

Engineering Properties of Self-Compacting Lightweight Concrete (SCLC) for High-Rise Building Applications

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Abstract: Self-Compacting Lightweight Concrete (SCLC) has gained significant attention as an advanced construction material for high-rise buildings due to its ability to combine reduced density with superior workability. The researchers conducted a study to test the engineering properties of SCLC material while they worked to enhance both its fresh state and hardened state properties which support structural uses. The use of lightweight aggregates in concrete construction provides essential benefits because it reduces concrete weight, which results in decreased dead loads that improve structural performance for tall buildings. The fresh properties of SCLC were assessed through standard tests which measured its flowability and passing ability and segregation resistance. The results show that SCLC mixtures which have been correctly designed can achieve self-compacting performance without needing external vibration because they distribute material evenly through areas with high reinforcement density. The research measured essential properties of the hardened material through tests which examined its compressive strength and tensile strength and elastic modulus and density. The results show that SCLC reaches sufficient load-bearing capacity while its unit weight remains much lighter than traditional concrete. The use of supplementary cementitious materials together with high-range water-reducing admixtures enhance durability through its ability to decrease permeability while providing better protection against environmental damage. The study concludes that SCLC offers a high strength-to-weight ratio and improved constructability, which makes it a sustainable building material for high-rise construction. The system provides construction benefits through foundation weight reduction and better earthquake protection and shorter building time, which meet current engineering standards.

Keywords: Self-Compacting Lightweight Concrete (SCLC); High-Rise Buildings; Lightweight Aggregates; Workability; Slump Flow; Compressive Strength; Tensile Strength; Strength-to-Weight Ratio; Durability; Supplementary Cementitious Materials; Structural Efficiency; Sustainable Concrete.

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I. INTRODUCTION

Rapid urbanization and the need for high-rise buildings have resulted in the requirement for modern construction materials that not only make construction more efficient but are environmentally friendly too. One of the biggest problems in the construction of high-rise buildings is to decrease the dead load without compromising on the strength and durability of the building. LWAC is an excellent material that has come up in response to the challenges posed by the construction of such buildings due to its low density, better insulation properties, and improved structural efficiency

(Chandra and Berntsen, 2002) [1].

As a way of solving the problems associated with construction quality and reliance on labor force, Self-Compacting Concrete (SCC) came into existence. It flows under its own weight with no need for vibration and is able to fill highly reinforced parts with ease (Okamura and Ouchy, 2003)[2]. The behavior of SCC is affected by several elements, including the low water- cement ratio, aggregate content, and superplasticizers. Besides, standards such as EFNARC (2005) have laid down the criteria for testing the fundamental characteristics of SCC.

Self-Compacting Lightweight Concrete (SCLC) is the product of a combination of the two materials discussed above and is an excellent blend of both self-compacting concrete and lightweight aggregates. The reason why SCLC is especially preferred for constructing tall buildings is due to its ability to ensure good workability without vibrations and to decrease the load-bearing capacity. According to the study by Boags et al.[3], SCLC can develop compressive strength in the range of 37–60 MPa, depending on proper mixing.

Moreover, there are internal curing techniques for optimizing the performance of lightweight concrete. Costa et al. (2012) emphasized that the use of lightweight aggregate material helps to minimize the process of shrinkage due to hydration and internal moisture content. Moreover, latest research findings from Kumar et al. (2026) [4] also indicate that the incorporation of supplementary cementitious material, such as silica fume and metakaolin, improves the performance of SCLC.

In terms of basic properties, the behavior of concrete depends on the factors like water-cement ratio, aggregates' properties, and the curing process (Neville, 2011) [5]. For instance, while working with SCC and SCLC, it is important to ensure that there will be a good balance between flowability and stability. According to Khayat (1999) [6], it is vital to make the correct mix design, reduce the amount of coarse aggregate, and use viscosity modifiers.

However, in spite of these improvements, further research is still necessary regarding the evaluation of the engineering behavior of SCLC from the perspective of fresh and hardened properties, especially for the use of SCLC in high rise and seismic-resistant buildings. In light of this situation, the current study is intended to conduct an analysis on the engineering properties of SCLC.

