Investigation on Self Compacting Concrete by Incorporating Lightweight aggregates and Steel Fibres

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Abstract - *This article interprets the performance of Self Compacting Concrete by Incorporating Lightweight aggregates as coarse aggregate and steel fibres at different proportions from 0% to 0.75%. But addition of Light weight aggregates as a complete replacement for coarse aggregate has some negative effect on its properties due to its water absorbing nature. In the same way, addition of steel fibres to fresh concrete has some effect on its fresh properties. However it satisfies the acceptance criteria of Self Compacting Concrete as per European Guidelines For Self Compacting Concrete-2005.Perhaps the properties of Self Compacting Concrete can be improved if Light weight aggregates are taken at varying Proportions.*

***Key Words*: Fibre reinforced light weighted Self Compacting Concrete, Self Compacting Concrete, light weight concrete, Steel Fibres.**

1.INTRODUCTION

As we all know, Concrete is one of the most widely used material in the world. Some recent study tells that the consumption of this material may reaches 4.42 billion tons by the year 2022. Consequently, concrete has no longer remained a construction material consisting of cement, aggregates and water only but becomes an engineered custom-tailored material with several new constituents to meet the specific needs of construction Industry. Though this material has wide application some notable disadvantages are lack of complete compaction, higher density and crack formation. In late 1980's, the University of Tokyo, Japan develop SCC to achieve full compaction. SCC is an innovative concrete that does not require vibration for placing and compaction. In India, during few decades attempts are carried out to develop and use SCC. However, large scale uses have been rare. The density of concrete can be reduced by adding Lightweight aggregates. Usually steel fibres are added in concrete to suppress the formation of cracks which occurs due to plastic and drying shrinkages. Steel fibres in SCC has additional benefit,(i.e.,flow easily in obstructed reinforced area.)

In present study, Expanded Clay Aggregates and Steel Fibres of 0% to 0.75% are added to SCC and its effects on Fresh and hardened Properties is reported.

2. LITERATURE REVIEW

Thomas Paul, Habung Bida, Bini Kiron, Shuhad A K, martin Varghese (1)– Observed that the addition of 1.2% steel fibre with SCC increased the compressive strength value (39.70 N/mm^2). The flexural strength of SCC at 0.8% addition of steel fibre increased the strength, but at 1.2% addition of Steel fibre, it get reduced about 1.12% strength than the value obtained at 0.8% addition. The split tensile strength of SCC at 0.8% (3.72 N/mm^2) addition of steel fibre reached the strength at peak extent and decreased about 0.53% of strength at 1.2% addition of steel fibre.

Jonbi, Restinur Arini, Marisa Agarwal , Partogi (2) – The research article mainly focused on addition of carbon and steel fibre in SCC. The percentage increase in carbon and steel fibre is 0.5%, 1% and 1.5%. The compressive strength increased with the value of 40.11, 28.41, 14.83, 36.92, 39.79 MPa when carbon and steel fibre of proportion 0.5%, 1%, 1.5% was added respectively. The split tensile strength at 28-day was observed as 3.92, 1.99, 3.4, 3, 4, 3.45 MPa when carbon and steel fibre of proportion 0.5%, 1% and 1.5% was added respectively. The observed flexural strength value was 3.30, 2.39, 3.72, 3.50, 3.67 MPa when carbon and steel fibre of proportion 0.5%, 1%, 1.5% was added respectively. It was observed that addition of 1.5% steel fibre was capable of increasing the compressive strength by 11%. However the research article concluded that carbon fibre was not suitable for use in SCC.

