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An Experimental Investigation on the Influence of LECA on the Durability 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. SCC is susceptible to deterioration due to abrasion and freeze-thaw cycles. It can also be adversely affected by strong acids, chloride ions, sulfate ions, aggressive chemicals, gasses, and even bacteria. Additionally, SCC may undergo self-destruction when reactive aggregates are present. 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 durability tests like weight loss, and acid attack (HCl, H_2SO_4) tests. The results were obtained by conducting the above tests – durability for cube, beam, and cylinders for 28 and 56 days of after curing in chemicals before that it was cured in water for 28 days.

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

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.

The compatibility of SCC's composition with traditional concrete by applying identical ingredients. The proportioning of the SCC mix is much more experimental than that of regular concrete mixes. The SCC mixture requires a to ensure high flowability and homogenous deformation, SCC should be designed with a low resistance to flow and moderate viscosity, high powder content, a reduced coarse aggregate content, maximum aggregate size, However, it also contains high-range water reducers (HRWRs) or superplasticizers and use of low water- cementitious material ratio or viscosity-modifying agents (VMAs) to provide the concrete mixture with both stability and flow.

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 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 like durability and strength of LWSCC
- To find out the weight loss, chemical attack & non-destructive tests of the SCC by using lightweight aggregates (LECA) at 7, 14, 28 and 56 days.

2. LITERATURE REVIEW

A modified version of Okamura's proposal was presented by K. Ozawa in 1988 [2]. 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 [3,4].

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. [5].

M.V. Seshagiri Rao et.al. (2015) studied the durability properties like Acid Strength Loss Factor (ASLF), Acid Attacking Factor (AAF), Acid Weight Loss Factor (AWLF), and Acid Durability Factor (ADLF) on different grades of SCC ranging from M20 to M70 and evaluated different factors and compared with normal concrete (NC). Sorptivity tests were also reported on SCC and NC [6].

Abdurrahman Nava Lotfy et.al (2015) investigated the durability properties of LWCC using three types of LWA i.e. furnace slag (FS), Expanded Clay (EC) AND Expanded Shale (ES). They observed that FSLWSCC has shown high resistance to salt scaling due to lower porosity and absorption properties of the aggregates compared to EWLSCC. All LWSCC specimens behaved reasonably well after 2 weeks of exposure to sulfuric acid. She observed that the fresh, hardened and durability of LWSCC mixes are affected by the CA to FA ratio and total aggregate proportion of LWA [7].

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 [8].

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 [9].

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 [10].

3.MATERIALS & METHODOLOGY

3.1 Materials 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.

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

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 Aggrgate	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 T50, V-funnel test and slump flow test were determined.
- Cube specimens of 150x150x150mm were prepared to determine the test for Compressive Strength after 28 days of water curing then immersed in acid for 28 and 56 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 acid curing periods of 28 and 56 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

4.1 RESULTS OF DURABILITY PROPERTIES OF LWSCC

4.1.1 Weight Loss Test:

The LWSCC concrete specimens are placed in the water for 28 days and then placed in acids for 28 and 56 days after water curing. The Specimens are taken out it and weighed using the weighing machine and then found out that the weight of some specimens is decreased and others the weight increased.

Table 7: Weight Loss test for 28 days results of SCC by using LECA

% of LECA Replacement	Weight Loss (Kg) – 28 days		
	Before Curing	After Curing HCL - 5%	After Curing H_2SO_4 - 5%
0	8.5	8.23	7.94
25	7.4	7.24	7.0
50	6.8	6.5	6.3
75	6.2	5.76	5.3
100	5.8	5.4	5.1

