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Effect of Different Types of Super Plasticizer on Fresh and Hardened Properties of Self Consolidating Geopolymer Concrete

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Abstract: Continuous increase in production of cement causes large amount of carbon-dioxide emission which results in greenhouse effects. In order to overcome this problem many researchers have put in their efforts to achieve optimum strength of concrete by replacing cement with fly ash and when it combine with alkaline solution emerge to a new technology called as Geopolymer concrete. Self-compacting geo polymer concrete (SCGC) is an improved way of concreting execution that does not require compaction and is made by complete elimination of ordinary Portland cement content. SCGC is synthesized from low calcium fly ash, activated by combination of sodium hydroxide and sodium silicate solution and by incorporation of super plasticizer for self-compatibility. This study is an attempt to observe strength characteristics of SCGC by suitable selection of super plasticizers available in market and testing their viability on SCGC. The fresh properties for molarity of 8M, 10M, 12M, 14M, and 16M of SCGC were assessed through T 50 Slump test, slump flow, L-box and U-box test methods. Strength tests such as cube compressive strength, splitting tensile test for cylinder, beam flexure was also tested for the period of 7 and 28 days in the heat curing method. Finally flexural response is also studied to analyse the stress variation taking place in SCGC beam.

Keywords: *Self Compacting geopolymer Concrete, low calcium fly ash, Workability, Hardened properties, Flexural response*

1. Introduction

Concrete is the most widely used construction material in the world. Ordinary Portland Cement (OPC) has been traditionally used as the binding material for concrete. The manufacturing of OPC requires the burning of large quantities of fossil fuels and decomposition of limestone which results in significant emissions of carbon-di-oxide (CO_2) to the atmosphere. This CO_2 emission is the main cause for global warming, which have become a major concern. In order to reduce this, Geopolymer technology was introduced.

The term 'Geopolymer' was used by Professor Davidovits in 1978 to describe the inorganic aluminosilicate polymeric gel resulting from reaction of amorphous aluminosilicates with alkali hydroxide and silicate solutions. Unlike ordinary Portland cement, Geopolymer do not form calcium silicate hydrates for matrix formation and strength but utilize the poly condensation of silica and alumina to attain strength. Two main constituents of Geopolymers are source materials and alkaline liquid. The source material should be alumina-silicate based and rich in both silica and alumina. In Geopolymer concrete, supplementary cementing materials such as Fly ash, Silica fume, Rice husk ash, Ground Granulated Blast furnace Slag (GGBS) and metakaolin are used as alternative binders to Portland cement.

Geopolymer concrete generally requires the use of Class F fly ash. In terms of chemistry, fly ash is composed of multiple chemical compounds, including arsenic, lead, cadmium, mercury, and uranium, as well as other harmful chemicals. In this project, low calcium (ASTM Class F) fly ash based geopolymer is used as the binder. The fly ash based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. As in the case of OPC concrete, the aggregates occupy about 75-80% by mass in geopolymer concrete. The silicon and the aluminum in the low calcium (ASTM Class 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. Currently, fly ash is recycled into ordinary Portland cement based concrete by acting as a substitute for Portland cement at a rate of 1 to 1.5 pounds of fly ash per 1 pound of cement to increase the overall strength of the concrete.

2. Material Properties

The properties of materials used in the concrete are discussed below:

A. Fly Ash

In this investigation, Class F type of fly ash is used Class F fl yash behave truly Pozzolanic and class C having some hydraulic properties. The color of fly ash is either grey or blackish grey. Fly ash particles are Spherical, having small Surface area. The size of the fly fash generally varies between silty sand and silty clay. Ash is characterized by low specific gravity, uniform gradation and lack of plasticity. The specific gravity of ash particles depends on chemical composition and generally varies from 2.0 to 2.6 with an average value of about 2.2.Chemical properties of Fly ash given below.

Table 1: *Chemical properties of fly ash*

Chemical	%
Sio_2	49-67
Al_2O_3	16-29
Fe_2O_3	4-10
CaO	1-4
MgO	0.2-2
SO_3	0.1-2
Loss of ignition	0.4-0.6

B. Alkaline liquid

Alkaline liquid the alkaline liquid used was a sodium silicate solution and sodium hydroxide solution. The sodium silicate solution was purchased from a local supplier in bulk. The sodium hydroxide (NaOH) in flakes or pellets form with 97%-98% purity was also purchased from a local supplier in bulk. The NaOH solids were dissolved in water to make the solution. For making NaOH solution eg 8M in one liter of water the 320 gm (molar* molecular weight) of flakes is dissolved.

