AN EXPERIMENTAL STUDY ON FIBER REINFORCED SELF COMPACTING CONCRETE INCORPORATED WITH SINTERED FLY ASH AGGREGATE

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ABSTRACT

The development of new type of high performance concrete, such as self- compacting concrete (SCC) or lightweight concrete (LWC) responds to some requirements of the construction industry. Due to the reduced weight LWCs have other advantages compared to normal-weight concrete, such as good fire resistance and improved heat insulation. Sintered fly ash aggregate is the best for the use in structural applications. In addition to the light weight aggregate fibres which are best known for resisting cracks, fatigue , bending , durability etc are also included to get more effective outputs from the members. Fibre reinforced concrete were developed to overcome the cracks and to provide additional strength. SCC is cast so that there is no additional vibration, necessary for the compaction. It has a high flowing property and has a very smooth surface level after placing. SCC has several advantages over normal conventional concrete and so thus SCC reinforced with steel fibre. It can flow easily in congested reinforced areas such as in beam column points. Hence the combination of SCC with steel fiber is a concrete mixture with dual advantage. In this project the hooked end steel fibers of 0.75mm Dia and 50mm length are added in reinforced concrete beam with concrete compressive strength of 30MPa (M30). The optimum percentage of 1% steel fibers added to concrete mix and sintered fly ash aggregates are replacing to the coarse aggregate with different percentages (i.e 0%, 10%, 20%, 30%) have been tested. Specimen were casted with fibres and sintered fly ash aggregate , allowed to cure for a period of 28 days and tested.

Key words: Sintered fly ash aggregate, steel fiber, compressive strength, split tensile strength, flexibility strength.

I.INTRODUCTION

1.1 GENERAL

The development of latest varieties of superior concrete, such as self-compacting concrete or light weight concrete responds to a number of necessities of the construction development. In structural applications, self-weight of a concrete is very important since it represents an oversized portion of the whole load. But light weight concrete has been used for variety of applications, is thought for its smart performance and durability. Due to the reduced or light weight LWCs produce other advantages compared to normal-weight concrete, such as improves the fire resistance to more and improves the heat insulation. In this project, lightweight aggregates (LWA) are fully replacing to the natural aggregates or combination of LWA and natural aggregates are used for these concretes. Lightweight aggregates are sintered expanding clays, expanded high-grade shale, perlite, sintered fly ash, expanded slate, clayey diatomite, pumice, bottom ash, aggregate etc. have used successfully in the making of LWCs. Bulk density and mechanical properties of these aggregates vary, therefore have different applications.

Self-compacting concrete (SCC) does not require any vibration for compaction and placing. It has a property of flowing under its self weight, completely occupies formwork and gain full of compaction without vibration, even the presence of congested reinforcement in structure, without segregation of material constituents (EFNARC,2005). Lightweight aggregate self compacting concrete (LWASCC), the properties of SCC, that are filling and passing ability and segregation resistance. Self compacting concrete flows by their own weight. Structural LWASCC must satisfy all requirements in fresh state while having a low density. When LWA is used there is no sufficient dynamic energy of the mixture during flow, and compared to the concretes containing natural aggregate, slightly slow in flow especially through reinforcement.

1.2 SELF COMPACTING CONCRETE

Self-compacting concrete (SCC), also called self-consolidating concrete, it is a highly flowable and non-segregating concrete that can fill and spread in formwork under its own weight with no mechanical vibration or compaction. Making and development of SCC done in prof. Okumara's laboratory in Japan in 1986 as a solution against the drawback of conventional concert in densely placed steel reinforcement and to overcome the declining number of qualified concrete workers (Okamura et al 2000; De schutter et al 2008; Aslain and kelin 2018). The utilization of SCC has reduced direct machinery usage and cost, labor work and costs, and construction period durations. Furthermore, SCC has substantial technical advantages on concreting high and thin walls containing dense reinforcement as well as posttensioning ducts.

The method of SCC design differs from that of ordinary concrete with relevance two opposite properties, flowability and segregation resistance. To optimization the workability of SCC less yield stress and a great viscosity are required to ensure that aggregate do not segregate during flow. The segregation resistance of SCC is because of the high viscosity and also the counter effect of small or fine particles in admixtures to prevent aggregates of agree from floating or sinking. While comparing the SCC to normal concrete, there are many benefits than normal concrete, the materials which are high cost are necessary to produce SCC and therefore the resulting high unit weight will produced as limiting factors of its application within the construction industry. Lightweight self-compacting concrete aims to combine the benefits of both SCC and Lightweight normal concrete (LWC), which may offer engineers greater freedom when it involves designing efficient concrete structural's with respect to project cost and time.

1.3 FIBRES IN CONCRETE

In plain concrete, there is weakness because of the presence of micro cracks in the mortor – aggregate interface. This weakness are often removed or are often made negligible by the including the steel fibers within the mixture. different kinds of fibres like polymer, glass, ect., may be utilized in composite materials which is to be introduced in to the concrete mixture to increment of its toughness, or ability to resist to crack growth. The concrete within which the fibres help to transfer loads at the internal micro cracks is named as fibre – reinforced – concrete (FRC).In plain concrete, structural cracks develop even before loading particularly because of drying shrinkage cracks may be caused even due to other volume change because of expansion and shrinkage. The width of those initial cracks is in the range of microns. When concrete is loaded this micro crack will propagate and hold. because of stress concentration, additional micro cracks are formed. The micro cracks are the mostly cause for elastic deformation in concrete. Fibre concrete were developed to overcome the cracks and to provide additional strength. SCC is cast in order that there's no additional vibration, necessary for the compaction. it has a high flowing property and contains a very smooth surface level after placing. SCC has more advantages over normal conventional concrete, so thus SCC reinforced with steel fibre. It can flow easily in congested reinforced areas such as in beam column points. Hence the combination of SCC with steel fibre is a concrete mixture with dual advantage.