Gopi Rajamanickam, Revathi Vaiyapuri (3) – revealed that replacing aggregate with lightweight aggregate (expanded clay aggregate) exhibit higher compressive strength, Split tensile strength, Flexural strength and elastic modulus upto its optimum range. Three specimens were tested for each mix to determine various properties of concrete. The replacement of aggregate was made from 0% to 25% by volume at 5% intervals. The mean Compressive strength value when the expanded clay aggregates was replaced with aggregate of proportion 5%, 10%, 15%, 20% and 25% at 7days and 28 days were 27.46, 28.33, 29.16, 26.13, 25.98MPa and 37.79, 43.60, 44.93, 41.03, 39.30 MPa respectively. The mean Split tensile strength value when the expanded clay aggregates was replaced with aggregate of proportion 5%, 10%, 15%, 20% and 25% at 7days and 28 days were 1.87, 1.91, 1.92, 1.72, 1.68 MPa and 3.37, 3.97, 4.32, 3.34, 3.14 MPa respectively. The mean Flexural strength value when the expanded clay aggregates was replaced with aggregate of proportion 5%, 10%, 15%, 20% and 25% at 7days and 28 days were 5.26, 5.39, 5.74, 5.28,5.12 MPa and 5.77, 6.52, 7.58, 7.2, 7.15 MPa respectively. The mean compressive strength of control mix at 7 and 28 days were observed as 38 MPa and 44.10 MPa respectively. The mean Split tensile strength of control mix at 7 and 28 days were observed as 2.96 MPa and 3.98 MPa respectively. The mean Flexural strength of control mix at 7 and 28 days were observed as 5.65 MPa and 6.63 MPa respectively. From the experimental result, it was observed that replacing 15% of Expanded clay aggregate it increase the compressive strength by 1.84% higher compared to its control mix and possess good Split tensile strength and Flexural strength.

Bashandy A.A., **Etman Z.A., Azier H.Y(4) –** observed that replacing Coarse aggregate with Lightweight aggregate (LECA) with replacement of 10%.,20%,30%,40%,50% and 60% exhibit lesser Compressive strength, Split tensile strength and Flexural Strength than the conventional ones related to the percentage of aggregate replacement.

3. MATERIALS

3.1 CEMENT

OPC 53 grade cement sample was tested and the obtained result values are listed below in table 1.

Table -1: Properties of Cement

Property	Experimental value
Specific gravity	3.31
Standard consistency	24%
Initial setting time	25 mins

3.2 FINE AGGREGATE

The fine aggregate used in concrete was M sand. The tests carried out on Fine aggregate are listed in table 2.

Table 2: Properties of fine aggregates

Property	Experimental value
Specific gravity	2.79
Fineness modulus	2.567
Zoning	Zone II
Water absorption	1.11%

3.3 COARSE AGGREGATE

The coarse aggregate used for the concrete mixes was light expanded clay aggregates (LECA) which was obtained from Perl Tech, Ahmedabad and crushed stone. The properties of LECA and crushed stone are mentioned in table 3.

Table 3: Properties of coarse aggregate

	Experimental value	
Property	**Crushed stone**	**Expanded Clay**
Shape	Angular	Spherical
Size	12.5mm	12.5mm
Density	1643kg/m^3	339 kg/m^3
Specific gravity	2.77	1.19
Water absorption	0.5%	11.48%

3.4 STEEL FIBRE

The Steel fibre used for the concrete mix was obtained from Chennai. The properties of steel fibre purchased are listed in table 4.

Table 4: Properties of Steel fibre

Property	Values
Deformation	Hook-end
Diameter	0.75mm
Length	50mm
Aspect ratio	66
Tensile Strength	>1150 MPa
Modulus of Elasticity	200 GPa

3.5 SUPERPLASTICIZER

The Superplasticizer use for the concrete mix was Conplast SP 430.The Specific gravity is 1.18 at 25^{0}C.

3.6 WATER

Potable water free from impurities was used for mixing and curing of concrete.

4. MIX PROPORTION

Mix design for M25 grade concrete was formulated as per IS10262:2019 along with European Guidelines for SCC(2005).The mix ratio for Conventional Self Compacting Concrete and Fibre reinforced Light weighted Self Compacting Concrete were 1:2.65:2.21(W/C-0.41) and 1:1.9:1.37(W/C-0.5).Both mixes had the same amount of Superplasticizer (1%). The addition of steel fibre was taken as the percentage by sum of the weight of Cement, Coarse Aggregate and Fine aggregate. Steel fibre was used with varying proportions from 0% to 0.75% only for fibre reinforced Light weighted Self compacting Concrete mix. Five different mixes were carried out and subjected to Experimental study. The quantities of the Constituents of the concrete are listed in table 5.

