EFFECT'S OF ALKALINE SOLUTION ON GEOPOLYMER CONCRETE

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Abstract— Geopolymer concrete technology has the potential to reduce globally the carbon emission and lead to sustainable development and growth of the concrete industry.This paper represents "Effects's off alkaline solution on geopolymer concrete". The main objective of this project is to study the various properties of the Geopolymer Concrete and compare it with the OPC concrete. The geopolymer concrete is the mixture of course aggregate, sand, fly ash and alkaline solution of Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) without water. The compressive, flexural, split tensile strength of Geopolymer concrete were carried out during the project work and it was found that, the above mentioned strength basically depend on the variation of different parameters such as the ratio of (Na_2SiO_3/ NaOH), molarity of the alkaline solution by keeping curing temperature constant of 80^0C. The variation of the ratio of (Na_2SiO_3/ NaOH) are 2.5, 3.0 and . Along with this by varying the molarity ofNaOHfor each ratio of (Na_2SiO_3/ NaOH) such as 12, and 14 Molar. Results obtained from the above variation, compressive strength of G.C. increases with increase in molarity of alkaline solution and the ratio of (Na_2SiO_3/ NaOH). For determination of details of the material to be bonded in complex form after 14 days.

Keywords— Fly ash, Sodium hydroxide, Sodium silicate, Geopolymer concrete, molarity,coarse aggregates, fine aggregates

1. Introduction

Geopolymer concrete is the greener concrete which has the potential technology to reduce the carbon emission and lead to sustainable developments and growth of the concrete industry. During the manufacturing of ordinary Portland cement, large amount of carbon dioxide is released in the atmosphere causing not only air pollution but also highly responsible factor of global warming. The compressive strength, flexural strength, split tensile strength of geopolymer concrete were carried out during the project work. The above mentioned strength basically depend on the variation of different parameter such as ratio of Na2SiO3/NaOH, molarity of thealkaline solution etc. The. Two other studies, conducted in parallel, dealt with long-term properties and structural applications of reinforced low-calcium flyash-based geopolymer concrete. The results of those studies will be described infuture exports.

The aims of this study are:

1. To develop a mixture proportioning process to manufacture low-calcium fly ashBased geo-polymer concrete.
2. To identify and study the effect of salient parameters that affects the properties oflow-calcium fly ash-based geo-polymer concrete.
3. To study the short-term engineering properties of fresh and hardened low calciumfly ash-based geo-polymer concrete.

2. MATERIALS USED

A. Fly-ash:

According to the American Concrete Institute (ACI) Committee 116R, fly ash isdefined as 'the finely divided residue that results from the combustion of ground orpowdered coal and that is transported by flue gasses from the combustion zone to theparticle removal system' (ACI Committee 232 2004).The colour of fly ash ranges from almost cream to dark grey essentially depending upon the proportion of unburnt carbon present and the iron content. Fly ashparticles are typically spherical, finer than Portland cement and lime, ranging India meter from less than 1 μm to no more than 150 μm.The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash. The major influences on the fly ash chemical composition come from the type of coal.

In the present experimental work, low calcium, Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the silos of Thermal Power Station, was used as the base material. Fly ash (Pozzocrete 63) is a high efficiency class F pozzolanic material confirming to BS 3892, obtained by selection and processing of power station fly ashes resulting from the combustion of pulverised coal. Pozzocrete 63 is subjected to strict quality control.

B. Alkaline Liquids:

A combination of sodium silicate solution and sodium hydroxide solution/potassium hydroxide solution was choosen as the alkaline liquid. The sodium hydroxide (NaOH) and potassium Hydroxide (KOH) solids were a commercial grade in form of flakes with 97% purity.

The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakesor the pellets in water. The mass of NaOH solids in a solution varied depending onthe concentration of the solution expressed in terms of molar, M. For instance,NaOH solution with a concentration of 12M consisted of 12x40 = 480 grams of NaOHsolids (in flake or pellet form) per litre of the solution, where 40 is the molecularweight of NaOH. The mass of NaOH solids was measured as 262 grams per kg ofNaOH solution of 8M concentration. Similarly, the mass of NaOH solids per kg ofthe solution for other concentrations were measured as 10M: 314 grams, 12M: 361grams, 14M: 404 grams, and 16M: 444 grams. Note that the mass of NaOH solidswas only a fraction of the mass of the NaOH solution, and water is the major component.

The chemical composition of the sodium silicate solution was Na_2O=14.7%, SiO_2=29.4%, and water 55.9% by mass. The other characteristics of the sodium silicate solution were specific gravity=1.53 g/cc and viscosity at 20°C=400 cp.

