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Experimental Program for Geopolymer Concrete

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Abstract: In 1978, Davidovits said when alkaline solution mixed with materials such a Fly ash and GGBS binder is obtained through polymerisation reaction. These alternative binder material must contain high amount of Silicon (Si) and Aluminium (Al) which in turn react with alkaline liquid. Hence this concrete is named as Geopolymer Concrete (GPC).The commonly used binder material in GPC are Fly ash, GGBS, Rice husk and Metakoline.
Geopolymers are formed when silicates and aluminates are linked with covalent bonds. Geopolymerisation is a reaction that synthetically incorporates minerals (geosynthesis) that involves naturally occurring alumina – silicates.
Keywords: Geopolymer, Ultrafine GGBS, Flyash
The experimental program tells the detailed step by step procedure that has been performed in this project work. Following are the steps that has been followed.

I. PRE REQUISITES

Some of the basic information's are collected from the earlier studies, including that one of the main material adopted in the present work is Ultra-fine GGBS.

Works that are performed in past based on literature
1) Experimental work on Fly ash based Geopolymer concrete.
2) Experimental work by replacing Fly ash with GGBS (50%, 75% and 100%) in Geopolymer concrete.
3) Some experimental work by varying concentration of Sodium Hydroxide (8M, 10M, 12M, 16M etc.) in GPC.
4) Experimental work by varying alkaline solution ratio from 1 to 3.5.
5) Experimental work with different curing conditions (ambient curing and oven curing).
6) Very little work on durability properties of geopolymer concrete.

A. Objectives

Following are the main objectives for the present dissertation work
1) To evaluate the compressive strength and durability properties by varying Fly ash and GGBS percentages.
2) To evaluate the compressive strength and durability properties by adding Ultra-fine GGBS to previous optimum mix proportion.
3) To compare the strength between ambient curing and oven curing.

In this project, 100mm cube size specimens were used for finding compressive strength at ambient curing and oven curing. Ultra-fine GGBS is replaced at 7.5%, 12% and 20% with GGBS.

II. MATERIAL COLLECTIONS AND TESTING

A. Binding Materials

Binding materials used in present work are Fly ash, GGBS and Ultra-fine GGBS. Chemical and Physical properties of these binding materials are shown in table 3.1 and 3.2 respectively.

Chemical property of Binding materials

Property	Fly ash	GGBS	Ultra-fine GGBS
SiO_2	64.60	32.94	35.28
Al_2O_3	23.86	17.23	16.82
Fe_2O_3	5.12	1.11	1.48
CaO	1.30	37.98	35.90
MgO	0.87	9.93	8.08
Cl	0.011	0.02	0.008

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Na_2O	0.32	0.48	0.34
K_2O	1.63	1.27	0.78
Loss of ignition	0.10	-	-
Insoluble residue	-	0.28	0.35
Sulphide sulphur	-	0.87	0.50
MnO	-	0.73	0.32

Physical property of Binding materials

Property	Fly ash	GGBS	Ultra-fine GGBS
Specific gravity	2.33	2.87	2.85
Fineness(m^2/kg)	533	310	11500
Residue remain on 45µ wash	3.8%	4%	1.18%

B. *Coarse and fine Aggregates*

According to literature, 77% mass of concrete was only due to coarse and fine aggregates. Hence this is one of the main material in concrete. Aggregates used are from Local source. In this work we have used 12mm. down size coarse aggregates, this only because the cube which we have casted for compressive strength was 100mm. Fine aggregates used in project was M Sand. Not very much research has been done under Geopolymer concrete. Aggregates are conforming to IS 2386 were used.

