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Research Article

Experimental Study on Self Compacting Concrete with Replacement Materials

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Abstract

The Self Compacting Concrete is a concrete mix which has a low yield stress, high deformability, good segregation resistance and moderate viscosity. SCC is relatively high cost due to the high cost of the materials used in it which continues to hinder its widespread over various segments of the construction industry. To avoid this limitation this project is going to be an attempt. In this project, we are replacing the cement by GGBS, sand by granite powder in varying proportions and specimens are casted accordingly. Each specimen is going to be tested with Tensile, Bending and Compression Tests. By the end of this project we can say that the overall cost of SCC can be reduced with no decrease in the strength or even slightly increase in strength.

Keywords

Self compacting concrete; Ground granulated blast furnace slag; Fillingability; Passing ability; Strength tests

Introduction

Self-Compacting Concrete is an innovative concrete which not only has property of Self compaction but also has a low yield stress, high deformability, good segregation resistance and moderate viscosity. Self-compacting concrete is also commonly known as Self Consolidating Concrete. SCC requires no vibration which in turn flows under its own weight completely filling formwork and achieving full compaction, even in the presence of congested reinforcement[1-5]. This concrete on hardening would have the same engineering properties and durability as that of the conventional concrete.The knowledge of SCC has moved from domain of research to application in various countries but in India this knowledge is to be wide spread. To produce SCC, the major work involves designing and appropriate mix proportion and evaluating the properties of the concrete thus considering these things Nan Su's mix design method for SCC being simplest and accurate, we are using this method for the mix design of SCC in our present project.

Objectives

SCC being the modernistic and focused on high performance, we are focusing on the improvement of the properties of it using replacement. Considering all the the motto of the project has been decided as follows:

- Laboratory Test's on Aggregate's and Cement ;
- Workability Test's and Strength Test's on Self Compacting Concrete

Literature Review

A Simple mix design method for Self-Compacting Concrete By Nan Su, Kung Chung Hsu, His-Wen Chai (Cement and Concrete Research) Dec-2001: In thispaper the authors designed a new mix design method for self-compacting concrete (SCC). First the amount of aggregates required is determined and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability, self-compacting ability and other desired SCC properties[6]. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests are carried out to examine the performance of SCC, and the results indicate that the proposed method could produce SCC of high quality. Compared to the method developed by the Japanese ready-mixed concrete association (JRMCA), this method is simpler, easier for implementation and less time consuming, requires a smaller amount of binders and saves cost. The paper was those concluded as follows:

- SCC designed and produced with the proposed mix design method contains more sand but less coarse aggregates, thus the passing ability through reinforcement can be enhanced.
- The aggregate PF determines the aggregate content and influences the strength, flow ability and self-compacting ability.
- The amount of binders used in the proposed method can be less than the required by other mix design method due to the increased sand content.
- This novel mix design method is simple and requires smaller amount of binders and saves cost.
- SCC has undergone workability tests such as V-funnel, Slump flow, L-box, U-box, and so on to check the characteristic properties of SCC before testing for strength and SCC produced from this method of mix design resulted to be good of filling ability, passing ability and segregation resistance.

This is considered to be the simplest procedure for Self-Compacting Concrete [7].

Materials used and Laboratory Tests on Materials

Materials:

Coarse Aggregate: Crushed Granite Stones of size less than 10mm were used in this project work. Of Size : <10mm; Bulk Density: 1614Kgs/m3; Specific Gravity: 3.25gms/cm3.

Fine Aggregate: Natural River Sand available in the locality was used. Of Size : <0.75mm; Bulk Density: 1481Kgs/m3; Specific Gravity: 2.27gms/cm3.

Cement

53Grade Cement was used.

Ground Granulated Blast Furnace Slag (GGBS): Locally available JSW GGBS was used in this project considering all the standards as per Indian standards. The different chemicals used for binding of GGBS individually compared as per this project. The chemicals used for binding are listed below with their molecular weights.

Sodium Hydroxide (NaOH) M.W. = 39.997 gms/mol;
Sodium Meta Silicite ($Na_2SiO3.5H_2O$) M.W. = 212.14 gms/mol;
Sodium Carbonate (Na_2CO_3) M.W. =105.99gms/mol.

Fly Ash: Fly Ash was available at a Ready Made concrete mix plant at Bongloor, Telangana State. Fly Ash has been used as the filler component when complete cement in concrete was replaced by GGBS.

Super Plasticizer: Consplax was the super plasticizer used in our project. Consplax is a concrete hyper plasticizer.