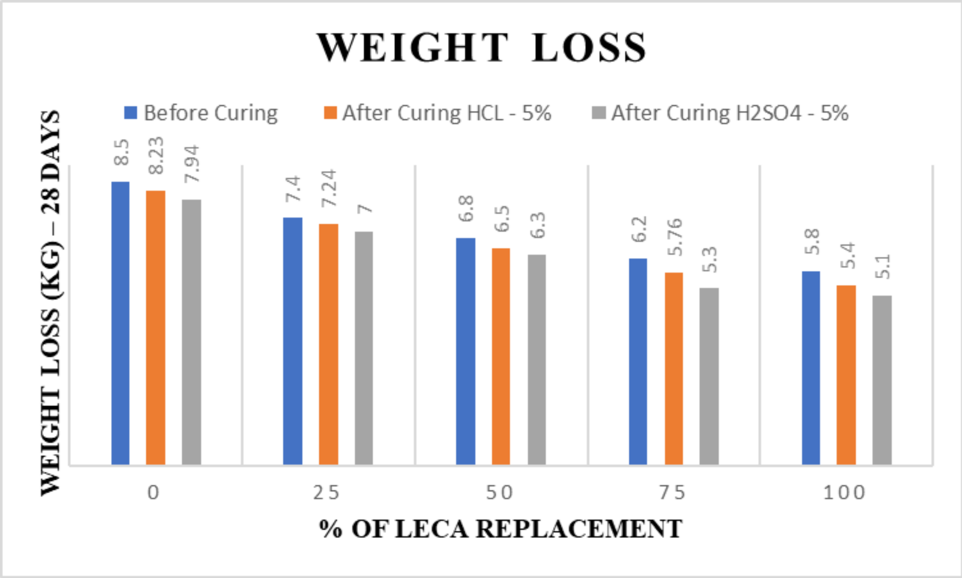

Fig. 2: Weight Loss Test conducted for 28 days

Table 8: Weight Loss test for 56 days results of SCC by using LECA

% of LECA Replacement	**Weight Loss (Kg) – 56 days**		
	Before Curing	After Curing HCL - 5%	After Curing H_2SO_4 - 5%
0	8.5	8.15	7.69
25	7.4	7.04	6.94
50	6.8	6.3	6.05
75	6.2	5.74	5.17
100	5.8	5.27	4.63

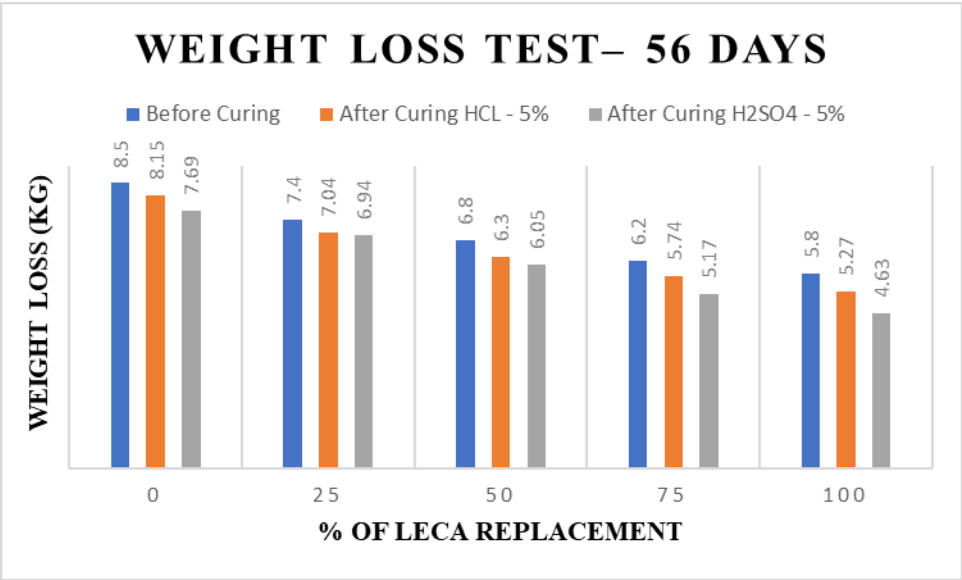

Fig. 3: Weight Loss Test conducted for 56 days

Fig. 4 Concrete cubes

From Fig. 6, the Acid weight loss factor (AWLF) is calculated as the % loss of weight of cubes by immersing the cubes in various types and concentrations of acids for different immersion periods.