One of the concrete which has undesirable characteristics as a brittle material is its gives less tensile strength, and strain capacity. Therefore it requires reinforcement in order to be used as the most widely construction material. Conventionally, this reinforcement is in the form of continuous steel bars placed within the structure in the appropriate positions to withstand the imposed tensile and shear stresses. Fibers, on the other hand, are generally short, discontinuous, and randomly distributed throughout the concrete member to produce a composite construction material known as fiber reinforced concrete (FRC). Fibers utilized in cement-based composites are primarily manufactured of glass, steel, and polymer or derived from natural materials. Fibers can control crack more due to their tendency to be more closely spaced than conventional reinforcing steel bars. It should been highlighted that fiber used as the concrete reinforcement isn't a substitute for conventional steel bars. Fibers and steel bars have different roles to play in advanced concrete technology, and there are many applications in which both fibers and continuous reinforcing steel bars should be used.Steel fiber (SF) is the most popular form of fiber used as concrete reinforcement. Initially, SFs are useful to prevent/control plastic and drying shrinkage in concrete. Further research and progress that addition of SFs in concrete significantly increases its flexural toughness; the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability This paper reviews the consequences of addition of SFs in concrete, and finds the mechanical properties, and applications of SF reinforced concrete (SFRC)

1.4 ADVANTAGES

The addition of light weight aggregates in concrete to produce LWC can result in a higher strength to weight ratio, enhance thermal properties and fire resistance, and load to decrease in dead loads. Decrease in dead loads is beneficial in the construction industry because they can result in cost savings, reduction of the size of structural elements and possibly the amount of steel rft required. The large difference in the densities of LWA's and binders increases the possibility of segregation. The main problems associate with porous LWA's are their high absorption of water during the mixing process and the tendency of lighter aggregates to float, increasing the risk of segregation. This segregation can be controlled the addition of sufficient viscosity – modifying admixtures (VMA's) or increasing the binder content, thereby ensuring that there is sufficient viscosity to suspend aggregates within the binder without significantly effecting its flow properties. SCC has several advantages over normal conventional concrete and so thus SCC reinforced with steel fibre. It can flow easily in congested reinforced areas such as in beam column points. Hence the combination of SCC with steel fibre is a concrete mixture with dual advantage.

II.MATERIALS OF SCC

In this chapter, Mechanical properties and durability studies on lightweight aggregate of SCC of grade of M30 was examined. For this different experimental research were carried out on the fresh and hardened properties of sintered fly ash lightweight aggregate of self-compacting concrete. This experimental programme was in the various steps to reach the following studies.

- To develop the SCC of M30 grade and get its fresh and hardened properties.
- To develop a sintered fly ash aggregates of SCC of M30 grade and get its fresh and hardened properties
- To study the durability properties of normal or plain SCC and sintered fly ash aggregates of SCC.

2.1 Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand(fine aggregate) and gravel (coarse aggregate) together. Cement is a mixture of calcareous, siliceous, argillaceous and other substance. Ordinary/normal Portland cement is one of the material most widely used type of cement. It was all introduced in 1824 by joseph Asp din England. Cement is a powdered material which has both adhesive property and cohesive properties when it is mixed with the water. Such cement materials are called hydraulic materials. It has complex chemical compositions, but the main cementing compound is calcium silicate hydrate. Cement primarily consists of aluminates and silicates of lime which is obtained from limestone and clay.

The chemical components of ordinary Portland cement (OPC) are

- Lime
- Calcium
- Silica
- Alumina
- Magnesia
- Iron oxide

The chemical compound which usually form in process of mixing

- Tricalcium silicate ($3CaO.SiO_2$)
- Dicalcium Silicate ($2CaO.SiO_2$)
- Tricalcium aluminates ($3CaO.Al_2O_3$)
- Tetra calcium alumino ferrite ($4CaO.Al_2O_3.Fe_2O$)

Fig 2.1 Cement

2.2 Coarse aggregate

Aggregates whose particles does not pass through 4.75mm termed as coarse aggregates Coarse aggregates are generally considered as a inner material and only its physical properties like shape, size, water adsorption and specific gravity is studied. Crushed granite material which is used as coarse material is locally available in the market. Most commonly used coarse aggregates are crushed stone, gravel broken pieces of burnt bricks The coarse aggregate should Sieve of 12mm and retained at 10mm IS Sieve were tested according to IS: 2386-1963 conforming specifications.

Fig 2.2 coarse aggregate

2.3 Fine aggregate

Aggregates whose particles pass through 4.75mm sieve is termed as fine aggregates. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent material of sand is silica, usually in form of quartz. River sand is locally available in the market which should pass IS Sieve 4.75mm were tested as per IS: 2386-1963 conforming specifications.

Fig 2.3 Fine aggregate

2.4.Sintered fly ash aggregate

Sintered fly ash less weight aggregate substitute's natural stone aggregate in concrete, reducing dead weight. It can also be used in production of light weight precast concrete blocks for useful in load and non load bearing elements. The fly ash nodules are made by the help of water are fired at 1200˚C. The fine or particles of fly ash melt at the plain surface and are welded together. The nodules crumble during the sintering process. Mixing 5, 10 & 20% plastic clay in fly ash produce good quality aggregate. This sintered fly ash aggregate concrete is spherical in shape, possessing 5-20 mm size and light grey colour. Water absorption is 15-25% in uncrushed material and 45-50% in crushed material; bulk density: 640-750 kg/m3, aggregate crushing strength: 5-8.5 t. Sintering machine, ribbon mixer, conveyor, handling equipment is the equipments used in this manufacturing process. Fly ash, plastic clay is used as raw materials in making sintered fly ash aggregate.

Fig 2.4 sintered fly ash aggregate

2.5 Mineral admixtures

Mineral admixtures are used for the requirement of flowability. These mineral admixtures must have the fineness to that of cement. Mineral admixtures will have different morphology and size distribution. This may improve in particle friction, viscosity deformability and stability of self-compacted concrete. These are all commonly used to improve and maintain the workability and also to reduce the heat of hydration. These are considered as fine inorganic material which normally use in industrial wastes.In this study, mineral admixture fly ash is used as replacement to cement. Mineral admixtures improve the flowing and strengthening characteristics of the concrete.

