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AN EXPERIMENTAL INVESTIGATION ON THE INFLUENCE OF LECA ON THE FRESH AND HARDENED PROPERTIES OF SCC

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Abstract: Self-Compacting Concrete (SCC) has gained a lot of popularity in recent decades because of its inherent properties. When concrete is very difficult to compact due to placing conditions or congested reinforcement. The flow ability, segregation resistance, and fresh concrete filling capacity have all been assessed in relation to SCC properties. The characteristics of SCC are influenced by aggregate shape. It was found that passing and flow ability decreased with increasing coarse aggregate maximum size. While SCC simplifies pouring and eliminates construction issues, Lightweight Concrete (LWC) is an excellent way to reduce the structure's dead load. Integrating the benefits of LWC and the SCC represents a new area of study. Lightweight Self – Compacting Concrete (LWSCC) could be the solution to the growing demands for more heavily reinforced, slender structural elements in construction because of its lightweight structure and ease of placement.

This study aims to investigate structural LWSCC with coarse Lightweight Expanded Clay Aggregates (LECA) and mineral admixtures. According to studies, lightweight aggregates have a promising future in SCC because they will exhibit good compressive strength, segregation resistance, filling ability and passing ability. The results were obtained by conducting the compressive strength of the cube, the flexural strength of the beam and split tensile strength of the cylinders for 7, 14 & 28 days of SCC by using lightweight aggregate (LECA).

Keywords: Self – Compacting Concrete (SCC), Lightweight Self - Compacting Concrete (LWSCC), Lightweight Expanded Clay Aggregate (LECA).

1. INTRODUCTION

General

SCC is an extremely flowable concrete that doesn't need to vibrate mechanically to spread into the formwork. Professor Hajime Okamura first introduced the idea of SCC in 1986, but Professor Ozawa (1989) of the University of Tokyo developed it in Japan in 1988 [1]. Unlike conventional concrete, SCC flows and deforms easily through the most complex shapes and around the most crowded reinforcement without requiring any internal or external vibration for consolidation.

Filling ability, segregation resistance and passing ability are the three crucial fresh properties of SCC [2, 3]. SCC's filling ability refers to its capacity to fill the formwork and it is capable of flowing under its own weight. The capacity of SCC to pass through and around obstructions like reinforcement and small areas without being blocked. SCC exhibits segregation resistance, which helps it stay homogenous both during and after placement and transportation. SCC is distinguished from other high-consistency concretes by its passing ability [4].

Objective

The objective of the SCC is

- The aim is to investigate the characteristics of SCC by using lightweight aggregates (LECA) and normal-weight aggregates. This study focused on the fresh and hardened states to evaluate the mechanical characteristics of SCC.
- The purpose of this project is to find the SCC mixes with different ratios and capacities that were created to satisfy the requirements for flowability, segregation resistance, and passing ability.
- To find out the compressive strength, flexural strength & split tensile strength of the SCC by using lightweight aggregates (LECA) at 7, 14, and 28 days.

2. LITERATURE REVIEW

A modified version of Okamura's proposal was presented by K. Ozawa in 1988 [5]. Ozawa's research on concrete workability led him to conclude that good flow ability could be achieved by SCC having a lower yield value.

In addition to its deformability, which allows it to adjust to its own weight, SCC has a locally increased coarse aggregate content when it comes to a narrow space since the mortar and coarse aggregate flow at different velocities [6,7].

According to Billberg et al., plastic viscosity does not affect SCC's ability to pass, but blocking is primarily dependent on yield stress. However, blocking is prevented because increases in the coarse aggregate are also inhibited by a paste with the appropriate viscosity. [8].

In the study, Choi et al. examined the effects of substituting artificial lightweight aggregates for either the fine or coarse fraction of Normal Weight Aggregates (NWA) on the mechanical and rheological characteristics of concrete [9].

Maghsoudi et al. demonstrated that natural aggregate concrete requires less internal energy of motion, SCC utilizing LECA aggregate, however, needs more internal energy. The spherical nature of the LECA is known to enhance the flowability and deformation properties of freshly mixed concrete. SCC combined with LECA can generate lightweight with adequate compressive strength and density that is less than or equal to 1900 kg/m^3 [10].