➤ Objectives of the Study

- To evaluate the engineering properties of Self-Compacting Lightweight Concrete (SCLC) in both fresh and hardened states.
- To analyze the effect of lightweight aggregates on strength and density of concrete.
- To study the workability characteristics of SCLC using EFNARC guidelines.
- To compare the performance of different mix proportions and identify the optimum mix for high-rise applications.
- To assess the suitability of SCLC for high-rise and seismic-resistant structures.

II. LITERATURE REVIEW

➤ General

Lightweight Aggregate Concrete (LWAC) is one construction material that has gained widespread recognition because of its lightweight property, increased thermal efficiency, and structural efficiency. LWAC has been utilized since the days of antiquity and remains highly relevant to construction practices even today, especially in tall structures where weight reduction is a major concern (Chandra and

Berntsen, 2002) [1]. Nevertheless, LWAC has certain constraints, including reduced strength and variability of aggregates, that have prevented its wider use in structural construction.

The problems concerning the quality of construction and compaction led to the development of Self-Compacting Concrete (SCC). SCC was formulated by Okamura and Ouchy (2003) [2], a concrete material capable of flowing through difficult and obstructive reinforcement regions without the need for vibration. The effectiveness of SCC is greatly influenced by the water-to- powder ratio, the amount of aggregates, and the addition of superplasticizers. Moreover, according to EFNARC (2005), there are standard test methods used to assess the workability of SCC, such as the slump flow, V-funnel, and L-box tests.

Taking into consideration the strengths of LWAC as well as SCC, the concept of Self- Compacting Lightweight Concrete (SCLC) was further explored by researchers. Bogas et al. (2012) [3] proved that SCLC possesses sufficient compressive strength (37-60 MPa) along with low density and high workability. This was an important development in the direction of making lightweight concrete that is highly flowable.

Additional research efforts were aimed at enhancing the performance of SCLC by means of optimizing its mixture and modifying its materials. For example, Wu et al. (2009)[7] stressed the necessity to account for the water absorption properties of the lightweight aggregates due to their impact on workability and homogeneity of aggregate placement. Moreover, Karamloo et al. (2016) [8] analyzed the influence of aggregate size on the strength parameters, revealing that larger aggregates increase its energy of fracture and plasticity.

Apart from mechanical performance, several attempts have been made in literature to increase the durability of lightweight concrete and make up for its weakness. For instance, Hassanpour et al. (2012)[9] found that the inclusion of fibers greatly increases tensile strength and makes it more durable and more crack-resistant, thus increasing its applicability for structural purposes. Similarly, Grabis et al. (2016)[10] showed that steel fiber reinforced SCLC had better properties, despite decreased workability.

In addition, internal curing techniques along with novel materials have also been incorporated to improve the performance of SCLC. According to Costa et al., (2012)[9], lightweight aggregate provides internal moisture, thus decreasing shrinkage and increasing hydration. It has been discovered through recent studies conducted by Kumar et al. (2026)[4] that the incorporation of supplementary cementitious material such as silica fume and metakaolin can improve various aspects of SCLC.

In its basic form, the physical properties of concrete depend on parameters like water-to-cement ratio, aggregate characteristics, and curing. For both SCC and SCLC, the ideal mix should have good fluidity while not compromising on stability to prevent segregation. According to Khayat

(1999)[6], achieving this fine balance requires proper mix design, minimizing coarse aggregate usage, and incorporating viscosity modifying agents. Even though many developments have occurred within this field, the research carried out so far has limitations since it only focuses on parameters such as workability, strength, or durability of material. In fact, what is needed is extensive research that covers all engineering aspects of its performance.

➤ *Research Gap*

- Limited studies on combined use of SCC and lightweight concrete (SCLC).
- Most research focuses only on either workability or strength, not both together.
- Lack of studies analyzing combined engineering properties.
- Insufficient research on SCLC behavior in high-rise building applications.
- Very few studies consider seismic performance of SCLC structures.
- Limited understanding of long-term durability of SCLC.
- Lack of optimized mix design for achieving balance between flowability and strength.
- Existing studies are mostly laboratory-based, with fewer real-life applications.

III. MATERIALS AND METHODS

➤ *Materials Used*

The materials used for preparing Self-Compacting Lightweight Concrete (SCLC) have been chosen following some specific standards that ensure that workability, strength,

and durability requirements are met. Some information about these materials is provided below:

- *Cement*

The Ordinary Portland Cement (OPC), which is grade 43/53, was used as the main binding agent. This type of cement meets the specifications set out in IS 8112 / IS 12269.