C.AGGREGATES:

- **Coarse Aggregates:**

For concrete, the coarse aggregate particles themselves must be strong. From both strength and rheological considerations, the aggregate particles should have roughly equal dimension; either crushed rock or natural gravels, particularly if they are of glacial origin, are suitable. In addition, it is important to ensure that the aggregate is clean, since a layer of silt or clay wii reduced cement aggregate bond strength.

- **Fine Aggregate:**

The fine aggregate should consist of smooth rounded particles, to reduce water demand. It is recommended that the grading should lie on the coarser side of the limits, a fineness modulus of 3.0 or greater recommended, both to decrease the water requirements and to improve the workability of theses paste-rich mixes. Of course, the sand too must be free of silt or clay particles.

TABLE I. Aggregates specifications:

Properties	**Coarse Aggregate**	**Fine Aggregate**
Type	Crushed angular	Spherical (River sand)
Maximum Size	20mm	4.75 mm
Specific Gravity	2.784	2.64
Material finer than 75 micron	Nil	1.25 %
Water Absorption	1.095 %	1.460 %
Silt Content (%)	0.4	1.1
Bulk density (g/cm³)	1.53	1.90
Organic matter	Nil	Nil

3. METHODOLOGY:

General

This presents the details of development of the process of making low calcium (ASTM Class F) fly ash-based geopolymer concrete. Also, it includes the preparation of alkaline solution such as sodium hydroxide of different molarity as per requirement. The materials that are required for the geopolymerisation process such as low calcium fly ash, coarse aggregates, sand and the alkaline solution as per design of mix proportion M40 are clearly mentioned in a tabular format as per IS 1026-2008.

- ***Low-calcium fly ash-based geopolymer concrete :***

In this work, low-calcium (ASTM Class F) fly ash-based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregate sand other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer 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 geopolymer concrete. The silicon and the aluminium in the low-calcium (ASTM lass F) fly ash react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

In order to develop the fly ash-based geopolymer concrete technology, therefore, a rigorous trail-and-error process was used. The focus of the study was to identify the salient parameters that influence the mixture proportions and the properties of low calcium fly ash-based geopolymer concrete.

As far as possible, the current practice used in the manufacture and testing of ordinary Portland cement (OPC) concrete was followed. The aim of this action was to ease the promotion of this 'new' material to the concrete construction industry. In order to simplify the development process, the compressive strength was selected as thebenchmark parameter. This is not unusual because compressive strength has an intrinsic importance in the structural design of concrete structures.

- ***Preparation, Casting and Curing of Geopolymer Concrete***

The alkaline activator solution used in GPC mixes was a combination of sodium hydroxide solution, sodium silicate solution and distilled water. The role of AAS is to dissolve the reactive portion of source materials Si and Al present in fly ash and provide a high alkaline liquid medium for condensation polymerization reaction. To prepare sodium hydroxide solution of 12 molarity (12M), 480 gm of sodium hydroxide flakes was dissolved in water. The mass of NaOH solids in a solution will vary depending on the concentration of the solution expressed in terms of molar, M. The solution of NaOH are dissolved in one liter of water for the required concentration. When sodium hydroxide and sodium silicate solutions mixed together polymerization will take place liberating large amount of heat, which indicates that the alkaline liquid must be used after 24 hours as binding agent.

GPC can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the aggregates were first mixed together dry on pan for about three minutes. The liquid component of the mixture is then added to the dry materials and the mixing continued usually for another four minutes. The addition of sodium silicate is to enhance the process of geopolymerization . For the present study, concentration of NaOH solution is taken as 12M with varying ratio of Na2SiO3 / NaOH as 2.5, and3 for all the grades of GPC mixes. The fly ash and alkaline activator were mixed together in the mixer until homogeneous paste was obtained. This mixing process can be handled within 5 minutes for each mixture with different ratios of alkaline solution. Heat curing of GPC is generally recommended, both curing time and curing temperature influence the compressive strength of GPC. After casting the specimens, they were kept in rest period for two days and then they were demoulded. The demoulded specimens were kept at 80°C for 24 hours in an oven.

- **Geopolymer Concrete.**

The following test which can be conducted for this experimental work

1. Compressive Strength Test
2. Flexural Strength Test
3. Split Tensile Strength Test

4. RESULTS AND DISCUSSION

Sr.No.	Number Of Day's	Strength Of Concrete (N/mm^2)
1	3	18.103
2	7	35.4766
3	28	42.8420

Table .1. Compressive strength of conventional concrete

Sr.No.	Number Of Day's	Strength of concrete for 12M (N/mm^2)	Strength of concrete for 14M (N/mm^2)	Strength of concrete for 16M (N/mm^2)
1	7	31.0166	31.840	33.0930
2	28	38.2230	40.1568	42.4814

Table. 2. Comparison of compressive strength of G.C. of ratio Na_2SiO_3/NaOH= 2.5 and between the molarity of 12M, 14M, 16M.

