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Mechanical Properties of Geo-Polymer Concrete by using Water Glass Solution

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Abstract*: The environmental concerns related to the production of cement in terms of the energy consumption and the emission of CO_2 lead to the search for more environmentally viable alternatives to the cement. One of those alternative materials is Fly ash and GGBS Where Fly ash (FA) and Ground Granulated Blast Furnace Slag (GGBS) is used not as a partial replacement to cement but as the sole binder in the production of concrete. The performance of fly ash and GGBS based materials with sodium silicate (water glass) as an activator was studied*

Keywords: water glass solution, GGBS, Fly ash, compressive strength

I. INTRODUCTION

Nowadays concrete plays a major role in the human life. It has become in such a way that the usage of concrete became second only to water around the world. In the last two decades environmental issues in the concrete industry have been paid a lot of attention, aiming at reducing the total environmental impact of concrete structures to a minimum, without compromising on their performance. A lot of different tools have been developed in order to reduce the environmental impact of concrete.

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 and to the high consumption of natural resources like limestone etc., we can't go on 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 aluminum.

So there is a need to economize the use of cement. One of the practical solutions to economize cement replace with supplementary cementations materials like fly ash, slag and metakaolin

DESCRIPTION MATERIALS

Fly ash and GGBS

Fly ash and ground granulated blast furnace slag are used as source materials in the present study. ground granulated blast furnace slag is obtained from Toshali Cements Private ltd, Bayyavaram India and Fly ash is collected from National thermal power plant, Ramagundam, India. Specific gravity of Fly ash and GGBS are 2.17 and 2.9 respectively.

Chemical composition of fly ash and GGBS (% by mass)

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*

Sodium Silicate Solution:

In the case of sodium hydroxide and sodium silicate solution, labour should have knowledge onthe mixing preparation which is done one day before the casting whereas for this silicate solution,no such skill is required and it can be directly used in the site, at the time of casting itself then and there. No release of heat occurs for this sodium silicate solution whereas in the case of combined sodium hydroxide and sodium silicate solution, heat evolves when the sodium hydroxide pellets are dissolved in the water during the preparation of solution.

Sodium Silicate Solution

Fine aggregate:

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

Sieve analysis of Fine Aggregate (Sand)

S.No	Sieve No/ size	Weight retained (gm)	Percentage weight retained	Cumulative percentage weight retained	Cumulative percent passing	
					Fine aggregate	IS 383 (1970) – Zone II requirement
1	3/8” (10mm)	0	0	0	100	100
2	No.4 (4.75mm)	12	1.2	1.2	98.8	90-100
3	No.8 (2.36mm)	35	3.5	4.7	95.3	75-100
4	No.16 (1.18mm)	135	13.5	18.2	81.8	55-90
5	No.30 (600µm)	366	36.6	54.8	45.2	35-59
6	No.50 (300µm)	290	29.0	83.8	16.2	8-30
7	No.100 (150µm)	132	13.2	97.0	3.0	0-10

Coarse aggregate

Typically refers to gravel, crushed stone, or recycled concrete with particle sizes larger than 4.75 milli meters (0.19 inches). It's commonly used in construction, particularly in the production of concrete, where it provides strength and stability to the mixture. Coarse aggregates are essential for the structural integrity of concrete, providing bulk and strength to the final product. They are often mixed with fine aggregates (such as sand) and cement to create concrete mixes of various strengths and characteristics

Mix Proportions of geopolymer Mortars using Sodium Silicate Solution for :

Five mixes were considered with varying the ratio of Fly ash -GGBS. The percentage ratio of Fly ash: GGBS was selected as 80FA:20GGBS, 20FA:80GGBS, 50FA:50GGBS, 40FA:60GGBS and 60FA:40GGBS for the source material. The alkaline liquid to binder ratios is maintained as 0.5 irrespective of mix. The density of geopolymer

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samples are varied is 1700-2200 kg /m^3. By knowing the density of Concrete the amount of binder and quantity of alkaline liquid was determined

Mix ID/ Proportion of binders	Fly ash (kgs)	GGBS (kgs)	Fine Aggregate (kgs)	Coarse aggregate	Alkaline liquid (kgs)
M_1F50G50	0.661kgs	0.997kgs	5.162kgs	10.3257kgs	2.065kgs
M_2F40G60	1.376kgs	2.065kgs	5.162kgs	10.3257kgs	2.065kgs
M_3F60G40	2.065kgs	1.376kgs	5.162kgs	10.3257kgs	2.065kgs
M_4F80G20	2.755kgs	0.6685kgs	5.162kgs	10.3257kgs	2.065kgs
M_5F20G80	0.688kgs	2.753kg	5.162kgs	10.3257kgs	2.065kgs

Scope of Work:

Huge amount of literature is available on fly ash based geopolymer concrete. But its application is limited due to its oven curing technique. To overcome this partial replacement of fly ash with GGBS isadvantageous. Lot of literature is available on mechanical and durability properties of geopolymer paste, mortar and concrete, there is very less literature available on low cost sodium silicate solution affecting the strength of geopolymer. The present work utilizes fly ash and GGBS as the base materials for making geopolymer mortars. An attempt was made to study the effect of GGBS content on fly ash and GGBS based geopolymer mortars under ambient condition.

