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RESEARCH ARTICLE

COMPARATIVE STUDY ON HARDENED PROPERTIES OF SELF COMPACTING CEMENT CONCRETE AND SCGC USING WASTE FOUNDRY SAND

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ABSTRACT

To resolve the problems of carbon emission from construction of concrete structures a sustainable concreting technique named "self-compacting geo-polymer concrete" is developed. The benefit of using this concreting technique is that the labour cost reduces due to its self compact-ability and it also solves the problem of disposal of industrial wastes. The present investigation is mainly focused on the hardened properties of self-compacting geo-polymer concrete with constant molarity alkaline solution and varying replacement of waste foundry sand with river sand to make low cost concreting technique. Test were performed such as Compression test, Split tensile test etc. Studies reveals that increasing the molarity of NaOH decreases the fresh properties but increased the compressive strength of SCGC.

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 tones 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 [1]. The two main constituents of geopolymer, namely the source materials and the alkaline liquids [1]. 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 [1].

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The material used as geo-polymer binders should be rich in silicon (Si) and Aluminium (Al). Both Fly Ash and GGBS in certain proportion were found to be geopolymer source materials to obtain sufficient strengths of geopolymer concrete [2]. Alkaline liquids are from soluble alkali metals that are usually sodium or potassium based [1]. 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 [1]. Both curing time and curing temperature influence the compressive strength of geopolymer concrete [1]. However recent studies revealed that GPC mixes can be developed for ambient room temperature [5]. 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 [2]. 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 [3]. 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 skilful 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[7]. It is found that on increasing molarity of NaOH the fresh properties of concrete decreases [6]. 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 [2-19]. In metal industries for various process 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 [4].

Table 1. Chemical Compositions of Fly Ash and GGBFS

Particulars	Class F Fly Ash	Ground Granulated Blast Furnace Slag.
Chemical Compositions	High Fe	
%Silica(SiO_2)	47	30.61
% Alumina(Al_2O_3)	23	16.24
% Iron Oxide(Fe_2O_3)	15	0.584
% Lime (CaO)	2.3	34.48
%Magnesia(MgO)	0.8	6.79
%Titanium Oxide(TiO_2)	1	-
% Sulphur Oxide(SO_3)	0.5	1.85
Loss on Ignition	0.37	2.1
Physical Compositions		
Specific Gravity	2.11	2.9
Fineness(m^2/kg)	330	400

Table 2. Chemical Composition of Waste Foundry Sand

Constituent	Value (%)
Silica(SiO_2)	87.91
Alumina(Al_2O_3)	4.7
Iron Oxide(Fe_2O_3)	0.94
Lime (CaO)	0.14
Magnesia (MgO)	0.3
Sulphur Oxide (Na_2O)	0.19
Potassium Oxide (K_2O)	0.25

Table 3. Properties of Admixtures

Chemical Admixture	Relative Density	pH	Chloride Content (%)	Main Component
SKY8630	1.08	≥ 6	<0.2%	Polycarboxylate Ether

Mix Proportions:

In the present research we examined how self compacting geopolymer concrete using waste foundry sand as replacement is good over conventional concrete. Its Fresh properties by conducting tests such as slump flow, T50cm, V-funnel and L-box as per EFNARC [10].

Experimental Studies

- Materials Used:

The materials used in this study were

- 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”.

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.

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.

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 is economical and also solve the problems of its disposal.

Coarse Aggregate

The aggregate having size more than 4.75mm is termed as coarse aggregate. In order to achieve self compactability and passibility 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 size at 60:40 ratio can be used.

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

Table 4. Mix Designations

Mix	AS/B	Binder	CA	FA	WFS	NaOH	Na_2SiO_3	Extra Water (%)	SP (%)	W/B
M1	0.45	450	712	984	0	58	145	20	3	0.4
M2	0.45	450	712	689	295	58	145	20	3	0.4
M3	0.45	450	712	394	590	58	145	20	3	0.4
M4	0.45	450	712	0	984	58	145	20	3	0.4

Mixing, Testing, Casting and Curing:

Table 5. Hardened property test result for SCC (0% sand replacement)

Compression Test (cubes 150*150*150)	S1	S2	S3	Average
7 days	31.67	33	32.8	32.49
28 days	46.28	47.52	48.93	47.58
Split Tensile Test (cylinder 150mm dia. And 300 mm height)	S1	S2	S3	Average
7 days	3.94	4.23	4.11	4.093
28 days	4.82	4.835	4.896	4.850

Table 6. Hardened property test results for 10 M (0% sand replacement)

