International Journal of Mechanical Engineering

EXPERIMENTAL INVESTIGATIONS ON THE MECHANICAL PROPERTIES OF SELF COMPACTING LIGHTWEIGHT CONCRETE

Yuva Raja G
[1]Former PG Student (2019-20 batch), Department of Civil Engineering, PSG College of Technology, Coimbatore- 641004, India.

Nalinaa K
[2] Professor, Department of Civil Engineering, PSG College of Technology, Coimbatore- 641004, India.
kna.civil@psgtech.ac.in

Abstract

Self Compacting Concrete (SCC) is a highly fluid form of concrete that can consolidate under its own weight, thereby reducing the need for any mechanical compaction processes. Light weight Concrete (LWC), which incorporates the use of light weight aggregates, can reduce the density of concrete and therefore the potential associated dead loads. In recent decades, there have been numerous studies in the production of Self Compacting Light weight Concrete (SCLWC) that aim to combine the benefits of both SCC and LWC. This paper aims to study about the fresh and hardened properties of self-compacting light weight concrete using Light weight Expanded Clay Aggregates (LECA) at varying replacement percentage of 25%, 50%, 75%, 100%. The fresh properties of SCLWC were investigated using the slump flow, T500, and V-Funnel tests. Hardened properties of SCLWC include 7-days compressive strength, tensile strength and flexural strength.

***Keywords* - Self Compacting Concrete (SCC); Self Compacting Light weight Concrete (SCLWC); Light weight Expanded Clay Aggregates (LECA).**

I. INTRODUCTION
II.

The advantage of SCC is a highly workable concrete that can flow and consolidate under its own self-weight without the need of mechanical vibration, which enables concrete to be cast easily in form works consisting of large areas of steel reinforcement. It is primarily used to decrease construction time, ensure sufficient compaction, and eliminate noises associated with mechanical vibration. LWC can also result in a higher strength-to-weight ratio, enhanced thermal properties and fire resistance, and lead to a decrease in dead loads [2]. The decrease in dead load is beneficial in the construction industry because it can result in cost savings by the reduction of the size of structural elements and possibly the amount of steel reinforcement required. When the density of light weight aggregate decreases, the flow ability of concrete increases. Self compaction behaviour of Self Compacting Light weight Concrete can be achieved by the properties in its fresh state. The three main properties of SCLWC are filling ability (flow under its own weight), passing ability (maintain its homogeneity) and segregation resistance[5].

With the advancement of concrete technology, several attempts have been made in developing new high-performance materials. An innovative concrete, Self Compacting Light weight Concrete (SCLWC), which possesses the advantage of both Light weight concrete (LWC) and Self Compacting Concrete (SCC) has been developed. SCLWC is produced by the replacement of normal coarse aggregates or fine aggregates by Light weight aggregates in SCC. SCLWC comprises the advantage of SCC and LWC. The aim of this paper is to study the mechanical properties of SCLWC ie, to reduce the self-weight of the structure, to reduce the risk segregation and to increase the internal curing. The water absorption of light weight aggregate is more and it holds the water in aggregates for a prolonged time and tends to increase the internal curing of concrete and also increase the segregation resistance[1]. In this study, Fresh and hardened properties of Self Compacting Light weight Concrete of a varying percentage of light weight aggregates of 25% (SCLWC25 - 25% replacement of NCA by LWA), 50%(SCLWC50 - 50% replacement of NCA by LWA), 75%(SCLWC75- 75% replacement of NCA by LWA) and 100% (SCLWC 100- Fully replacement of NCA by LWA) have been determined and compared with Self Compacting Concrete. Zhimin Wua, Yunguo Zhang ,Jianjun Zhengand Yining Ding, 2008, [10], proposed the mix proportion design for SCLWC and its workability. By considering the water absorption of Lightweight aggregates (LWA) ,two mix proportions for SCLWC are designed. The workability of the two type so fresh SCLWC is quantitatively evaluated by the slump flow, V-funnel, L-box and U-box tests. The uniformity of distribution of LWA along the specimen is also evaluated by the column segregation test. Both the types of fresh SCLWC have good fluidity, de-formability, filling ability, uniform aggregates distribution and minimum resistance to segregation. Xi Liu, Tao Wu, Xue Yang and Hui Wei, 2019, [7], have studied the effect of steel, polypropylene fibers and silicafume on the rheological properties, mechanical properties and microstructure of Self Compacting Light weight Concrete Self Compacting Concrete. The Self Compacting characteristic of concrete is evaluated by means of slump flow, V-funnel, L-box and U-box tests. Compression, splitting tensile and flexural tests have been performed to characterize the mechanical properties of SCLC. In addition, a microscopic study on the aggregates / paste and fibers / paste interfaces were also studied using Scanning Electron Microscopy (SEM). It is found that the fresh SCLCs have good fluidity, deformability, filling ability ,uniform aggregates distribution and minimum resistance to segregation and a good bond between aggregates/paste and fibers/paste interfaces were observed.

