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A STUDY ON PROPERTIES OF SELF COMPACTING CONCRETE WITH SLAG AS COARSE AGGREGATE

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Abstract –

Self compacting concrete is a type of concrete that does not require external or internal compaction because it becomes leveled and compacted under its own weight. Self compacting concrete is highly engineered concrete with much higher fluidity without segregation and bleeding. The three main requirement of self compacting concrete are filling ability, passing ability and resistance to segregation.

. Abundant availability of natural resources has become a dream for present day engineering society due to large scale consumptions. To overcome the problem of scarcity of natural aggregates and to save the environment from the pollution due to dumping of slag, civil engineers opined that there is significance potential for reuse of slag for use in value added application to maximize economic and environment benefit. Here an attempt has been made in this investigation to determine the strength characteristics of slag for application in self compacting concrete (SCC).

The scope of this project is to determine and compare the self compacting concrete by using different percentage of blast furnace slag aggregates. The investigation was carried out using workability test such as (slump flow test, Slump flow T50cm test, V-funnel test, V- funnel T5min test and L-Box), compressive test and split tensile test. There were total of six batches of concrete mixes, consists of 0% ,10%,20%,40% and 60% increment of slag aggregate replacement for a particular design mix.

To achieve the objectives the entire project is divided into two phases. In the Phase-I, casting and testing of specimens for a particular grade concrete was carried out. In Phase-II, the test results are compared with different code values.

Key Words: *Slag V-funnel Test, L Box, Slump, Compressive strength*

1. Introduction

The development of new technology in the material science is progressing rapidly. In last three decades, a lot of research was carried out throughout globe to improve the performance of concrete in terms of strength and durability qualities. Consequently concrete has no longer remained a construction material consisting of cement, aggregate, and water only, but has becomes an engineered custom tailored material with several new constituents to meet the specific needs of construction industry. The growing use of concrete in special architectural configurations and closely spaced reinforcing bars have made it very important to produce concrete that ensures proper filling ability, good structural performance and adequate durability. In recent years, a lot of research was carried out throughout the world to improve the performance of concrete in terms of its most important properties, i.e. strength and durability. Concrete technology has under gone from macro to micro level study in the enhancement of strength and durability properties from 1980's onwards. Till 1980 the research study was focused only to flow ability of concrete, so as to enhance the strength however durability did not draw lot of attention of the concrete technologists. This type of study has resulted in the development of self compacting concrete (SCC), a much needed revolution in concrete industry. Self compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of form work under its self weight only (Okamura 1999) [1]. Thus SCC eliminates the needs of vibration either external or internal for the compaction of the concrete without compromising its engineering properties.

For several years, the problem of the durability of concrete structures has been a major problem posed to engineers. To make durable concrete structures, sufficient compaction is required. Compaction for conventional concrete is done by vibrating. Over vibration can easily cause segregation. In conventional concrete, it is difficult to ensure uniform material quality and good density in heavily reinforced locations. If steel is not properly surrounded by concrete it leads to durability problems. This is the problem mainly with heavily reinforced sections where a very high congestion of reinforcement is seen. In this case, it becomes extremely difficult to compact the concrete. Then what can be done to avoid honeycombing?

The answer to the problem may be a type of concrete which can get compacted into every corner of form work and gap between steel, purely by means of its own weight and without the need for compaction. The SCC concept was required to overcome these difficulties. The SCC concept can be stated as the concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and curing practices. The SCC is an engineered material consisting of cement, aggregates, water and admixtures with several new constituents like colloidal silica, pozzolanic materials, and chemical admixtures to take care of specific requirements, such as, high-flow ability, compressive strength, high workability, enhanced resistances to chemical or mechanical stresses, lower permeability, durability, resistance against segregation, and possibility under dense reinforcement conditions. The properties, such as, fluidity and high resistance to segregation enables the placement of concrete without vibrations and with reduced labour, noise and much less wear and tear of equipment. Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period. Self-compacting concrete is growing rapidly, especially in the precast market where its advantages are rapidly understood and utilized.

Slag is bi-product of Ferro alloys industries. It creates problems in dumping to environment and requires a vast area for deposition. As this material is densely packed, this material can be used as coarse aggregate.

