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USE OF GEOPOLYMER CONCRETE AS CONSTRUCTION MATERIAL

Chiguru Nikhitha[*1], Dr. S Sunil Pratap Reddy2 & Syed Riyaz[3]

[*1]PG Scholor, Dept. Of Civil Engineering, Vaagdevi College of Engineering, Warangal, Telangana-506002

[2]Professor, Dept. of Civil Engineering, Vaagdevi College of Engineering, Warangal, Telangana

[3]Asst. Professor, Dept. of Civil Engineering, Vaagdevi College of Engineering, Warangal, Telangana

ABSTRACT

Nowadays, Portland cement (PC) concrete is the most popular and widely used building materials, due to its availability of the raw materials over the world. By the usage of this portland cement there may exist several problems .About 1.5 tonnes of raw materials is needed in the production of every ton of Portland cement, At the same time about one tonne of carbon dioxide (CO2) is released into the environment during the production. 3 kg of nitrous oxide released. 0.4 kg smog is released. Portland cement production accounts for about 7% of total CO2 emissions. Durability of ordinary Portland cement concrete is under examination, is less. Built in corrosive environments start to deteriorate after 20 to 30 years. So, to minimise these issues, the world needs. An environmentally friendly construction material because of the desire to reduce CO2 emissions, Save nonrenewable energy resources, provide aesthetically pleasing and healthy surroundings and at the same time minimize waste. In this article flyash is used as replacement of cement mixed with ggbs and NAOH(sodium hydroxide) the mixes are f100g0, f90g10, f80g20, f70g30, f60g40, with molarity 8M concentration of M25 grade compressive strength, spilt tesile strength, flexural strength are calculated . Indoor outdoor and oven curing is done. The results show that spilt tensile strength 40% slag has better results.

Keywords: *flyash , ground granulated blast furnance slag, geopolymer concrete.*

I. INTRODUCTION

Ordinary Portland cement (OPC) is the primary binding material used in the preparation of concrete. As we know cement is the backbone for global infrastructural development. It was estimated that 7% of the world's carbon dioxide is attributable to Portland cement industry. Because of the significant contribution to the environmental pollution & to the high consumption of natural resources like limestone etc., we can't go producing more and more cement. 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 aluminium. In 1978, *Davidovits* (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geo polymers.

Palomo et al (1999) suggested that pozzolana 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. In this scheme, the main contents to be activated are silicon and calcium in the blast furnace slag. The main binder produced is a C-S-H gel, as the result of the hydration process.

In 2001, when this research began, several publications were available describing geo polymer pastes and geo polymer coating materials *(Davidovits* 1991; *Davidovits*1994; *Davidovits*. 1994; *Balaguru*,. 1997; *van Jaarsveld*,.

1997;*Balaguru* 1998; *vanJaarsveld*. 1998; *Davidovits* 1999; *Kurtz*. 1999;*Palomo*. 1999; *Barbosa*. 2000). However, very little was available in the published literature regarding the use of geo polymer technology to make low calcium (ASTM Class F) fly ash-based geo polymer concrete.

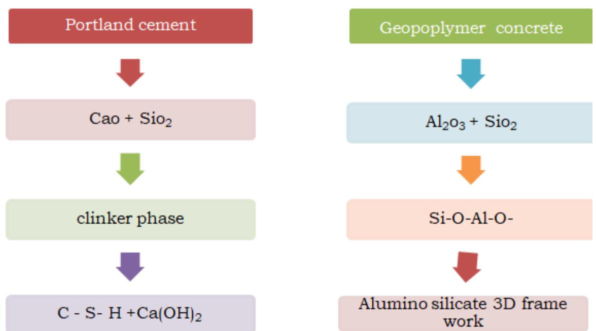
This research was therefore dedicated to the development, the manufacture, and the engineering properties of the fresh and hardened low-calcium (ASTM Class F) fly ash-based geo polymer concrete.

