A STUDIES ON BEHAVIOUR OF GEOPOLYMER CONCRETE

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Abstract - *Cement is the world's most reliable construction material. The rate of consumption and production of Ordinary Portland cement (OPC) increases, which leads to environmental pollution by the emission of carbon dioxide (CO_2) .In this study cement, is replaced by class F fly ash in concrete which will be activated by sodium hydroxide and sodium silicate solution, act as a binding material. This study is focus on comparison between the conventional concrete pavement and geopolymer concrete pavement.*

Keywords: Geopolymer concrete, Fly ash, Mix design, Molarity, etc...

1 INTRODUCTION

Cement is the world's most versatile, durable and reliable construction material. Large quantities of Portland cement are required for concrete. The Ordinary Portland Cement (OPC) causes pollution to the environment due to the emission of CO_2. Geopolymer concrete was mainly used to reduce environmental pollution that causes by production of Portland cement. Each one of the constituent material of concrete has some adverse effects on the environment. Portland cement is responsible for emission of about 7% of the total CO_2 gas is the key greenhouse gas held responsible for the global warming and climate. On the other hand, there are possibilities for recycling of suitable industrial by-product materials for their high-volume high-end utilization in the concrete. Cement from the concrete. Reduction of greenhouse gas emissions from cement-based industries.

1.1 GEOPOLYMER CONCRETE

Geopolymer concrete (GPC) proposed by Davidovits is currently recognized as an innovative technology for the cement-based construction industry. Instead of Portland cement, industrial by-product materials rich in Silicon (Si) and Aluminium (Al) such as fly ash, rice-husk ash, silica fume, slag, and other similar materials are added to react with highly alkaline liquid to produce binders. The use of this geopolymerisation process in concrete-making could significantly reduce the CO_2 emission into the atmosphere caused by the cement industry. This technology further reduces or eliminates the need for large amounts of raw materials for the manufacture of Portland cement and provides additional potential for recycling of Al and Si rich by-products materials. The main constituent of today's GPC is the ASTM Class F fly ash (a by-product from coal-fired thermal plants) because of its availabilities in the most parts of the world. Such low-calcium fly ash, with Si and Al constituent of about 80% are being used at experimental levels for making geopolymer concrete as the ultimate structure of geopolymer depends largely on the ratio of Si to Al. Geopolymer paste acts as binder. The geopolymerisation process occurs through alkaline solution. It starts when fly ash dissolves. Coarse and fine aggregates constitute about 75-80% of the mass of GPC. A combination of sodium silicate and sodium hydroxide solution is commonly used as alkaline liquids to start the polymerization of the resource material. For Geopolymer concrete heat curing or steam curing or dry curing is required for the low-calcium fly ash based GPC.

1.2 SCOPE AND OBJECTIVE

The objective of this project is to study the changes on mechanical properties of low calcium flyash based geopolymer concrete while using different kinds of sodium silicate solutions in alkaline solution. The experimental work involves the short-term tests on low-calcium fly ash based geopolymer concrete. The conventional tests currently available for Portland cement concrete were used for the experimental work. In this project, low-calcium fly ash (Class F) from Mettur thermal power station and locally available crushed angular coarse aggregate are used. Manufactured sand is used as fine aggregate and various types of sodium silicate solutions such as Sodium Meta-silicate, Sodium silicate used in textile industry and Sodium Tri-silicate are used in alkaline solution for manufacturing of geopolymer concrete.

2. MATERIAL USED

2.1 Fly ash-Class F fly ash is easily available at low cost. The specific gravity of Fly ash is found out by Pyconometer.

Table 1 Physical properties of Fly ash

S.No.	Property	Value
1	Specific gravity	2.46
2	Fineness	23%
3	Consistency	36%
4	Color	Light grey

2.2 Tests on coarse Aggregate

The coarse aggregate of 20mm size has been used and the properties are given in table 3 below

Table 3 Properties of Coarse aggregate

S.NO	Property	Value
1	Specific gravity	2.84
2	Impact value	14.6%
3	Crushing value	24%
4	Water absorption	1.67%
5	Fineness modulus	1

2.3 Tests on Fine aggregate (M- sand)

Aggregate almost passes through 4.75 mm sieve is called as Fine aggregate. Manufactured Sand (M-Sand) bought from local supplier is used as fine aggregate conforming to IS 383 (1970): Specification for Coarse and Fine Aggregates from Natural Sources for Concrete.