Laboratory Tests on Materials:

The materials used in the project underwent few laboratory tests so that the results of the tests can be used to determine the proportionate of the materials. The different tests and their results are listed below:

- Specific Gravity of Coarse Aggregate: 3.25;
- Specific Gravity of Fine Aggregate: 2.77;
- Specific Gravity of Cement: 3.15;
- Bulk Density of Coarse Aggregate: 1392.5;
- Bulk Density of Fine Aggregate: 1481.5.

The above Tests to find out specific gravity and bulk density were carried out using the procedures mentioned in IS: 2720-Part3-1980 (Table 1), (Fig. 1).

S.No.	PARAMETER	FINE AGGREGATE	COARSE AGGREGATE
1	Weight	5kgs	4.69kgs
2	Volume	0.15 X 0.15 X 0.15 mts	0.15 X 0.15 X 0.15 mts
3	Bulk Density	1481.5	1392.5

Table 1: Bulk Density of Aggregates

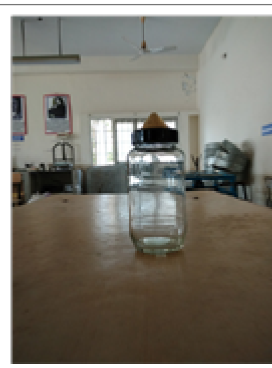


Figure 1: Pycnometer used for finding out Specific Gravity of materials.

Mix Proportion

Using Nan Su Method for Mix Design of Self Compacting Concrete the amount of materials to be added were calculated and are mentioned in below Table 2.

S.No.	MATERIAL NAME	CONTENT (Kg/m^3)
1;	Fine Aggregate	962.38
2;	Coarse Aggregate	655.032
3;	Cement	217.55
4;	Filler (Fly Ash)	487.669
5;	Water	484.77
6;	Super Plasticizer	0.01%

Table 2: Material Contents to be added to SCC (Kg/m^3)

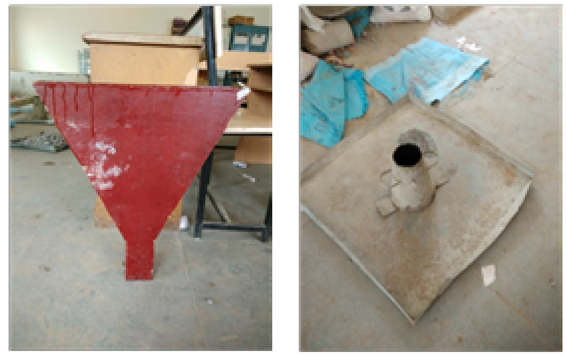


Figure 2: V-Funnel and Slump Flow Apparatus.

Using the above proportions the fine aggregate (sand) was replaced by granite powder and cement was replaced with GGBS completely, additionally 4% of the GGBS content was added with three different chemicals (4% of Na Content) used for binding separately and compared in this project.

Methodology

As of every Concrete testing procedure we followed the same to this Self Compacting Concrete. After Batching of Aggregates and materials to be added to SCC using Nan Su method for Mix Design of Self Compacting Concrete, the following steps were followed similar to that of conventional concrete [8-12].

- Workability Tests;
- Casting of Specimens;
- Curing of Specimens;
- Strength Tests for Specimens;

These are the vital steps in this project after the mix design procedure.

Workability Tests

The main objective of SCC is to have good workability with following characteristics of the SCC in its fresh state:

- Filling Ability;
- Passing Ability;
- Segregation Resistance.

Several methods have been developed in attempts to characterise the properties of SCC. So far so no single method or combination of methods, have achieved universal approval to include in national and international organisations (Fig. 2). The Workability Tests conducted are as follows:

- Slump Flow Test;
- V-Funnel Test.

Casting and Curing of Specimens:

As discussed earlier in this project we used self-compacting concrete and we replaced cement with GGBS and Sand with Granite Powder and various chemicals were added for binding of GGBS, below list gives a brief about the number of specimens casted (Table 3).

