Geopolymer Concrete With Binary Composition In Ambient Curing

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Abstract- *Geopolymer is a material occurring from the reaction of a source material which is rich in silica and alumina with alkaline solution. Geopolymer concrete is completely OPC free concrete. In geopolymer material, Binding property is shown by siliceous material and activation is carried out by alkaline solution. Siliceous material and alkaline activator undergo geopolymerization process to produce alumino silicate gel. Alkaline solution used for present study is combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) with specific ratio.*

There is huge scope for using various materials as a binder material like Siliceous and aluminous material in geopolymer. In this study we choose Fly ash and Ground Granule Blast furnace Slag (GGBS) as binding material which helps to reduce various problems regarding dumping and handling of the waste material of big industries. We can use naturally occurring materials like Red mud, Micro silica etc. as binder which performs well in geopolymer . But instead of that if we use waste materials from various industries like as Flyash, GGBS, Pond Ash, Bottom ash, Rice husk ash etc. which also gives good strength and mechanical property comparatively while using in Geopolymer solves many problems in Industries and Human beings.

Geopolymer concrete helps in reducing carbon footprints along with excellent engineering properties. It happens because it replaces Ordinary Portland cement which is responsible for huge carbon emission along with it also helps with the problem of handling industrial waste like Flyash and GGBS by consuming it in Geopolymer Concrete. Now a day's Geopolymer concrete becomes a popular construction material due to these positive aspects.

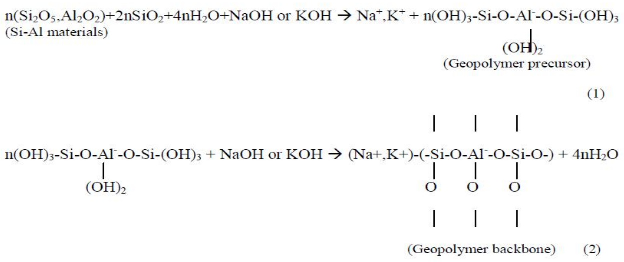
Most of the previous works on fly ash-based geopolymer concrete reveals that hardening is due to heat curing, which is considered as a limitation to cast in situ applications at low ambient temperatures. This study aimed to achieve geopolymer concrete suitable for curing at ambient temperature. GGBS was added in mix to enhance the early age properties of concrete. Setting times of geopolymer concrete, workability of fresh concrete and compressive strength after curing at 25-35ºC are investigated.

Keywords- Geopolymerisation, OPC Free Concrete, Binder and Activator,Reduction in Carbon footprint, Utilisation of Industrial waste like GGBS and Flyash.

I. INTRODUCTION

As Concrete is the second most consuming fluid after water in the world, It is used as a construction material because of their many benefits like easily available, more durable, comparatively cheaper etc. Among all constituents of concrete ordinary Portland cement (OPC) is the main ingredient which binds the aggregates together. However, the manufacturing of OPC requires huge energy which is generating by burning of fuels and it is responsible for almost 5% of CO_2 emission in the world environment, which is the main cause of global warming. In another estimate it was found that the production of one tone of OPC releases approximately one tone of carbon dioxide to the atmosphere Due to an increase in global population and urbanization the increasing use of concrete in construction is unavoidable in near future. This geopolymer technique leads us to the new generation concrete or binding construction material which has potential to replace OPC partially or completely.

Davidovits [1988] proposed that an alkaline liquid can be used to react with Siliceous and Aluminous materials, which may be the naturally occurring material or any industrial waste product like Flyash, Slag etc to produce binder. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term "Geopolymer" to represent these binders. The polymerisation process is a chemical reaction between alumina-silicate materials and alkaline solutions under elevated curing temperatures. It was found that the production of geopolymer based binding material requires approximately 60% less energy and it leads to 80% less CO2 emissions compared to the manufacture of OPC. So far, huge research work has been done on goepolymer binders and its applications worldwide to promote geopolymer as an sustainable and durable construction material for the future. Geopolymers are binders that exhibit good physical and chemical properties, and have a wide range of potential applications.



