

J Rakesh , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9989291221.,

P Gopichand , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9908287788.,

P Suvarna Raju , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9908265027., Suvarna

made to verify the possibility of preparing low calcium (ASTM Class F) fly ash based geopolymer concrete economically to suit the Indian conditions.

In order to develop the fly ash based geopolymer concrete technology, therefore, a rigorous trail-and error process was adopted. In order to simplify the development process, the compressive strength was selected as the benchmark parameter. The focus of the study was mainly on the engineering properties of fly ash based geopolymer concrete and also for partial replacement of fly ash with cement. The current practice used in the manufacture and testing of Ordinary Portland Cement (OPC) concrete was followed, even for geopolymer concrete. It is to ease the promotion of this „new" material to the concrete construction industry.

Although geopolymer concrete can be made from various source materials, in the present study only low-calcium (ASTM class F) dry fly ash was used, as it is easily available at low price in India. Also, as in the case of OPC, even in the geo-polymer concrete, the aggregates occupy 50-75 % of the total mass of matrix.

III. MATERIALS

FLY ASH& GGBS

Fly Ash: The Fly ash was used as a partial replacement for cement. The fly ash used in the experiments was from Ramagundam thermal power station (NTPC). The specific gravity was 2.17. The fly ash had a silica content of 63.99%, silica+ alumina +iron oxide content of 92.7%, Calcium oxide of 1.71% , Magnesium oxide of 1.0%, Sulphuric anhydride of 0.73% , water and soluble salts of 0.04%, ph value of 10 and a loss on ignition of 2.12

Here we are using ground granulated blast furnace slag (GGBS) about 4 to 5 % for 1 cube.

Diameter of wire mesh (mm)	Grid spacing of mesh wire (mm)		Yield strength of mesh wire (Mpa)	Ultimate strength (Mpa)
	Longitudinal	Transverse		
0.46	2.8	2.8	350	450

Figure Sodium Silicate and Sodium Hydroxide Solution

ALKALINE LIQUID

Fly ash+ GGBS	Coarse agg	Fine agg	NAOH	Water	NaSIO3	Water
900gm + 444gm	3.58 kg	2.8 kg	85 gms	110 ml	240 ml	345 ml

In the present study we have used a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), 98% purity, and obtained from National scientific company, Vijayawada, or a commercial grade in pellets form with 97% purity, obtained from National Scientific center, Vijayawada.

The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in the Potable water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. Molar concentration or molarities is most commonly in units of moles of solute per litre of solution. For use in broader applications, it is defined as amount of solute per unit volume of solution.

AGGREGATES

The fine aggregate conforming to Zone-2 according to IS: 383[1970]was used. The fine aggregate used was obtained from a nearby river source. The bulk density, specific gravity and fineness modulus of the sand used were 1.43g/cc, 2.62 and 2.59 respectively.

WATER

Potable water was used in the experimental work for both mixing and curing.

GALVANIZED IRON MESH

Galvanized Iron Wire mesh: The galvanized iron wire mesh of square grid fabric is used in the Ferro cement. The properties of the wire mesh are

MOULD

Cubes: Standard cube moulds of 150mmx150mm x 150mm made of cast iron were usedfor casting and
testing specimens in compression.

MIXTURE PROPORTIONS OF GEOPOLYMER CONCRETE

The primary difference between Geopolymer concrete and Portland cement concrete is the binder. The silicon and aluminum oxides in the low –calcium fly ash reacts with the alkaline liquid to from the geopolymer paste that binds the loose coarse and fine aggregates and other unreacted materials to form the geopolymer concrete. As in the case of Portland cement concrete the coarse and fine aggregates occupy about 75% to 80% of the mass of Geopolymer concrete. This component of Geopolymer concrete mixtures can be designed using the tools currently available for Portland cement concrete. The compressive strength and workability of geopolymer concrete are influenced by the proportions and properties of the constituent materials that make the geopolymer paste.

Table Galvanized Iron mesh Properties

EXPERIMENTAL RESULTS HAVE SHOWN THE FOLLOWING

As the H20- Na20 molar ratio increases, the compressive strength of Geopolymer concrete decreases

Higher the concentration of Sodium hydroxide solution results in higher compressive strength of geopolymer concrete.

Higher the ratio of Sodium silicate to Sodium hydroxide by mass higher the compressive strength.