1.1 Need for Self Compacting Concrete with Blast furnace slag

The ferroalloys industries generate historically substantial solid waste. The accumulated waste needs a huge space to be dumped and causes serious problems to the environment. This low carbon slag, which is considered as third class hazardous waste chemically composed of carcinogenic, such as hexavalent chromium. By exposure to the environment creates health hazard to the human beings like problems in respiration and nervous system disorder. When the slag is dumped it pollutes the ground water. The slag can be easily eroded by the water and wind to contaminate the air and surface water. As per the survey conducted by a single ferroalloys industry produces 220,000 tons of low carbon slag per year [1]. Ferroalloy production has been a problem for many years in the international market particularly in China [2]. The present day researchers are in the opinion that preservation of environment and conservation of rapidly diminishing natural resources should be the essence of sustainable development. To save the environment from the pollution caused due to the slag and to meet the scarcity of natural aggregate in the construction field, the possibility of use of the low carbon slag as coarse aggregate cannot be overlooked. Here an attempt is made to replace natural coarse aggregate with slag in production of concrete. The strength of the concrete depends on the properties of its constituent materials along with their volumetric fraction, water cement ratio, admixture added, curing methodology and degree of control. To find out the optimum volume fraction of slag as a coarse aggregate for making of concrete, the volume fraction of slag is varied in this research work keeping other parameters constant.

This experimental work aims in preparation of self compacting concrete of grade M_{30} and to investigate the fresh workability properties at its fresh stage and hardened stage.

2. Literature Review

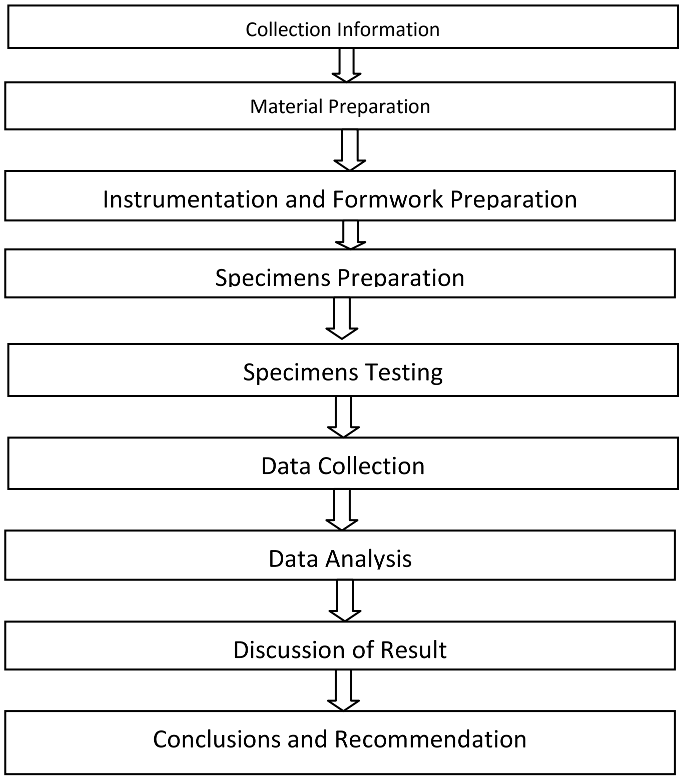
To use the slag aggregate as coarse aggregate for making concrete, it is required to know the properties of slag aggregates and research works carried so far.

The coarse and fine aggregate contents are kept constant so that self-compatibility can be achieved easily by adjusting the water/cement ratio and super plasticizer dosage only [3]. A new mix design method for self-compacting concrete in which the amount of aggregates required was determined, and the paste of binders was 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 [4]. According to [5] elastic modulus, creep and shrinkage of SCC did not differ significantly from the corresponding properties of NCC. Economical SCC mixes could be successfully developed by incorporating high volumes of Class F fly ash [6]. An attempt was made to increase the stability of fresh concrete (cohesiveness) using increased amount of fine materials in the mixes. It was also reported that fly ash in self-compacting concrete helps in improving the strength beyond 28 days [7]. A proposed a mix design method for SCC based on paste and mortar studies for super plasticizer compatibility followed by trail mixes [8].A a procedure was presented for the design of self-compacting concrete mixes based on an experimental investigation [9]. Copper slag was used as fine aggregate in high strength concrete to improve its strength and durability characteristic [10]. According to [11] 50 to 100% coarse recycled aggregate decreases the tensile strength by 2.79 to 13.95. EAF (Electric Arc Furnace) slag aggregate was used replacing 30% of crushed lime stone aggregate and it was found that the compressive strength increased in all ages [12]. According to [13], slag as coarse aggregate in normal strength concrete increases workability, compressive, flexure and split tensile strength increased with increase in percentage of slag. But they silent about the self compacting concrete. SCC with 15% of silica fume gives higher value of compressive strength than those with 30% of fly ash and water cured specimen for 28 days gives highest value of compressive strength [14]. Slag as replacement of normal crushed coarse aggregate and fine aggregate by [15] was found that the compressive strength increased by 4% to 7%. The workability of self compacting concrete with ground granulated blast furnace slag up to 30% replacement is very good [16]. A new mix design methodology for self compacting concrete with GGBFS as replacement material for cement was proposed [17] . According to their method they replaced GGBFS up to 80% for 30 MPa. Fly ash replacements of around 30% to 50% will be ideal for developing self compacting concrete [18]. An experimental study on cement content in the SCC mix is replaced with various percentage of limestone powder and the fresh and hardened properties were studied by [19].

