COMPARATIVE STUDIES ON FRESH AND HARDENED PROPERTIES OF SELF-COMPACTING GEOPOLYMER CONCRETE (SCGC) USING WASTE FOUNDRY SAND ON CHANGING MOLARITY OF ALKALINE SOLUTION

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Abstract : Preparation of Self-Compacting Geopolymer Concrete (SCGC) using waste foundry sand is an approach to make concreting technique economical and environmentally sustainable. Self-Compacting Geopolymer Concrete is a blended version of Self-Compacting Concreting and Geopolymer Concrete. Self-Compacting Concrete is a concreting technique prepared to make concreting practice economical by reducing requirement of compacting equipment's while Geopolymer Concrete is a concreting technique prepared to make concreting environmentally sustainable by replacing Ordinary Portland Cement(OPC) with other cementitious material. In the present investigation we have prepared a mixes of SCGC using Waste Foundry Sand for M40 grade and tested for fresh and hardened property test of concrete by changing the molarity of NaOH at 10M, 12M and 14M. It is found that on increasing the molarity of NaOH the flow ability of concrete decreases and the strength of concrete increases but the concrete becomes brittle which is not acceptable.

Keywords : self-compacting geopolymer concrete, Fly Ash, ground granulated blast furnace slag, waste foundry sand and molarity of NaOH solution.

I. INTRODUCTION: -

Concrete is the primary material in construction industry. It consists of cement, coarse aggregate, fine aggregate, water and other admixtures. Generally Ordinary Portland cement is used in concreting but the production of OPC causes a huge amount of carbon emission and also it uses a huge amount of non-renewable natural resources. The concrete construction practice in use is considered as unsustainable because it consumes a huge quantity of sand, stone and water and 2.5 billion tons of OPC per year. So to resolve the problem of emission of greenhouse gases Davidovits developed a innovative concreting technique. Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and Aluminum (Al) in a source material of geological origin or in by-products materials such as Fly Ash (FA) and Rice Husk (RHA) to produce binders. The two main constituents of geopolymer, namely the source materials and the alkaline liquids. This could be natural mineral such as kaolinite, clays etc. Alternatively, by-products such as fly ash, silica fume, slag, rice husk, GGBS, red mud etc. The material used as geo-polymer binders should be rich in silicon (Si) and Aluminum (Al). Both Fly Ash and GGBS in certain proportion were found to be geopolymer source materials to obtain sufficient strengths of geopolymer concrete. Alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or Potassium Hydroxide (KOH) and Sodium Silicate or potassium silicate. Many of the GPC mixes earlier tested required the use of high temperature curing. Heat curing substantially assists the chemical reaction that occurs in the geo-polymer paste. Both curing time and curing temperature influence the compressive strength of geopolymer concrete. However recent studies revealed that GPC mixes can be developed for ambient room temperature. It was noticed that fresh GPC was highly viscous with low workability and hence, super plasticizer (SP) was found to be used to attain adequate workability.

One of the major problem faced in construction industry is the lack of skillful labors for concreting but to resolve this problem Japanese scientists Okamura et al and Ozawa et al proposed a new concreting technique named "self-Compacting concrete" in which the concrete compacts due to its self-weight and can pass through congested reinforcement easily. Self-Compacting concrete has the follow properties: higher slump flow, high viscosity, passing ability and resistance to segregation. Use of self-Compacting geopolymer concrete in construction industry can solve the problem of greenhouse gas emission as well as it reduces the problems faced due to lacking of skillful labour and using waste foundry sand as replacement of river sand can solve the problems of river mining, solves problems of disposal of waste foundry sand and reduces the cost of concreting. Studies reveals that the compressive strength of SCGC increases when thermal cured at 60-70 0C, but it decreases when temperature exceeds 70 ^{0}C. It is found that on increasing molarity of NaOH the fresh properties of concrete decreases. It is observed that the alkaline solution, super plasticizer and extra water should be premixed before adding to the dry mix of concrete to get improved workability of SCGC. In metal industries for various processes in metal casting foundry sand is used. After the casting of metal, the burnt fine grained foundry sand can be re-used for various purposes in construction industry. It will reduce the cost of construction. But split tensile strength decreases on increasing the percentage of waste foundry sand.

In the present research we examined the changes in fresh and hardened properties for SCGC using waste foundry sand on increasing the molarity of NaOH (10M,12M and 14M). we have performed various fresh property test such as slump flow test, T_{50cm} test, V-funnel test and L-box test and hardened property test such as compressive strength test and split tensile test.

II. EXPERIMENTAL STUDIES: -

- Materials Used: -

The materials used in this study were

2.1 Class F fly ash:

Nowadays fly ash is the material which is most extensively used in construction industry as a partial replacement of cement. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to a Class F ash can form a geopolymer. We are using class F fly ash obtained from "Wanakbori Thermal Power Station, Gujarat, India".