C. *Alkaline Activator Solution*

Alkaline Activator Solution is the chemicals used in Geopolymer concrete to activate the binding properties by reacting with silicates and Aluminates which are present in Fly ash and GGBS. Basically Alkaline Activator Solution is combination of Silicates and Hydroxide solution. There are potassium based solution and sodium based solution. As potassium based solution are very costlier, sodium based solutions are used in this project work. Sodium hydroxide pellets are dissolved in distilled water to obtain required molarity and solution is prepared 2 hours before the use. This is to avoid the liberation of excessive heat due to exothermic reaction. This solution is mixed with Sodium silicates in the ratio of 2.5

D. *Sodium Silicate (Na_2SiO_3)*

Sodium Silicate is one of the main solution which enhances the strength properties by giving out silicate to react. In the present project work, the ratio of SiO_2 to Na_2Oin the solution was 1.9. The chemical properties of sodium silicate are shown below

E. *Sodium Hydroxide (NaOH)*

Dissolution of Fly ash is connected with the concentration of NaOH. Generally NaOH provides more leaching of Al and Si ions than KOH solution. Hence, concentration of alkaline solution is one of the important property in producing strength. In the present work 10M concentration NaOH was used. To prepare 10M NaOH, 10x40 = 400 grams of NaOH pellets is to be dissolved in 1 litre distilled water.

III. MIX DESIGN OF GEOPOLYMER CONCRETE

In normal conventional concrete, the main component for strength was cement. Cement is manufactured under controlled manner. Where as in geopolymer concrete there are mainly three parameters to be kept in controlled that is Binder materials (Fly ash, GGBS, Metakoline etc.), Alkaline activator solution (NaOH + Na_2SiO_3 or KOH and K_2SiO_3) and to some extent zone of aggregates. Keeping all the three parameters in controlled manner is very difficult and hence till date there is no standard Mix design for geopolymer concrete. Even in this paper we are assuming some of the data and worked out the mix design as shown below.

1) *Step 1:* First and fore most assumption is unit weight of concrete. This is based on type of concrete required, if we require light weight concrete then value should be in the range of 600 to 1800 kg/m^3, for normal purpose value should be from 1800 to 2500 kg/m^3 and for high density concrete unit weight should be above 2500 kg/m^3. In the present case unit weight of concrete assumed is 2450 kg/m^3.

2) *Step 2:* Based on experience, mass of aggregates should be assumed to be 75% to 80% of mass of concrete. This assumption is based on conventional concrete. In the present work 77% mass of concrete is assumed to be mass of aggregates. Hence weight of aggregates is 2450 x 0.77 = 1886.5 kg/m^3.

Mass of aggregates contains both coarse and fine aggregates. From the experience and observation made by researchers 70% by mass of aggregates is filled with coarse aggregates and 30% is finned with fine aggregates. Hence,
Mass of coarse aggregates = 1886.5 x 0.7 = 1320.55 kg/m^3
Mass of fine aggregates = 1886.5 x 0.3 = 565.95 kg/m^3
Mass of Binder and Alkaline liquid = 2450 – 1886.5 = 563.5 kg/m^3

3) *Step 3:* Ratio of Alkaline liquid to Binder can be assumed to be 0.35 to 1.5. Here in the present project assumed ratio of Alkaline liquid to Binder is 1. Hence,

Mass of Binder = 563.5/2 = 281.8 kg/m^3
Mass of Alkaline liquid = 563.5/2 = 281.8 kg/m^3

4) *Step 4:* From the literature, ratio of sodium silicate to sodium hydroxide can be assumed from 1 to 3.5. But in most of the literature optimum ratio was 2.5 and hence in present project work 2.5 is the assumed ratio of sodium silicate to sodium hydroxide. Therefore,

Mass of NaOH = 281.88/3.5 = 80.5 kg/m^3
Mass of Sodium silicate = 281.88 – 80.5 = 201.38 kg/m^3
Molarity of NaOH assumed = 10M

IV. CASTING AND CURING OF SPECIMENS

Before casting of specimens, we need to fix the percentage variation of binding material such as Fly ash, GGBS and Ultra-fine GGBS. First we have casted only for Fly ash and GGBS. From the previous optimum percentage GGBS is replaced by Ultra-fine GGBS by 7.5, 12 and 20%. Optimum percentage obtained for Fly ash and GGBS is 25 and 75% respectively.
Once the mix proportion of geopolymer concrete is done, quantity of concrete required for each mix should be calculated. Quantity is found based on tests are to be carried out. Compressive strength – ambient curing (1, 3, 7, 28 and 56 days)