3.0 OBJECTIVE AND SCOPE:

Even though extensive work is reported on self compacting concrete, not much work is reported on the behavior of self compacting concrete with blast furnace slag as replacement of coarse aggregate. Keeping this in view, the present experimental program is taken up to study the behaviour of blast furnace slag aggregate and natural aggregate in different percentage of concrete mixes. The main objective is to obtain specific experimental data, to understand fresh and hardened properties of the self compacting concrete with BFSA (Blast Furnace Slag aggregate) and NCA(Natural coarse aggregate). For this design of M_{30} grade self compacting concrete is prepared with NCA and comparison of its strength is compared with substitution of blast furnace slag as aggregate.

To achieve the above objectives, the total work was divided into two phases. A mix design was prepared for 30 MPa and it was cast and tested in the Phase-I. workability test(Slump flow, V Funnel, L Box ratio, T500 (sec), T5minute), Cubes, cylinders and prisms were casted to determine cube strength, split tensile strength and flexural strength respectively with natural coarse aggregate. The same were cast and tested with 10%, 20%, 40% and 60% replacement of NCA with blast furnace slag aggregates(BFSA) in the Phase-I. In Phase-II, the test results were analyzed and compared with theoretical values obtained from various codes.



4.0 MATERIAL AND THEIR PROPERTIES

Preparation of specimens is mainly done by taking trial of concrete mixes. Concrete samples are tested through a series of test methods. The arrangement of experimental program can be summarized in the flow chart as shown in Fig.2.

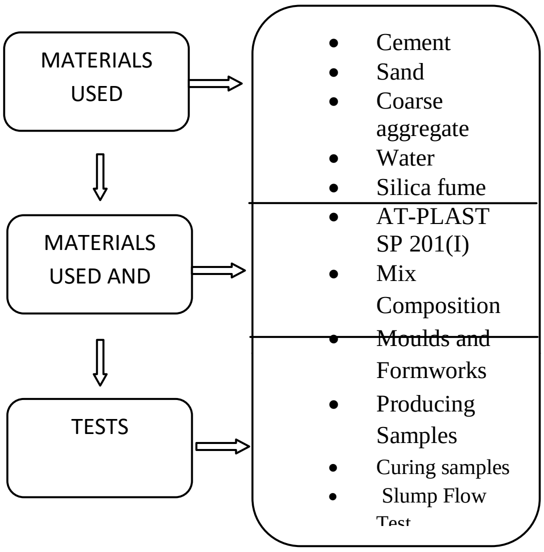


Fig.2 Flow chart of Experimental work

Commonly the material used for the self compacting concrete are cement, fine aggregate (Sand), Coarse Aggregate, mineral admixture and super plasticizer.

4.1 Cement

Ordinary Portland Cement of 53grade (zuari cement) conforming to[20] was used and properties are shown below in Table-1.

TABLE-.1: PHYSICAL PROPERTIES OF CEMENT

S.N	Properties of cement	Value obtained experimentally	Value as per IS 12269-1987
1	Normal consistency (%)	31	NA
2	Fineness	6	< 10
3	Initial setting time	120 min	30(min)
4	Final setting time	250min	600(max)
5	Specific gravity	3.13	3.15
6	Compressive strength of cement at 28 days	55.6 N/mm^2	53 N/mm^2

4.2 Fine Aggregate

Fine aggregate used in the present study is from the river bed of Baitarani, Panikoili (Sathipur) having specific gravity 2.68, bulk density 1600 kg/ m^3 and fineness modulus 2.81. The sieve analysis of fine aggregate has been carried out as per [21] and found that fine aggregate confirmed to grading zone-III.

4.3 Coarse Aggregate

In this investigation, two types of coarse aggregates were used for preparation of self compacting concrete.

4.3.1 Normal Coarse Aggregate.(NCA)
4.3.2 Blast furnace slag Aggregate.(BFSA)

4.3.1. Normal Coarse Aggregate.

Normal coarse aggregate of size below 20mm available in local market is used and tested as per [21] specifications and the properties are shown in Table-2.

TABLE-2: PROPERTIES OF COARSE AGGREGATE

S.N	Properties of coarse aggregate	Value obtained Experimentally for NCA IS 383-1978	Value obtained Experimentally for BFSA IS 383-1978
1	Maximum nominal size, mm	20	20
2	Bulk density Kg/m^3	1460	1940
3	Specific gravity	2.7	3.5
4	Impact value (%)	7.1	6.1
5	Crushing value (%)	54.8	35.5
6	Water absorption (%)	0.5	0.4

4.3.2. Blast furnace slag Aggregate

4.3.2.1. Source of Blast furnace slag Coarse Aggregate

Blast furnace slag aggregate is a non-metallic product obtained from Facor Bhadrak. Blast furnace slag aggregate is the crystal material formed when molten chromites blast furnace slag is rapidly chilled by immersion in water. It is a crystal product with very limited granular formation. The chemical properties of slag aggregate are shown in Table-3.