2.6 Fly ash

Fly ash is uneconomical used by-product materials in the construction field. It is an inorganic, non-combustible finely divided residue which is collected from exhaust gases of any industrial furnace. The particle size of fly ash is about 20 microns which is commonly similarly to average particle size of Portland cement. The properties of fly ash are used as investigation confirms to grade I.

Table 2.1 Chemical composition of fly ash:

Compounds	**%**
SiO_2	38-63
Al_2O_3	27-44
TiO_2	0.4-1.8
Fe_2O_3	3.3-6.4
Mno	0.2-0.5
MgO	0.01-0.5
CaO	0.2-8
K_2O	0.04-0.9
Na_2O	0.07-0.43
Ph	6-8

Table 2.2 Physical properties of fly ash:

Parameters	**Fly-ash**
Bulk density	0.9-1.3
Specific Gravity	1.6-2.6
Plasticity	Lower or non-plastic
Shrinkage limit	Higher
Grain size	Major fine sand/silt and small percent of clay size particles
Clay(percent)	Negligible
Free swell index	Very slow
Classification(Texture)	Sandy silt to silty loam
Porosity (Percent)	30-65
Lime reactivity (MPA)	1-8

2.7 Super plasticizer

Master Ease 3709 is an admixture of a new generation based on modified polycarboxylic ether. It is free of chloride & low alkali. It is compatible with all types of cements. It ensures that rheoplastic concrete remains workable in excess of 45 minutes at +25°C. Workability loss is dependent on temperature, and on the type of cement, the nature of aggregates, the method of transport and initial workability.

Fig 2.5 Master ease 3709

2.8 Water

In this investigation, Portable water which was confirming to IS: 3025-1986 part 22 and 23 and IS:456-2000 were used.

2.9 Fibres

Fibres are usually utilized in concrete to regulate plastic shrinkage cracking and drying shrinkage cracking. Generally fibres don't increase the flexural strength of concrete, so it cannot replace moment resisting or steel reinforcement. Some fibres are reduce the strength of concrete.

The measure of filaments added to a substantial blend is estimated as a level of the general volume of the composite (cement and strands) named volume portion; volume division commonly goes from 0.1 to 3%. proportion (l/d) is determined by isolating fiber length by its measurement (d). Strands with a non-roundabout cross area utilize a comparative breadth for the computation of proportion. Increment inside the proportion of the fiber typically fragments the flexural strength and sturdiness of the grid. In any case, strands which are excessively long tend to "ball" inside the blend and construct usefulness issues. Some new exploration demonstrated that utilizing strands in concrete has restricted impact on the effect opposition of substantial materials. This finding is critical since generally individuals think the flexibility increments when cement built up with filaments. The outcomes additionally perceived that the miniature filaments is best in sway obstruction contrasted and the more extended strands. It expands the strength of the substantial.

Reinforced concrete itself could be a material, where the reinforcement acts because the strengthening fibre and therefore the concrete because the matrix. it's therefore imperative that the behavior under thermal stresses for the materials be similar in order that the differential deformations of concrete and also the reinforcement are minimized. it's been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

Different Types of Fiber Reinforced Concrete

Following are the different type of fibers generally used in the construction industries.

1. Steel Fiber Reinforced Concrete
2. Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
3. GFRC Glass Fiber Reinforced Concrete
4. Asbestos Fibers
5. Carbon Fibers
6. Organic FibersSteel Fiber Reinforced Concrete

The standard diameter lies within the range of 0.25 to 0.75mm. Steel fibers having an oblong c/s are produced by silting the sheets about 0.25mm thick. Fiber made of low-carbon steel drawn wire. Conforming to IS: 280-1976 with the diameter of wire varying from 0.3 to 0.5mm has been practically employed in India. Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s starting from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm wide are produced by silting flat sheets. This could be avoided by adding fibers bundles, which separate during the blending process.

Fig 2.6 steel fibre

III. PRELIMINARY INVESTIGATION

3.1. MATERIALS:

Materials that are used in this LWASCC

1) Cement (OPC 53 grade)
2) Fly ash
3) Fine Aggregates
4) Coarse aggregate:12.5mm
5) Super plasticizer:
6) Sintered fly ash aggregate
7) Water

3.2. Preliminary tests on materials

The different tests are conducted on the materials as shown in below

S. No.	Material	Test
1	Cement	Standard consistency
		Specific Gravity
		Initial & Final Setting Time
		Soundness
2	Fly ash	Specific Gravity
		Fineness
3	Fine aggregate	Bulk density
		Fineness modulus
		Specific gravity & water absorption
4	Coarse aggregate	Bulk density
		Fineness modulus
		Specific gravity & water absorption
5	Sintered fly ash aggregate	Specific gravity & water absorption
		Bulk density

Table 3.1 Preliminary tests on materials

3.3. Cement, Fly ash

The cement used was fresh and without any lumps.

OPC 53 grade used for this investigation. Flyash is a pulverized fuel ash of coal combustion.

3.3.1 SPECIFIC GRAVITY

Equipment and appartus

- Le Chatiler's flask
- Weighing balance
- Kerosene (free from water).
- Weighing Balance

Procedure for Specific Gravity Test on Cement, Fly ash

- The flask is allowed to dry completely and made free from liquid and moisture. The weight of the empty flask is taken as W1.
- The bottle is filled with cement to its half (Around 50gm of material) and closed with a stopper. The arrangement is weighed with stopper and taken as W2.
- To this kerosene is added to the top of the bottle. The mixture is mixed thoroughly and air bubbles are removed. The flask with kerosene, cement with stopper is weighed and taken as W3.
- Next, the flask is emptied and filled with kerosene to the top. The arrangement is weighed and taken as W4.

Observations and Calculations

Table No. 3.2 Specific gravity test on cementitious materials

Observations	Cement	Fly ash
Weight of empty flask (w_{1})	58	58
Weight of flask with material (w_{2})	138	138
Weight of flask with material & Kerosene (w_3)	189	181
Weight of flask with kerosene (w_4)	120	120

*all weights in grams.