- *Fine Aggregate*

Natural river sand was chosen as fine aggregate. Sand belongs to Zone II according to IS 383. This sand is devoid of organic contaminants. Sand serves a vital function in enhancing the flowability of SCLC.

- *Lightweight Coarse Aggregate*

Low-density materials like expanded clay and pumice were utilized as aggregates in this concrete mixture. They have high water-absorption properties and thus ensure that concrete is light in weight. The proper pre-soaking of aggregates was done to ensure uniformity in the mixture.

- *Chemical Admixtures*

To make sure that there is adequate workability of the concrete mix, a superplasticizer having a water-reducing ratio based on polyether carboxylate was used. Also, in order to reduce bleeding and segregation in the mixture, a viscosity modifying admixture (VMA) was employed.

- *Water*

The concrete mixing process used drinking water that met IS 456 standards because it had no dangerous contaminants. The hydration process and concrete workability depend on water as an essential component.

Table 1 Physical Properties of Materials

Material	Property	Value
Cement (OPC)	Specific Gravity	3.15
Fine Aggregate	Specific Gravity	2.65
	Fineness Modulus	2.6
Lightweight Aggregate	Specific Gravity	1.5–2.0
	Water Absorption	10–20%
Superplasticizer	Type	Polycarboxylate
Water	pH Value	6–8

➤ *Mix Design*

The mix design of Self-Compacting Lightweight Concrete (SCLC) was conducted according to EFNARC (2005) guidelines which require specific trackable values for flowability and strength and stability testing. The concrete mix design process aimed to create a mix which would achieve both self-compacting properties and lightweight characteristics needed for vertical building construction.

- *Design Approach*

The mix design of Self-Compacting Lightweight Concrete (SCLC) was developed by combining the principles of self-compacting concrete (SCC) and lightweight concrete (LWC). The design approach was based on achieving an optimum balance between flowability, stability, strength, and reduced density, in accordance with the guidelines of

EFNARC (2005). The design method was developed to achieve two essential goals which required the concrete mixture to achieve maximum workability without vibration usage while delivering required strength for structural purposes. The research team selected lightweight aggregates because their properties determine both concrete density and concrete strength.

The mix was proportioned to achieve adequate filling ability, passing ability, and resistance to segregation, which are the essential characteristics of SCC. The process involved optimizing lightweight aggregate usage to achieve weight reduction in concrete while maintaining its performance standards. The controlled chemical admixtures which included superplasticizers and viscosity modifying agents to achieve better flowability while preventing material

segregation. The final mix design was obtained through a series of trial mixes which ensured that both fresh and hardened properties met the required standards.

• *Steps in Mix Design:*

The mix design of Self-Compacting Lightweight Concrete (SCLC) was carried out in a systematic manner according to EFNARC (2005) guidelines. The process included the execution of specific steps.

✓ *Step 1: Selection of Target Strength*

The target compressive strength of concrete was selected based structural requirements. The study investigated M30 and M40 grades because these grades provide sufficient strength for high-rise building construction.

✓ *Step 2: Selection of Water–Cement Ratio*

The water–cement ratio was selected to achieve the desired balance between strength and workability. A lower water–cement ratio was preferred to ensure higher strength and durability while maintaining flowability with the help of admixtures.

✓ *Step 3: Determination of Cement Content*

The cement content was determined through calculations which used the selected water-cement ratio and required strength as the foundation. The appropriate cement content must be maintained at a specific level which creates enough paste material to enable self-compacting characteristics.

✓ *Step 4: Selection of Aggregate Proportions*

The ratio of fine aggregates to coarse aggregates was established to validate the required performance attributes of filling ability and passing ability. The concrete mix used more fine aggregate than typical mixes to achieve better flow properties.

✓ *Step 5: Incorporation of Lightweight Aggregate*

The introduction of lightweight aggregates created a solution to decrease concrete weight. The team conducted pre-soaking tests on aggregates because their water absorption ability required them to do so in order to achieve consistent results during the mixing process.

✓ *Step 6: Addition of Chemical Admixtures*

A high-range water-reducing admixture (superplasticizer) was added in the range of 0.8–1.5% by weight of cement to achieve the required flowability. A viscosity modifying agent (VMA) was also used to prevent segregation and bleeding.

