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Experimental Investigation on Strength Properties of GEO Polymer Concrete using GGBS

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Abstract : Geo polymer concrete utilizes an alternate material including GGBS as binding material in place of cement[6]. This GGBS reacts with Sodium silicate (SiO_2) and Sodium Hydroxide (Na_2O) to form a gel which binds the fine and coarse aggregates. Since Geo polymer concrete is the emerging field, the guidelines from the Bureau of Indian Standards are yet to be formulated. An attempt has been made to find out an optimum mix for the Geo polymer concrete. Concrete cubes of size 150 X 150 X 150mm were prepared and cured under ambient curing for 28 days. The compressive strength was found out at 7days, 14 days and 28 days. The results are compared. The optimum mix is GGBS : Fine aggregate : Coarse aggregate (1:1.5:3) with the solution (Na_2O & SiO_2 combined together). High early strength was obtained in the Geo polymer concrete mix.
Keywords : Geo polymer concrete, optimum mix ratio, ambient curing.

1.0 Introduction

Geo polymer cement (Davidovits, 1984, 2008, 2010)[7] represents a broad range of materials characterized by networks of inorganic molecule. The GGBS is rich in silicate and alumina; hence it reacts with alkaline solution to produce high strength concrete. The compressive strength increases with the increase in GGBS fineness and thus the reduction in GGBS is replaced 100% by cement and thereby making it Geo polymer concrete. In India, early production of 1tonne of cement produces 0.587 tonne of carbon-di-oxide into the atmosphere, by the usuage of GGBS instead of cement will reduce atmospheric pollution to bout 24.8%

Annually about 1478 tonnes has been manufactured in India, it produces about 2517.88 tonnes of carbon-di-oxide by the usage of GGBS such amount of carbon-di-oxide can be the major problem now-a-days is the water scarcity by replacing 100% cement using GGBS, thereby water curing can be neglected and ambient curing is appropriate[9]. Annually in India, of about $225X10^6$ litres (approx) of water is used for curing alone.

Activation of alumina silicate materials such as fly ash, blast furnace slag (GGBS) and metakaolin using alkaline solutions to produce binders free of Portland cement is a major advancement towards increasing the beneficial use of industrial waste products and reducing the adverse impacts of cement production.

2.0 Literature Review

In the works carried by Kolli, Ramujee[8] etc. all is to develop the mic=x design for geo polymer concrete in different grades of concrete that is low, medium and higher grades. They have considered the design parameters s alkaline liquid to fly ash ratio and water to geo polymer different mixes for each grade is casted,

tested and optimized. Based on results they have suggested water to binder ratio of 0.27, 0.21 & 0.158 and alkaline to binder ratios of 0.5, 0.40 and 0.35 are suggested for M20, M40 & M60 respectively.

Mohamed Aquib Javeed[5] had made an attempt on mix design of suitable geo polymer concrete which says that Geo polymer is a type of amorphous alumino-hydroxide product that exhibits the ideal properties of rock forming elements, i.e., hardness, chemical stability and longevity [3.] Geo polymer binders are used together with aggregates to produce geo polymer concretes which are ideal for building and repairing infrastructures and for pre-casting units, because they have very high earlier strength, their setting times can be controlled and they remain intact for very long time without any need for repair.

3.0 Aim of Investigation

Earlier researchers have investigated in making Geo polymer concrete more greener by adopting ambient curing for the development of strength in Geo polymer concrete. This could be done by full replacement of cement by GGBS along with Na_2O & SiO_2 [5] . Mix design of M-15, M-20 & M-30 grade Geo polymer concrete is made and it is optimized using Taguchi's principles and its strength properties are evaluated.

4.0 Objectives

1. To make a concrete without using cement (i.e., Geo polymer concrete).
2. To study the different strength properties of geo polymer concrete with percentage replacement of GGBS.
3. To evaluate the optimum mix proportion of Geo polymer concrete with GGBS replaced in various percentage by GGBS.
4. To compare the cost variation of geo polymer concrete with normal concrete.

5.0 Methodology

To determine properties of materials:

The propertied of following materials are determined as listed below:

5.1 Ground Granulated Blast Furnace Slag:

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry. Blast furnace slag is defined as the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace[4]. The percentage of GGBS passing through 45µm IS Sieve was found to be 97% and its specific gravity was 2.93.