- Specific Gravity of material is given by the formula $S=(w_2-w_1)/ ((w_2-w_1)- (w_3-w_4)*S_k)$

Here, the specific gravity of kerosene is 0.79g/cc

- Specific gravity of cement (S_c)=3.13
- Specific gravity of Fly ash (S_f)=2.5

3.3.2 Standard Consistency Test on Cement

Apparatus:

- Vicat Apparatus Conforming to IS: 5513-1976.
- Balance of capacity 1Kg and Sensitivity to 1gram.
- Gauging trowel

Procedure:

1. Take 400 g of cement and place it within the enamelled tray.
2. Mix about 25% water by weight of dry cement thoroughly to urge a cement paste. Total time taken to get thoroughly mixed water cement paste i.e. ―Gauging time‖ shouldn't be over 3 to five minutes.
3. Fill the vicat shape, settling upon a glass plate, with this concrete glue.
4. Subsequent to filling the shape totally, smoothen the outside of the glue, making it level with top of the form.
5. Place the full assembly (i.e. mould + cement paste + glass plate) under the rod bearing plunger.
6. Lower the plunger gently so on touch the surface of the test block and quickly release the plunger allowing it to sink into the paste.
7. Measure the profundity of infiltration and record it.
8. Get ready preliminary glues with shifting rates of water content and follow the means (2 to 7) as depicted above, until the profundity of infiltration becomes 5 – 7 mm

Table 3.3 Consistency Test Result

Sl.No.	Quantity of cement(g)	Quantity of water (ml)	% of water	Penentration from bottom
1	350	100	28.57%	8
2	350	98	28%	5

Result:

The consistency of the taken cement sample is 28 %.

3.3.3 Initial and Final Setting Time of Cement

Reference Standard:

IS:4031 (part 5) -1988

Procedure:

Initial setting time:

1. Spot the test block restricted in the shape and laying on the nonporous plate, under the bar bearing the needle.

2. Lower the needle delicately until it interacts with the outside of test square and speedy delivery, permitting it to enter into the test block.

3.In the starting the needle totally punctures the test block. Rehash this methodology for example rapidly delivering the needle after like clockwork till the needle neglects to puncture the square for around 5 mm estimated from the lower part of the form.Note this time (t).

Final setting time:

1.For deciding the last setting time, supplant the needle of the Vicat's contraption by the needle with an annular connection.

2.The concrete is viewed as at last set when after applying the last setting needle delicately to the outside of the test block. The needle establishes a connection consequently, while the connection neglects to do as such. Note this time (t)

Sample Test of Initial Setting Time:

Quantity of water to be added = 0.85 P = 0.85 × 98 = 83.3 ml

Table 3.4 initial and final setting time results

Sl.No.	Quantity of cement (g)	Quantity of water(ml)	Initial setting time	Final setting time
1	350	83.3	46min	370min

3.1 Vicat apparatus

3.4. Fine aggregate

Locally available river sand without organic impurities and confirming to IS : 383:1970

3.4.1 Specific gravity & water absorption

Reference Standard:

- IS: 2386 part-3 1963

Apparatus

- Pycnometer
- Oven
- Weighing machine
- Tray
- Funnel

Observations and calculations

Table 3.5 specific gravity and water absorption

Details	Trial
Weight of empty pycnometer (W_1)	700 g
Weight of pycnometer + Weight of fine aggregate (W_2)	1200 g
Weight of pycnometer + weight of sand + weight of water (W_3)	1900 g
Weight of pycnometer + water (W_4)	1580 g
Weight of empty pan	640 g
Weight of dry sand (W_d)	494 g

Trial-1

G=(W2-W1)/((W2-W1)-(W3-W4))=2.6

Water absorption:

$w=(w_s-w_d)/w_d*100=2.12\%$

Result

- The specific gravity of a sample of fine aggregate = 2.6
- Water absorption of fine aggregate = 2.12%

Fig 3.2 pycnometer

3.4.2 Gradation on Fine aggregate

Particle size distribution of Fine Aggregates results in the gradation of material based on its size.

Reference Standard:

- IS: 2386 (Part 1) – 1963

Apparatus:

- Balance (0-10kg)
- Sieves
- Oven

Sample preparation

Take a sample of fine aggregate in pan and placed it in dry oven at a temperature of 100 – 110°C. After drying take the sample and note down its weight.

PROCEDURE:

- Take the sieves and arrange them in descending order with the largest sieve on top. If mechanical shaker is using then put the ordered sieves in position and pour the sample in the top sieve and then close it with sieve plate.
- Then switch on the machine and shaking of sieves should be done at least 5 minutes.
- After sieving, record the sample weights retained on each sieve.
- Then find the cumulative weight retained. Finally determine the cumulative percentage retained on each sieve.
- Add the all cumulative percentage values and divide with 100 then we will get the value of fineness modulus.

Observations & Calculation

- Let us say the dry weight of sample = 2000g

Table 3.6 fineness modulus test results

Sieve size	Weight retained (g)	Cumulative weight retained(g)	Cumulative % retained	Cumulative % passing
4.75mm	41	41	2.05	97.95
2.36mm	62	103	5.15	94.85
1.18mm	307	410	20.5	79.5
0.6mm	418	828	41.4	58.6
0.3mm	970	1798	89.9	10.1
0.15mm	121	1919	95.95	4.05
pan	81	2000	100	0

Therefore, fineness modulus of aggregate = (sum of cumulative % retained up to 0.15)/100

= (254.95/100)
= **2.55**

Table 3.7 Fineness modulus range

Type of sand	Fineness modulus range
Fine sand	2.2 – 2.6
Medium sand	2.6 – 2.9
Coarse sand	2.9 – 3.2

Results:
It is confirmed to ZONE-II type of sand
Based on fineness modulus, sand is fine sand

3.5COARSE AGGREGATE

Specific Gravity and Water Absorption Test on Coarse Aggregate=2.66 and 1.2%

3.6 Sintered fly ash aggregate

Specific Gravity and Water Absorption Test on Coarse Aggregate=1.57 and 5.04%
The Bulk density (Dry Rodded Unit Weight) of the SFA Sample is 0.91 kg/lit, loose bulk density is 0.85 kg/lit

IV. TESTS ON SELF COMPACTED CONCRETE

4.1. GENERAL

There are workability test methods for conventional concrete, but these workability methods are not suitable for self-compacting concrete. Different methods are developed for SCC to find the fresh properties are filling ability, passing ability and segregation resistance. Among other fresh properties are plastic shrinkage, unit weight and air content. Self-consolidating concrete should satisfy flowability, filling ability and segregation resistance ability in its fresh state. Immediately after mixing the subsequent properties of fresh LWASCC were evaluated: slump-flow, time required to achieve 500 mm of slump -flow T500 and passing ability (confined flowability) using L-box (H2/H1). Repeated after 60 min (slump- -flow and T500) . The visual stability index (VSI) was useful for assess the degree of segregation of mixtures.

