STUDY ON STRENGTH OF GEOPOLYMER CONCRETE WITH AMBIENT TEMPERATURE CURING AND LOW ALKALI CONTENT

PAWAN KUMAR K R[1], SURENDRA B V[2],

[1] Asst Professor, Dept of Civil Engineering, New Horizon College of Engineering, Bangalore, India
[2]Associate professor, Dept of Civil Engineering, New Horizon College of Engineering, Bangalore, India

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***Abstract** - In a quest to make concrete without the use of cement, the process of Geo-Polymerization of cementetious materials concrete was discovered. The benefits of reduced CO_2 derived by usage of Geo-Polymer instead of Cement are not obtained fully as the Geo-Polymerization to occur a higher temperature is required. This study is an attempt to obtain Geo-Polymer concrete in the ambient room temperature without creating any specialized curing conditions.*

Keywords—Geo-Polymer,Ambient temperature curing, Molarity, Ageing of Concrete, Compressive Strength

1.INTRODUCTION

Concrete is the most widely material used in construction and Portland cement is indispensible component for making concrete. Ordinary Portland cement (OPC) is used conventionally as main binder to bind fine and coarse aggregates. The production of cement liberates carbon dioxide due to burning of fossil fuels like coal and conversion of calcium carbonate to calcium silicate compounds. Carbon dioxide emission will be reduced if there is an alternative to cement is realized at the same cost with the same ease of handling. The harmful Green house gasses can be reduced and wastes like fly ash, GGBS etc can be utilized by partial replacement of cement. An effort to make environmentally friendly concrete is the development of inorganic alumina-silicate polymer, with material like GGBS that are rich in silicon and aluminum called as Geopolymer, synthesized from materials of geological origin or by-product materials such as Fly ash and GGBS that are rich in Aluminum and Silicon. GGBS (Ground Granulated Blast Slag) is a by-product material Generated in iron extraction. GGBS has a high percentage of amorphous silica and calcium oxide which is ideal for Geo-Polymerization process.

2. LITERATURE REVIEW

Irjet There are several published literatures of the effect of GGBS in production of Geo-Polymer material.

In 1930's, alkali such as sodium or potassium hydroxide was ground with slag to determine if slag would set when added to Portland cement. In this course Purdon discovered that alkali addition produced a new rapid hardening binder. Following this initial investigation in Europe, much research into alkali activation technology then moved eastward for several decades. Alkali activated slag cements were being used in Russia to produce concrete pipe, tunnel lining, wall, decks and structural beams.Chinese researchers developed a range of materials throughout the 1980s.

Palomo , Grutzeck and Blanco [1] studied the alkali activation of various by-product materials. This has become a prime area of research in many research laboratories as there is a possibility to use the materials to synthesize relatively inexpensive and green binder like cement which can be used for construction with durability properties of cement. In this present paper, the activation of puzzolona material; fly ash with alkaline solutions with high alkalinity is studied. The solutions, used for research were made using NaOH(Sodium Hydroxide) ,KOH (Potassium Hydroxide), Na2Sio3 (Soidum Silicate/water glass).The reaction products were a alumino-silicate gel with cpmpressive strengths of the order of 60 MPa were observed after curing the mix at 85º C for 5 h duration.

Pradip and Prabir [2] in their investigation, investigated that Fly ash Geo-polymer mixtures were designed with GGBFS upto 30% in increments of the total binder content and cured at ambient temperature. Addition of 30% GGBFS led to Compressive Strength of about 55 Mpa .The density of the mix also increased with the increase in GGBFS content.

Madheshwaran, Gnansundar, Gopalkrishnan [3] in their study found that higher curing period improved the polymerization and resulted in increase of compressive Strength. Usage of high Molarity alkaline solution (7 M) with 100% GGBS will result in the higher compressive strength and split tensile strength. Compressive Strength observed was in the spread of 45Mpa to 60 Mpa . Aside of reduced energy demand for binder material, the GPCs utilize the industrial waste for production of the binding action in concrete. There are twin ecological and environmental benefits of GGBS. It was also observed that any addition of Super Plasticizer(Naphthalene based) beyond 2% reduced the Compressive Strength.

Mathew Sudhakar and Natarajan [4] in their investigation found, when two binders,fly-ash and GGBS used in combination with the increase in percentage content of GGBS compressive strength increased .It was also ascertained that Coal Ash and GGBS Combination when used along with 15M Alkaline Solution and replacement of 30% by GGBS Compressive Strength up to 57Mpa was observed.

Adhiseshu et al [5] in their study created 5 Geo-Polymer mixes with combination of binders Fly ash and GGBS by increasing the GGBS content from 0% to 40% . 8M NAOH solution and NA2SIO3/NAOH ratio was taken as 2.5 the result revealed that with the increase of GGBS content , the observed compressive Strength was in a range of 30 to 40 MPa at 3 days was observed. It can also be concluded that that ambient curing was sufficient to achieve the desired compressive strength. The density of Geo-polymer concrete could be comparad to that of concrete made from OPC.