Table 5: Mix proportion

Mix	Coarse Aggregate used	Cement (kg)	Steel Fibre (g)	Msand (kg)	CA (kg)	Water (lts)	Superplasticizer (ml)
CSCC	Crushed Stone(12.5mm)	34.75	0	92	77.09	14.35	348
LWSCC0	Expanded Clay(12.5 mm)	34.75	0	65.92	47.73	19	348
LWSCC0.25	Expanded Clay(12.5 mm)	34.75	371	65.92	47.73	19	348
LWSCC0.5	Expanded Clay(12.5 mm)	34.75	742	65.92	47.73	19	348
LWSCC0.75	Expanded Clay(12.5 mm)	34.75	1113	65.92	47.73	19	348

*CSCC – Conventional Self Compacting Concrete; LWSCC – Lightweight Self Compacting concrete.

**The numbers in the end of each mix indicates the Proportion of Steel fibre.

5. EXPERIMENTAL RESULTS

Six concrete cubes of size 150 x 150 x 150 mm, Six Cylinders of diameter150mm and height 300mm, Six Prisms of length 500mm,breadth 100mm and depth 100mm were casted for each mix and allowed for curing for a period of 28 days to determine the compressive strength, Split Tensile strength and Flexural Strength respectively. Each specimen were tested for 14 days and 28 days.

5.1 FRESH CONCRETE PROPERTIES

The Fresh Properties of Conventional Self Compacting Concrete and Lightweight Self Compacting Concrete were determined by performing slump Flow test, V-Funnel Test, L-Box test and the variation of each concrete mix was plotted and shown in chart 1,2and 3 respectively.

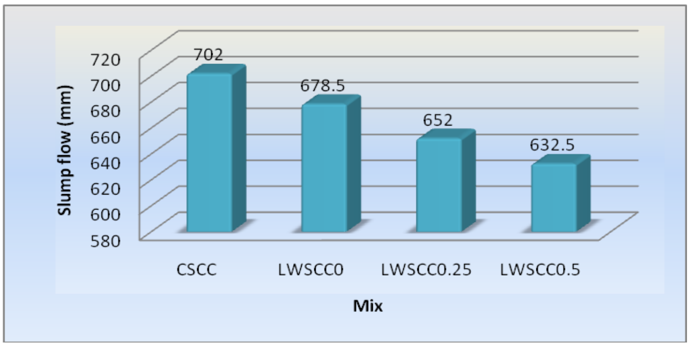

Chart-1: Slump Flow test

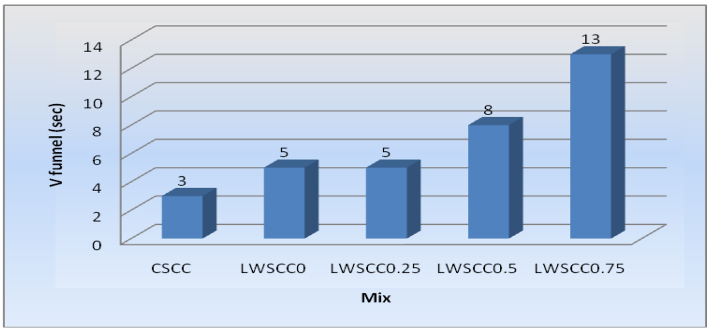

Chart -2 : V-Funnel test

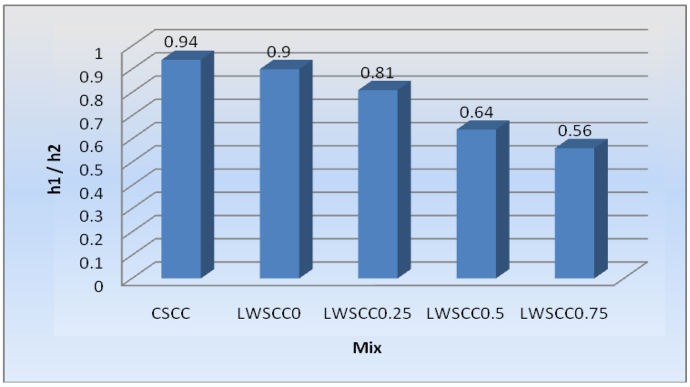

Chart-3 : L-Box test

Chart 1,2 and 3 illustrates the fresh properties of Conventional Self Compacting Concrete and Lightweight Self Compacting Concrete. From the results, it was observed that the workability of SCC concrete get reduced with increasing the steel fibre proportions. However the fresh properties value of all the concrete mixes consent with the criteria of European Guidelines for SCC (2005).(i.e., results are satisfactory in fresh state)

5.2HARDENED CONCRETE PROPERTIES

5.2.1 DENSITY

The density of hardened concrete was determined by dividing the weight of concrete cube by its volume. The difference in the density of hardened concrete of each mix is shown in Chart 4.