There are four classes of stability, determined on the idea of a visible assessment (ACI 237R-07:2007; Gołaszewski & Szwabowski, 2011). All SCC specimens were cast without hand compaction or mechanical vibration into cubic moulds of 150 mm x 150mm for compressive strength and cylinder size of 150 mm diameter and with 300mm in length for split tensile strength. They were then demoulded and immerse in the water tanks with portable water until testing. The compressive strength was determined after 7 and 28 days. After 28-day splitting tensile strength was tested.

4.2. Passing ability

The SCC of passing ability is verified by L-Box test and U-Box test.

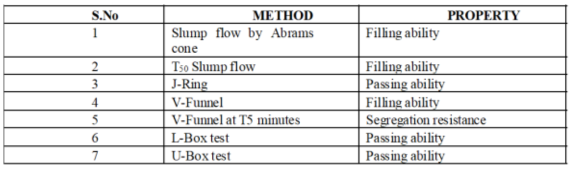
Filling ability

The filling ability primarily depends on aggregate content, W/B ratio, and binder content. The filling ability is measured by slump flow and flow time.

Segregation resistance

Segregation resistance refers the ability to remain constant and uniform during and after placing the concrete without having any loss of stability due to bleeding, separation of mortar of cement and settlement of coarse aggregate. A good segregation resistance can obtain a proper mixture composition.

Table 4.1 tests on fresh SCC



S.No	METHOD	PROPERTY
1	Slump flow by Abrams cone	Filling ability
2	T_{50} Slump flow	Filling ability
3	J-Ring	Passing ability
4	V-Funnel	Filling ability
5	V-Funnel at T5 minutes	Segregation resistance
6	L-Box test	Passing ability
7	U-Box test	Passing ability

4.3. Tests on fresh SCC mix

Slump flow test and T50 slump flow test

The slump flow is used to determine the flow of self-compacting concrete without any obstacles.

The slump cone mould is in the shape of truncated cone with the inner dimension of 200mm at the 4 base, 100mm diameter at the top and height of 300mm. The base plate circle is marked at least 700mm square at the central location of slump cone and further concentric circle is about 500mm diameter. The required apparatus for the test as mentioned below.

- Trowel
- Stopwatch
- Scoop
- Ruler

Procedure for slump flow

- In the test, 6 litres of concrete is required.
- The inside surface and the base plate of the slump cone must be moisten first.

- The base should be placed on a stable ground and place the slump cone centrally on base plate and hold it to fill the concrete.
- Now fill the slump cone with SCC with the help of scoop and tamping should not be done.
- Now, vertically lift the cone and SCC will flow freely on base plate, measure the time with the help of stopwatch for flowing of concrete on base plate throughout the circle is marked (T50 time).
- Measure the final diameter of the concrete which is flow/spread in perpendicular direction.
- Then calculate the average of diameters.

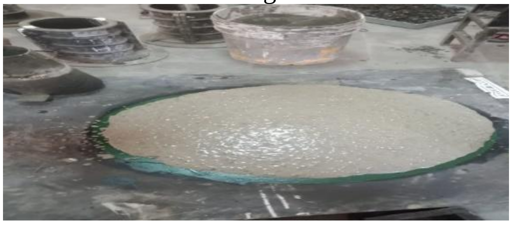


Fig 4.1 slump flow

4.3.1. J-Ring test

The J-ring defines the passing ability of SCC concrete. The equipment consist of rectangular section which is 30mm*25mm open steel ring drilled vertically with holes to accept threaded section of reinforcing bars of 10mm diameter 100mm length. The bar sections can be placed at different distance apart to stimulate the congested reinforcement at the site. Generally, these sections are placed at 3 maximum sizes of aggregates. The diameter of the ring is formed by vertical sections is 300mm and 100mm height.

Apparatus required

- Slump cone without foot pieces
- Base plate about 700mm square
- Trowel
- Scoop
- Tape
- J-ring rectangular section of 30mm*25mm with planted vertically to form a ring of 300m diameter generally spacing of 48mm (+/-)

Procedure

- To perform this test, 6 litres of concrete is needed
- Base plate and slump cone must be moisten.
- Place the J-ring should be at centrally on base plate and slump cone centrally inside the j-ring
- Pour the concrete into slump cone and fill it with the help of scoop
- Strike the top surface of concrete with trowel to remove surplus concrete
- Raise the cone vertically and allow the concrete to flow through-out the j-ring
- Measure the final diameter in both perpendicular directions
- Calculate the average diameter
- Measure the final diameter in height between the concrete which is just inside the j-ring and outside the j-ring bars
- Calculate the average of difference in height at four different locations
- The acceptable difference in height between inside of j-ring and outside of j-ring should be 0 and 10mm

Fig 4.2 J-ring

4.4. V Funnel Test and V Funnel test at T5 minutes

This apparatus of this test consists like a triangular or V-type shape, which gives an order to pass the concrete through the v-type channel. This test is used to determine viscosity of self-compacting concrete.

Apparatus required

- V-funnel Bucket
- Trowel
- Scoop
- Stopwatch

Procedure

- To perform this test, 12 litres of concrete is needed.
- V-funnel should be set up on firm ground
- Moisten the inner surface of the funnel
- Close the trap door and place a bucket.
- Fill the concrete in the funnel without compacting
- Strike off the concrete on the top surface with trowel

- Open the trap door to flow the concrete under its gravity
- Open the trap door, start the stopwatch and note the time readings of the passing. This test will take 5 minutes to perform

Procedure of flow time at T5 minutes

- Close the trap door of v-funnel and refill the concrete immediately after measuring the flow time
- Place a bucket underneath.
- Fill the concrete in the v-funnel without compacting.
- Strike off the concrete at the top surface with the help of trowel.
- Open the trap door after 5 minutes after the fill of funnel.
- Similarly open the door, start the stopwatch and record the time for the passage of concrete (flow for 5 minutes).