Compression Test (cubes 150*150*150)	S1	S2	S3	Average
7 days	36	34.7	35.81	35.50
28 days	48.55	47.88	48.21	48.21
Split Tensile Test (cylinder 150mm dia. And 300 mm height)	S1	S2	S3	Average
7 days	4.5	4.21	4.39	4.366667
28 days	5.13	4.98	5.01	5.01

Table 7. Hardened property test results for 10M (30% sand replacement)

Compression Test (cubes 150*150*150)	S1	S2	S3	Average
7 days	29.28	31.07	32.51	30.953
28 days	45.23	47.21	44.93	45.79
Split Tensile Test (cylinder 150mm dia. And 300 mm height)	S1	S2	S3	Average
7 days	3.78	3.90	3.99	3.89
28 days	4.71	4.81	4.692	4.737

Table. 8. Hardened property test results for 10M (60% sand replacement)

Compression Test (cubes 150*150*150)	S1	S2	S3	Average
7 days	26.24	24.32	25.01	25.19
28 days	41.08	39.87	38.83	39.93
Split Tensile Test (cylinder 150mm dia. And 300 mm height)	S1	S2	S3	Average
7 days	3.585	3.452	3.50	3.512
28 days	4.48	4.41	4.36	4.416

Table 9: Hardened property test results for 10M (100% sand replacement)

Compression Test (cubes 150*150*150)	S1	S2	S3	Average
7 days	22.74	23.21	20.87	22.247
28 days	34.634	35.51	31.79	33.978
Split Tensile Test (cylinder 150mm dia. And 300 mm height)	S1	S2	S3	Average
7 days	3.34	3.372	3.197	3.302
28 days	4.12	4.171	3.946	4.079