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Researchers J. A. Bogas, A. Gomes, and M. F. C. Pereira investigated the use of LECA in place of some natural coarse aggregate in LWSCC. The study found that LECA can be used to produce LWSCC with good mechanical properties and durability [11].

Hubertova and Hela investigated the chemically aggressive liquids and gases' effect on the durability of SCC with LECA. According to findings, SCC based on LECA had greater compressive strength and was more resilient to aggressive environments [12].

According to M. L. Bin Othman et al., the ideal mix achieves a lightweight density category of D1.8 and, after 28 days, a compressive strength of 19.5 MPa with 60% LECA and 50% expanded perlite aggregate (EPA) replacements. He concludes that LECA and EPA can be used to produce lightweight structural concrete with lower weight, density, and strength, but higher workability and quality [13].

3.MATERIALS & METHODOLOGY

3.1Materials Used in Light-Weight Self-Compacting Concrete

3.1.1 Cement

The JSW Company's Ordinary Portland Cement of class 53 is used in this investigation which is confirmed with IS:12269. To keep it safe from moisture, the cement is stored in an atmosphere with controlled humidity in an airtight container. Following laboratory testing in accordance with Indian Standards, the physical characteristics of cement are shown below.

Table 1: Physical characteristics of the Cement

Physical Property	Obtained Value	IS:12269 Specifications
Normal Consistency (%)	31	-
Initial setting time – Vicat (min)	105	>= 30 min
Final setting time - Vicat (min)	360	<=600min
Specific gravity	3.15	-

3.1.2 Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag was purchased for this project from Astraa Chemicals in Chennai and used in the production of SCC. Table 2 lists the chemical and physical properties of GGBS that were supplied by the supplier. The physical characteristics of GGBS have a specific gravity of 2.78 and a bulk density of 1200 kg/m^3.

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3.1.3 Metakaolin

In this present project, Metakaolin (MK) is bought from Astraa Chemicals, Chennai and it was used in the cement replacement in conventional concretes. Alumina and silica represent 90% of MK's chemical composition. MK is a material that has a specific gravity of 2.5 and its bulk density is 350 kg/m^3.

Table 2: Physical properties of GGBS & Metakaolin

Physical properties	GGBS	Metakaolin
Specific Gravity	2.78	2.5
Bulk Density (Kg / m^3)	1200	350

3.1.4 Fine Aggregate

The present project uses the Fine Aggregate taken from Penna River beds. The sand conforms to IS 383- 1970. Fine aggregate going through an IS sieve measuring 4.75 mm and retained on a 75-micron IS sieve is employed. It belongs to Zone II from sieve analysis. The physical and mechanical characteristics of Fine aggregate are provided in the Table below.

Table 3: Characteristics of Fine aggregate

Property	Fine Aggregate
Specific gravity	2.65
Fineness modules	2.51
Water absorption (%)	1.0
Bulk density (kg/m^3)	1481

3.1.5 Natural Coarse Aggregate

Normal-weight aggregates should conform to IS 383 and meet durability requirements. Coarse is defined as the total that is held over an IS Strainer at 4.75 mm. The following table describes the coarse aggregate's physical properties.

Table 4: Properties of Natural Coarse aggregate

Property	Coarse aggregate
Specific gravity	2.74
Fineness modules	7.04
Water absorption (%)	0.5
Bulk density (kg/m^3)	1659

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3.1.6 LECA (Lightweight Expanded Clay Aggregate)

Fig. 1 LECA (Lightweight Expanded Clay Aggregate)

LECA is a naturally occurring lightweight aggregate that is bought from Indiamart. LECA is a naturally occurring product that was burned at high temperatures without the use of hazardous chemicals in a rotating kiln and it was created from specific clay. Granules sinter during firing, expanding into honeycombs as each granule's surface melts due to the burning of the organic compounds in the clay. As a result, light, porous, and highly tensile ceramic pellets are produced. LECA offers good sound and thermal insulation, is resistant to chemicals and frost, does not break down in water, and is neither biodegradable nor flammable. The table below lists the mechanical and physical characteristics of LECA.