✓ *Step 7: Preparation of Trial Mixes*

Trial mixes were prepared to evaluate the performance of the designed mix. Adjustments were made in proportions of materials and admixtures based on the results of fresh and hardened concrete tests.

✓ *Step 8: Optimization of Mix Design*

The final concrete mix proportions were developed after the team confirmed that the concrete mix met all requirements for self-compacting behavior and strength and durability. The optimized mix was then used for further experimental investigation.

Table 2 Mix Proportions

Mix ID	Cement (kg/m ³)	Fine Aggregate (kg/m ³)	LWA (kg/m ³)	Water (kg/m ³)	SP (%)
SCLC-1	400	750	600	180	1.0
SCLC-2	420	730	580	175	1.2
SCLC-3	440	700	550	170	1.3

➤ *Preparation of Concrete*

The preparation of Self-Compacting Lightweight Concrete (SCLC) was conducted through standard methods which created a stable concrete mixture. The batch process required weight- based measurement of all components which included cement fine aggregate lightweight coarse aggregate water and chemical admixtures according to the established mix design. The team started with an initial process to mix all dry materials for a duration of 1 to 2 minutes until they achieved complete material distribution. The team added water together with superplasticizer and other admixtures in a controlled manner while they continued mixing for 3 to 5 minutes until they achieved a consistent and workable mix.

The freshly prepared concrete was then poured directly into moulds which included cubes and cylinders and prisms because SCLC maintained its self-compacting properties. The team used careful methods to complete placement because they wanted to maintain proper material distribution and achieve full mould capacity. The top surface of the

specimens was levelled and finished smoothly using a trowel.

The specimens stayed undisturbed at room temperature for a complete day after their casting process. The process started with demoulding and continued with water curing which took place at a temperature of 27 ± 2°C until the testing dates of 7, 14, and 28 days arrived. The research team implemented essential safety measures throughout the study which included pre- soaking of lightweight aggregates to reduce water absorption, control of mixing duration, and establishment of proper curing conditions for dependable outcomes.

➤ *Testing Methods*

- *Fresh Concrete Tests (SCC Tests)*

Table 3 Fresh Concrete Tests (SCC Tests)

Test Name	Purpose	Standard
Slump Flow	Flowability	EFNARC
T50 Time	Flow rate	EFNARC
V-Funnel	Viscosity	EFNARC
L-Box	Passing ability	EFNARC

- *Hardened Concrete Tests*

Table 4 Hardened Concrete Tests

Test Name	Purpose	Standard
Compressive Strength	Load capacity	IS 516
Split Tensile Test	Tensile behavior	IS 5816
Flexural Strength	Bending resistance	IS 516
Density Test	Lightweight verification	ASTM C567

➤ *Data Collection and Analysis*

The testing data from multiple tests on Self-Compacting Lightweight Concrete (SCLC) was thoroughly documented and analyzed to determine its engineering performance characteristics. The researchers conducted fresh and hardened concrete tests at three different curing ages which were 7 days, 14 days, and 28 days to examine how strength and performance developed with time.

Measured the fresh concrete properties through slump flow testing and T50 time testing and V- funnel time testing and L-box ratio testing to determine the concrete's flowability and viscosity and passing ability. The researchers measured the hardened concrete properties of compressive strength and split tensile strength and flexural strength and density through standard testing procedures.

The study examined how SCLC behaves through three parameter relationships which included strength development with age and density changes through different mix compositions and workability changes based on different admixture amounts.

The study compared SCLC performance with traditional concrete performance to assess its potential use in high-rise

construction. The analysis focused on three main objectives which included studying trends and variations and assessing how different materials affected the complete concrete performance. The results established optimal mix design through which SCLC demonstrated its ability to achieve lightweight construction with sufficient strength and durability properties.

IV. RESULT

The experimental results obtained from the tests conducted on Self-Compacting Lightweight Concrete (SCLC) are presented in this section. The study assessed the fresh and hardened performance of three different mix proportions which included SCLC-1 and SCLC-2 and SCLC-3.