2.2 Ground Granulated Blast Furnace Slag:

It is obtained as a by-product of iron and steel-making from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. It is used as a partial replacement of cement, when it is used in certain proportion with fly ash it significantly helps in increasing the compressive strength. The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al2O3 (8-24%), and MgO (1-18%). In general, increasing the CaO content of the slag results in raised slag plasticity and an increase in compressive strength.

2.3 River Sand:

Aggregate contains almost 75-80% of the concrete volume. While in SCGC for self-compaction the fine aggregate content should be 40% of the mortar volume. Ordinary sand which pass through 4.75mm IS sieve and having no more than 5% coarser material are included in fine aggregate. River sand is obtained by river mining which is a non-renewable source. fine aggregate fills the voids and increases the workability of concrete.

2.4 Waste Foundry Sand:

Mostly metal industries prefer sand casting system. In this system mould made of uniform size and uniform sand with high silica content is used. After the casting of metal foundries reuse and recycle the sand but after several time of using it the sand is discarded and it is called waste foundry sand. Their uses in construction industry are economical and also solve the problems of its disposal.

2.5 Coarse Aggregate:

The aggregate having size more than 4.75mm is termed as coarse aggregate. In order to achieve self-compatibility and pass ability of concrete through congested reinforcement coarse aggregate of two different sizes are used in SCGC. In SCGC the coarse aggregate content is 50% of the solid volume and coarse aggregate in two different sizes at 60:40 ratio can be used.

2.6 Super Plasticizer:

Self-Compacting concrete can be prepared by compounding admixture with high efficiency water reducing agent. According to requirement of performance of SCGC, climate conditions and the construction technology, combined with concrete raw materials performance, adaptability to cement and mix proportion and other factors, the species and dosage of admixture can be determined through the test.

2.7 Alkaline Solution:

Generally, sodium hydroxide or potassium hydroxide and sodium or potassium silicate is used as alkaline activators for formation of C-S-H gel. Studies reveal that only using sodium hydroxide or sodium silicate is not much effective. So combination of sodium hydroxide and sodium silicate is used generally. Sodium hydroxide pellets is 97-8% purity is generally used and sodium silicate with Na2O = 13.7%, SiO2 = 29.4% and water = 55.9% is generally used. With the increase in concentration of solution in terms of molarity (M) the concrete becomes brittle with increased compressive strength. Cost of sodium hydroxide solids is high and preparation is very caustic. Generally, sodium silicate-to-sodium hydroxide ratio of 2 to 2.5 is maintained in concrete casting which will help in gaining the strength after 24h of casting.

2.8 Water:

Water plays an important role in concrete while in self-Compacting geopolymer concrete water does not play any important role in gaining strength rather it helps in improving the workability. As studies reveals that geopolymer mix is less workable so to attain self-compact ability extra water is needed to add in the mix.

III. MIX DESIGNATION: -

Table 1: Mix Designation for M40 grade SCGC using waste foundry sand for 10M, 12M and 14M

Mix	AS/B	Binder	CA	FA	WFS
M1	0.45	450	712	984	0
M2	0.45	450	712	689	295
M3	0.45	450	712	394	590
M4	0.45	450	712	0	984

Table 2: Mix Designation for M40 grade SCGC using waste foundry sand for 10M, 12M and 14M.

Mix	NaOH	Na_2SiO_3	Extra Water (%)	SP (%)	W/B
M1	58	145	20	3	0.4
M2	58	145	20	3	0.4
M3	58	145	20	3	0.4
M4	58	145	20	3	0.4

Table 3: Gram of NaOH per liter solution

Molarity of NaOH	gram of NaOH per liter solution
10M	400gm
12M	480gm
14M	560gm

IV. MIX PROCEDURE: -

Mix is prepared in two stages. In first stage coarse aggregate, fine aggregate, fly ash and ground granulated blast furnace slag are dry mixed for 3-4 minutes. In the second stage the alkaline solution, super plasticizer and water is mixed properly and then mixed with the dry mixed materials for 3 minutes. To ensure homogeneity of concrete the materials are allowed to mix for 2-3 minutes more. To access the fresh properties of self-Compacting geo-polymer concrete test such slump flow, T_{50cm}, V funnel and L-box were conducted as mentioned by EFNARC. The fresh concrete mixtures are then filled into cubes of 150mm x 150mm x 150mm and cylinders of 150mm diameter and 300mm height. Then the moulds are placed in oven for 24-48 hours at 60-70^{0}C. Then test for compression and tensile strength is performed.