(Fig 01) Geopolymerization Process

Products from geopolymers have certain advantages, including high early strength, high strength, low shrinkage, and resistance to chemical agents. The important raw materials of geopolymers include fly ash, blast furnace slag, and metakaolin (MK) or calcined kaolin clay containing SiO2 and Al2O3, which are the main chemical constituents.

Low calcium fly ash is considered an important source of geopolymer due to its widespread availability. It has been reported that heat cured fly ash geopolymer achieves compressive strength of the same order as that of OPC binder in normal concrete with excellent durability. Geopolymer binders can be more resistive to acid attacks and alkali-aggregate reactions; it can also be sustained at high temperature and fire also. Geopolymer is also a corrosion resistant binder which also provides better bond between reinforcement and concrete. However, the biggest constraint of geopolymer concrete is that it will not provided sufficient strength in ambient curing conditions. Different admixtures and base material can be used to increase its initial strength at room temperature.

A number of researchers indicated that the addition of slag is more advantageous in fly ash geopolymer due to its easy activation in an alkaline medium. It contains a high content of free CaO ions, both SiO2 and Al2O3 in an amorphous state, whereas a much larger crystalline phase exists in fly ash which requires elevated temperature curing to accelerate the reaction. Upon alkali activation, an exothermal reaction between the activator and the additional CaO present in base material releases heat, which promotes the geopolymerization process. However, despite the source material modification, geopolymer binder is very sensitive to type/nature or composition of the alkali activators. Usually, sodium hydroxide (NaOH) based geopolymer is considered more sustainable as compared to water glass (Na2SiO3). It was concluded that the solubility of fly ash depends on the molarity of NaOH solution, where an optimum concentration is required for the leaching of Al3+ and Si4+ ions and subsequent reaction at elevated temperature.

Xu and Van Deventer demonstrated that when different source materials are used to produce geopolymer, an additional silica (Si) is required for the polymerization reaction. The alkali hydroxides are necessary for the dissolution process, while the alkali silicates act as a binder. The most commonly used alkali activators are a combination of NaOH and Na2SiO3 solutions, where a critical factor that influences the mechanical properties of geopolymer, is the Na2SiO3/NaOH ratio. Furthermore, other factors such as fly ash fineness, particle size distribution were also influence the mechanical properties of geopolymers.

Grades adopted for the investigation were M30. The mixes were designed for molarities of 12M, 14M and 16M. The test results have shown that compressive strength increases with increase in molarities up to certain extent.

II. TEST SPECIMEN

A. Material used

- *GGBS:* The GGBS is obtained from JSW Steel plant, Pen, Maharashtra. GGBS having particle size 0.1 to 40 microns, specific surface area will be 400 – 600 m^3/Kg and relative density is 2.85 to 2.95.
- *Fly*-Ash: The Fly ash use is a locally available It was classified as class F according to ASTM C618-12a, (SiO2 + Al2O3 + Fe2O3 = 89.15% > 70% and CaO < 10%), also having average particle size of 6.92 microns and specific gravity of 2.288.
- *Activating Solution:* The activating alkali solution consisted of Na2SiO3 and NaOH solutions. Both the chemicals has been used is made by Deccer & Pedder chemical company, Mumbai.

The composition of Na2SiO3 is (wt.%) Na2O = 14.7, SiO2 = 29.4 and water = 55.9. The other characteristics of Na2SiO3 solution are: specific gravity = 1.53 g/cc, viscosity at 20^0 C = 400 cp and molecular weight of Sodium silicate is 122.06.

The NaOH solution is prepared from analytical grade NaOH pellet having purity of 99.95% and Molecular weight 475.73, it can be easily soluble in water to make their solution. Although it can be easily used in elevated temperature condition because its melting point is 318^0C (lit.). The 12 M Solution of Sodium Hydroxide in made one day prior to the day of mixing by using tap water.

- *Fine Aggregates:* Crushed sand having Specific Gravity 2.32gm/cc and Fineness Modulus as 4.212 has been used.

- *Coarse Aggregate:* Crushed stone aggregate of 20 mm size, having Specific Gravity 2.59gm/cc and Fineness Modulus as 6.45 has been used.