Sr.No	Number Of Day's	Strength of concrete for 12M (N/mm^2)	Strength of concrete for 14M (N/mm^2)	Strength of concrete for 16M (N/mm^2)
1	7	32.8870	33.3093	33.470

2	28	38.4150	41.8755	46.4149

Table. 3. Comparison of compressive strength of G.C. of ratio $Na_2SiO_3/NaOH$= 3.0 and between the molarity of 12M, 14M, 16M.

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm^2)**
1	7	32.7777	33.0667	34.6841
2	28	39.9085	44.6568	47.7480

Table. 4. Comparison of compressive strength of G.C. of ratio $Na_2SiO_3/NaOH$= 3.5 and between the molarity of 12M, 14M, 16M.

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm)**
1	28	5.5920	5.9856	6.8136

Table. 5. Comparison of Flexural Strength test of G.C. of ratio $Na_2SiO_3/NaOH$= 2.5 and between the molarity of 12M, 14M, 16M

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm)**
1	28	5.7516	6.7458	7.0026

Table. 6. Comparison of Flexural Strength test of G.C. of ratio $Na_2SiO_3/NaOH$= 3.0 and between the molarity of 12M, 14M, 16M

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm)**
1	28	5.6760	6.5058	7.1256

Table. 7. Comparison of Flexural Strength test of G.C. of ratio $Na_2SiO_3/NaOH$= 3.5 and between the molarity of 12M, 14M, 16M

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm^2)**
1	28	2.4566	3.4482	3.916

Table. 8. Comparison of Split Tensile Strength of G.C. of ratio $Na_2SiO_3/NaOH$= 2.5 and between the molarity of 12M, 14M, 16M

Sr.No	**Number Of Day's**	**Strength of concrete for 12M (N/mm^2)**	**Strength of concrete for 14M (N/mm^2)**	**Strength of concrete for 16M (N/mm^2)**
1	28	2.7031	3.2795	4.4595

Table. 9. Comparison of Split Tensile Strength of G.C. of ratio $Na_2SiO_3/NaOH$= 3.0 and between the molarity of 12M, 14M,16M

Sr.No	Number Of Day's	Strength of concrete for 12M (N/mm²)	Strength of concrete for 14M (N/mm²)	Strength of concrete for 16M (N/mm²)
1	28	2.8407	3.3710	4.5033

Table. 10. Comparison of Split Tensile Strength of G.C. of ratio $Na_2SiO_3/NaOH$= 3.5 and between the molarity of 12M, 14M,16M

CONCLUSION

On the basis of results obtained during the experimental investigations, following conclusions were drawn:

- As the GPC do not have Portland cement, they can be considered as less energy intensive, since Portland cement is highly intensive energy material next only to Steel and Aluminium.
- GPC utilises the industrial waste for producing the binding material in concrete, hence it can be considered as eco-friendly material.
- Economic benefit of G.P.C-Heat-cured low-calcium fly ash-based geopolymer concrete offers several economic benefits over Portland cement concrete. The price of one ton of fly ash is only a small fraction of the price of one ton of Portland cement. Therefore, after allowing for the price of alkaline liquids needed to the make the geopolymer concrete, the price of fly ash-based geopolymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete. In addition, the appropriate usage of one ton of fly ash earns approximately one carbon-credit that has a significant redemption value.
- One ton low-calcium fly ash can be utilized to manufacture approximately three cubic meters of high quality fly ash-based geopolymer concrete, and hence earn monetary benefits through carbon-credit trade.
- Furthermore, the very little drying shrinkage, the low creep, the excellent resistance to sulphate attack, and good acid resistance offered by the heat-cured low-calcium fly ash-based geopolymer concrete may yield additional economic benefits when it is utilized in infrastructure applications.
- We also conclude that when the ratio of $Na_2SiO_3/NaOH$ increased (e.g.2.5,3.0,3.5) then the strength of concrete also increase.
- We also conclude that the molarity (e.g. 12M, 14M, 16M) increased the strength of concrete also increased.
- In case of geopolymer concrete, much higher compressive strength can be gain in initial 24 hours, hence this short of concrete can accelerate the speed of construction.
- Geopolymer concrete with properties such as abundant raw resource, little CO2 emission, less energy consumption, low production cost, high early strength, fast setting, resistant to corrosive environment. These properties make geopolymer concrete to find great application in civil engineering.

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