Based on the above guide lines the trial mixture is designed as follows. DESIGN MIX OF G 40.

Design stipulations

Assume density of aggregate as unit weight of concrete = 2400 kg/m^3

Mass of Combined aggregate = 75-80 % (consider 0.77%)
= 2400 x 0.77%

= 1848 kg/m3
Now, mass of combined aggregate= 1848 kg/m3
Mass of Fly ash and alkaline Liquid= 2400-1848
= 552 kg/m3
let us take alkaline liquid to fly ash ratio as 0.4.
Now the mass of fly ash = (552)/ (1+0.4) = 394.28 kg/m^3
Mass of alkaline liquid = 552-394.28 = 157.21 kg/m3
Let us consider the ratio of NaoH to Na2sio3 as 2.5.
Now mass of NaoH solution= (157.21)/ (1+2.5)
=45.06 kg/m^3
Mass of Na_2sio_3 solution= 157.21-45.06 =112.64 kg/m3

Calculating the total amount of mass of water and mass of solids in the sodium hydroxide and sodium silicate solution,

Sodium Hydroxide solution (NaoH):
Considering 16M concentration, where in the solution consists of 44.4% of solids (pallets) and 63.5% of water.
Mass of solids = (44.4/100) x (45.06) = 20.00 Kg
Mass of water = 45.06 - 20.00 = 25.06 Kg

Sodium Silicate Solution (Na_2sio_3):
Journal of Civil Engineering and Technology (JCIET), ISSN 2347 –4203 (Print), ISSN 2347

4211 (Online) Volume 1, Issue 1, July-December (2013), © IAEME18
The water content in the **silicate solution** in observed as 63.5%. So, the Mass of Water = 63.5/100) x (112.64) = 71.52 Kg Mass of solids = 112.64 – 71.52 = 41.11 Kg
Total mass of water:
Mass of water in NaoH solution + mass of water in Na_2sio_3.Solution = 25.60 + 71.52 = 96.58 Kg.
Total mass of solids:
Mass of solids in NaoH solution+ mass of solids in Na2sio3solution + mass of Fly ash = 20.00+ 41.11 + 394.28 = 455.39 Kg.
Ratio of water to Geopolymer Solids:
Ratio = (96.58) / (455.39) = 0.21.

Till today the published literature contained very little on the manufacture of fly ash basedgeopolymer concrete and much of the work was done on using the geopolymer pastes and mortars. Based on the limited past research on geopolymer pastes available in the literature and the experience gained during the preliminary experimental

work, fly ash is partially replaced with cement to produce geopolymer paste.

CASTING

For casting the specimens of geopolymer concrete, the following procedure was adopted. The fine aggregate were prepared in saturated-surface-dry condition, and were batched and were kept in the gunny bags just before casting.

The solids constituents of the fly ash-based geopolymer concrete, i.e. the fine aggregate and the fly ash, were dry mixed in the pan mixer for about three times. Then the liquid part of the mixture, the alkaline solution was added to the initially mixed fly ash and the fine aggregate. The whole mix is thoroughly mixed for about 5 to 10 minutes. The above procedure is done casting the geopolymer specimens when fly ash was partially replaced by cement
The fresh fly ash-based geopolymer concrete was dark in color and shiny in appearance. The mixtures were usually cohesive. The fresh concrete in the moulds was compacted by applying sixty manual strokes per layer in three equal layers.

The Ferro cement mesh was kept in the layers along with mortar. After compaction the top surface was leveled with a trowel. Then the specimens were cured at room temperature.

CURING

Preliminary tests also revealed that fly ash based geo polymer concrete did not harden immediately at room temperature was less than 30^0c, the hardening did not occur at least for 24 hours. The handling time is amore appropriate parameter (ratherthan
setting time used in case of OPC concrete) for fly ash based geo polymer concrete.
The demoulded specimens were left in sunlight until tested without any special curing regime. For each set of parameter, 3 prisms were cast, three each for determining 28 days strengths.
Detention period
After the curing process, the moulds are taken out and cooled at room temperature for 1 day before demoulding for test.