TABLE-3: PROPERTIES OF BLAST FURNACE SLAG COARSE AGGREGATE

S.N	Properties of slag aggregate	Value obtained as per Facor plant
1	Calcium oxide (%)	48
2	silicon dioxide (%)	25
3	manganese oxide (%)	11
4	iron, sulfur, aluminum, chromium (%)	16

4.4 Silica Fume

Silica fume as very fine non crystalline silica produced in blast furnace as by product of the production of elemental silicon or alloys containing silicon. Silica fume is usually categorized as a supplementary cementitious material. It has excellent pozzolanic properties. The silica fume was used in this experiment conforms to [22].The silica fume is in white colour powder form. Silica fume has been procured from Singhania chemicals Ltd-Jharshuguda, Sambalpur and properties are shown in Table-4.

TABLE-4: PROPERTIES OF SILICA FUME

S.N	Properties of silica fume	Value obtained by manufacture IS 15388:2003
1	Particle size, mm	0.5µm-1µm
2	pack density Kg/m^3	$0.76gm/cm^3$
3	Specific gravity	2.63
4	Moisture content (%)	0.058

4.5 Water

Fresh, colourless, odourless and tasteless potable water is used.

4.6 Super Plasticizer

AT-PLAST SP 201(I) super plasticizing admixture procured from ADO Additives Mfg. Pvt. Ltd Kolkata. It is brown in colour having density 1.2 kg/lt, air entrainment 1% and pH value of 8.

5.0 Mix design

In the present study Normal Vibrated Concrete (NVC) of M_{30} grade was designed by using [23] method and SCC of M_{30} grade was designed by EFNARC specifications. For this water cement ratio was taken 0.43. Different mixes prepared for the study is presented in Table-5.

Table- 5 Percentage of aggregate used in 6 batches of mixes.

Mix Designation	Mix 0	Mix 10	Mix 20	Mix 40	Mix 60
Natural Coarse Aggregate (%)	100	10	20	40	60
Slag (%)	0	90	80	60	40

The mix proportion for M_{30} grade concrete with 100% natural coarse aggregate was 1: 1.18: 2.64 with water cement ratio was 0.43.

6.0 Experimental Programme

The performance of slag aggregate self compacted concrete is influenced by the mixing. This means that a proper and good practice of mixing can lead a better performance and quality of slag aggregate concrete. A proper mix of concrete is encouraged to the strength of the concrete and better bonding of cement and aggregate. Before the concreting, all the mix materials were weighted and prepared according to the mix design proportion.

6.1 Preparation of Concrete Mould.

Concrete moulds were oiled for the ease of concrete specimen stripping. The specimen for conducting tests on fresh concrete was ready and oiled.

6.2 Preparation of Concrete

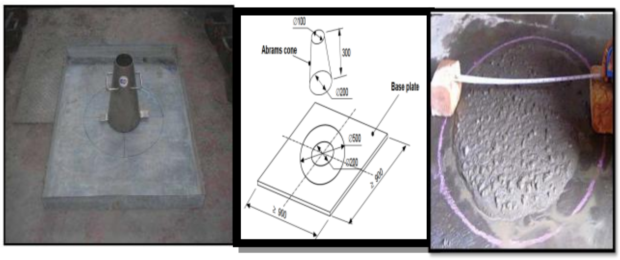
Concrete was prepared in the mixture and dumped in iron tray placed on the surface. Again the concrete manually properly before placing in the moulds.

6.3 Tests on Fresh Concrete

The 3 main properties of SCC in plastic state are as given below.

6.3.1 Filling Ability:

Self compacting concrete must be able to flow into all the spaces within the formwork under its own weight. This is related to workability, as measured by slump flow test and slump flow T50cm test shown in Fig.3.



a Slump flow b. Dimensions of Base plate and c. Slump Flow Test

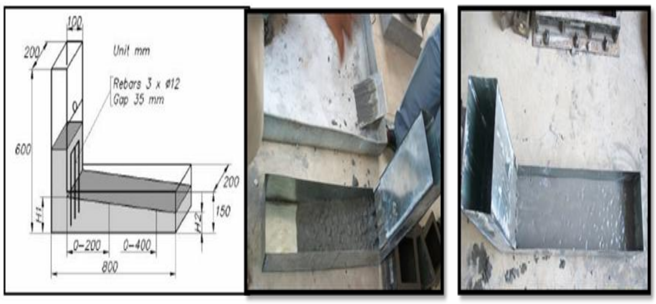
Fig.3.Measurement of Slump Flow Test

6.3.2 Passing Ability:

Self compacting concrete must flow through tight openings such as spaces between steel reinforcing bars under its own weight. The mix must not 'block' during placement. The L-Box test and U-Box test are the most common methods used to assess this property.