AWLF = (Loss of weight after immersion of cube / original weight of cube) * 100

4.1.2 Compressive Strength Test

According to IS 516:2021, the study used 150x150x150 mm concrete cubes to calculate the compressive strength of LWSCC. After the acid curing period of 28 days, 56 days the cubes were tested for the weights and compressive strength. The cured LWSCC specimens of different grades viz. LW0, LW25, LW50, LW75, and LW100 were kept exposed to 5% solutions of both sulfuric acid and hydrochloric acids.

Figure 5. Compressive Test

Chloride Attack:

Cubes were continuously immersed in hydrochloric solution for 28 days and 56 days after 28 days of water curing. The cube specimens were put through testing in an extremely dry environment. For every test, cube specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix. A compressive testing device capable of 2000 kN was used for testing the cube specimen. According to 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 9: Compressive strength test results of SCC by using LECA

% of LECA Replacement	**Compressive Strength Test (N/mm^2)**	
	28 days	**56 days**
0	33.74	27.67
25	27.49	25.12
50	24.65	21.54
75	20.25	18.45
100	19.17	16.49

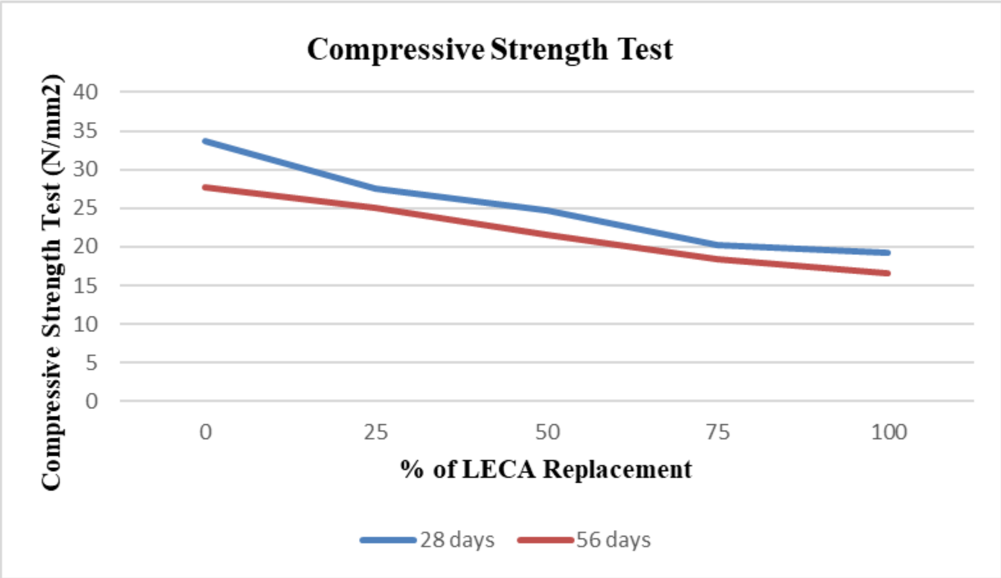

Fig. 6 Compressive Strength Test of LWSCC with various replacements of LECA

Sulphate Attack:

Cubes were continuously immersed in sulfuric solution for 28 days and 56 days after 28 days of water curing. The cube specimens were put through testing in an extremely dry environment. For every test, cube specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix. A compressive testing device capable of 2000 kN was used for testing the cube specimen. According to IS: 516, a load applied at a rate of 140 kg/cm^3/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 10: Compressive strength test results of SCC by using LECA

% of LECA Replacement	**Compressive Strength Test (N/mm^2)**	
	28 days	**56 days**
0	33.05	30.55
25	30.85	28.34
50	28.49	26.95
75	26.69	24.26
100	25.05	23.14

According to Figure 13, Compared to conventional concrete (CC), the compressive strength of SCC with LECA is significantly lower for a maximum of 7 days. From then on, however, SCC mixes (LW25, LW50) show a notable increase in compressive strength, comparing them to the CM mix after 28 days and even surpassing it at later ages. To provide SCC with the maximum compressive strength, the ideal ratio to replace natural coarse aggregate with is 25% of LECA, according to the study. Compressive strength slightly decreased and was less than CC mix above 25% of LECA content. CC mix.