The sand sieved through 4.75 mm sieve is used having specific gravity of 2.6. The fine aggregates belonged to grading zone I.

C. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 10 mm is used. The specific gravity of coarse aggregate that was taken was 2.67.

D. Fine aggregate

In the investigation, sand used was river sand. The sand used was confirming to Zone – III. Fineness modulus and specific gravity of the sand were found to be 2.33 and 2.60.

E. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Potable water available in the laboratory was used.

F. Super plasticizer

The viscocrete 10R3 super plasticizer is used for improving the workability of concrete.

3. Experimental Investigation

3.1 Mix Proportions

Based on the EFNARC guidelines the mix proportions of SCGC were prepared.

3.2 Mixing Method

The concrete mixing procedure consists of dry and wet mixings. The solids components of SCGC, i.e. fly ash, lime, fine aggregate and coarse aggregate, were dry mixed in the mixer for about 2.5 minutes. The sodium silicate solution and the sodium hydroxide solution are added directly in dry mix and solution is prepared during mixing time individually added. The water and super-plasticizer were added after solution is mixed thoroughly to achieve the workability. It was believed that the chemical reaction between alkaline solution, superplasticizer and water took place and the reaction played an important role in giving the required workability for SCC. The fresh SCGC had a flowing consistency and with high tendency of filling ability, passing ability and resistance to segregation.

3.3 Mix Proportion

The mix design proportion was calculated The ratio of sodium silicate to sodium hydroxide solution by mass of fly ash and 6% dosage of SP add in the mixture. The different molarity of NaOH solution was settled as 8M, 10M, 12M, 14M & 16M respectively. All the other test parameters were kept constant while the molarity.

Table 2: mix design of SCGC

Material	Weight(kg/m^3)
Fly ash	400
Coarse Aggregate	900
Fine Aggregate	750
Sodium Silicate	143
Sodium Hydroxide	57
Super-plasticizer (6%)	24
Water (12%)	48

3.4 Comparison of different types of Super Plasticizer

In these research different types of super plasticizer tested in order to get more suitable one for scgc. Sika viscocrete 10R3, Viskocrete 20HE & Glenium these are Super plasticizer used this research. Based on the mechanical properties test each superplasticizer behaves as different properties. Finally Viscocrete 10R3 more suitable for this research.

Table 3*: Workability properties test result for different types of Super plasticizer used*

Workability Test	Super Plastisizer		
	10R3	20HE	Glenium
T_{50} Slump flow test(sec)	5	5.5	5.5
Slum flow test(mm)	680	670	700
L-Box test	0.82	0.85	0.83
U-Box test	2.6	2.8	2.5

3.5 Marsh cone test

Marsh cone method is most commonly used to find the saturation point of the Superplastisizer.

Table 4: *Marsh Cone TEST for Various Super Plastisizer by Fly Ash*

SP % by Fly ash	Trial 1(sec)	Trial 2(sec)
2	67	66
3	66	66
4	64	65
5	63	64
6	56	55
7	53	52
8	53	52
9	52	52

3.6 Workability test on SCGC

In this research tested the workability testes on each molarity ratio such as 8M, 10M, 12M, 14M & 16M.

Table 5: *workability test result on scgc*

Molarity	Slump Flow Test (in mm)	T50 cm Slump Flow Test	L -Box test	U- Box test
8M	720	5	0.82	2.6
10M	710	5.2	0.80	2.7
12M	690	5.5	0.80	2.9
14M	690	6	0.90	2.9
16M	680	7	0.95	3

3.7 Hardened properties of SCGC

1. Compressive Strength

In order to find the mechanical properties Compressive strength tests were conducted at 7days and 28 days of cube (150 X 150 X 150 mm) specimens. For each combination, two specimens were tested.