6.3.3 Resistance of Segregation:

Stability or resistance to the segregation is the property that characterizes the ability of the SCC to avoid the segregation of its components, such as the coarse aggregates. The V- Funnel T5min test is the most common method used to assess this property.



a .Dimensions of L-Box b. Flow through rebar in L-Box

Fig.4 Passing Ability Test

6.3.3 Resistance of Segregation:

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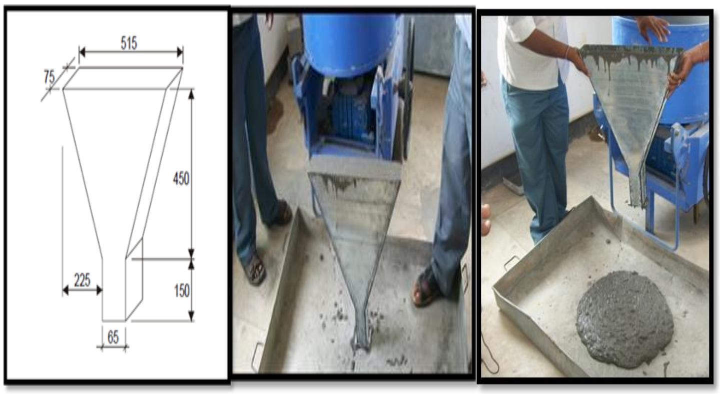


a. Dimensions of b. V- Funnel test c. V- Funnel flow

Fig.5 Segregation resistance Test by V- Funnel

6.3.4. Compacting factor Test

Compacting factor also used to determine the workability of fresh concrete. It was also known as drop test, which measure the weight of fully compacted concrete and compared it with the weight of partially compacted concrete.

6.4. Preparation of Samples

While SCC beams does not require any vibration since it spread by its own weight throughout the formworks. Then beam are ready for curing process.

The placing process of the concrete mix is the most critical moment. For sample which need in compacted condition, the normal compaction procedure is applied. The concrete is poured into the cubes mould in three layers where each layer is compacted 25 times using steel bar. Whereas, for SCC mixes which requires not require any compaction works, the mixes being poured into cubes mould left for 1minute and then again poured this is done until its fully filled space. The cubes are removes from the moulds after 24 hours of curing process.

In placing the concrete mixes in beam formworks, the same process being applied for both compacted and non-compacted conditions between NVC(Natural Vibrated concrete) and SCC mixes respectively. For casting the NVC beams, vibrator is used in the compaction work.

6.5 Stripping

After leveling the fresh concrete in the mould, it was allowed to set for 24 hours. The identification of concrete specification was done with permanent markers and the specimens were removed from the mould. The moulds were cleaned and oiled for the next batch of concrete mix.

6.6 **Curing**

Curing is an important process to prevent the concrete specimens from losing of moisture while it is gaining its required strength. Lake of curing will tends to lead the concrete specimen to pot form less well in its strength required. Inadequate curing will caused the unexpected cracks appear on the concrete specimen. All concrete specimens were cured in water at room temperature further for 28 days. After 28 days curing concrete specimens were removed from the curing room to conduct tests on harden concrete.

6.7 LABORATRY TEST RESULT

6.7 Fresh Properties of SCC:

6.7.1 Slump Flow Test and Slump Flow T50cm Test Results:

The results obtained from the slump flow test, slump T50 flow test are shown in Table 6.3. The acceptable range of SCC criteria for slump flow is 650mm to 800mm.The higher the slump value, the greater its ability to fill formwork under its own weight. The results of slump flow T50 for sample SCC-0, SCC-10, SCC-20, SCC-40 and SCC-60 are within the acceptable ranges of SCC criteria. The T50 time is a secondary indication of flow. A lower time indicates greater flow.

Table-6 Slump Flow test and slump flow T50 test results

Sample	Slump flow test(mm) (500-700)mm	Slump flow T50 test (sec) (2- 5 sec)	Concrete condition	remarks
SCC0	690	3.36	Flow	Satisfied
SCC10	685	3.4	Flow	Satisfied
SCC20	682	3.5	Flow	Satisfied
SCC40	675	3.9	Flow	Satisfied
SCC60	670	4.5	Flow	Satisfied

6.7.2 L-Box Test Results:

The L-Box test results of the sample S5 and S6 indicates high blocking ratio (H2/H1) which are within the acceptance criteria for SCC. Results of the tests are given in the Table-7. Higher value of blocking ratio indicates highly flow able concrete to self compact, excellent passing ability, without blockage, through closely spaced obstacles and the concrete flows freely as water until it will horizontal at rest.