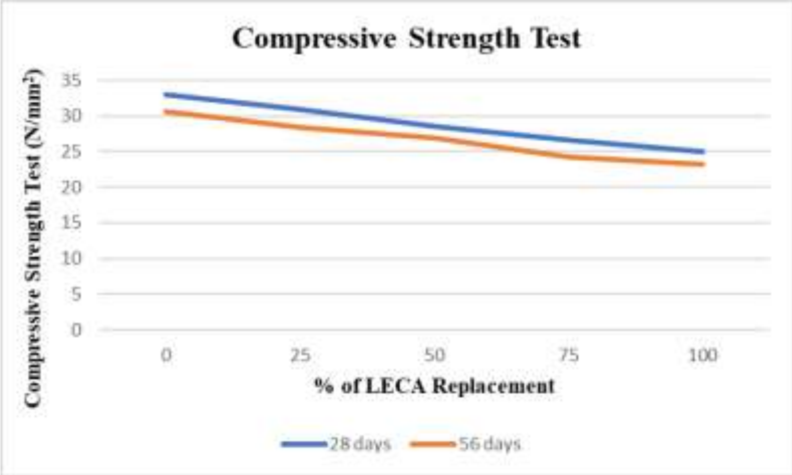

Fig. 7 Compressive Strength Test of LWSCC with various replacements of LECA

4.1.3 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

Chloride Attack:

Cylinders were continuously immersed in hydrochloric solution for 28 days and 56 days after 28 days of water curing. The cube specimens were put through testing in an extremely dry environment. For every test, cylinder specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix.

The cylinder was gradually loaded until it failed, at which point the readings were noted. We measured the Split Tensile Strength of SCC by using LECA at 28 and 56 days of age. The test results are provided in the table below.

Table 11: Results of the SCC split tensile strength test using LECA

% of LECA Replacement	**Spilt Tensile Strength Test (N/mm^2)**	
	28 days	**56 days**
0	5.57	5.47
25	5.49	5.12
50	4.65	4.04
75	3.45	3.25
100	1.97	1.49

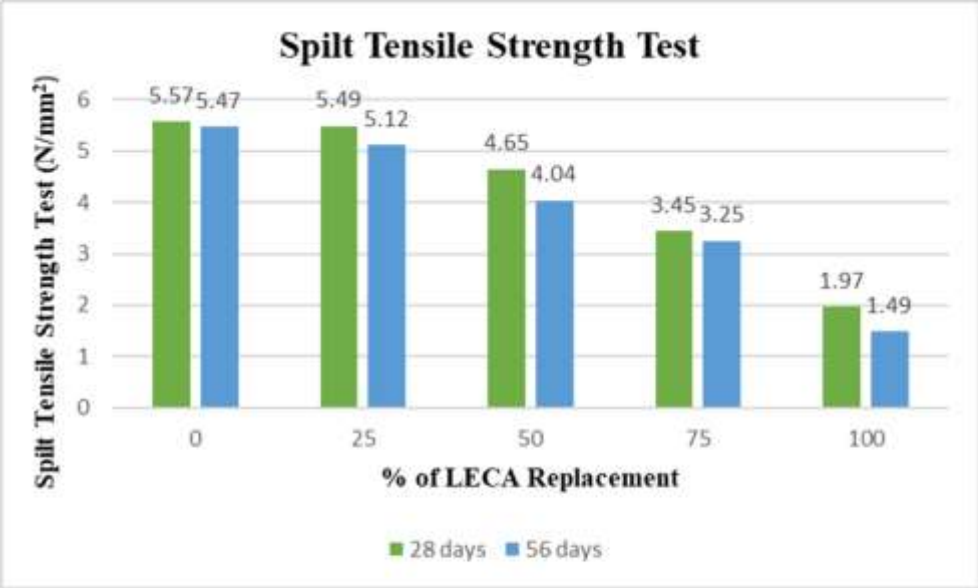

Fig. 9 Split Tensile Strength Test of LWSCC with different LECA Replacements

Sulphate Attack:

Cubes were continuously immersed in sulfuric solution for 28 days and 56 days after 28 days of water curing. The cube specimens were put through testing in an extremely dry environment. For every test, cube specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix.