S.No.	**Mix**	**No. of Specimen**		
		Cubes	Cylinders	Beams
1.	Normal SCC	3	2	3
2.	Replaced with GGBS and NaOH is binding chemical	3	2	3
3.	Replaced with GGBS and Na2CO3 is binding chemical	3	2	3
4.	Replaced with GGBS and Sodium meta silicate is binding chemical	3	2	3

Table 3: Number of Specimen for each mix;

The Cubes casted were used for Compression Test, the cubes casted were of 150 X 150 X 150mm size. The Cylinders were used for Tensile Test, the cylinders casted were of 150mm diameter and 300mm height. The beams were used for Flexural Test, the size of beams were 150 X 150 X 700mm. These moulds were available in market and are generally used for testing. These Specimens were mixed in a tilting type stationary mixer. After 24hours of Casting of Specimens, they are de-moulded and kept for curing in the curing tank. All the Specimens of Normal Self Compacting Concrete, SCC with replacement materials with NaOH as binding chemical, SCC with replacement materials with Na_2CO_3 as binding chemical and SCC with replacement materials with Sodium Meta Silicate as binding chemical. When Sodium Carbonate cubes were kept for curing in the curing tank, within a few minutes of time they started to collapse thus deterioration took place during curing. The reason would be either due to chemical reaction between Sodium Carbonate and water or else due to Reaction between Sodium carbonate and Super Plasticizer (Fig.3, Fig. 4).

Figure 3: Curing of Specimen:

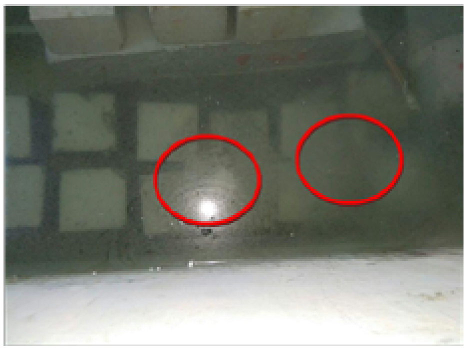


Figure 4: Failure of SCC with replacement material and Sodium carbonate used as binding material during curing;

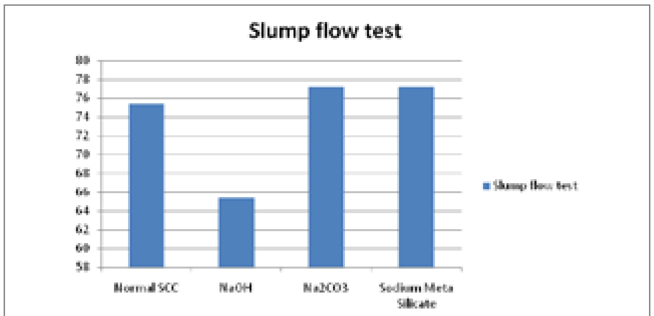
Strength Tests on Specimens:

In this project we have done compression strength testing, tensile strength testing and flexural strength testing. Cubes of size 150X150X150mm were used for Compression strength testing, Cylinders of 150X300mm were used for Tensile Strength Testing. Beams of size 150X150X700mm were used for Flexural Strength Testing.

Results for Workability and Strength Tests

Slump Flow Test Results: (Slump Spread in cms)

From Above Graph we can say that there was high flow with the mix with sodium carbonate and sodium meta silicate as chemical binders for GGBS with replacement materials in self compacting concrete (Fig. 5).



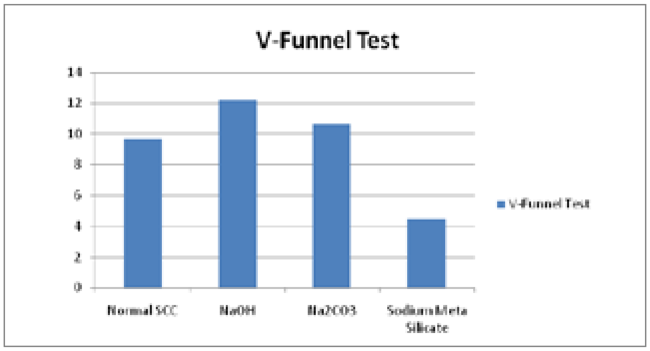
With NaOH chemical binder added to SCC with replacement material there was a decrease in the slump flow value as the NaOH acted as and water reducer. But when they were added to the mould they expelled water out compacting themselves.

V-Funnel Test Results: (Flow Time in Seconds)

V-Funnel Test was carried out to know the filling ability of the concrete. As per standards the funnel must get empty within 8-12secs. The below graph shows the V-Funnel Test Results where the all mixes passed through V-Funnel approximately within the time period suggested according to Nan Su in his mix design procedure for self-compacting concrete. (Not accurate because proper equipment was not used) (Fig. 5).