Table-7 L-Box test results

Sample	H1 (mm)	H2(mm)	H2/H1 (0.8-1.0)	T20 (1-2sec)	T40 (2-3 sec)
SCC0	42	42	1.0	2	3
SCC10	41	39	0.95	7	9
SCC20	40	37	0.925	6	8
SCC40	40	34	0.85	4	6
SCC60	38	32	0.842	2	3

6.7.3 V- Funnel Test & V-Funnel T5 Minutes Test:

The V-Funnel test results of the sample SCC-0 indicates greater flow ability which are within the acceptance criteria for SCC. Results of the tests are given in the Table-8. Shorter flow times indicate greater flow ability. The result of V- funnel test as shown in Table-7. By doing V-funnel at T5 minutes we can determine the segregation of concrete. If concrete shows segregation then flow time will increase significantly.

Table-8: V- Funnel test results

Samples	V- Funnel Test (sec) (6-12 sec)	V- Funnel T5 minutes test(≤6 sec)	Remarks
SCC0	7	3.4	Satisfied
SCC10	8	3.8	Satisfied
SCC20	9.2	4.2	Satisfied
SCC40	9.8	4.5	Satisfied
SCC60	10.4	5	Satisfied

6.8. Testing of harden properties

6.8.1. Compressive Strength

Compressive strength can be defined as the measure maximum resistance of a concrete to axial loading. The specimens used in the compressive test are: 150 mm x 150mm x 150mm. There are three specimen were used in the compression testing for each mixes.

Table-9: Experimental test results of different mixes

% of slag	cube strength after 7 days (N.mm^2)	cube strength after 28 days (N.mm^2)	Split tensile strength after 7 days (N.mm^2)	Split tensile strength after 28 days (N.mm^2)	Flexural strength after 28 days (N.mm^2)
NVC	28.95	41.19	2.59	3.42	4.40
SCC 0	29.48	41.26	2.69	3.59	4.46
SCC 10	31.04	41.56	2.74	3.66	4.62
SCC 20	34.15	42.10	2.83	3.73	4.67
SCC 40	37.56	44.67	2.85	3.80	4.74
SCC 60	40.00	46.96	2.95	3.82	4.82

6.8.2. Split Tensile Strength Test.

Normally concrete is very strong in compression and weak in tension. This test is used to determine the brittle nature of concrete specimen that contain natural aggregate as well as slag aggregate.

6.8.3. Flexural Strength:

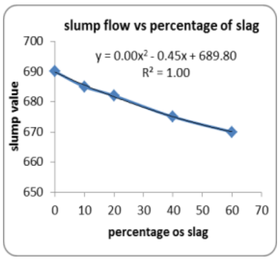
This test is conducted to measure the resistance of concrete in bending. It is recorded in Table-9.

7.0 Interpretation of Test Results:

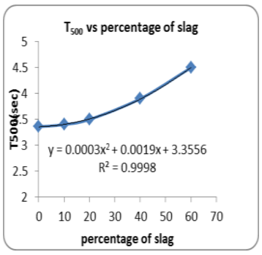
Fresh and hardened properties of SCC were investigated in this section. In the present investigation, fresh properties like workability and properties in hardened stage such as compressive strength, split tensile strength and flexural strength of SCC produced with slag as replacement of natural aggregate were investigated.

7.1 Workability

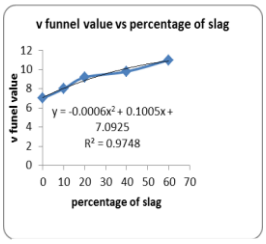
The value of fresh properties of different SCC mixes was presented in Table-. In terms of slump flow, all SCC mixtures exhibited satisfactory slump flows in the range of 690–670 mm, which is an indication of a good deformability. Due to its spherical shape, silica fume can disperse agglomeration of cement particles.



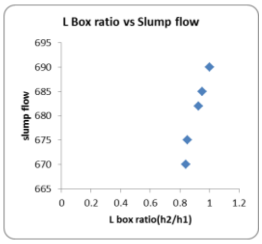
a. Slump Flow vs slag



b. T500 vs Percentage of Slag



c. V Funnel value vs Percentage of Slag



d. L Box ratio vs

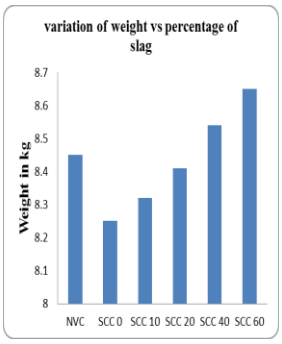
Fig. 6 Variation on Test results on fresh properties of with percentage of slag Funnel value vs Percentage of Slag