L box test

The apparatus consists of a vertical hopper with a gate at the bottom. There are three bars representing reinforcing steel and a horizontal trough the gate. Fresh concrete is placed in the vertical hopper without consolidating. Lifting the slide gate allows the concrete to flow past the bars into the horizontal trough. Final depth of the concrete at the gate of the trough is measured and the proportional difference expressed as a blocking ratio. Some versions of this procedure require timing the flow with a stopwatch. To access the passing ability the ratio height at the end of the horizontal section, and the height of the remaining concrete in the vertical section has been proposed (H2/H1).This is usually referred to as the blocking ratio and a minimum value of 0.8 has been suggested.

Fig 4.3 L - box

U box test

U box test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometimes the apparatus is called a ―box shaped‖ test. U Box test is used to measure the filing ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments; an opening with a sliding gate is fitted between the two sections. Reinforcing bar with nominal diameter of 134 mm are installed at the gate with centre to centre spacing of 50 mm. this create a clear spacing of 35 mm between bars. The left hand section is filled with about 20 liter of concrete then the gate is lifted and the concrete flows upwards into the other section. The height of the concrete in both sections is measured.

Fig 4.4 U box

Size of specimens used

The self-compacting concrete has checked the fresh properties of self-compacting concrete specifications according to EFNARC [2002]. The cube is of size 150 mm x150 mm x150 mm and size of beam is 100 mm x 100 mm x 500 mm and size of cylindrical moulds are 300mm height x 150 mm diameter. The moulds were fabricated with steel sheets. It is slight difficulty in assembling and removing the mould specimen. Moulds are provided with base plate having smooth surface to support the material.

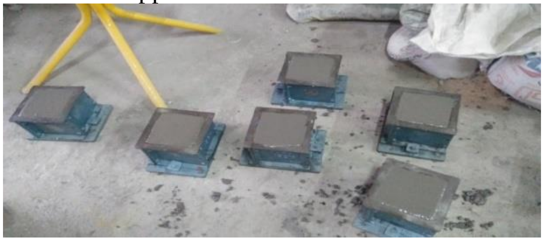


Fig 4.5 casting the cubes

Curing of specimens

Specimens are cured after the 48 hours of casting by removing from the moulds and immense in clean fresh water. The specimens, those were cured for 7 and 28 days respectively. The fresh water tank is used for curing of specimens. All the specimens are under immersion were always kept well under water and it was observed that at least 15 cm of water was above the top of specimens.

Tests on hardened concrete

Testing of hardened concrete plays a vital role in controlling the quality and strength of self-compacting concrete.

Compressive strength

In SCC mixes the standard cube specimen of compressive strength were compared with traditional concrete with water-cement-ratios. In civil engineering, while comparing the traditional concrete and SCC the cube strength was nearer to traditional concrete than those of housing mixes; this is typical strength of concrete. In vertical components of the structure, in-situ strengths of both SCC and traditional concrete were higher at bottom than top, In case of beams for both types of concrete strength is lower at horizontal component. In this investigation, the cube specimen size is of about 150 mm x 150 mm x 150 mm are tested. The testing was done on compression testing machine of 300 tons capacity.

Fig 4.6 compressive testing machine and cubes after test

Tensile test

For SCC, both the tensile strengths themselves determine the relationships between tensile and compressive strengths were of similar order to those of traditional concrete.

Fig 4.7 Split tensile strength test

Flexure test

Flexure strength is a measure of tensile strength of an reinforced concrete beam or slab which resist failure in bending. Modulus of rupture is also known as flexural strength or bond strength which defines stress in a material before it yields in a flexure test. Flexure strength is about 10 to 20% of compressive strength depend - on the type, size and volume of coarse aggregate. Modulus of rupture was carried out the beam of size 100 mm x 100 mm x 500 mm as per IS: 516. By considering the material is homogenous. The beams were tested on a span of 400 mm for 100 mm specimen by applying two equal loads placed at third points.

Fig 4.8 Flexural strength test

V.MIX PROPORTION

5.1. GENERAL

- Following are some of the approaches for the mix design:
- Gibbs (1999) states that the following particle riles of thumb for the proportioning of SCC mixture exist.
- Coarse aggregate content should be limited to 700-800Kg/m3 (about 50%of the total volume)
- Paste not less than 40% of the volume of the mixture.
- Low stand content in the mortar (40-50%byvolume).
- Water/power ratio nit more than 0.5(power being solids < 0.003 5 in, 0.09 mm).
- Okamura and Ozawa (1995) have proposed a simple proportioning system assuming supply from ready-mixed concrete plants.
- The "Standardized mix design method of SSC" proposed by the JRMCA (1998) is a simplified version of Okamura‟s method. This method can be employed to produce SCC with a large amount of powder materials, and water-binder ratio of <0.30.
- Several methods for determining mixture proportions of SCC exist, and two main philosophies of SCC mixture design contain these differing methods: mixture design based on SCC theology and mixture design based on fresh SCC field tests. The rheological philosophy involves large,

expensive immobile equipment suitable for the laboratory. The results are very helpful in determining behaviour of SCC as fluid material. This method is described by Oh et al (1999) and Saak et al.(2001). The fresh SCC field test philosophy is much faster, very mobile, and suited to laboratory or field conditions. These are several proposed tests, and work is currently being done by several standardization organizations to create a unified set of tests. All of these tests can be performed in the field just prior to concrete placement.