Table 5: Properties of LECA

Property	LECA
Specific gravity	0.45
Fineness modules	5.98
Water absorption (%)	11
Bulk density(kg/m^3)	347

3.1.7 Water

In this experiment, potable tap water that complied with the regulations set forth by IS 456 and was readily available locally was used.

3.1.8 Super Plasticizer (SP -430)

Superplasticizer based on conplast SP430 (G) from Fosroc, which has a specific gravity of 1.08 and is dosed at 1.2% of the weight of cement in LECA concrete.

3.2 METHODOLOGY

The purpose of this study is to assess the properties of LWSCC using lightweight aggregates (LECA) and normal-weight aggregates and to research concrete mix M30, the full and partial substitution of coarse aggregate with different percentages of LECA such as 0%, 25%, 50%, 75%, and 100%.

LWSCC concrete was analyzed both when it was still fresh and when it had hardened.

Table 6: Mix Proportions of LWSCC in Kg/m^3

S.no	Mixes	Cement	GGBS	Meta kaolin	Fine Aggregate	Coarse Aggregate		Super Plasti cizer (%)	W/C Ratio
						Natural Aggre gate	LECA		
1.	CC	70	20	10	100	100	0	1.2	0.43
2.	LW25	70	20	10	100	75	25	1.2	0.43
3.	LW50	70	20	10	100	50	50	1.2	0.43
4.	LW75	70	20	10	100	25	75	1.2	0.43
5.	LW100	70	20	10	100	0	100	1.2	0.43

- Immediately after the mixing, the value of the L-box test, slump flow T_{50}, V-funnel test and slump flow test were determined.
- Cube specimens of 150x150x150mm were prepared to determine the test for Compressive Strength after 7, 14, and 28 days.
- The Cylinder Specimens which are of size 150x300mm are tested to find tensile strength. At least three specimens shall be tested for each age of tests (IS: 516), and the average value at curing periods of 7,14, and 28 days are to be taken.
- The standard beam test is used on beams to evaluate the Flexural Strength of the beam with dimensions of 100mmx100mmx500mm (IS:516), assuming the material is homogeneous. Two equal loads applied at two points on a 400 mm span for specimens measuring 100 mm are used to test the beams.

4.RESULTS & DISCUSSIONS

4.1Results of Fresh Properties of LWSCC

4.1.1 Slump Flow Test:

In LECA-based SCC mixes, an incremental rise in slump flow values is observed with an increase in the amount of LECA. The flowability property may have been affected by the size effect and the LECA material's specific gravity, which was employed in the SCC mix. Since the LECA-based SCC mixes' slump flow values ranged from 660 to 750 mm, they are classified as slump flow SF2 class.

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(As per IS1199 (Part 6): 2018 guidelines). LWSCC mixes had good flowability compared to conventional concrete which was concluded from the fresh properties results.