➤ *Fresh Concrete Properties*

Table 5 Slump Flow Values

Mix ID	Slump Flow (mm)
SCLC-1	650
SCLC-2	700
SCLC-3	730

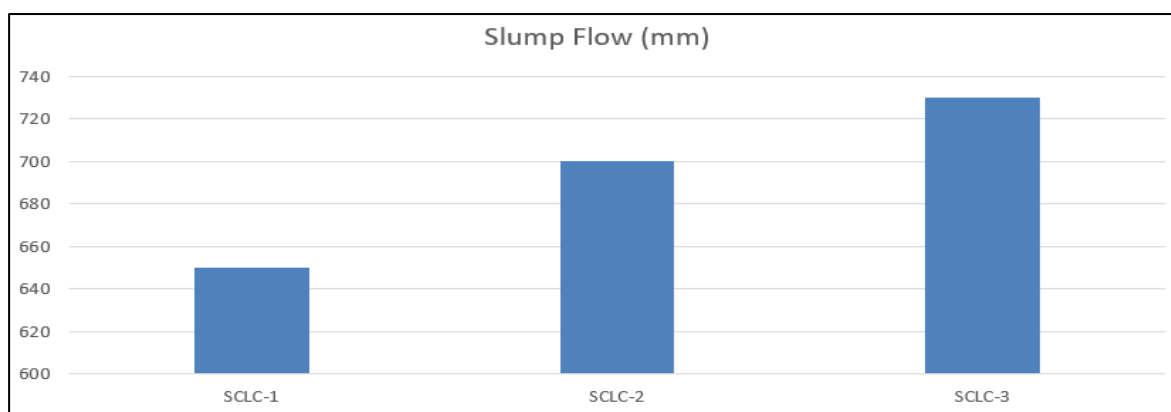


Fig 1 Slump Flow (mm)

Table 6 V-Funnel Time

Mix ID	V-Funnel (sec)
SCLC-1	12
SCLC-2	10
SCLC-3	9

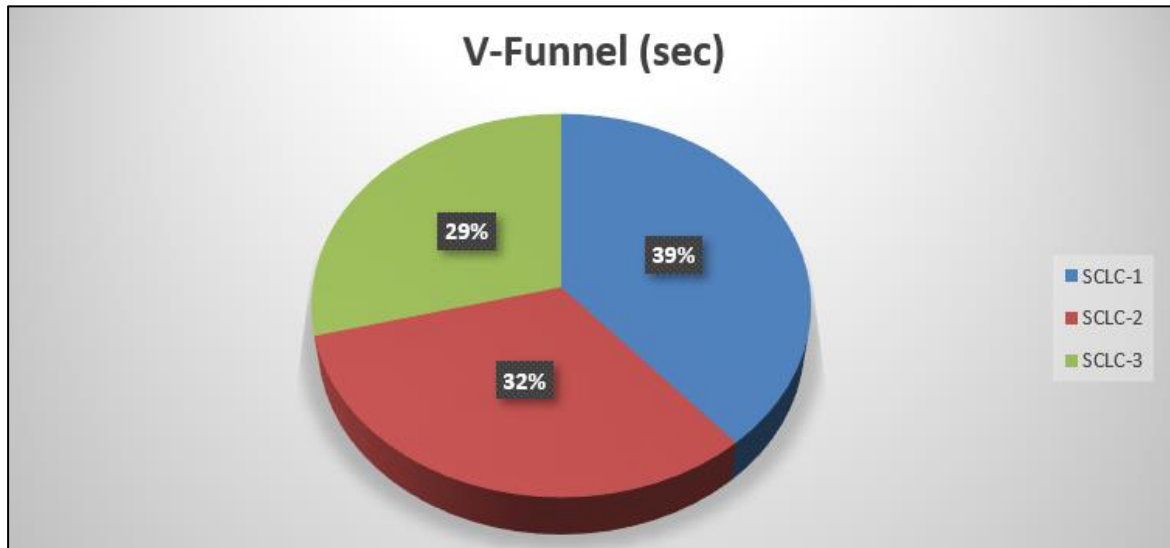


Fig 2 V-Funnel (sec)

➤ *Compressive Strength*

Table 7 Compressive Strength Results

Mix ID	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
SCLC-1	20	26	32
SCLC-2	22	28	35
SCLC-3	24	30	38