- The mixture design by Su et al. (2001) utilizes the High Fines Approach by using an appropriate amount of cement to achieve the design strength and incorporating additional fine material (in the form of fly ash) to obtain sufficient viscosity. The report states that testing in the fresh as well as hardened state was completed to examine the performance of SCC, and the method could produce SCC of high quality. Su et al. (2001) States that the principal consideration of their method is to fill the paste of binders into voids of the loosely piled aggregate. The reports continues by pointing state, while the workability of SCC is provided by the fresh state, while the workability of SCC is provided by the binding of paste at the fresh state. Therefore, the contents of the coarse and fine aggregates, binders, mixing water and super-plasticizer will be the factors influencing the properties of SCC.all that needs to be done is to select the approved materials, do the calculations, conduct mixing tests and make some minor adjustments and SCC with good flow ability, deformability and segregation resistance can be obtained with as specified by the JSCE (Su 2001).

5.2. GENERAL REQUIREMENTS IN THE MIX DESIGN

A high volume of paste

The friction between the aggregates limits the spreading and the filling ability of SCC. This is why SCC contains a high volume of paste (cement + additions + sufficient water + air), typically 330 to 400 1t/m3 , the role of which is to maintain aggregate separation.

A high volume of the fine particles

sufficient workability, while limiting the risk of segregation or bleeding. SCC contains a large amount of fine Nevertheless, in order to avoid excessive heat generation, the Portland cement is generally partially replaced by mineral admixtures like limestone filler or fly ash (Cement should not be used as a filler). The nature and the amount of filler added are chosen in order to comply with the strength and durability requirements.

A high dosage of plasticizer

Super plasticizers are introduced in SCC to obtain the fluidity. Nevertheless, a high dosage near the saturation amount can increase the proneness of the concrete to segregate.

The possible use of a viscosity agent (water retainer)

These products are generally cellulose derivatives, polysaccharides or colloidal suspensions. These same role as the fine particles, minimizing segregation by thickening the paste and retaining the water in the skeleton. The introduction of such products in SCC seems to be justified in the case of SCC with high water to binder ratio. On the other hand, they may be less useful for high performance SCC (strength higher than 50Mpa) with low water to binder ratio. For intermediate SCC, the introduction of viscosity agent has to be studied for each case. Viscosity agents are assumed to make SCC less sensitive to water variations in water content of aggregate occurring in concrete plants. Because of the small quantities of viscosity agents required, however, it may be difficult to achieve accuracy of dosage.

A low volume coarse aggregate

It is possible to use natural rounded, semi-crushed or crushed aggregates to produce SCC. Nevertheless, as the coarse aggregate plays role of SCC in congested areas, the volume has to be limited. Generally speaking, the maximum aggregate size, D max, is between 10 and 12.5 mm. The passing ability decreases when D max increases, which leads to a decrease of the coarse aggregate content. The choice of a higher D max is thus leads to a decrease of the coarse aggregate content. The choice of a higher D max is thus possible but is only justified with low reinforcement content. Admixture added to SCC can have a resulting effect on strength and the temp. fresh concrete, and have to be borne in mind in the construction process.

5.3. MIX DESIGN

Mix design of self compacting concrete (M30) (As per EFNARC: 2000Guidelines)

SCC Mix Scenario:

A SCC mix with 45% coarse aggregate content of concrete volume with a water/ binder ratio 0.42 (by weight). Cement has been replaced with flyash by 26.48% percentage weight of cementitious material. Coarse aggregate of sizes 12.5 mm in percentage weight of total aggregate are used in this mix. Super plasticizer MASTER EASE 3709 is used. Air content assumed as 2% of concrete volume.

Table 5.1 Quantities of materials for conventional SCC

Grade	Cement Kg/m³	FA Kg/m³	CA Kg/m³	Fly-ash Kg/m³	S.P % Kg/m³
M30	445.8	870	760.5	190.8	6.36

Table 5.2 Quantities of materials for conventional LWASCC

Grade	Percentage replacement	Cement	FA	CA	SFA	Fly-ash	S.P	Water
M30	10%	445.8	870	684.45	40.95	190.8	6.36	214.1
	20%,	445.8	870	608.4	81.9	190.8	6.36	214.1
	30%	445.8	870	532.35	122.85	190.8	6.36	214.1

VI. EXPERIMENTAL RESULTS

6.1Results of fresh properties of SCC and sintered fly ash aggregate replaced concrete

Table 6.1. fresh SCC Properties

Type of mixes	Grade of Concrete	Coarse Aggregate %		Fresh properties				
		Gravel %	SFA %	Slump flow value	T_{50}cm	V-Funnel	L-box	U-Box
				In mm	(2-5) sec	(6-12) sec	(H_2/H_1) mm	Diff. of heights (mm)
NWS CC	M30	100	-	732	3	8	1	15
LWS CC	M30	90	10	706	5	9	0.9	17
		80	20	689	4	8	1	19
		70	30	677	6	9	0.9	20

Compressive strength results

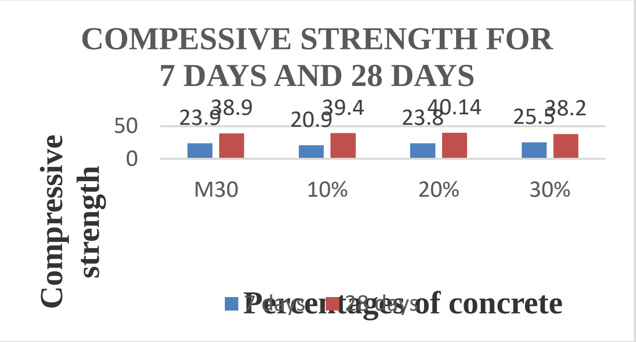
The compressive strength of various trails on self-compacting concrete are as follows

Table No. 6.2 Compressive strength of cubes – 7 days

S.No.	Mix	% of replacement	Surface area in mm²	Gauge reading in KN	Compressive strength in N/mm²
1	M30	0	22500	519.7	23.1
				553.5	24.6
				540	24
				Avg	**23.9**
2	M30	10%(SFA),1%(Steel fiber)	22500	488.3	21.7
				472.5	21
				450	20
				Avg	**20.9**
3	M30	20%(SFA),1%(Steel fiber)	22500	537.7	23.9
				524.3	23.3
				544.5	24.2
				Avg	**23.8**
4	M30	30%(SFA),1%(Steel fiber)	22500	560.3	24.9
				576	25.6
				585	26
				Avg	**25.5**