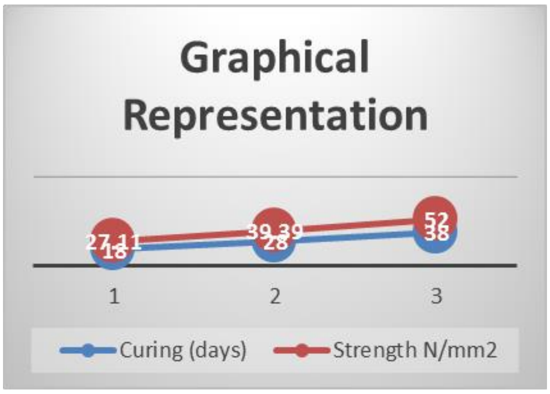
Date of Casting	Date of curing	Date of testing	Result
12-01-2016	13-01-2016	201/2016	39.39 N/mm2

Date of Casting	Date of curing	Date of testing	Result
25-02-2015	26-02-2015	26-03-2015	52 N/mm2

IV. RESULTS AND DISCUSSIONS

3 Days compression test For Fly ash:

7 days compression test For Fly Ash:
28 days compression test For Fly Ash:



V. CONCLUSIONS

From the experiments conducted on the geopolymer concretes developed in the concrete technology lab

The geopolymerconcrete specimens load carrying capacity is more than cement mortar specimens

The cost of fly ash based geopolymer concrete is high compared to Ordinary Portland Concrete.

Workability of geopolymermortar decreases with the increase in concentration of sodium hydroxide.

All geo polymer concrete mixes does not exhibited similar nature as that of ordinary Portland cement concrete 28 day for compression strength.

VI. LIMITATIONS OF STUDY

Due to the constraints of equipments such as temperature controlled air-drying, for finding the chemical composition of the materials, the work was limited only to some extent.

Curing temperatures influences the compressive strength of the geopolymer concrete.

3.2 SCOPE FOR FURTHER WORK

For a particular alkaline/fly ash ratio the strength variations may be studied by varying, the rest period from 1 to 4 days

Further investigation may be done by decreasing the molarities of NaOH and attain the same strength at the ordinary temperatures only.

Further investigation may also be made by replacing the fly ash with pozzolanic materials like Metakaolin& G.G.B.S

LIMITATIONS OF GEOPOLYMER CONCRETE

The followings are the limitations

Bringing the base material fly ash to the required location

High cost for the alkaline solution

Safety risk associated with high alkalinity of the activating solution

Practical difficulties in applying steam curing / high temperature curing process

ACKNOWLEDGMENT

We express our gratitude to our principal **Dr. SHEYD KAMALUDHIN** and director **Er. T.ASHOK KUMAR** for supporting us in completing our project work successfully by providing the required facilities and assurance. We are also grateful to our faculty for their moral support and good wishes

REFERENCES

[1] In Concrete. Farmington Hills, Michigan, ACI Committee 232 (2004). Use of Fly Ash USA, American Concrete Institute: 41.

[2] Bakharev, T. (2005b). Geopolymeric materials prepared using Class F fly ash and elevated temperature curing. Cement and Concrete Research

[3] Geopolymer Chemistry and Properties. Paper presented at the Davidovits, J. (1988b). First European Conference on Soft Mineralurgy, Compiegne, France. [4] 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.

[5] Hardjito, D., Wallah, S. E., &Rangan, B. V. (2002a). Research into Engineering Properties of geopolymer. Paper presented international, Melbourne.

[6] Hardjito, D., Wallah, S. E., Sumajouw, D. M. J., &Rangan, B. V. (2004b). On the Development of Fly Ash-Based Geopolymer Concrete. ACI Materials Journal, 101(6), 467-472.

[7] Rangan, B.V., Hardiito, D., Wallah, S.E., &Sumajouw, D.M.J. (2005b). Studies of fly ash-basedgeopolymer concrete. Paper presented at the World Congress Geopolymer 2005, Saint-Quentin, France

[8] P Chandraprasitet all Workability and strength of coarse high calcium fly ash geopolymer

[9] Suresh Thokchomet all Effect of water absorption, porosity and sorptivity on durability of geopolymer mortars

[10] P.NACHIYAPPAN et all Experimental investigation of Geopolymer concrete

A Pavani , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9553115362.,

J Rakesh , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9989291221.,

P Gopichand , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9908287788.,

P Suvarna Raju , Department Of Civil Engineering, Chirala Engineering College, Chirala, India,9908265027., Suvarna