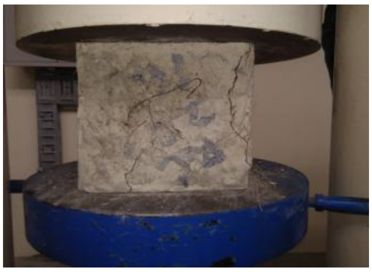

Figure 1*.Compressive strength test*

Table 6: *Compressive Strength of SCGC*

Molarity	Compressive strength in Mpa	
	7 Days	28 Days
8M	22.2	28
10M	23	30
12M	24	31
14M	26	34
16M	28	38

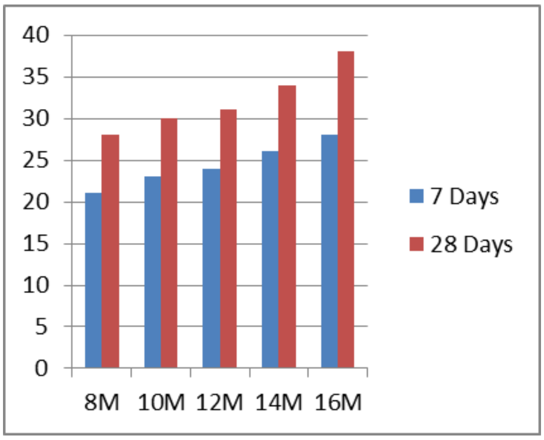

Figure 2*.Chart for compressive strength of SCGC*

2. Split Tensile Strength Test

In order to find the split tensile strength of concrete 7 days and 28 days of cylinder (150 X 300 mm) specimen are cast. For each combination, two specimens were tested.

Figure 3*.Split Tensile strength test*

The following table shows the split tensile strength of SCGC.

Table 7*: Split Tensile Strength of SCGC*

Molarity	Split Tensile Strength Mpa	
	7 Days	28 Days
8M	2.33	2.54
10M	2.45	2.94
12M	2.75	3.0
14M	2.73	3.20
16M	3.0	3.42

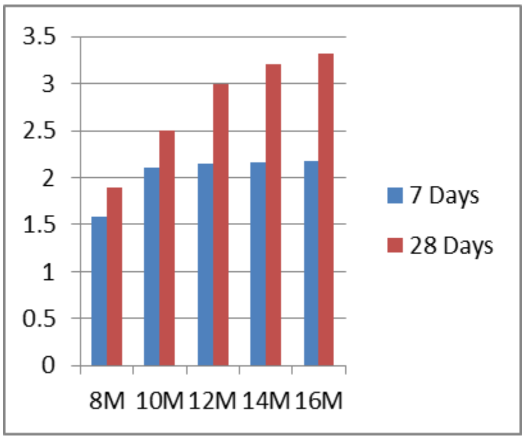

Figure 4*.Chart for compressive strength of SCGC*

3. Flexural Strength

The test was carried out on 100 x 100x 500 mm size prism. The prism tested for 7 and 28 days strength.

***Table 8**: Flexural strength*

Molarity	Flexural Strength in Mpa	
	7 days	28 days
8M	2.47	3.10
10M	2.74	3.35
12M	2.86	3.65
14M	3.12	3.85
16M	3.24	4.0

4. Crack patterns and Failure mode

As expected, the flexural cracks are initiated in the pure bending zone. As the load increased, existing cracks propagated and new cracks developed along the span. In the case of beams with larger tensile reinforcement ratio some of the flexural cracks in the shear span turned into inclined cracks due to shear effect of shear force. Near peak load the beam deflected significantly, thus loading that the tensile steel must have yielded at failure. The final failure of the beams occurred when the concrete in the compression zone crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that an under.

***Figure5.** Initial Crack pattern*

***Figure 6.**Flexural cracks at Ultimate Load*

***Table 9:** Load vs. Deflection test results for Flexural beam.*

NM		12M mix	
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0	0	0
10	0.18	10	0.20
20	1.33	20	1.48
30	2.52	30	2.68
40	3.25	40	3.45
50	4.02	50	4.25
55	4.55	60	4.65
52	10.2	55	12.20

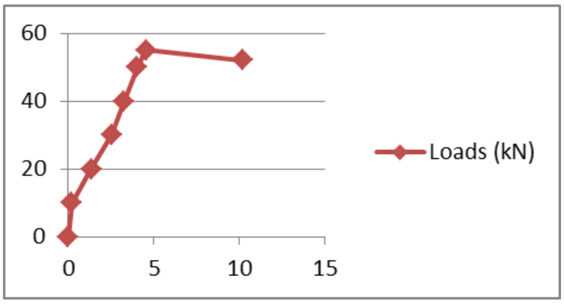

***Figure 7.**Load deflection curve plot for NM.*

4. Conclusion

It observed the molarity increases the compressive strength, split tensile strength and flexural strength is increased. After testing of different types of superplastizers the viscocrete 10r3 is suitable for self-consolidating geopolymer concrete. From load deflection curve we have predicted that after yielding point load fails but curvature starts increasing and that will lead to failure.

5. Acknowledgements

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