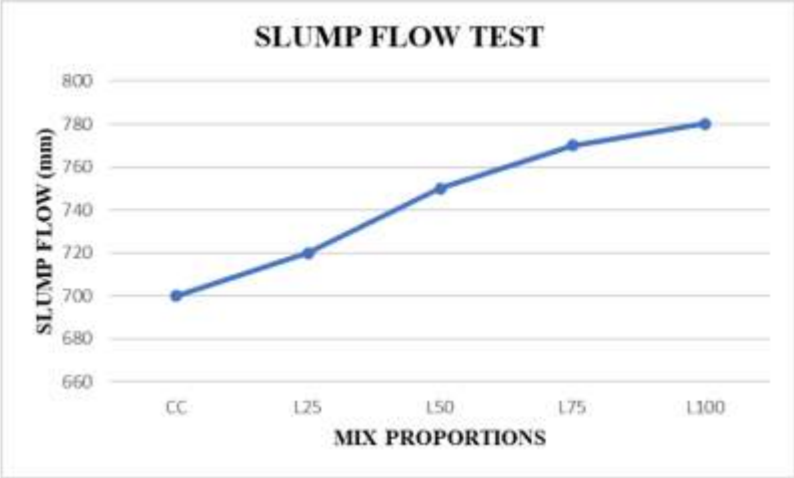

Fig. 2 Flowability of Slump of LWSCC

4.1.2 T_{50}:

According to the IS guidelines, the time taken for the T_{50} test should be between 2 to 5 seconds. The measured time in "seconds" has been used to categorize the viscosity class according to IS guidelines. A time taken in less than or equal to two seconds is classified as belonging to the VS1 class; time taken in more than two seconds is classified as belonging to the VS2 class. All SCC mixes were found to be in the VS2 class based on the results obtained. The graph below demonstrates an increase in flow rate as the viscosity increases in the mix. The slump flow time of CC & 25% of LECA replacement is good, however, as LECA proportions increase, the slump flow time decreases.

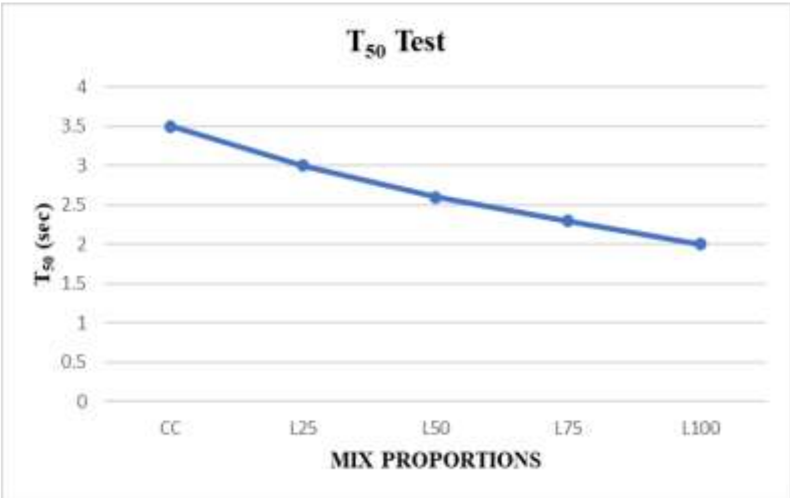

Fig. 3 Flowability of Slump T_{50}

4.1.3 V- Funnel:

For LWSCC mixes, the flow time is ascertained using the V-funnel test. The flowing time falls between 6 and 12 seconds, per IS 1199 (Part 6): 2018 guidelines. The IS 1199 (Part 6) has classified the filling ability of concrete into two classes: VF1 and VF2. VF1 has a filling time of less than or equal to 8 seconds, moderate to high flow rate, and good filling ability. VF2 has a low to moderate filling ability, a low flow rate, and a filling time of 9 to 25 seconds. As seen in the figure below, all LWSCCs have excellent filling ability, a high flow rate, and a filling time of less than 8 seconds.