Table 4 Properties of M- sand

S.NO	Property	Value
1	Specific gravity	2.58
2	Fineness modulus	1.0 (Zone II)
3	Water absorption	2.53%

2.4 Sodium Hydroxide

Sodium hydroxide in pellet form is used in this experimental program. This type of sodium hydroxide is colorless pellets and soluble in water. Molecular weight of NaOH is 40 g/mole. Specifications of NaOH is given in Table 5.

Table 5 Specification of sodium hydroxide

Chemical Composition	
Purity	97%
Na_2CO_3	2.0 %
Cl	0.01 %
SO_4	0.01 %
SiO_2	0.02 %

2.4 Sodium Meta-Silicate (Na_2SiO_3)

Sodium Meta-Silicate is the first member of Sodium compound family having the general molecular formula as $(Na_2SiO_2)_{n0}$. It is in the form of solid particles. Specifications of Na_2SiO_3 is given in Table 6.

Table 6 Specifications of Sodium Meta-Silicate

Purity	99%
Na_2O	21.7%
SiO_2	21.80%
Molecular Formula	$Na_2SiO_3.9H_2O$
Molecular Weight	284.2 g/mole

2.6 Sodium Tri-Silicate ($Na_2Si_3O_7$)

Sodium Tri-Silicate is the third member of Sodium compound family having molecular formula as $(Na_2SiO_2)_3O$. Sodium Tri-silicate is used in liquid from.

Table 6 Specifications of Sodium Tri-Silicate

Chemical Composition	
Purity	98%
Na_2O	7.5%
SiO_2	25%
Molecular Formula	$Na_2Si_3O_7$
Molecular Weight	242.2 g/mole
Density	1390 kg/m^3
pH	11.2

2.7 Sodium Silicate (Textile Grade)

A dark greenish grey colored viscous gel used in textile industry is used in this project. It is normally available in the market and No specification is available about the gel. Density of the solution is 1720 kg/m^3.

3. MIX DESIGN (GPC 40)

Fly ash = 492.5 Kg/m^3

Coarse aggregate = 1230.5 Kg/m^3

Fine aggregate = 631.2 Kg/m^3

NaOH solution = 56.28 Kg/m^3

Mass of NaOH solids = 22.51 Kg/ m^3

Mass of Na_2SiO_3 solids = 56.28 Kg/ m^3

Na_2SiO_3 solution = 140.72 Kg/m^3

Extra water = 15% by mass of Flyash

Ratio of Mix = 1: 1.28: 2.5

4 EXPERIMENTAL PROCEDURE

4.1 Preparation of alkaline solution

A combination of sodium silicate solution and sodium hydroxide (NaOH) solution is used as the alkaline liquid. As specified on P. Nath et al (2010). The alkaline solution is prepared 30 minutes before casting of specimens. Based on previous research it is recommended that the ratio of sodium silicate to NaOH is should be maintained within 0.4 to 2.5. In this project the ratio is taken as 2.5.

In this project there are three types of sodium silicate solutions are used. Hence their preparation method will differ. When using Sodium Meta-Silicate, the solid particles weighing equal to 2.5 times the NaOH pellets is taken and mixed in 2.5 times the water taken for NaOH solution preparation. For both Sodium Silicate Gel (Textile Grade) and Sodium Tri-Silicate Solution, it is taken about 2.5 times the NaOH solution.

For NaOH solution, it is necessary to dissolve the pellets in water to a required concentration. The concentration of NaOH in water will vary between 8 Molar to 16 Molar. For this experimental program 10 Molar NaOH solution is used. The 10 Molar NaOH solution consist of 10x40 = 400 grams of pellets per litre of water when the molecular weight of pellets equal to 40 g/mole. If superplasticizer used it will be mixed with the alkaline solution prior to use.

Fig. 4.1 Preparation of Alkaline Solution

4.2 Mixing

The conventional mixing method used for conventional OPC concrete is used for the geopolymer concrete manufacturing. The mixing process having two stages. Initially Flyash, M-sand and Coarse aggregate are mixed for about two minutes as dry mixing. After that alkaline solution is added to the dry materials and mixed for about four minutes as wet mixing. If required addition of 2 % of superplasticizer and 15% of extra water will be added to the mix.

Fig. 4.2 Mixing of geopolymer concrete

4.3 Casting

For specimen preparation, procedures that specified in IS 516-1959 Methods of Tests for Strength of Concrete are properly followed.

Fig. 4.3 Casting of geopolymer concrete specimens

4.4 Curing

After casting the specimen moulds are left for one day to set the concrete. And if the concrete had more workability the specimens might be left upto three days. Thus period is known as "Rest period". After the rest period the specimens are allowed to steam curing for about 24 hours at $60^{o}C$. The specimens are left for ambient curing i.e. left at room temperature for upto the time at which the specimens are to be tested.