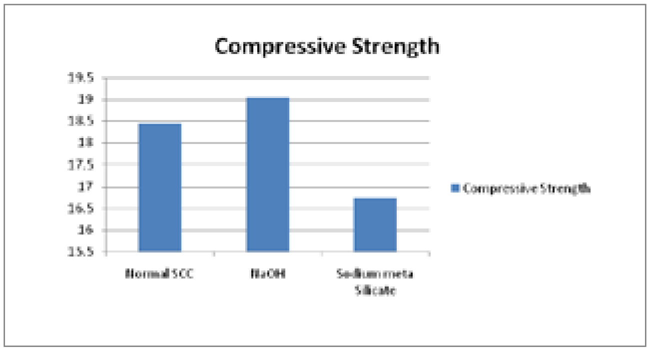
Compressive Strength Test Results:

Compressive Strength test was carried out for all the mixes where there was a rapid increase in compressive strength of SCC with replacement materials with NaOH as chemical binder. But with Sodium Meta Silicate as binding chemical with replacement materials there was a decrease in the compression test. But the percentage of 7days compressive strength as per standards i.e; 60-65% was reached (Fig. 6).



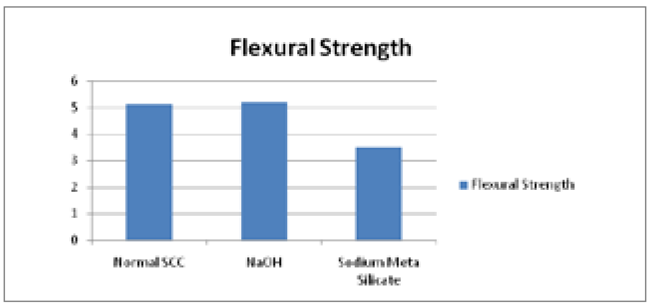
Tensile Strength Test Results:

Tensile Strength was carried for 14days after curing, 90% strength was attained. There were small graduations in SCC with replacement materials binded with NaOH and Sodium Meta Silicate (Fig. 7).



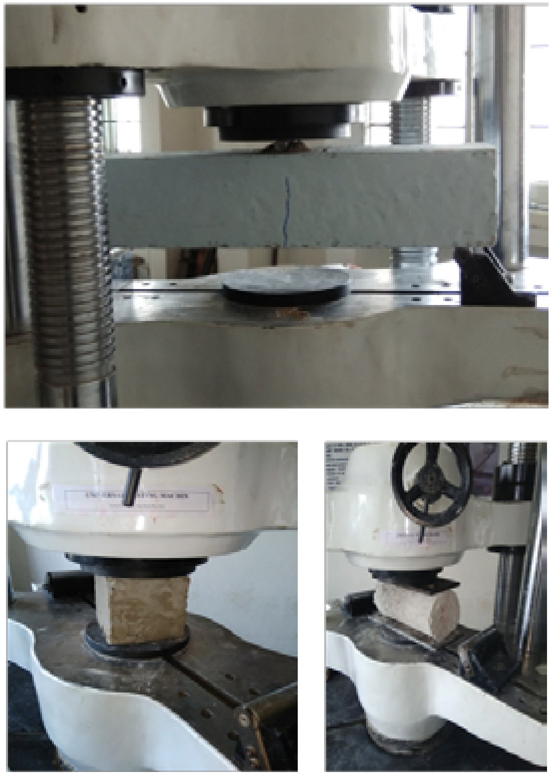
Flexural Strength Test:

Flexural Strength was carried out for 14days where all the specimens reached the 90% strength while all the mixes had more flexural strength compared to that of normal self-compacting concrete (Fig.8).



Conclusion

As per this experimental study we can say that NaOH would be the proper chemical to be used for binding of GGBS when replaced completely by cement instead of sodium meta silicate and sodium carbonate. And even if the sand is replaced by granite powder there was no differences in strength properties of workability properties of concrete. M30 being the present day high strength concrete generally used in construction industry we considered this entire work using M30. Thus providing a platform for further generations to recycle and use the waste materials like GGBS, Fly ash and Granite powder in concrete. Not only these properties but individually self-compacting concrete has its own uniqueness. GGBS costing lower than cement this would decrease the cost percentage of the project. And even usage of self-compacting concrete would decrease the usage of coarse aggregate. This is the reason this project has been carried out for decreasing the cost and increasing the properties of concrete.



Fly ash can replace a significant part of the necessary filler when used into a self-compacting concrete composition. The elimination of vibrating equipment improves the environment protection near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. SCC is favourably suitable especially in highly reinforced concrete members like bridge decks or abutments, tunnel linings or tubing segments, where it is difficult to vibrate the concrete, or even for normal engineering structures. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction. Based on these facts it can be concluded that SCC will have a bright future.

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