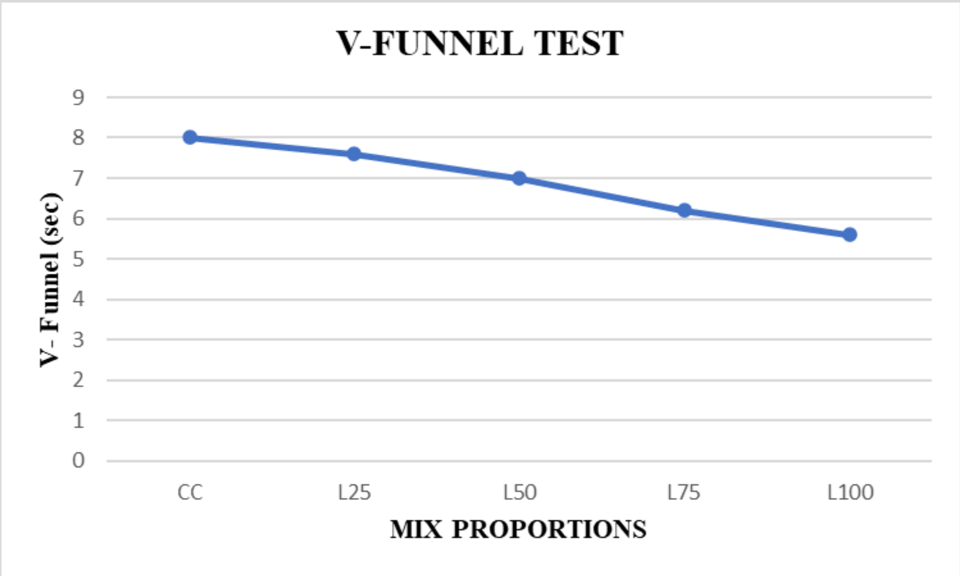

Fig. 4 Filling ability of LWSCC in V- Funnel

4.1.4 L – Box:

According to IS 1199 (Part 6): 2018, The blocking ratio needs to be between 0.8 and 1 to satisfy the passing ability standards. There are two classes according to IS 1199 (Part 6). PA1 has two rebars and PA2 has three rebars; both are less than 0.8. All mixtures showed excellent passing ability overall; 0.8 and above 0.8 indicate that they belong to class PA2, according to IS 1199 (Part 6): 2018 limits. The mixtures exhibit a smooth flow and can easily go through the reinforced area with their weight.

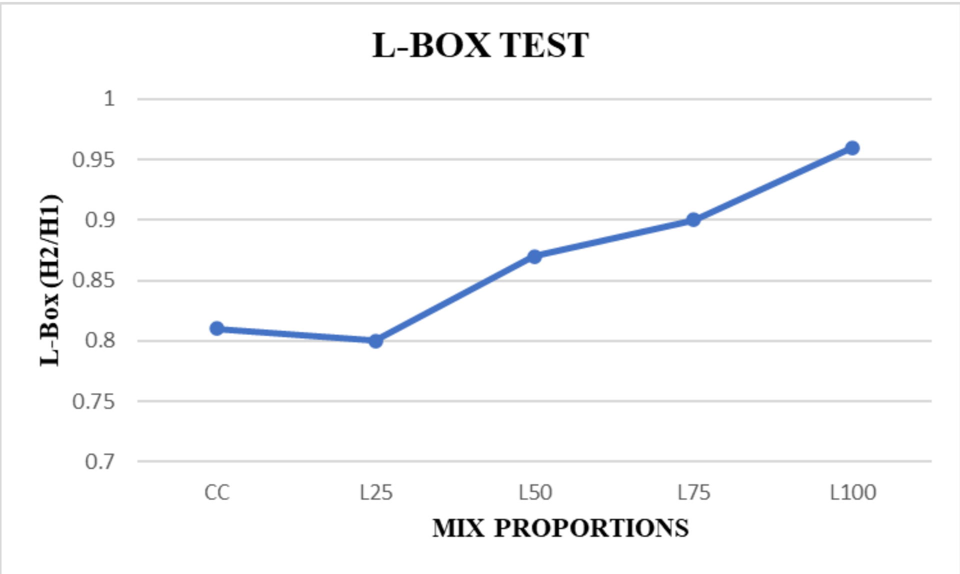

Fig. 5 Passing ability of LWSCC in L–Box

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4.2 RESULTS OF MECHANICAL PROPERTIES OF LWSCC

4.2.1 Compressive Strength:

A compressive testing apparatus with a 2000 kN capacity was used for the experiment. As per IS: 516, a load applied at a rate of 140 kg/cm³/min was applied to the specimen until it broke. The highest load that could be placed on the specimen before it failed was noted.

Table 7: Compression strength of test results of SCC by using LECA

% of LECA Replacement	Compression Strength (N/mm^2)		
	7 days	**14 days**	**28 days**
0	20.07	34.46	40.44
25	18.07	31.01	36.4
50	16.26	27.91	32.76
75	14.63	25.12	29.48
100	13.17	22.61	26.54

Fig. 6 Compressive Test

From Fig. 7, Compared to conventional concrete (CC), the compressive strength of SCC incorporating LECA is significantly lower for up to 7 days. After that, though, SCC mixes (LW25, LW50) show a notable increase in compressive strength, which shows up in the CC mix at 28 days and surpasses it at later ages. According to the study, replacing natural coarse aggregate with 25% LECA is a good solution to give SCC its optimum compressive strength. When the LECA content in the mix was increased above 25%, the compressive strength exhibited a slight decrease and was less than the CC.