III. OBJECTIVES OF THE STUDY

The following are the objectives of the study:

- To study the fresh and hardened state properties of Self Compacting Lightweight Concrete and Self Compacting Concrete.
- To achieve the self compaction in concrete with lightweight aggregates.
- To compare the mechanical and thermal performance of Self Compacting Lightweight Concrete with Self Compacting Concrete.
- To find the optimum mix proportion of Self Compacting Lightweight Concrete.

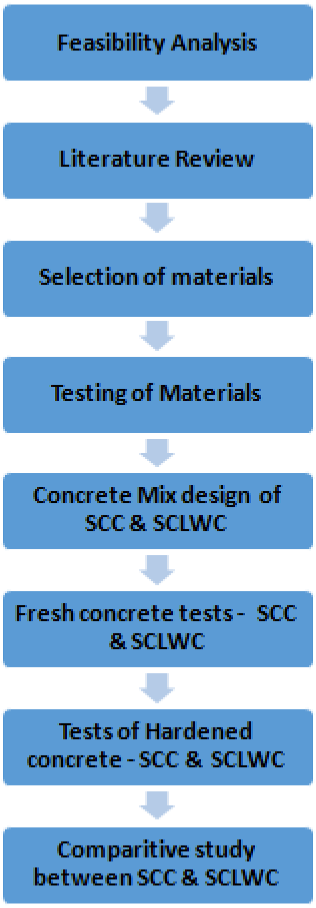
Form ability, filling ability, uniform aggregates distribution and minimum resistance to segregation.

EXPERIMENTAL STUDY

A. Materials

Concrete is a mixture of binder and filler materials. In this experimental study cement, fly ash and water are used as binders and Light weight Expanded Clay Aggregates and M-sand are used as filler material and Super-plasticizer is added to improve the workability.

Fig.1. Methodology of the Study



1. *Cement:* In the present study OPC 53 grade cement is used. The properties of OPC 53 are shown in Table1.

2. *Fly ash:* The fly ash is used as partial replacement of cement in order to increase the pozzolanic activity and to

increase the workability of concrete also improves the filling pores and the durability of concrete [14]. \
The chemical properties of fly ash are shown in Table2.

3. *Water*: The quality of water is the same as that of conventional SCC.

4. *Binder:* In the experiment, Cement and Fly ash are used as binder material (70 % of cement and 30% of flyash). The physical properties of binder material are shown in Table3.

5. *Natural Aggregates:* In this study, 10 mm natural crushed aggregates were used as coarse aggregates. The physical properties of natural coarse aggregates coarse are shown in Table4.

6. *Lightweight Aggregates:* In this study, Lightweight Expanded Clay Aggregate (LECA) of size 10 mm were used as shown in Fig.2, which is manufactured by heating the clay particles at a temperature greater than 1200°C and forms a honey combed structure. The physical properties of LECA are shown in Table5.