When cement is replaced by silica fume, perhaps a higher dosage of super plasticizer is required to maintain the same filling ability. As the test is conducted with same super plasticizer dosage, the slump value was found to be decreased with increase in percentage of slag. Fig-7.1 shows the slump value of different SCC mix. T500 times indicate the viscosity of highly flowable concrete mixes. T500 times means the time required to reach 500 mm diameter of slump flow. Lower time indicates greater flowability. The T500 was influenced by the dosage of water and super plasticizer. V funnel test was performed to assess the flowabilty and stability of the SCC. Fig 7.2 shows the relation between T500 test result and V-Funnel results of percentage of slag. The increase in slag percentage causes the increase in T_{500} time. This might be due to more absorption of water for slag. The increase in slag percentage causes the increase in V-Funnel time. The same has been reported by [24]. L-box ratio indicates the filling and passing ability of each mixture. L-box test is more sensitive to blocking. Fig.6 shows the comparison of L-Box test and Slump test.

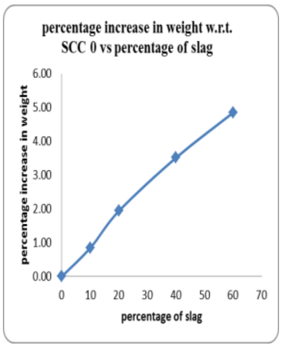
There is a risk of blocking of the mixture when the L-box blocking ratio is below 0.8.The obtained L-box values are tabulated in Table-7. If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The effect of increase in the volume of coarse aggregate on the L-Box test indicated a significant decrease of the blocking ratio.

7.2 Weight

The weight of the specimen depends on specific gravity of its constituents materials. To verify the effects of weight of the specimen on strength parameters, individual weight of cubes were taken. The average weight of specimen prepared with NCC, SCC-0, SCC-10, SCC-20, SCC-40, and SCC-60 was found to be 8.45 Kg, 8.25 Kg, 8.32 Kg, 8.41 Kg, 8.54 Kg and 8.65 Kg respectively. The values are plotted in Fig.7.a. From the figure it is clear that the increase in weight is not marginal. So, when the natural aggregate is to be replaced with slag having higher specific gravity increases the self weight of the specimen. The increase in self weight is negligible which is reflected in Fig.7.b. The weight of the cube with natural coarse aggregate and proportion mentioned in the experimental program mathematically found to be 8.02 kg against the experimental value of 8.45 kg. When the natural aggregate is replaced by 10%, 20%, 40% and 60% with slag, the percentage increase is 0.85%, 1.94%, 3.52%, and 4.85% respectively. As the increase in self weight for 60% slag is only 4.85% of natural aggregate, it can be inferred that slag can be used as replacement of natural coarse aggregate in the construction field.



a. Average weight vs

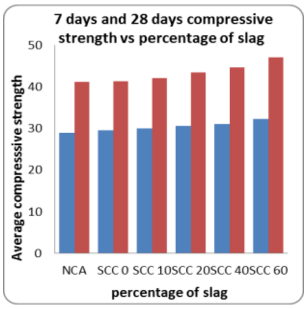


b. Percentage increase in weight w.r.t. SCC 0 vs percentage of slag

Fig.7Variation of parameters with respect to Percentage of slag

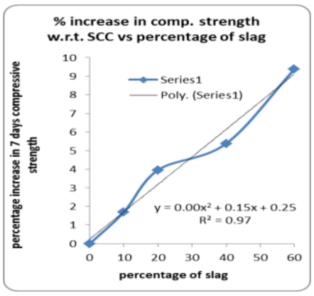
7.3 Compressive Strength:

Compressive strength is an important property of harden concrete which influences other mechanical properties of concrete. Compressive strength of concrete specimen prepared with NCA, SCC-0, SCC-10,SCC-20, SCC-40, and SCC-60was found to be 28.96 MPa, 29.48 MPa, 29.98 MPa, 30.65 MPa, 31.07MPa, and 32.24 MPa in 7 days and 41.19 MPa, 41.26 MPa, 42.00 MPa,43.44 MPa, 44.67MPa, and 46.96 MPa in 28 days respectively. The same is plotted in Fig.8.a It is found that compressive strength increases with increase in the percentage of slag content. A crushed specimen of SCC-60 is shown in Fig.8.b. It is clearly observed that the failure is due to the failure of mortar.