Studies by Djwantoro.Hardjito et.al [6] the effect on compressive strength of geo-polymer concrete prepared with fly ash was studied. The test variables included were the age of concrete, curing time, curing temperature, quantity of super plasticizer, the rest period prior to curing, and the water content of the mix. Cylinders of 100mm x 200mm were cast and after casting, samples were covered by film and left in room temperature for 30 to 60 min and then kept in oven for heat curing. 8M sodium hydroxide solution was used with 2 molar ratio of sodium silicate solution and sodium silicate to sodium hydroxide ratio was kept constant at 2.5. Water to geopolymer solids (by mass) ratios chosen for the study was 0.175, 0.2 and 0.225. The strength results obtained showed a decreasing trend with increase in the water to geopolymer solids ratio.

3. MIX DESIGN

The principle change between geopolymer concrete and Portland cement concrete is the system of binder, Portland cement hydrates to produce C-S-H gel; giving the strength to concrete whereas in Geo-Polymer systems the polymerization reaction happens between Slicates and aluminates giving strength to the matrix of concrete. The aluminium and silicon oxides existing GGBS reacts with the alkaline liquid to form the Geopolymer binder that holds coarse aggregates, fine aggregates and un reacted binder in a matrix is called as a Geo-Polymer concrete. The binder system of Geopolymer concrete may be designed using certain different parameters unlike normal Portland cement concrete.The mechanical compressive strength and the workability of geopolymer concrete are affected by the bulk of Geopolymer solids and their proportions(Puzzolona+Sodium Silicate+Sodium Hydroxide).The aggregates both fine and coarse act as a rigid filler material as in the Portland Cement Concrete. The mass of aggregates in combination will be usually between 75% and 80% of the mass of materials of concrete for a sound performance.

Acronyms

Geo Polymer solids- The total of mass of Puzzolonic binder, Sodium Silicate & Sodium Hydroxide.

Alkaline Activator Solution- Solution prepared by mixing of Sodium Hydroxide and Sodium Silicate together.

Steps followed for creation of Mix-Design:

Step 1: Density of geopolymer concrete was assumed as same as normal concrete. It was taken as 2400kg/cum.

Step 2: Total aggregate content in the mix was fixed

Step 3: Coarse aggregate to fine aggregate ratio was fixed based on workability and strength requirement.

Step 4: Binder content was fixed at Kg/m^3

Step 5: Binder to alkaline liquid ratio was fixed

Step 6: Ratio of sodium silicate to sodium hydroxide solution is fixed based on experimentation and target strength required.

Step 7: Total quantity of sodium silicate and sodium hydroxide is calculated

Step 8: Water to Geopolymer solids ratio was chosen (Mass of Geopolymer solids include GGBS, Sodium Hydroxide and Sodium Silicate)

Step 9: Total water content in liters/ m^3 was found out and water contribution from sodium hydroxide solution was subtracted from the above water content

Step 10: Plasticizer dosage was found out that 2% by total binder content

MIX DESIGN DETAIL

	Density of Concrete	2400 kg/m^3
1	Take mass of combined aggregate 75% of mass of concrete	0.75 x 2400 1800 kg/m^3
2	Take fine aggregate to coarse aggregate ratio	1:1
3	Weight of Fine aggregate:1800/2	900 kg/m^3
4	Weight of Coarse aggregate:1800/2	900 kg/m^3
5	Take alkaline liquid/binder ratio	0.5
6	Weight of binder	375 kg/m^3
7	Weight of alkaline liquid	187.5 kg/m^3
8	Weight of extra water	37.5 kg/m^3
9	Sodium hydroxide: sodium silicate as "1:0.8"	187.5/.8 = 104.16kg/m^3
10	Sodium Hydroxide pellets for 4 Molar solution (i.e.160g per 1kg of water)	14.36 kg/m^3
11	Sodium silicate solution	83.34 kg/m^3
12	Weight of Superplasticizer (2% of GGBS weight)	02*375= 7.5 kg/m^3
13	Total Weight of Water	160 Kg/m^3

4. PARAMETERS CONSIDERED FOR STUDY

Effect of Change of Sodium Hydroxide to Sodium Silicate ratio on the compressive strength of Concrete

Three different ratios of Sodium Hydroxide : Sodium Silicate were considered

SL NO	Sodium Hydroxide : Sodium Silicate
1	1:0.8
2	1:1
3	1:1.2

5. Results & Discussions

a. Effect of Change of $NaOH: Na_2SiO_3$ ratio

Sl no	Sodium Hydroxide : Sodium Silicate	Cube Compressive Strength in N/mm²	
		7 DAYS	28 DAYS
1	1:0.8	45.23	55.30
2	1:1	51.17	63.40
3	1:1.2	56.39	70.56