Table 12: Results of the SCC split tensile strength test using LECA

% of LECA Replacement	**Spilt Tensile Strength Test (N/mm^2)**	
	28 days	**56 days**
0	5.35	5.27
25	5.11	4.97
50	4.35	3.74
75	3.25	3.01
100	1.86	1.47

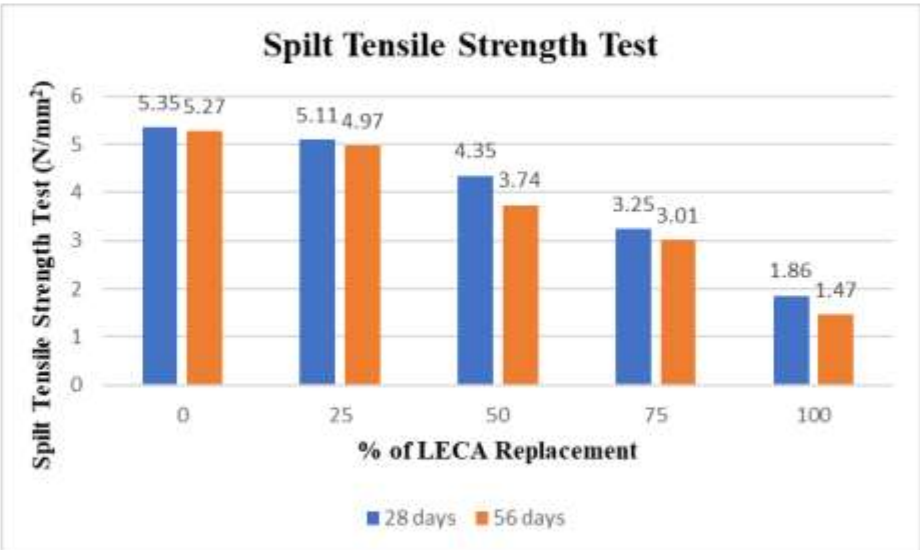

Fig. 10 Split Tensile Strength Test of LWSCC with different LECA Replacements

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.

4.1.4 Flexural Strength Test:

Fig. 11 Flexural Strength Test – Failure Beam

Chloride Attack:

Beams were continuously immersed in hydrochloric solution for 28 days and 56 days after 28 days of water curing. The beam specimens were put through testing in an extremely dry environment. For every test, cube specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix.

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 28 and 56 days of age; thus, 45 specimens in total were cast for every test. The following figure depicts a typical test setup.

Table 13: Flexural Strength test results obtained from SCC using LECA

% of LECA Replacement	**Flexural Strength Test (N/mm^2)**	
	28 days	**56 days**
0	4.3	4.0
25	3.8	3.75
50	3.52	3.04
75	2.45	2.25
100	1.97	1.31