V. RESULT AND CONCLUSION: -

This section discusses the effect on hardened properties of self-Compacting geo-polymer concrete due to replacement of sand by certain amount with waste foundry sand and changing the molarity of alkaline solution.

Table 4: Fresh Property Test Result for SCGC using Waste Foundry Sand (10M)

Mix Designation	Slump Flow(mm)	$T_{50\ cm}$ (seconds)	V-funnel (seconds)	L-box (H2/H1)
M1 (0% replacement)	750	3	9.3	0.9
M2 (30% replacement)	670	4.5	12	0.83
M3 (60% replacement)	450	Fail	Fail	Fail
M4 (100% replacement)	Fail	Fail	Fail	Fail

Table 5: Fresh Property Test Result for SCGC using Waste Foundry Sand (12M)

Mix Designation	Slump Flow (mm)	$T_{50\ cm}$ (seconds)	V-funnel (seconds)	L-box (H2/H1)
M1 (0% replacement)	727	4	9.8	0.87
M2 (30% replacement)	657	5.1	12.7	0.78
M3 (60% replacement)	426	Fail	Fail	Fail
M4 (100% replacement)	Fail	Fail	Fail	Fail

Table 6: Fresh Property Test Result for SCGC using Waste Foundry Sand (14M)

Mix Designation	Slump Flow (mm)	$T_{50\ cm}$ (seconds)	V-funnel (seconds)	L-box (H2/H1)
M1 (0% replacement)	703	4.2	9.89	0.85
M2 (30% replacement)	614	5.4	12.73	0.78
M3 (60% replacement)	407	Fail	Fail	Fail
M4 (100% replacement)	Fail	Fail	Fail	Fail

Table 7: Hardened Property test result for SCGC using waste foundry sand (10M)

Note: - Here mean strength of three moulds are mentioned

10 M	COMPRESSIVE STRENGTH TEST			SPLIT TENSILE STRENGTH TEST		
Mix Designation	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days
M1(0% replacement)	33.50	48.21	50.16	4.367	5.01	5.36
M2(30% replacement)	30.953	45.79	47.18	3.89	4.53	4.92
M3(60% replacement)	25.19	39.93	43.18	3.512	4.416	4.62
M4(100% replacement)	22.247	33.978	37.23	3.302	4.079	4.29

Table 8. Hardened Property test result for SCGC using waste foundry sand (12M)

Note: - Here mean strength of three moulds are mentioned

12 M	COMPRESSIVE STRENGTH TEST			SPLIT TENSILE STRENGTH TEST		
Mix Designation	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days
M1(0%	35.21	49.73	52.28	4.48	5.23	5.48

replacement)						
M2(30% replacement)	33.29	47.732	49.23	4.11	4.67	5.11
M3(60% replacement)	27.28	41.06	45.28	3.77	4.51	4.91
M4(100% replacement)	24.31	35.98	39.21	3.41	3.72	3.89

Table 9. Hardened Property test result for SCGC using waste foundry sand (14M)

Note: - Here mean strength of three moulds are mentioned

14 M	**COMPRESSIVE STRENGTH TEST**			**SPLIT TENSILE STRENGTH TEST**		
Mix Designation	7 Days	28 Days	56 Days	7 Days	28 Days	56 Days
M1(0% replacement)	36.78	50.23	53.78	4.57	5.31	5.57
M2(30% replacement)	34.29	48.39	51.11	4.39	4.89	5.23
M3(60% replacement)	29.28	43.17	47.88	3.89	4.53	4.97
M4(100% replacement)	25.72	37.55	40.16	3.53	3.81	4.07

VI. CONCLUSION: -

a. On replacing river sand with waste foundry sand by certain amount can solve the problems of river mining and reduce the cost of concreting.

b. This will reduce the labour cost in concreting due to its self-Compacting properties.

c. Problems of disposal of Fly Ash and Ground Granulated Blast Furnace Slag are resolved.

d. Special curing condition is required for this method of concreting.

e. On increasing the amount of waste foundry sand the flexural strength of concrete decreases.

f. The concrete formed by replacing sand up to 30% performs better in both compression and flexure.

g. Alkaline activators help in gaining strength.

h. Increasing the duration of heat curing increases the strength of concrete.

i. The early strength of SCGC is lower than SCC but the 28 days' strength is approximately same.

j. Increasing the molarity of alkaline solutions affects the fresh property of concrete i.e. workability and pass ability of concrete reduces.

k. Increasing the molarity of alkaline solution increases the compressive and flexural strength of concrete but the concrete becomes brittle which is not acceptable.

l. Increasing the molarity of alkaline activators increases the total cost of concreting.

m. On replacing river sand by 30% and keeping the molarity of alkaline solution 12M we are getting optimum mix i.e. best results for fresh and hardened property test.

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