II. MATERIALS

1. Low-calcium fly ash-based geo polymer concrete

In this work, low-calcium (ASTM Class F) fly ash-based geo polymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geo polymer paste binds the loose coarse aggregates, fine aggregate sand other un-reacted materials together to form the geo polymer concrete, with or without the presence of admixtures. The manufacture of geo polymer concrete is carried out using the usual concrete technology methods

As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in geo polymer concrete. The silicon and the aluminium in the low-calcium (ASTM Class F) fly ash react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geo polymer paste that binds the aggregates and other un-reacted materials.



2. Aims of the research

The aims of this study were:
The methodology for the present work will consists of following steps

- To develop geopolymer concrete using fly ash and GGBS as a source material
- To develop the process of mixing with optimized use of alkaline activators like sodium hydroxide and sodiumsilicate.
- Setting up of curing regimens applied to the geopolymers concrete to study the effect of indoor curing, sun curing heat curing.
- To observe the hardened properties of fly ash-based geopolymer concrete, mainly its compressive strength, Split Tensile Strength, Flexural Strength.
- To study the effect of super plasticizer on low calcium fly ash and GGBS based geopolymer concrete.

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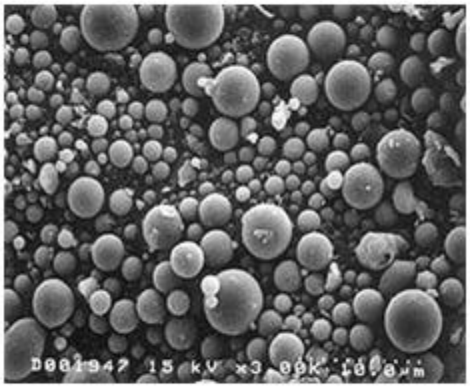

3. The use of fly ash in concrete

Use of fly ash as a partial replacement for Portland cement is generally limited to Class F fly ashes. It can replace up to 30% by mass of Portland cement, and can add to the concrete's final strength and increase its chemical resistance and durability. Development of high volume fly ash (HVFA) concrete successfully replaces the use of OPC in concrete up to 60% and yetpossesses excellent mechanical properties with enhanced durability performance.

Due to the spherical shape of fly ash particles, it can also increase workability of cement while reducing water demand. The replacement of Portland cement with fly ash is considered by its promoters to reduce the greenhouse gas "footprint" of concrete, as the production of one ton of Portland cement produces approximately one ton of co2 as compared to zero CO_2 being produced using existing fly ash.

4. Ground Granulated Blastfurnace Slag (GGBS)

In the present experimental work, Ground Granulated Blast Furnace Slag (GGBS) was obtained from the Thosali Cement Pvt Ltd, Bayyavaram and Andhra Pradesh and used as the base material

5. Physical Properties of GGBS

Particle Size

The BS EN 15167-1 requires that the minimum specific surface area of GGBS shall be 2750 cm2/g (BS EN 15167-1:2006). In China, GGBS is classified in three grades, namely S75, S95 and S105. The GB/T18046 requires a minimum surface area of 3000 cm2/g for grade S75 GGBS, 4000 cm2/g for grade S95, and 5000 cm2/g for grade S105, which are higher than the BS EN's requirements (GB/T18046-2008). It has been reported that slag with a specific surface area between 4000 cm2/g and 6000 cm2/g would significantly improve the performance of GGBS concretes. Both BS EN 15167-1 and GB/T18046 adopt a requirement on the specific surface area rather than the particle size of GGBS. Some researchers reported that the reactivity of GGBS would be improved when the particle

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size was less than 45µm. They suggested that less than 2% of the GGBS particles should be retained on the 45µm sieve and that the specific surface area shall be greater than 4200 cm2/g.

Density

There are no specific requirements in BS EN 15167-1 on the density of Portland cement and GGBS. GB/T18046 requires the relative density of GGBS to be not less than 2.85 (GB/T18046-2008). The Concrete Society (1991) reported that the relative density of GGBS was about 2.9 as compared to 3.15 for Portland cement. The inclusion of GGBS in a concrete mix as an equal mass replacement for Portland cement would cause a slight increase in the total volume of the cementitious content.