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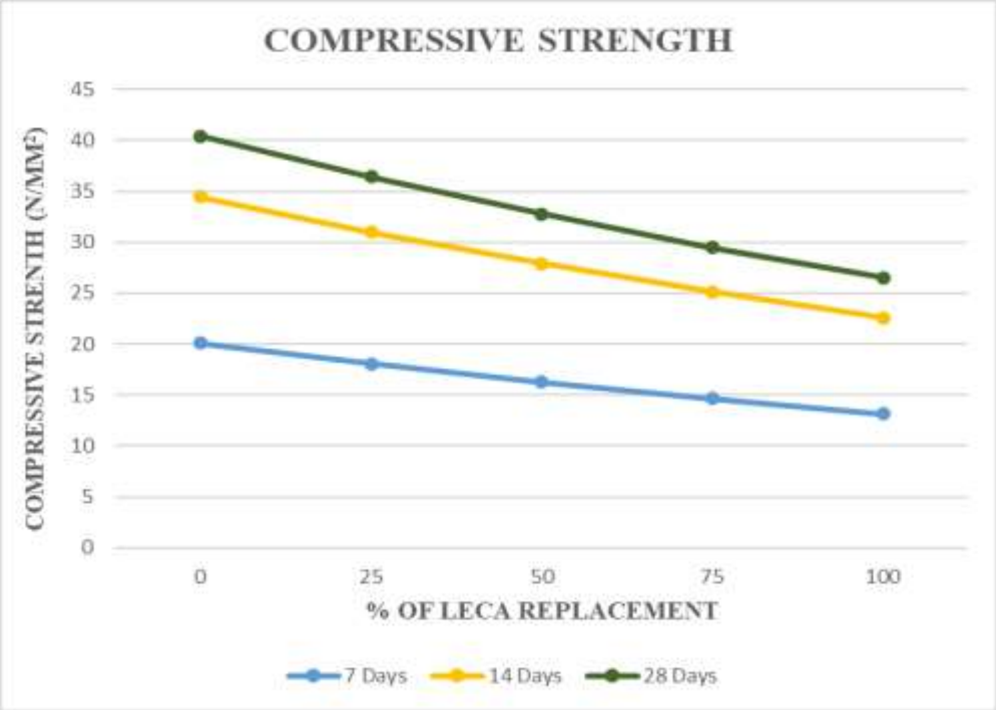

Fig. 7 Compressive Strength Test of LWSCC with various replacements of LECA

4.2.2 Split Tensile Strength Test:

The cylinder was gradually loaded until it failed, at which point the readings were noted.

Fig. 8 Split Tensile Strength Test Setup

We measured the Split Tensile Strength of SCC by using LECA at 7, 14, and 28 days of age. The test results are provided in the table below.

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Table 8: Results of the SCC split tensile strength test using LECA

% of LECA Replacement	Split Tensile Strength (N/mm^2)		
	7 days	14 days	28 days
0	3.81	5.17	5.98
25	3.19	4.34	5.07
50	2.62	3.59	4.24
75	2.1	2.91	3.48
100	1.63	2.28	2.78

Fig. 9 Split Tensile Strength Test of LWSCC with different LECA Replacements

According to the above graph, at early ages (7 days), SCC with LECA has a relatively lower tensile strength than conventional concrete, which is comparable to compressive strength. Nevertheless, after 28 days, SCC with LECA shows an obvious increase in tensile strength. Despite all the SCC mixes, the study found that the LW25 mix had the highest tensile strength.

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4.2.3 Flexural Strength Test:

From IS: 516, the study used a flexural strength testing machine with a 100 kN capacity to perform a flexural test on prism samples that are with dimensions of 100 x 100 x 500 mm in order to ascertain the modulus of rupture. For every mix, three matched samples were examined at 7, 14 and 28 days of age; thus, 45 specimens in total were cast for every test. The following figure depicts a typical test setup.