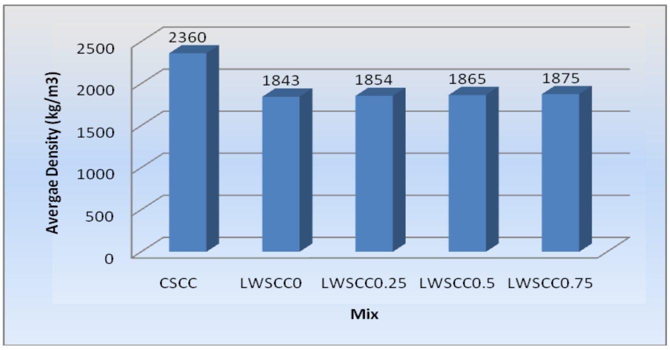

Chart-4: Density

Chart 4, illustrates the density of hardened concrete. From the plotted values, it was observed that the concrete containing crushed stone (CSCC) as coarse aggregate owned higher density than the concrete containing Expanded Clay Aggregate (LWSCC) as coarse aggregate. The use of Expanded Clay Aggregate as coarse aggregates reduced the density of concrete by 21.91%.

Furthermore, On addition of Steel Fibre from 0 to 0.75%, the density of concrete slightly increased. The density of LWSCC 0.5 and LWSCC0.75 exceeded the acceptance range.

5.2.2 COMPRESSIVE STRENGTH TEST

Cubes were subjected to uniaxial compressive load at a rate of 140 kg/cm2/min after 14 and 28 days of curing respectively. For each mix, three cubes were tested and its average compressive strength values obtained were presented in Chart 5.

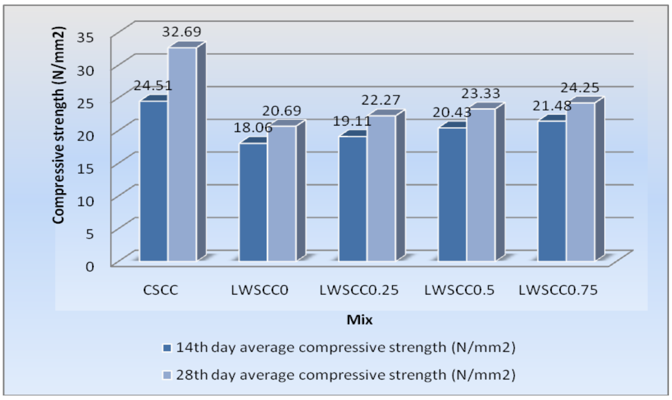

Chart-5: Average Compressive strength

Chart 5, illustrates the average compressive strength of Conventional Self Compacting Concrete and Lightweight Self Compacting Concrete with steel fibre at varying Proportions. From the test result, it was observed that the reduction in the average Compressive strength of Lightweight SCC without steel fibre was about 26.32% and 36.7% than the Conventional SCC after 14 and 28 days of curing respectively. Though the average compressive strength of LWSCC slightly increased on addition of Steel fibre, the obtained strength value at 0%,0.25%,0.5% and 0.75% proportion of steel fibre was lesser than the average Compressive strength of Conventional SCC. (i.e., the results obtained are not satisfactory).

5.2.3 SPLIT TENSILE STRENGTH TEST

Cylinders were tested in Compression Testing Machine by placing the cylinder in the longitudinal axis which is perpendicular to the application of uniaxial compressive load. The test was carried out after 14 and 28 days of curing. For each mix, three cylinders were tested and its average split tensile strength values obtained were presented in Chart 6.