Table 1: Chemical composition of fly ash and GGBS

Chemical Composition	Fly ash	GGBS
SiO_2	60.11	34.06
Al_2O_3	26.53	20
Fe_2O_3	4.25	0.8
SO_3	0.35	0.9
CaO	4.00	32.6
MgO	1.25	7.89
Na_2O	0.22	NIL
LOI	0.88	NIL

6. Super plasticiser

To improve the workability of the fresh geo polymer concrete, a naphthalene Sulphonate super plasticiser, Conplast SP430

7. Alkaline liquids

In the present study we have used a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) 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, Vijayawada.

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The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in distil 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. For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 262 grams per kg of NaOH solution of 8M concentration. Sodium meta silicate ($Na_2O_3.Si.9H_2O$)solution with a concentration of 8M consisted of 8 x 282.40=2259.2 grams of sodium meta silicate solids per litre of the solution, where 284.20 is the molecular weight of sodium Meta silicate

8. Aggregates

20 mm aggregate is 30%,
16 mm aggregates is 20%,
12.5 mm aggregates is 25%,
10 mm aggregates is 25%.
The coarse aggregates are taken in saturated surface dry condition (SSD).

Coarse aggregate

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Fine aggregate

Mixing

It was found that the fresh fly ash-GGBS based geo polymer concrete was dark in colour (due to the dark colour of the fly ash), and was cohesive. The amount of water in the mixture played an important role on the behaviour of fresh concrete. When the mixing time was long, mixtures with high water content bleed and segregation of aggregates and the paste occurred. This phenomenon was usually followed by low compressive strength of hardened concrete. **MIX DESIGN**

Design mix = 1:1.5:3:0.48

Molarity of 8M Concentration

Table 2. Details of Mechanical properties of geo polymer concrete for different curing

S.No	compressive strength N/mm^2			Flexural strength N/mm^2			Split tensile strength N/mm^2		
	indoor	Outdoor	oven	indoor	Outdoor	oven	indoor	Outdoor	Oven
$A_1F_{100}G_0$	11.45	13.60	18.82	1.31	1.55	1.72	1.140	1.42	1.47
$A_2F_{90}G_{10}$	14.33	16.56	21.33	1.65	1.82	1.98	1.160	1.372	1.7
$A_3F_{80}G_{20}$	19.40	23.30	26.40	1.85	2.15	2.32	1.27	1.495	2.42
$A_4F_{70}G_{30}$	22.54	27.68	27.50	2.19	2.42	2.75	1.30	1.9	2.58
$A_5F_{60}G_{40}$	29.52	45.91	51.32	2.68	2.91	3.16	1.70	2.09	3.49

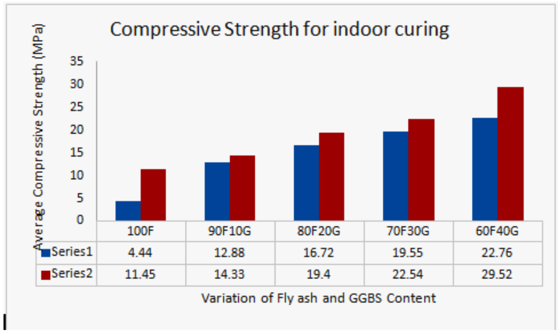

Fig 1 Compressive strength Vs % of replacement of binder in indoor curing For 7 days and 28 days

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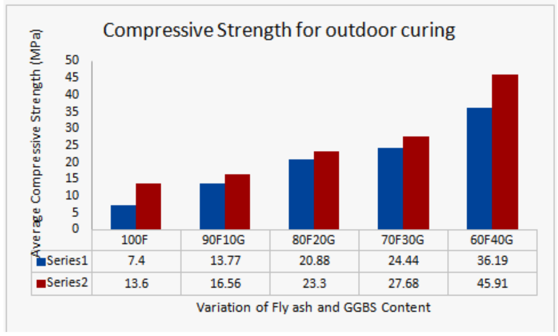

Fig .2 Compressive strength Vs % of replacement of binder in sun curing For 7 days and 28 days