Fig. 10 Failure of Beam Specimen

Table 9: Flexural Strength test results obtained from SCC using LECA

% of LECA Replacement	Flexural Strength (N/mm2)		
	7 days	14 days	28 days
0	2.73	3.76	4.01
25	2.21	3.06	3.26
50	1.77	2.48	2.63
75	1.42	2	2.12
100	1.11	1.59	1.67

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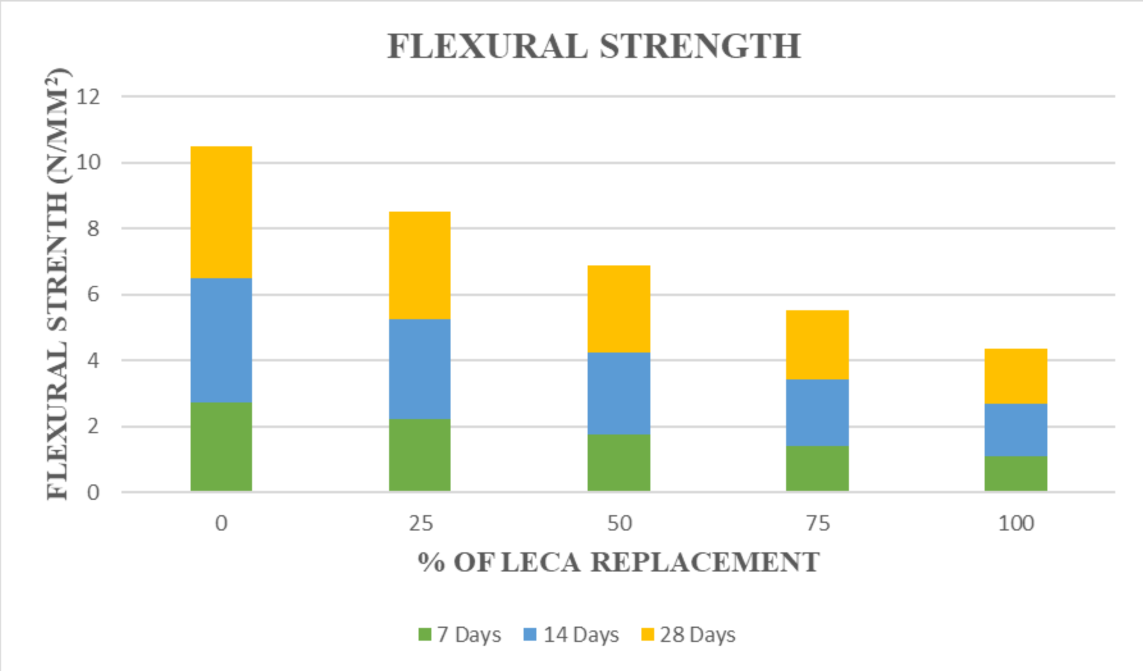
The LWSCC with 25% LECA was showing flexural strength at optimum level grade as other SCC mixes with LECA.

Fig. 11 Flexural Strength Test of LWSCC with various replacements of LECA



5 CONCLUSION

The following are the conclusions of the experimental research and observations:

1. It is demonstrated that LECA can produce lightweight structural concrete with low density and high self-compacting properties.
2. The workability characteristics of SCC mixes meet IS 1199 requirements. However, when SCC contains more than 25% of LECA, a decrease in the concrete's weight leads to a decrease in passing ability.
3. To attain the highest compressive strength in SCC, it is recommended to substitute natural coarse aggregate with LECA at a rate of 25%. And above 25%, the compressive strength of LWSCC is decreasing.
4. When up to 25% of the normal aggregate was replaced with LECA, good tensile and flexural strength was obtained; however, As LECA was raised in LWSCC, split tensile and flexural strength decreased.
5. Using LECA up to a 25% ratio as a substitute for coarse aggregates produces LWSCC with improved performance, reduced weight, and low density which helps in increasing in flow ability of LWSCC in congested areas.

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