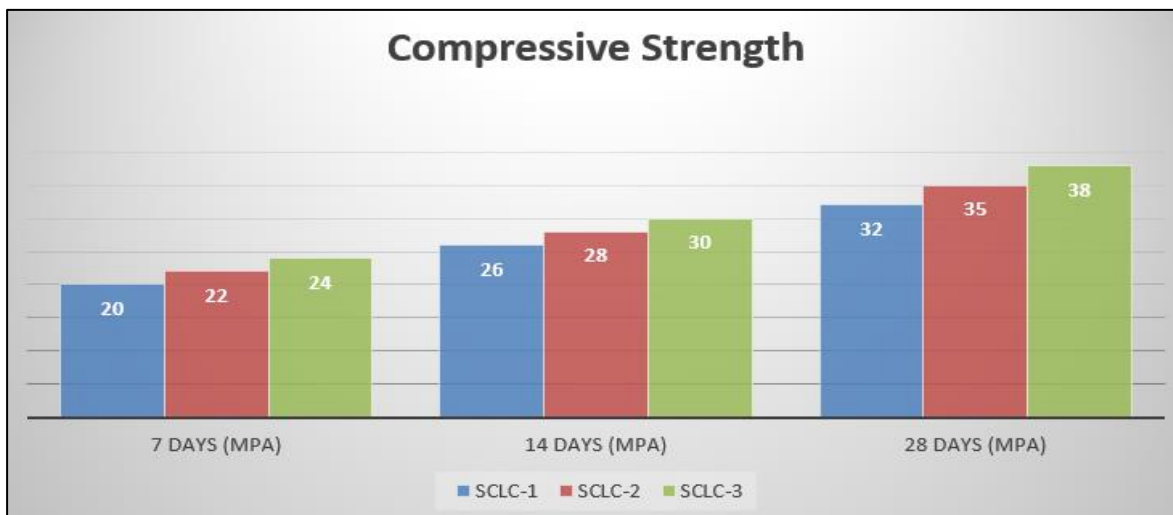


Fig 3 Compressive Strength

➤ *Split Tensile Strength*

Table 8 Tensile Strength

Mix ID	Tensile Strength (MPa)
SCLC-1	2.5
SCLC-2	2.8
SCLC-3	3.1

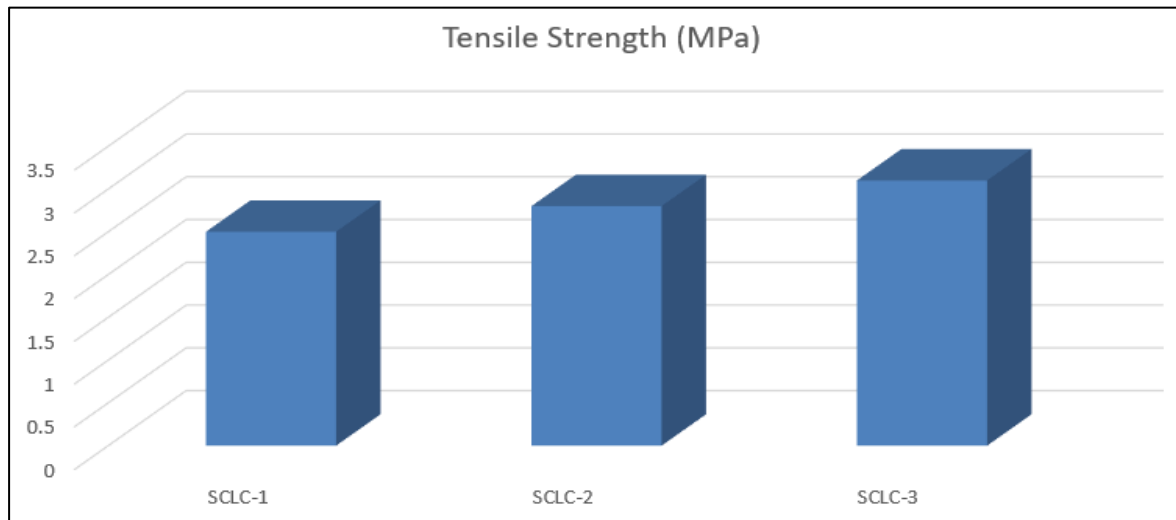


Fig 4 Tensile Strength (MPa)