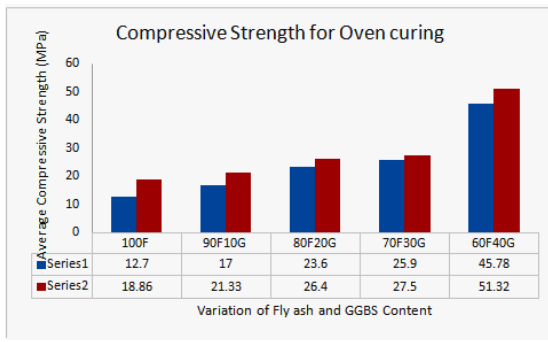

Fig 3 Compressive strength Vs % of replacement of binder in oven curing For 7days and 28 days

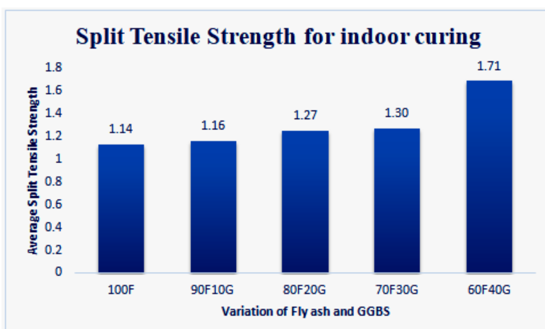

Fig 4 Split Tensile strength Vs % of replacement of binder in indoor curing

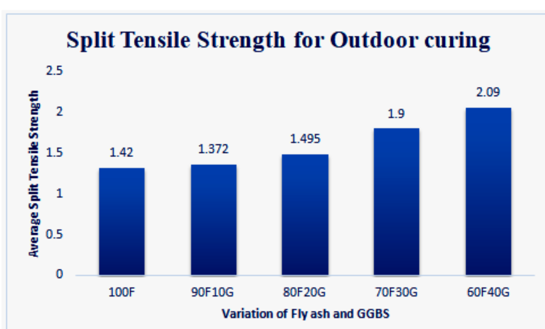

Fig 5 Split Tensile strength Vs % of replacement of binder in outdoor curing

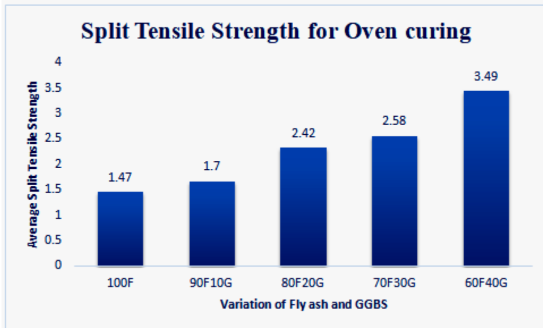

Fig 6 Split Tensile strength Vs % of replacement of binder in oven curing

III. DISCUSSIONS

From Table 2 and Figs 1-6 shows the details of compressive and split tensile strength results for different variations of Fly ash and GGBS.

- It is observed that geo polymer concrete is completely based on the polymerisation of chemicals which should have high amount of heat to process the chemicals to form strong polymer bonds in concrete.
- It is clear that geoploymer specimens cured in indoor has fewer properties than that of remaining curing methods i.e. sun curing
- It is evident that by replacement of Fly ash with GGBS upto 40% increases the performance of the geo polymer concrete

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IV. APPLICATIONS

There are many applications of geopolymer concrete, Especially in pre-cast concrete structures

In the short term,

1. There is large potential for geopolymer concrete applications for bridges such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites.
2. Geopolymer technology is most advanced in precast applications due to the relative ease in handling sensitive materials (e.g., high-alkali activating solutions) and the need for a controlled high-temperature curing environment required for many current geopolymer.
   Other potential applications are precast pavers & slabs for paving, bricks and precast pipes etc…..
3. High-energy efficient, low-carbon footprint homes using geopolymer filled insulated concrete forms (ICF). High temp grout material for oil/gas wells casing (2,500 F; 16,000 psi in 24 hrs).

V. CONCLUSIONS

1. Compressive strength of (40% replacement of slag) concrete shows better result than other mixes.
2. From the test results, it is observed that higher concentration (in terms of molarity) of sodium hydroxide solution results in higher compressive strength of fly ash-based geo polymer concrete.
3. As the percentage of GGBS increases in the total content, the final setting time decreases and compressive strength increases.

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