Fig. 4.4 curing of geopolymer concrete specimens

5. TESTING OF SPECIMENS

5.1 Compressive Strength

For cubes, compressive strength test was conducted at the curing age of 3, 7, and 14 days as shown in figure 5.1.

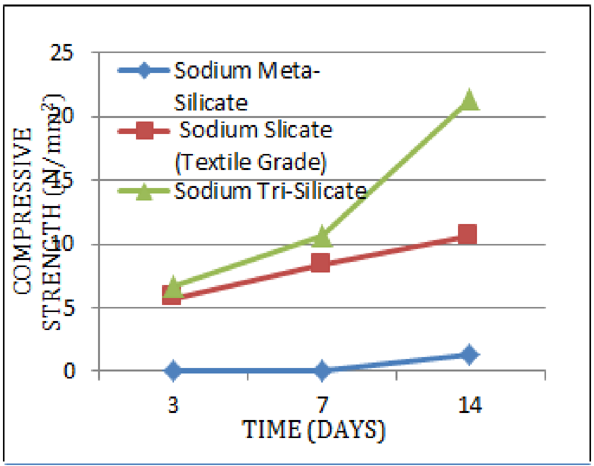

Fig. 5.1 Compressive strength with age

5.2 Flexural Strength

For prism strength test was conducted at the curing age of 3, 7, and 14 days. The results are shown in Figure 5.2

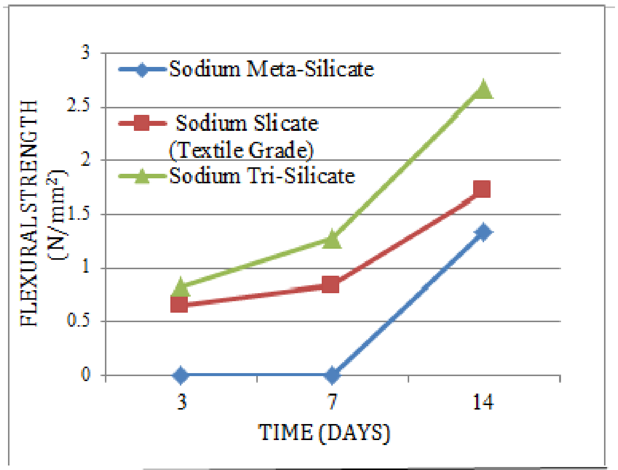

Fig. 5.2 Flexural strength with age

5.3 Split Tensile Strength

For cylinder strength test was conducted at the curing age of 3, 7, and 14 days. The results are shown in figure5.3.

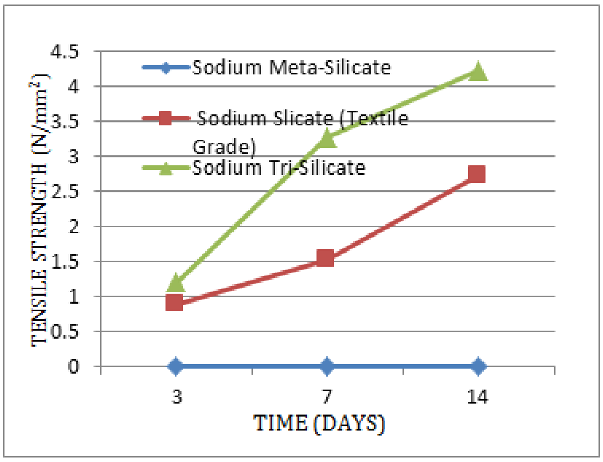

Fig. 5.3 Tensile strength with age

6. CONCLUSION

1. The fresh geopolymer concrete produce low workability, as it shows high plasticity.

2. The fresh geopolymer concrete shows too sticky property, there is no possibility of pumping of fresh geopolymer concrete.

3. From this experimental work, it founds that the following factors affect the strength of the concrete. They are,
    a. Dosage of silicate solution
    b. Alkaline activator to Flyash ratio,
    c. Water to geopolymer solid ratio,
    d. NaOH to Na_2SiO_3 ratio,
    e. Concentration of NaOH in Water,
    f. Curing temperature and its duration.

   Hence it recommended that more awareness is mandatory on the above factors while working on geopolymer concrete.

4. Among the three Sodium Silicate solutions, Sodium Tri-silicate solution is more suitable for higher strength geopolymer concrete.

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