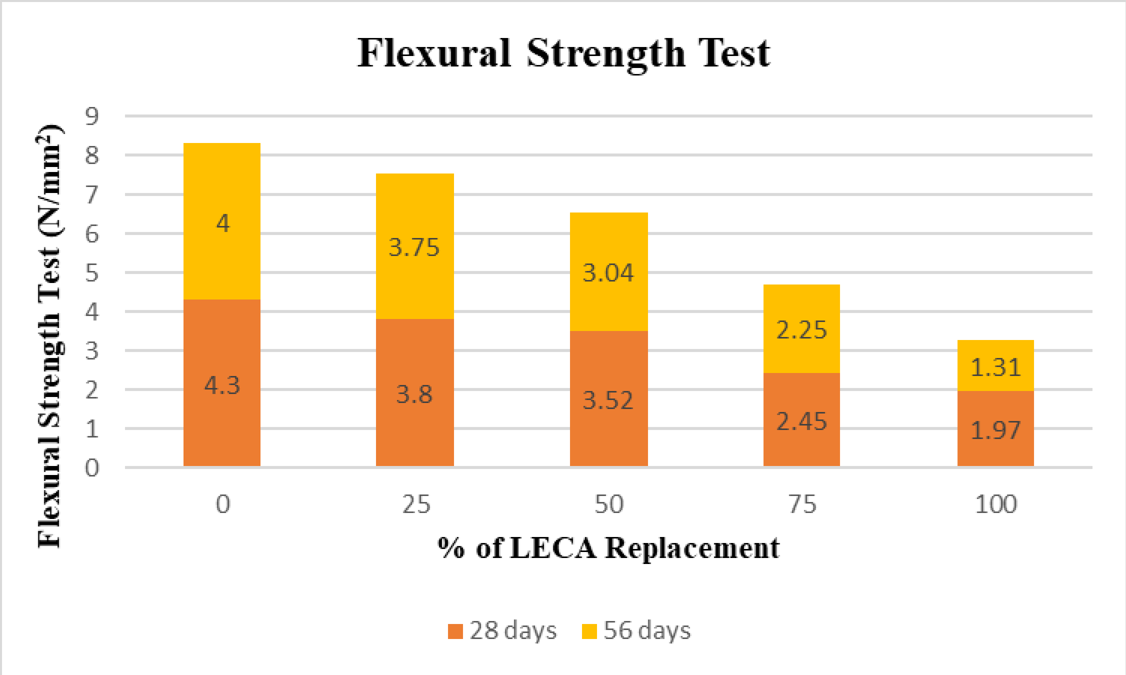

Fig. 12 Flexural Strength Test of LWSCC with various replacements of LECA

Sulphate Attack:

Beams were continuously immersed in sulfuric solution for 28 days and 56 days after 28 days of water curing. The beam specimens were put through testing in an extremely dry environment. For every test, cube specimens in total were cast, with 3 identical specimens tested at twenty-eight days of water curing and then immersed in chemical for 28 days and 56 days for each mix.

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 28 and 56 days of age; thus, 45 specimens in total were cast for every test. The following figure depicts a typical test setup.

Table 14: Flexural Strength test results obtained from SCC using LECA

% of LECA Replacement	**Flexural Strength Test (N/mm^2)**	
	28 days	**56 days**
0	3.97	3.54
25	2.81	2.74
50	2.52	2.42
75	2.25	2.15
100	1.86	1.27

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

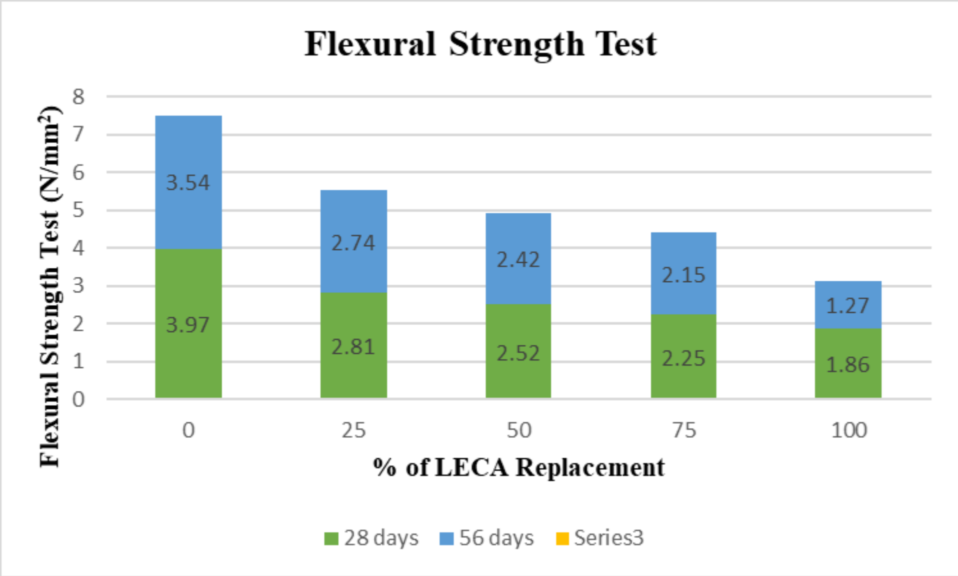

Fig. 13 Flexural Strength Test of LWSCC with various replacements of LECA

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 loss of weight and loss of strength in LWSCC increases as the duration of exposure to acids and sulphates increases.
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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