5.2 Sodium Hydroxide:

Sodium hydroxide is available in solid state by means of pellets and flakes. The cost of Sodium hydroxide is mainly varied according to the purity of the substance. Since the Geo polymer concrete is homogeneous material, the commercial grade of the Sodium hydroxide of purity 98% is used. Here, Sodium hydroxide pellets are used.

Fig.4.I.1 Sodium Hydroxide

5.3 Sodium Silicate solution:

Sodium silicate is also known as water glass or liquid glass. It is available in liquid (gel) form. Silicates were supplied to the detergent company and textile industry as bonding agent.

Fig.5.I.2 Sodium Silicate

5.4 Fine Aggregate:

Fine Aggregate confirms to grade II from the sieve analysis test. Its specific gravity was found to be 2.55, its Fineness Modulus was found to be 2.67, its loose density was found to be 1666.882 Kg/m^3 and its dry compacted density was found to be 1912.201 Kg/m^3.

5.5 Coarse Aggregate:

Coarse Aggregate used is of 12.5mm nominal size and its specific gravity was found to be 2.602. It has also passed the tests of aggregate impact value and aggregate crushing value.

5.6 Super Plasticizer:

Conplast-SP-430 grade super plasticizer was used in this mix and its dosage was 1.5% of the mass of binder material comprising of GGBS.

5.7 Trail mix of M-15, M-20 & M-30 grade sustainable Geo polymer concrete.

As the Geo polymers concrete are new construction materials they don't have any standard mix design. To identify the mix ratios for different grades of Geo polymer concrete the trial and error method is followed. To identify the best mix or optimum mix for the Geo polymer paver block the various parameters and ingredients are varied. The parameters changed in the mix proportions are density, molarities and percentage ratio between the GGBS. The density is varied from 1800 – 2400 Kg/m^3. The molarity or the concentration of Sodium hydroxide pellets solution is varied around 4–8M. And the major parameter is the ratio between the GGBS which is fully replaced for ordinary cement and the percentage is varied in range of 0,25,50,75,100.

Table 5.1 MIX PROPORTION FOR GPC

MATERIAL	**WEIGHT per m^3 (Kg/m^3)**
GGBS	428.57
Fine Aggregate	560
Coarse Aggregate	840
NaOH pellets	57.14
Water	49.2
Na_2SiO_3	114.28

6.0 Fresh concrete test:

6.1 Slump cone test:

Fig.6.1 Slump cone test

The slump test is a practical means of measuring the consistency of mix. Since changes in the values of slump obtained indicate material changes in the water content or proportions of the mix. It is therefore useful in controlling the quality of the mortar produced.

Table 6.1 Inference

S.NO	TYPE OF WORK	SLUMP (mm)
1.	Concrete for road work	20 to 30
2.	Ordinary RCC work for beams and slabs	50 to 100
3.	Column, retaining walls and thin vertical sections	75 to 150
4.	Vibrated concrete	12 to 25
5.	Mass concrete	25 to 50

Table 6.2 Geo Polymer Concrete Slump

WGT. OF GGBS (Kg)	WGT OF SAND (Kg)	WGT OF AGGREGATE (Kg)	RATIO OF NaOH to Na_2SiO_3	SLUMP (mm)
18	23.4	41.4	2%	95
24	31.2	55.2	2.50%	135
18	23.4	41.1	3%	143
18	23.4	41.4	3.50%	148

7.0 Hardened concrete test:

7.1 Compressive strength of concrete cubes:

Fig.7.1 Compressive strength

The compression test is carried out on either cube or cylindrical samples taken from a cross section of mixes during the casting of cubes and any other section of construction that is cast on a different day. The size of the cubes and cylinders will be laid down by the local testing authority.