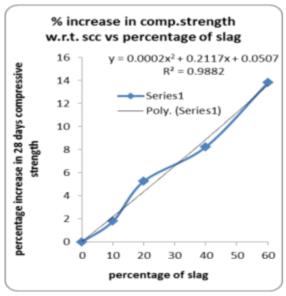


a Average compressive Strength vs Percentage of slag

b Crushed specimen of



c Percentage increase in 7 days Compressive Strength w.r.t. SCC 0 vs Percentage of Slag



d Percentage increase in 28days Compressive strength w.r.t. SCC 0 vs Percentage of Slag

Fig.8 Compressive strength Vs Percentage of Slag

Percentage increase in compressive strengths of SCC-10, SCC-20, SCC-40, and SCC-60 over SCC-0 was found to be 1.70%, 3.96 %, 5.38%, and 9.37% in 7 days. The same was increasing by 1.80%, 5.28%, 8.26% and 13.82% in 28 days respectively. Percentage increase in compressive strength along with percentage of slag is plotted in the Fig.8.

The percentage increase in Strength was found to be 13.87% for 60% replacement of NCA with slag and the variation was found to be linear except for SCC-20. The same has been reported by earlier researchers when natural aggregate is replaced by recycled aggregates [13] . This may be possible due to low volume fraction of slag. The use of slag with high specific gravity might be the cause of enhancement of compressive strength. So, concrete with slag can be used for design of compression members.

7.4 Split Tensile Strength:

The split tensile strength of concrete specimen with natural aggregate (SCC-0) and with slag (SCC-60) was found to be 2.69 MPa and 2.95MPa in 7 days and 3.58 MPa and 3.82 MPa in 28 days respectively. The increase in the spilt tensile strength is nominal. The split tensile strength of specimen prepared with SCC-10, SCC-20, SCC-40 and SCC-60 was found to be 2.69MPa, 2.74MPa, 2.83MPa, 2.85MPa and 2.95 MPa in 7days and3.66 MPa, 3.73 MPa, 3.8 MPa and 3.82 MPa in 28 days respectively. The increase in 28 days split tensile strength w.r.t. percentage of slag is presented in Fig.9.

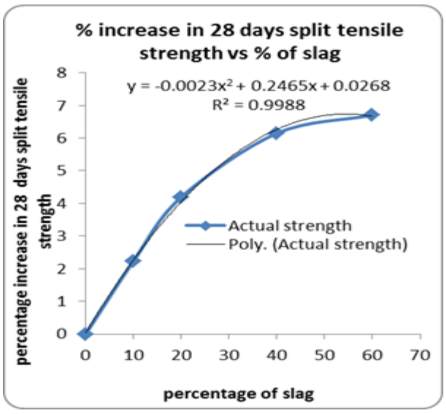


Fig.9 Percentage increase in 28 days split tensile strength w.r.t test value vs Percentage of slag

7.5 Flexural Strength:

Flexural strength of concrete specimen prepared with SCC-0, SCC-10, SCC-20, SCC-40 and SCC-60 was found to be 4.46 MPa, 4.62 MPa, 4.67 MPa, 4.74 MPa and 4.82 MPa respectively. The percentage increase in flexural strength of SCC-10, SCC-20, SCC-40 and SCC- 60 over SCC-0 was found to be 3.68%, 4.63%, 4.82%, and 8.07% respectively. The percentage increase in flexural strength with respect to slag is plotted in Fig.10.

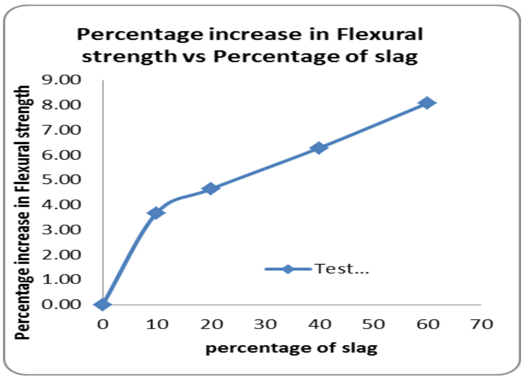


Fig 7.16 Percentage increase in flexural test

8. CONCLUSION

The tests were performed to determine the fresh and mechanical properties of Self-Compacting Concrete mixtures and the results of the tests are as follows.

1. All the self-compacting concrete with replacement of slag as coarse aggregate up to 60% mixes had a satisfactory performance in the fresh state.
2. The T50 time value increases with increase in percentage of slag.
3. The slump value decreases from 690 mm to 670 mm with increase in percentage of slag from SCC-0 to SCC-60.
4. The compressive strength increases with increasing percentage of slag contain.
5. There is an increase of 13.82% in compressive strength for SCC-60 over SCC-0.
6. The split tensile strength increases with increase in percentage of slag and the increase is not prominent as compressive strength.
7. The increase in split tensile strength is up to 6.70% over self compacting concrete SCC-0 with natural aggregate for 60% replacement.
8. The flexural strength also increases with increase in percentage of slag.
9. The increase in split tensile strength is up to 8.07% over SCC-0 with natural aggregate for 60% replacement.
10. The changes in properties are found to be almost same up to 20% replacement of NCA with slag.

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