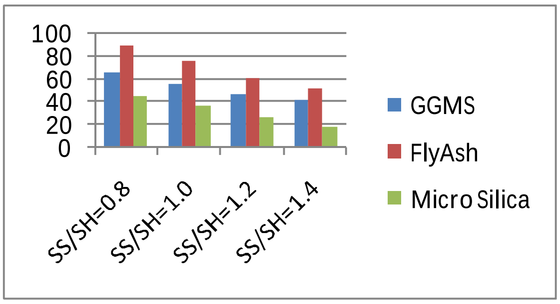
B. Mix proportion and basic investigation.

Throughout hand mixing over a tray was done. Coarse aggregate with the percent replacement of recycled aggregate were put in the tray first, after that crushed sand followed by cement were added. Concrete was then placed in IS specified moulds in three layers, each layer was being compacted by standard tamping road with more than 35 strokes. Exposed surface was finished with trowel to avoid uneven surface.

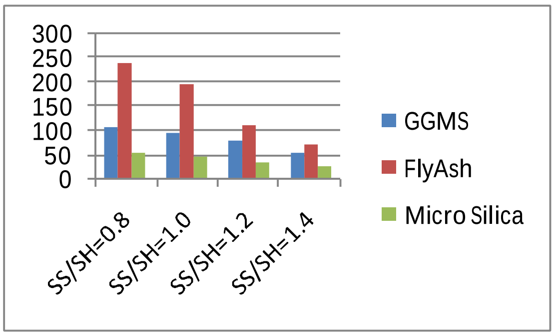
The Standard Consistency Test has been performed and the liquid to binder ratio in find out as (0.40), According to that we use this ratio as it is for Initial and final setting time test of various binding material individually with different Sodium silicate to sodium hydroxide ratio.

(TABLE 01) INITIAL AND FINAL SETTING TIME FOR VERIOUS BASE MATERIAL (in minutes)

Sodium silicate/Sodium Hydroxide ratio	GGBS		FLYASH		MICRO SILICA	
	IST	FST	IST	FST	IST	FST
0.8	65	105	90	240	45	52
1.0	55	92	75	195	37	46
1.2	47	79	60	108	25	31
1.4	42	54	52	70	17	24



(Graph 01) INITIAL SETTING TIME



(GRAPH 02) FINAL SETTING TIME

The Compressive test is also need to perform for investigating the strength of the binding materials individually at various sodium silicate to sodium hydroxide ratio (SS/SH) which helps us to take decision for finalizing (SS/SH) for final mix design test to obtain a best suitable mix for geopolymer concrete. We are going to use the liquid to binder ratio as (0.53) by using IS method where, ratio=p + (p/4+3) %. The mortar is prepares by using binder to IS sand ratio 1:3 and IS sand is prepared by using equal amount if Grade I, Grade II & Grade III of sand respectively. The cube of (7.07x7.07x7.07) mm has been used for this test and the results have been investigated on 7th, 14th, and 28th day from casting. Immediately on next day of casting the casted cubes in removed from molds and kept it for ambient curing at a place of controlled temperature, the temperature is maintained in between 22^{o}C-35^{o}C.

(TABLE 02) COMPRESSIVE STRENGTH TEST OF VERIOUS BASE MATERIAL (N/MM^2)

Sodium silicate/Sodium Hydroxide ratio	GGBS			FLYASH			MICRO SILICA		
	7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
0.8	2.13	7.57	17.60	1.20	16.70	27.60	2.40	4.90	6.61
1.0	6.84	21.10	29.64	3.78	23.80	41.30	6.40	9.57	14.70
1.2	6.54	19.53	32.64	3.40	27.60	37.52	7.94	8.32	13.10
1.4	5.32	17.40	33.52	2.94	29.40	40.21	6.90	7.63	13.80

This results of Setting time and Compressive strength of mortar is observed and we come to a conclusion that the (SS/SH) ratio of 1.2 gives best results all round.