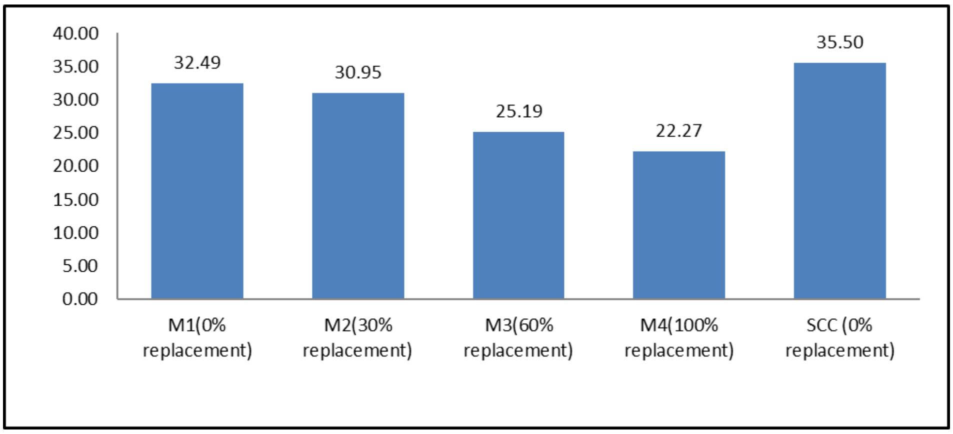

Figure 1- 7 Days Compressive Strength of Concrete

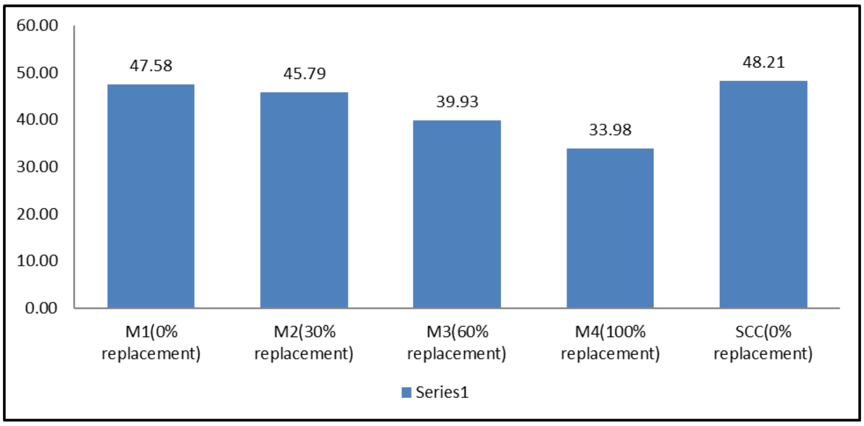

Figure 2- 28 Days Compressive Strength of Cubes

Flexural strength test results

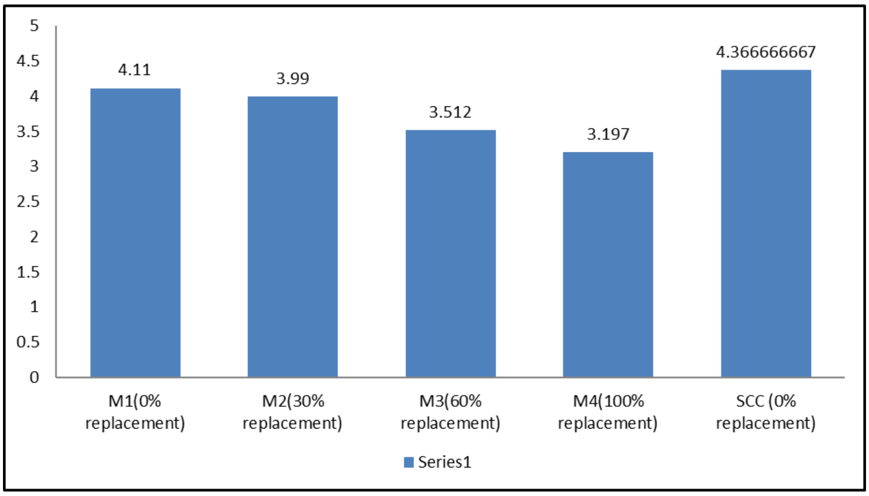

Figure 3- 7 Days Flexural Strength Test Results for Cylinders

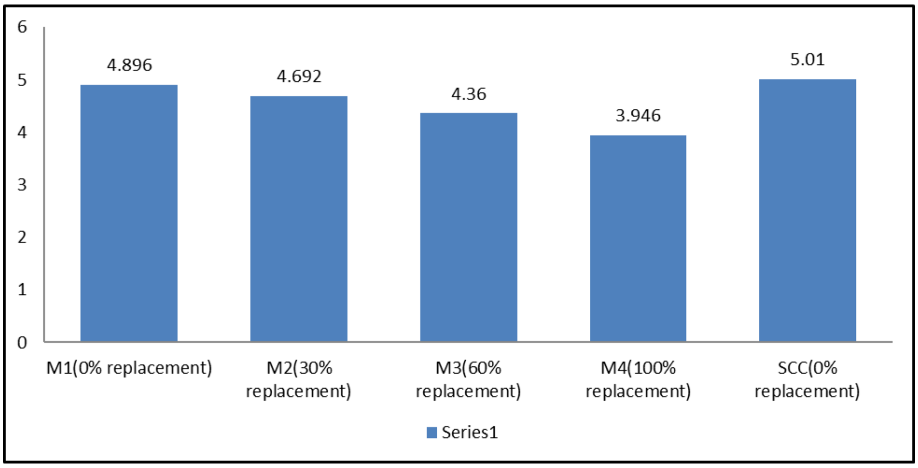

Figure 4- 28 Days Flexural Strength Test Results For Cylinders

and mix proportion and other factors, the species and dosage of admixture can be determined through the test.

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.

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.

Scope of Research

In this study we used Class F Fly Ash and Ground Granulated Blast Furnace Slag (GGBFS) in ratio of 70:30 as binder materials. In the first study we conducted fresh property test with 0% replacement of river sand and then we have conducted fresh property test by replacing river sand with waste foundry sand in an amount of 30%, 60% and 100%. We used Coarse Aggregate passing through 12.5 mm sieve and retaining on 10mm sieve. We have used sodium silicate (40% solids) and sodium hydroxide (97-98% purity) as alkaline solution in ratio of sodium silicate-to- sodium hydroxide is 2.5. To attain higher workability we used masterglenium SKY8630 as super plasticizer which is a blended version of Super Plasticizer (SP) and Viscosity Modifying Agent (VMA). Alkaline solution is prepared 24 hours before the practical to be performed. A specified amount of extra water (other than water used in preparation of alkaline solution) is added to attain higher workability because geopolymer mix is having less workability (dry mix). The chemical compositions of materials and mix designation table are as shown below.

Conclusion

- On replacing river sand with waste foundry sand by certain amount can solve the problems of river mining and reduce the cost of concreting.
- This will reduce the labour cost in concreting due to its self-compacting properties.
- Problems of disposal of Fly Ash and Ground Granulated Blast Furnace Slag are resolved.
- Special curing condition is required for this method of concreting.
- On increasing the amount of waste foundry sand the flexural strength of concrete decreases.
- The concrete formed by replacing sand up to 30% performs better in both compression and flexure.
- Alkaline activators help in gaining strength.
- Increasing the duration of heat curing increases the strength of concrete.
- The early strength of SCGC is lower than SCC but the 28 days strength is approximately same.

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