Objectives of the Work:

The effect of compressive strength of geopolymer concrete by varying fly ash/GGBS ratio at different ages (7 days, 14 days and 28 days) is investigated.

The aims of the study are:

study the effect of GGBS in fly ash based geopolymers with different replacement levels such as 80FA:20GGBS, 20FA:80GGBS, 50FA:50GGBS, 40FA:60GGBS and 60FA:40GGBS

Evaluate the mechanical properties (Compressive Strength) of geopolymer concrete with different percentages of Fly ash and GGBS.

Investigate the properties of Geopolymer concrete using Sodium Silicate Solution.

II. TESTS

Compressive strength results of fly ash – GGBS based geopolymer

The 28 day compressive strength of geopolymer Concrete prepared with sodium silicate solution for 50% fly ash sad 50% ggbs strength vary from 3.68 to 76 mpa .has very low strength compared with 40% GGBS its vary from 35mpa,the minimum strength for all above specimens for 7 days is 3.68 and also for 14 days is 6.9 and also for 28 days is 16mpa,the maximum strength obtained for above specimens are for 7 days is 56.16 and also for 14 days is 69.16 and also for 28 days is 87.92 mpa , increase in the GGBS content in the mix the compressive strength also increases. The reason for increase in compressive strength due to GGBS can be attributed to higher calcium content present in GGBS. . To utilize both fly ash and GGBS, a mix with 50FA-50GGBS mix is desirable. GGBS plays an important role for compressive strength development. A higher dosage of GGBS results in a higher compressive strength of geopolymer concrete. Mix with 100% fly ash shows the less compressive strength among all the mixes. The mixes with 80FA:20GGBS, 20FA:80GGBS, 50FA:50GGBS, 40FA:60GGBS and 60FA:40GGBS shows the higher compressive strength with inclusion of GGBS content in the mix produced the highest strength, while a further decrease in the GGBS content reduced the compressive strength. Another reason is that the quantity of soluble Calcium content depends on the volume of GGBS present in the mixture, which has a direct effect on the compressive strength. The attainment of the strength in geopolymer concrete mainly depends on the GGBS content in the mix. The calcium present in the GGBS content dissolution will be more compared with silica and alumina present in the fly ash. Due to the faster dissolution the formation of the dissolution reactants like N-A-S-H gel and C-A-S-H gel will be formed and which contribute the strength for Geopolymer Concrete.

Preparation of Concrete

The fly ash and GGBS are mixed until homogeneity is obtained, then fine aggregate is added and allowed to mix for 2 minutes in an electrically operated Concrete mixer. Alkaline solution is added to the mixture of fly ash, GGBS, fine aggregate and continued to mix for another 3 minutes in mortar mixer to ensure homogeneity. The fresh mixes prepared are cohesive and segregation resistant. Geopolymer Concrete s filled into the cubes of dimensions 150*150*150mm after 24 hours of casting and cured in outdoor. For outdoor curing, specimens are left out in outdoor (Temperature- 35±2^{0}C and relative humidity - 75%) until age of testing

III. RESULTS AND DISCUSSIONS

The work has attempted to estimate the strength of geopolymer mortar at 7, 14 and 28 days strength. The strength of geopolymer Concrete depends mainly on curing regime, type of binder content and concentration of sodium silicate solution. The gain of strength is faster at early age compared to that later age. This was observed in Outdoor curing in order to eliminate the hot air oven curing. The Concrete cubes were cast and cured for 7, 14 and 28 days were tested for evaluating its compressive strength. The initial curing temperature influences the polymerization process. Before the age of 7 days, the gain in the strength was very less in the outdoor curing for all the mixes. In outdoor curing the gain in the strength is less due to slow polymerization process. Compressive strength of all the combinations increased over the time and higher at 28 days. The gels which are formed during polymerization is responsible of the mechanical development of fly ash and GGBS based materials. With the age of curing, a higher amount of gels was formed. The mixes containing the more slag gives the better strength than other mixes due to their chemical composition and their slag content had much effect on strength development of the geopolymer samples at any age

Percentage Variation in the strength of Geopolymer Concrete.

Specification	7 Days	14Days	28 Days
M_1F50G50	3.68mpa	6.9mpa	16mpa
M_2F40G60	25.2mpa	28.56mpa	35mpa
M_3F60G40	28.81mpa	44.46mpa	57mpa
M_4F80G20	56.16mpa	59.15mpa	65mpa
M_5F20G80	34.28 mpa	69.16 mpa	87.92mpa

IV. CONCLUSION

The combination of fly ash and GGBS used for the development of geopolymer mortar has yielded satisfactory levels of compressive strength without the need for any heat curing. The maximum compressive strength obtained at 28 days is 87.92MPawhen using the sodium silicate solution.

- Maximum compressive strength obtained for 7 days is 56.16mpa
- Maximum compressive strength obtained for 14 days is 69.16mpa
- Maximum compressive strength obtained for 28 days is 87.92mpa
- Minimum compressive strength obtained for 7 days is 3.68mpa
- Minimum compressive strength obtained for 14 days is 6.9mpa
- Minimum compressive strength obtained for 28 days is 35mpa

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