III. TEST PROGRAM

A. Compression testing of cubes:

The final procedure to investigate the best suited mix for geopolymer concrete will be finalized according to the results we get. We are going to test six mixes M1, M2, M3, M4, M5, M6, from which M1, M2 & M3 are the mixes having Fly-Ash and GGBS in (80%-20%), (60%-40%), and (40%-60%) proportion by weight respectively. The other mix M4, M5, & M6 is also incorporate with Micro Silica, because it helps to gain more initial strength in geopolymer concrete. Hear the Micro Silica replaces GGBS by 10% in every mix, so the proportion will become (70%-20%-10%), (50%-40-10%), & (30%-60%-10%) by weight of total binder respectively.
Cubes as casted of size 150 x 150 x 150mm were tested using Compression testing machine (CTM) of capacity 2000 kN, capable of giving load at the rate of 140 kg/sq.cm/min. Testing of the cubes was done at the age of 7th and 28th day.

The wet cubes were placed in the machine between wiped and cleaned loading surfaces and load is given approximately at the rate of 140 kg/sq.cm/min. and ultimate crushing load is noted to calculate crushing strength of concrete according to IS: 516-1959.

The measuring strength of specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross section area.

IV. RESULTS AND DISCUSSION

Following are the obtained results of Compression Test and Flexural Test.

A. Compressive Strengt.

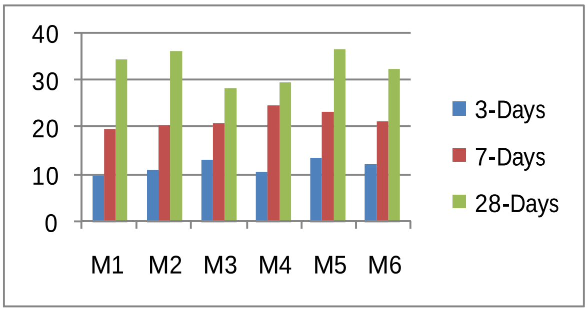
(TABLE 03) COMPRESSIVE STRENGTH OF CONVENTIONAL (M30) CONCRETE (N/MM^2)

Sample Name	Percentage of total binder			Aggregate (Kg/m3)		Weight of a test cube (Kg)	Strength of a test cube (N/mm^2)		
	Fly ash	GGBS	Micro Silica	*Fine*	*Coarse*		3 days	7 days	28 days
M1	80	20	-----	1178	3354	6.64	9.76	19.86	34.76
M2	60	40	-----	1178	3354	5.92	11.32	20.64	36.21
M3	40	60	-----	1178	3354	5.87	13.20	20.84	28.49
M4	70	20	10	1036	3247	6.10	10.87	24.60	29.68
M5	50	40	10	1036	3247	5.88	13.47	23.54	36.54
M6	30	60	10	1036	3247	5.79	12.45	21.40	32.45

(TABLE 04) COMPRESSIVE STRENGTH TEST RESULTS OF GEOPOLYMER CONCRETE SAMPLES M1-M6 (N/MM^2)

Percentage Variation (%)	Curing Age		
	3 Days	*7 Days*	*28 Days*
0	10.37 N/mm^2	21.76 N/mm^2	32.43 N/mm^2

Graph will be plotted with percentage variation on abscissa and Compressive Strength of concrete on ordinate.



(GRAPH 03) Compressive Strength of Geopolymer concrete

From the results obtained, it was observed that the development of compressive strength of Geopolymer concrete is satisfactory in compare to conventional concrete. Apart from that it also exhibits better performance in workability.
The Graph 1 shows the setting time of geopolymer binder where we come to know that use of micro silica reduces the setting time in opposite flyash have very high setting time, this indicates that we can use the base material in various proportions according to our requirement.

Similarly, Graph 2 shows that the use of flyash will increase the ultimate strength and GGBS will frovide good strength in early age.

Ultimately by Graph 03, indicates that the best test result for compressive strength is Mix Design no. 5, which consist 50% Flyash, 40% GGBS, and 10% Microsilica, of total binder.

V. CONCLUSION

From the experimental work carried out the following conclusion can be drawn:

- The geopolymer concrete gives satisfactory results to being used as an alternative of OPC concrete.
- It has been proved that we can use giopolymer concrete in ambient curing conditions.
- We can use binary or Tartary composition to obtain required results.
- By this study we can state that Mix no. 6, consist of 50% Flyash, 40% GGBS, and % Microsilica, of total binder to get the best results of strength.

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