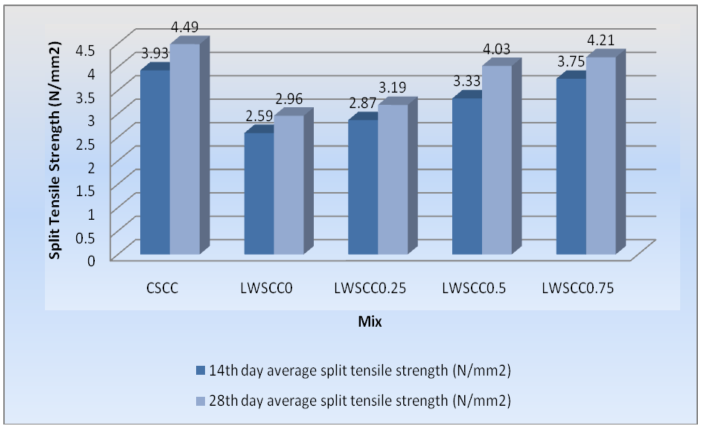

Chart-6:Average split tensile strength

Chart 6, illustrates the average split tensile strength of Conventional Self Compacting Concrete and Lightweight Self

Compacting Concrete with steel fibre at varying Proportions. From the result, it was observed that the average Split Tensile strength of Lightweight SCC concrete without steel fibre was 34.09 %and 34.07% lesser than the Conventional SCC after 14 and 28 days of curing respectively. As the proportion of steel fibre increased from 0.25% to 0.75%, the average split tensile strength of 14 and 28 days of curing was found to be increasing slightly. The average split tensile strength of 0.75% steel fibre incorporated concrete mix (LWSCC0.75) possessed nearly equal compared with Conventional SCC value.

5.2.3 FLEXURAL STRENGTH TEST

Prisms were tested in Universal Testing Machine and subjected to two point loading. The test was carried out after 14 and 28 days of curing. For each mix, three prisms were tested and its average Flexural strength values obtained were presented in Chart 7.

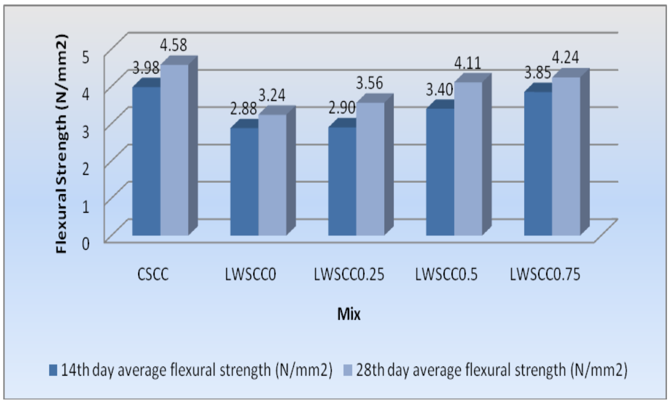

Chart- 7:Average Flexural strength

Chart 7, illustrates the average Flexural strength of Conventional Self Compacting Concrete and Lightweight Self Compacting Concrete with steel fibre at varying Proportions. From the result, it was observed that the reduction in the average Flexural strength of Lightweight SCC without steel fibre was about 24.63% and 29.25% than the Conventional SCC after 14 and 28 days of curing respectively. As the proportion of steel fibre increased from 0.25% to 0.75%, the average Flexural strength of 14 and 28 days of curing was found to be increasing slightly when compared to LWSCC0. The Flexural strength of 0.75% steel fibre incorporated concrete mix (LWSCC0.75) possessed nearly equal compared with Conventional SCC value.

6 . STUDY OUTCOME

From the experimental study carried out on self-compacting concrete added with Hook-end steel fibre, the following observations were made:

- The use of LECA results in workable concrete and also self-compacting.
- With increase in Hook-end steel fibre content in concrete from 0% to 0.75%, the fresh concrete property tests like slump flow, V funnel and L box tests get decreases in their corresponding values. The decrease in the fresh properties of concrete is due to addition of steel fibres. However, value of all the concrete mixes consent with the criteria of European Guidelines for SCC (2005).(i.e., results are satisfactory in fresh state)
- The use of LECA reduces the density of concrete of about 21.91%.The influence of Hook-end steel fibre was not significant on the density of concrete when its proportion increases above 0.5%.Reason should be identify.
- The strength of concrete containing LECA is less than the strength of conventional SCC. However, It can be improved if LECA is added at varying Proportions rather than complete replacement for coarse aggregate.
- The addition of 0.75% of Hook-end steel fibre slightly increases the compressive strength, split tensile strength flexural strength after 14 and 28 days of curing respectively. But, it does not achieve the target strength value. If steel fibre Proportion increases gradually, the strength may attain.
- Fresh Properties of SCC with steel fibre may decreases on increasing the percentage of steel fibre. However it can be corrected by increasing the dosage of Superplasticizer.

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