Table 7.1 OBSERVATION OF COMPRESSIVE STRENGTH (150mmX150mmX150mm)

S. No	Grade	Age (Days)	Ultimate Load (N)	Ultimate Compressive Stress (N/mm^2)
G1	M15	7	305000	14
G2	M15	14	390000	17
G3	M15	28	420000	19
G4	M20	7	390000	17
G5	M20	14	575000	26
G6	M20	28	650000	29
G7	M30	7	680000	30
G8	M30	14	760000	34
G9	M30	28	820000	36

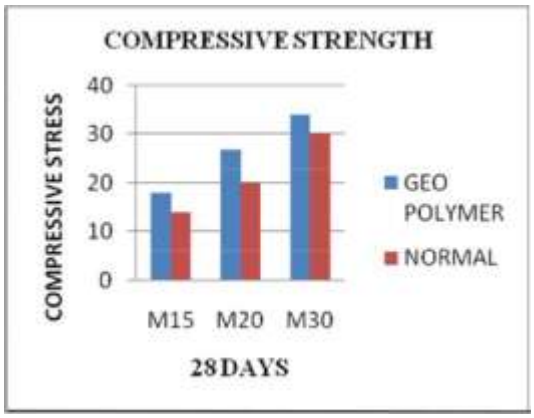

Fig.7.2 Compressive strength chart

7.3 Split tensile strength:

Split tensile strength of cylinders for 7days, 14days and 28 days are tested and their results are given below in the form of tabulation.

Fig.7.3 Split tensile strength

Table 7.2 Observation of Split Tensile Strength (150mmX300mm)

S. NO	GRADE	AGE (DAYS)	ULTIMATE LOAD (N)	SPLIT TENSILE STRENGTH (N/mm^2)
G1	M15	7	160000	9
G2	M15	14	215000	12
G3	M15	28	245000	14
G4	M30	7	280000	16
G5	M30	14	395000	23
G6	M30	28	440000	25

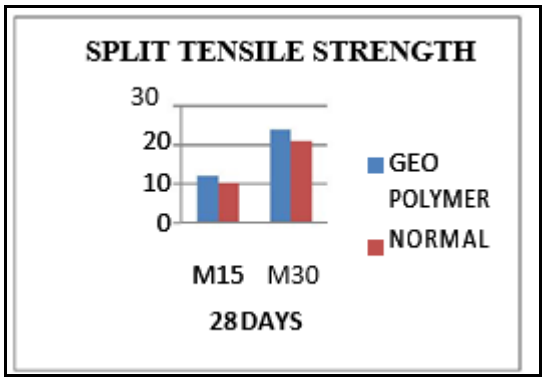

Fig.5.IV.4 Split tensile strength chart

8.0 Casting and Curing:

Steel or cast iron cube and cylinder moulds are to be used. A 150mm cube and cylinder should be filled in three layers; each layer should be rammed at least 25 times with steel bar 600mm long and having a ramming face of $16mm^2$.it is usual to produce six cubes at a casting from three different mixes (at work site) and send two 150mm cubes for testing at 7days, 14days & 28days after casting. Remove mould pieces after 48 hours.

Fig.8.1. Casting

After casting, specimens were left in the room temperature for curing. At the end of 48 hours curing period, test specimens were removed from the moulds and placed in room temperature conditions for ambient curing until the test day. A data sheet should be kept as a record.

9.0 Results and Discussion:

Geo polymer concrete using GGBS vs Normal concrete.

Table 6.I.1

M30	**GPC**	**NORMAL**
Slump value	145mm	155mm
Initial setting time	126 minutes	30 minutes
Final setting time	Ambient curing	Water curing
Curing	48 hours	24 hours
De-moulding period	38 N/mm^2	32 N/mm^2
Max. compressive strength	26 N/mm^2	23 N/mm^2
Max. split tensile strength	580N	390N
Max. deflection	4.2mm	6.2mm

10.0 Conclusion:

It is analyzed that replacement of cement with ground granulated blast furnace slag increases the workability as the percent of replacement increase as the slump factor and also the compressive strength does not increase favorably. But it is found that the flexural strength increase with respect to 50 times.

GGBS can be used as a replacement for cement as there is marginal difference in strength between GGBS and conventional cement. This review study tried to focus on the most significant effects in addition of GGBS to concrete mixes.

According to many researchers, the addition of geo polymer into concrete creates low workable or inadequate workability to concrete, therefore in order to solve this problem, super plasticizer may be introduced without affecting other properties of concrete. Thus, further study is needed for increasing the workability of GGBS concrete.

11.0 References:

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