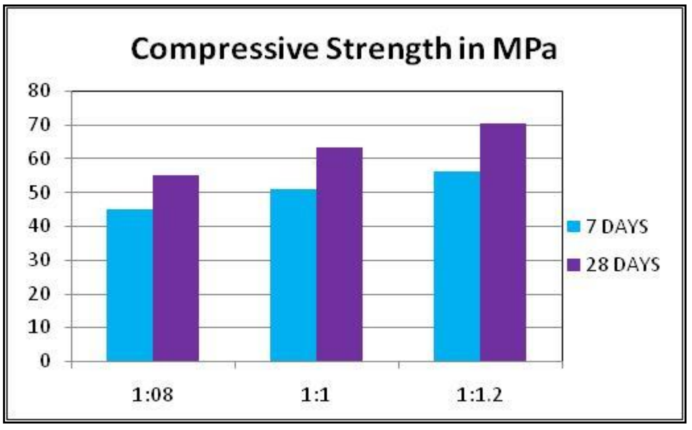

Figure 1: Graph showing Variation of Strength with increase in NaOH:Na2SiO3 ratio

b. % Strength increase due to Aging

Sl no	Sodium Hydroxide : Sodium Silicate	COMPRESSIVE STRENGTH N/mm²		% Increase
		7 DAYS	28 DAYS	
1	1:08	45.23	55.3	122.26
2	1:1	51.17	63.4	123.90
3	1:1.2	56.39	70.56	125.13

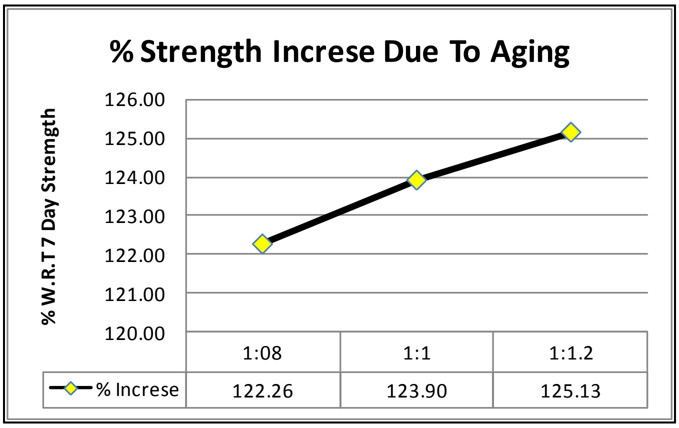

Figure 2 Graph showing percentage increase in Compressive Strength due to Increase in curing period

c. % Strength increase W.R.T. Lowest considered Sodium Hydroxide : Sodium Silicate ratio

Sl no	NaOH : Na_2SiO_3	Comp Strength N/mm2		7 Days % Increase W.R.T (1:0.8)	28 days % Increase W.R.T (1:0.8)
		7 DAYS	28 DAYS		
1	1:08	45.23	55.3	100.0	100.0
2	1:1	51.17	63.4	113.1	114.6
3	1:1.2	56.39	70.56	124.7	127.6

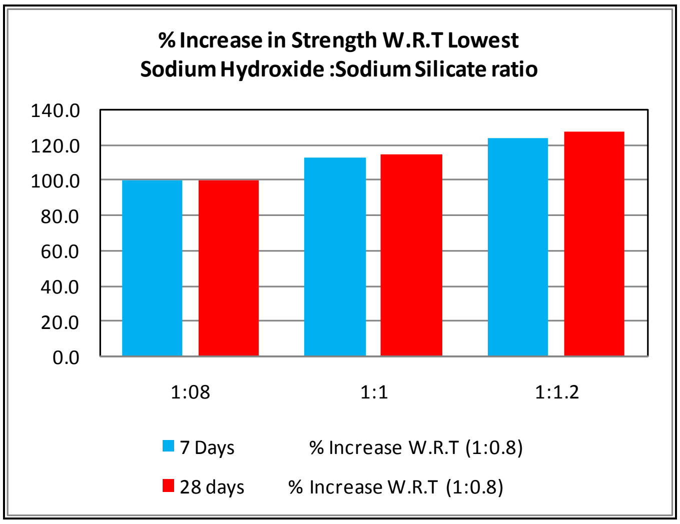

Figure 3 Graph Showing increase in the Compressive Strength of Concrete with increase in the ratio of NaOH: Na2SiO3

6. CONCLUSIONS

1. It was observed that with low ratio of Sodium Hydroxide to Sodium Silicate, 45 MPa strength was attainable at 7 days without any curing
2. There was an average strength increase of 25% at 28 days taking 7 days as baseline, this indicates that the rate of strength gain after 7 days is slow
3. As ratio of Sodium Hydroxide to Sodium Silicate increased the strength at 7days and 28 days also increased without the need for extra binder content, which shows that polymerization increases with increase in alkali content
4. There was a linear increase in strength as the Sodium Hydroxide to Sodium Silicate ratio increased

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