Fig. 2. Lightweight Expanded Clay Aggregates.

7. *Fine aggregates:* In the present study, M-sand of size less than 4.75 mm were used as fine aggregates with a uniform grade and powder content of particle size lesser than 0.125 mm are used [13]. The physical properties of M-sand are shown in Table 6.

8. *Chemical admixture:* In the experimental study, High-performance super plasticizer based on Polycarboxylic Ether (Mater Glenium SKY 8233) is used. The properties of Master Glenium SKY 8233 are shown in Table 7.

TABLE1 PROPERTIES OF CEMENT

Properties	**Values**
Chemicals	
Cao	63.40%
SiO_2	20.10%
Al_2O_3	4.60%
Fe_2O_3	2.78%
SO_3	1.30%
MgO	0.60%
Physical	
Specific Gravity	3.14
Fineness	0.06%
Normal Consistency	6
Initial Setting Time	290min
Final Setting Time	460min
Soundness	0.83mm
Mechanical	
Mortar Compression Strength	
f'_c at7days	34.45MPa
f'_cat28days	51.94MPa

TABLE2 CHEMICAL PROPERTIES OF FLYASH

Chemical Properties	**Values**
Cao	10%
SiO_2	49%
Al_2O_3	13%
Fe_2O_3	19%
MgO	9%

TABLE3 PROPERTIES OF BINDER

Properties	**Values**
Physical	
Fineness	0.1%

Normal Consistency	7
Initial Setting Time	365minutes
Final Setting Time	510minutes
Soundness	1.16mm
Mechanical	
Mortar Compression Strength	
f'c at7days	35.76MPa
f'cat28days	58.37MPa

TABLE4 PHYSICAL PROPERTIES OF NATURAL COARSE AGGREGATES

Physical Properties	**Values**
Specific gravity	2.78
Water absorption	0.73%
Bulk density(loose state)	1532kg/m^3
Bulk density(rodded state)	1709kg/m^3

TABLE5 PHYSICAL PROPERTIES OF LIGHT WEIGHT AGGREGATES

Physical Properties	**Values**
Specific gravity	1.42
Water absorption	19.04%
Bulk density(loose state)	689kg/m^3
Bulk density(rodded state)	1000kg/m^3

TABLE6 PHYSICAL PROPERTIES OF M-SAND

Physical Properties	**Values**
Specific gravity	2.68
Water absorption	4.73%
Bulk density(loose state)	1500kg/m^3
Bulk density(rodded state)	1750kg/m^3

TABLE7 PROPERTIES OF CHEMICAL ADMIXTURE

Properties	**Results**
Aspect	Reddish-brown liquid
Relative density	1.08±0.02 at 25°C
pH	≥6
Chloride ion content	<0.2 %

TABLE8 FRESH PROPERTY TEST RESULTS

Mix Notation	Sl**ump Flow(mm)**	**T500 (sec)**	**V-Funnel(sec)**
SCC	625	4.38	7.12
SCLWC25	612.5	4.09	7.49
SCLWC50	580.5	4.53	6.35
SCLWC75	536	5.01	6.52
SCLWC100	522.5	3.42	7.21

Fig. 3. Slump Flow Test.

Fig. 4.T500 Test.

Fig. 5. V-Funnel Test.

IV. MIXTURE PROPORTIONS

Mix Design is a process of determining suitable proportions of various materials constituting the concrete in order to achieve the desired strength, required workability and durability in an economical manner. The Mix Design of Self Compacting Lightweight Concrete (SCLWC) differs from that of conventional concrete. In the mix design, proportions are calculated similar to SCC. The only difference is Lightweight aggregates called LECA is used instead of natural coarse aggregates. The conventional SCC mix design methods can be used for the mix design of SCLWC as it is capable of meeting the multiple requirements of SCLWC [12]. The binder composition of mixes consists of 70% of cement and 30% of fly ash (class F) [9]. A water-cement ratio of 0.45 was constant throughout the experimental study and depends on their percentage of lightweight aggregate content. Water absorption of coarse aggregate in each mix is different. SCC is highly sensitivity aggregate size and grading, so natural coarse aggregates were replaced by lightweight aggregates. In SCLWC mix, natural coarse aggregates were replaced with lightweight aggregates by 25%, 50%, 75%, 100% increment [4]. The proportions of these mixtures are shown in Table 9.