A. Compressive strength – Oven curing (3, 7, 28 and 56 days)
B. Water permeability
C. Sorptivity
D. Abrasion
E. RCPT
F. Water absorption
G. Acid attack
H. Sulphate attack
I. Drying Shrinkage

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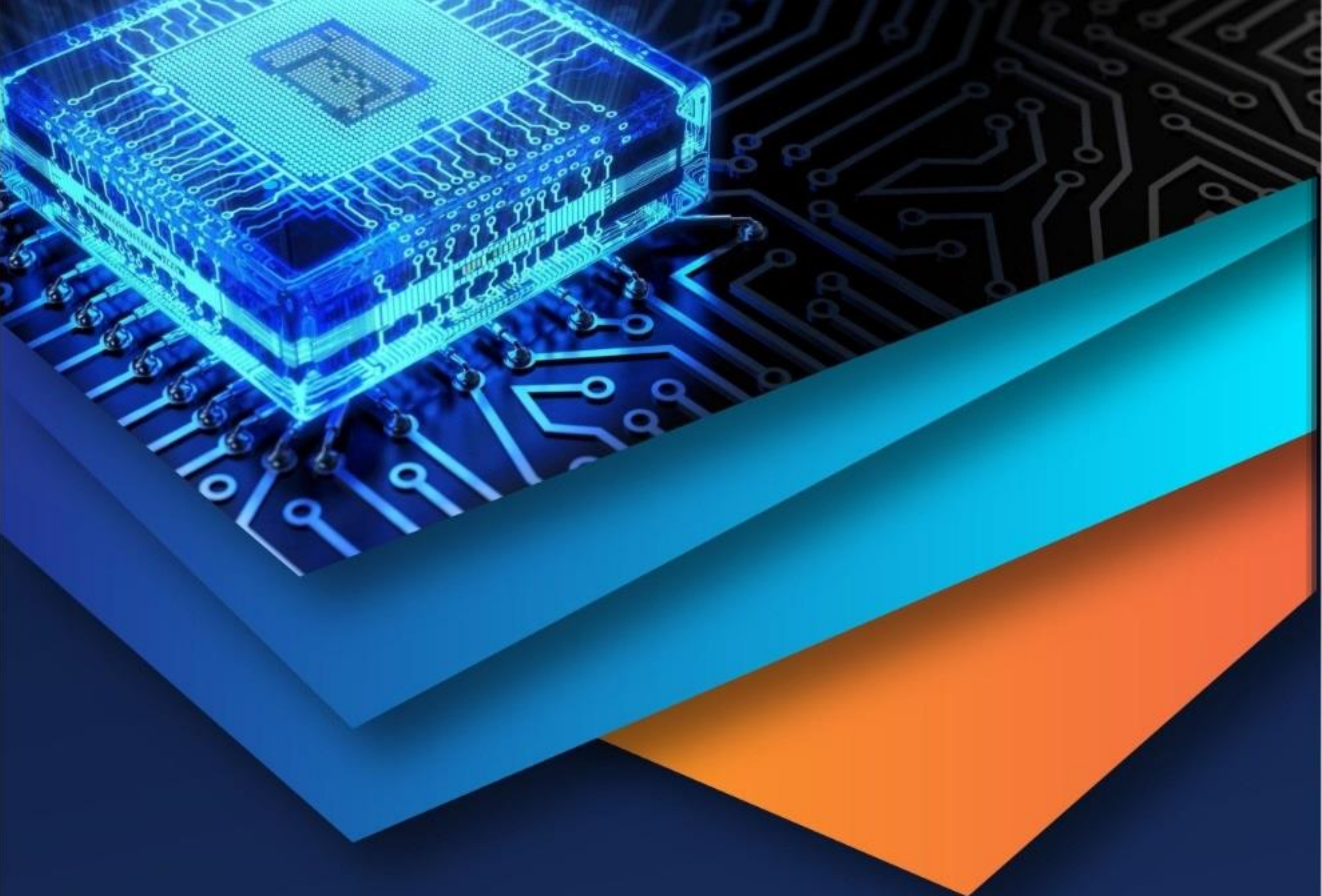

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