➤ Density

Table 9 Density of Concrete

Mix ID	Density (kg/m ³)
SCLC-1	1950
SCLC-2	1850
SCLC-3	1750

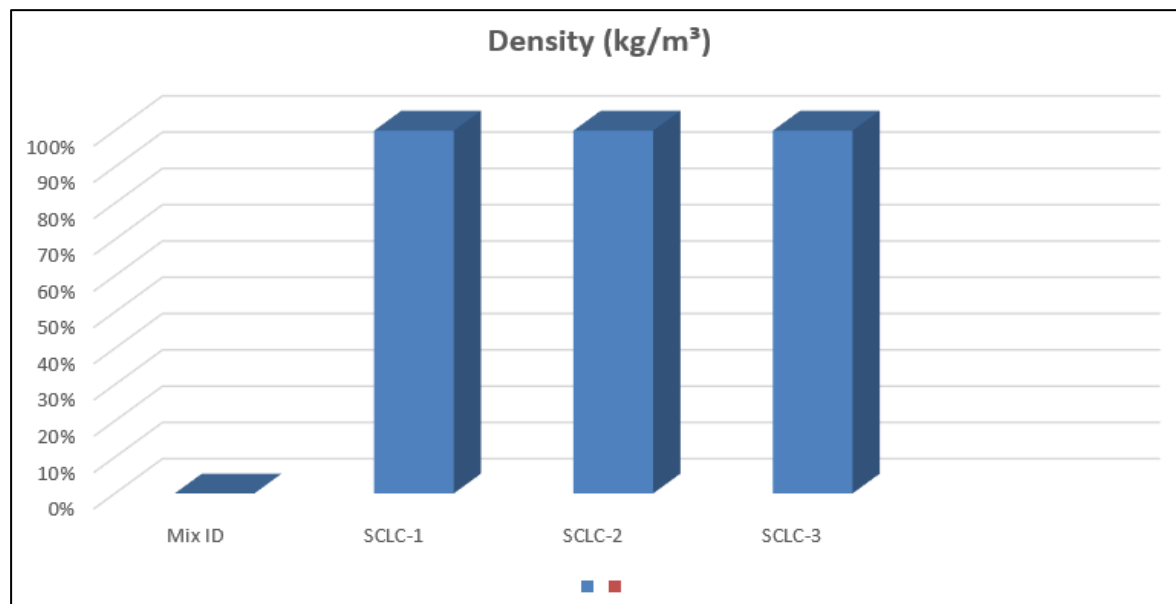


Fig 5 Density (kg/m³)

V. DISCUSSION

The results of the experimental study say that SCLC performs well both in its fresh and hardened states. The fresh concrete test results show that all mixes fall within the acceptable limits specified by EFNARC guidelines. The slump flow measurements showed increasing values when superplasticizer content was increased, which demonstrated that flowability had improved. The decrease in V-funnel time shows better workability of SCLC-3 because its viscosity has been reduced, which makes SCLC-3 the most effective mix.

All mixes showed increasing strength through the entire curing period. The strength values of the material show a slight decrease compared to standard concrete because lightweight aggregates were used but the material remains suitable for structural design. The highest compressive strength was achieved by SCLC-3 which shows that this mix design achieved optimal balance between its components.

The split tensile strength results demonstrated upward improvement with better mix design. The results showed improved bonding strength between cement paste and aggregates. The density results show that unit weight

decreases substantially from normal concrete which provides high-rise construction an advantage because it decreases dead weight.

The results demonstrate that SCLC establishes a suitable equilibrium between its practical usability and its structural strength and its decreased material weight. The optimized mix (SCLC-3) exhibited superior performance which makes it appropriate for use in high-rise buildings and earthquake-resistant construction projects.

VI. CONCLUSION

➤ *Based on the Experimental Investigation, the Following Conclusions can be Drawn:*

- Self-Compacting Lightweight Concrete (SCLC) exhibited excellent flowability and self-compacting behavior without the need for external vibration.
- The compressive strength of SCLC increased with curing age and was found to be adequate for structural applications, although slightly lower than conventional concrete.
- The use of lightweight aggregates significantly reduced the density of concrete, making it suitable for high-rise buildings by decreasing dead load.
- The split tensile strength showed satisfactory results, indicating good bonding between cement paste and aggregates.
- Among all mixes, SCLC-3 demonstrated the best overall performance in terms of workability, strength, and reduced density.
- The study confirms that SCLC provides a good balance between strength and weight reduction, making it a sustainable and efficient material for modern construction.

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