Table No.6.3 Compressive strength of cubes – 28 days

S.No.	Mix	% of replacement	Surface area in mm²	Gauge readings in KN	Compressive strength in N/mm²
1	M30	0	22500	852.75	37.9
				884.25	39.3
				888.70	39.5
				Avg	**38.9**
2	M30	10%(SFA),1%(Steel fiber)	22500	875.25	38.9
				902.25	40.1
				882.7	39.2
				Avg	**39.4**
3	M30	20%(SFA),1%(Steel fiber)	22500	909.45	40.4
				895.5	39.8
				904.5	40.2
				Avg	**40.14**
4	M30	30%(SFA),1%(Steel fiber)	22500	873.00	38.8
				884.25	39.3
				882.00	39.2
				Avg	**39.1**



GRAPH No.6.1 compressive strength for 7 days and 28 days

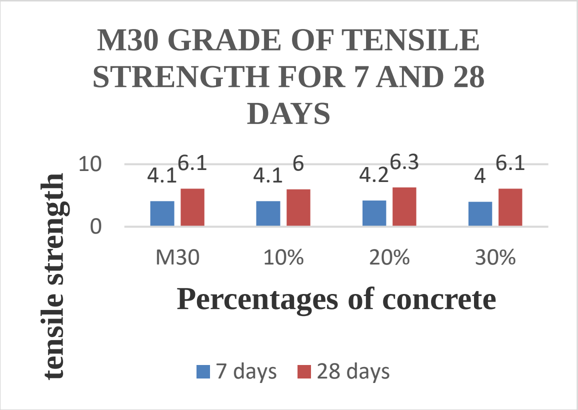
Split tensile strength test

Table No.6.4 split tensile strength of cylinders – 7 days

S.No.	Mix	% of replacement	Load in KN	Tensile strength in N/mm²
1	M30	0	282.7	4
			339.3	4.8
			247.45	3.5
			Avg	**4.1**
2	M30	10%(SFA), 1%(Steel fiber)	296.9	4.2
			311.05	4.4
			261.54	3.7
			Avg	**4.1**
3	M30	20 %(SFA),1 %(Steel fiber)	303.95	4.3
			318.1	4.5
			296.85	4.2
			Avg	**4.2**
4	M30	30 %(SFA),1 %(Steel fiber)	268.60	3.8
			303.95	4.3
			275.70	3.9
			Avg	**4**

Table No.6.5 split tensile strength of cylinders – 28 days

S.No.	Mix	% of replacement	Load in KN	Tensile strength in N/mm²
1	M30	0	409.95	5.8
			417.05	5.9
			445.3	6.3
			Avg	**6.0**
2	M30	10%(SFA), 1%(Steel fiber)	452.4	6.4
			388.75	5.5
			452.4	6.4
			Avg	**6.1**
3	M30	20%(SFA), 1%(Steel fiber)	438.25	6.2
			438.25	6.2
			459.45	6.5
			Avg	**6.3**
4	M30	30%(SFA), 1%(Steel fiber)	431.2	6.1
			445.95	6.3
			452.35	6.4
			Avg	**6.26**

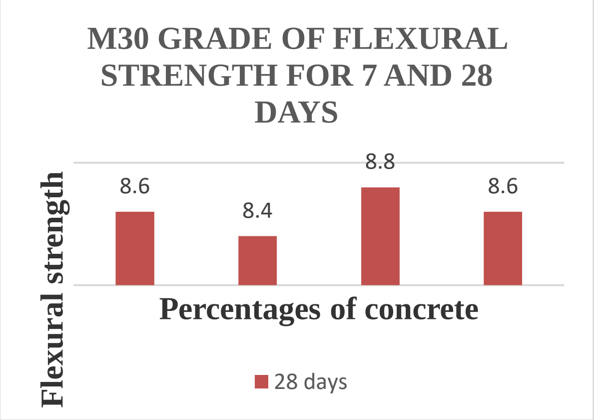


GRAPH No.6.2 M30 grade of LWSCC tensile strength for 7 days and 28 days

Flexural strength test

Table no.6.6 Flexural strength of beams at 28 days

S.No.	Mix	% of replacement	Tensile strength in N/mm^2
1	M30	0	8.4 8.2 8.6 **8.4(Avg)**
2	M30	10%(SFA),1% (Steel fiber)	8.5 9 8.3 **8.6 (Avg)**
3	M30	20%(SFA),1% (Steel fiber)	9 8.9 8.5 **8.8 (Avg)**
4	M30	30%(SFA),1% (Steel fiber)	9.3 8.8 9.1 **9.1 (Avg)**



GRAPH 6.3 M30 Grade of LWSCC flexural strength for 28 days

VII. CONCLUSIONS

1. In M30 grade of concrete at 10% replacement of SFA aggregate and addition of 1% of steel fiber is resulted 1.2% increased in compressive strength,2.3% increased in flexural strength, 1.6% increased in split tensile strength
2. In M30 grade of concrete at 20% replacement of SFA aggregate and addition of 1% of steel fiber resulted 3.18% increase in compressive strength, 4.76% increase in flexural strength, 5% increase in split tensile strength
3. In M30 grade of concrete at 30% replacement of SFA aggregate and addition of 1% of steel fiber resulted 0.5% increase in compressive strength, 8.3% increase in flexural strength, 4.3% increase in split tensile strength
4. Addition of fibres increases the strength and cracking with normal SCC. The addition of sintered fly ash aggregate in concrete it decreases the weight and increases the slump flow.
5. As the percentage of SFA is increased it has been noted that the Slump flow, T500 mm, U-Funnel, V-Funnel, L-box Values (Fresh Concrete properties) are undesirable when compared to EFNARC standard values. This results in the decrease of workability of concrete.
6. Decrease in dead loads is beneficial in the construction industry because they can result in cost savings stemming from the reduction of the size of structural elements and possibly the amount of steel reinforcement required.
7. From all the trails it is observed that the addition of 20% SFA (by the weight of coarse aggregate),1% of steel fiber is taken as optimum as it is increasing the strength of concrete and the fresh concrete properties are within limits of EFNARC standard value.

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