PROPERTIES OF FRESH CONCRETE

The self compaction behaviour of SCLWC was accessed through the test specified under the guideline of the European Federation of Specialist Construction Chemical and Concrete Systems (EFNARC) [11]. These experiments assess the flow-ability, passing ability, filling ability and segregation resistance of concrete through Slump cone, T500 and V-Funnel tests. Flow ability of concrete is determined through slump flow diameter shown in the Fig. 3, filling ability of concrete is determined through T500 (time required to pass the 500 mm diameter ring) shown in the Fig.4, the passing ability of concrete is determined through V-Funnel tests (time required to flow of concrete from the V-Funnel) shown in Fig. 5. The Fresh property tests results for five different mixes are shown in Table8.

SAMPLING AND CURING CONDITION

For compressive, tensile and flexural strength tests, each mix required 3 numbers of cubes of size 150 mm X150 mm X 150 mm for compressive strength test, 3 numbers of cylinder of size 150 mm X 300 mm for tensile strength test and 3 numbers of prism of size 400mm X 100mm X 100mm. The specimens were prepared by pouring the concrete directly in to the moulds without any compaction, de-moulded after 24hrs and allowed to cure until the testing age.

HARDENED PROPERTIES OF CONCRETE

Hardened properties were assessed by compressive, tensile and flexural strength tests. Density and compressive strength for each mix were tested at 7 days using weight balancing and UTM, respectively and the compressive axial load is applied on the cubes at a rate of 140 kg/cm2/min until failure occurs as shown in Fig6, Split tensile strength for each mix were tested at 7days using UTM and the load is applied continuously at the rate of approximately 14 - 21 kg/cm2/min until failure occurs and flexural strength test for each mix were tested at 7 days using UTM as shown in Fig 7 and the load is applied at extreme fibre continuously at the rate of 7kg/cm2/min until failure occurs as shown in Fig.8.

Fig.6.Compressive Strength Test.

Fig. 7. Split Tensile Strength Test.

Fig.8. Flexural Strength Test

TABLE 9 MIX PROPORTIONS

Parameters	**SCC (kg/m^3)**	**SCLWC25 (kg/m^3)**	**SCLWC50 (kg/m^3)**	**SCLWC75 (kg/m^3)**	**SCLWC100 (kg/m^3)**
Binder					
Cement	310.50	310.50	310.50	310.50	310.50
Fly ash	133	133	133	133	133
Water	242	264.20	286.60	309.20	332.50
Aggregates					
Coarse aggregate	1022	756.60	505	252.50	-
Light weight	-	128.33	257.50	285.80	515

aggregate(LECA)					
Fine aggregates(M-sand)	703	703	703	703	703
Chemical admixture					
Super-plasticiser (Master Gelnium SKY8233)	1.32	1.32	1.32	1.32	1.32

TABLE 10 HARDENED PROPERTY TESTS RESULTS OF CONCRETE

Mix Notation	**Density of cube (kg/m^3)**	**Age(days)**	**Compressive Strength (MPa)**	**Tensile Strength (MPa)**	**Flexural Strength (MPa)**
SCC	2372	7	23.54	2.86	5.60
SCLWC25	2186	7	21.43	2.53	5.32
SCLWC50	1963	7	19.66	2.36	5.01
SCLWC75	1757	7	16.47	2.12	4.53
SCLWC100	1553	7	13.35	1.83	3.72

TEST RESULTS AND DISCUSSIONS

A. *Effect of LECA in fresh properties of concrete*

As per IS 10262:2019 Self Compacting Light weight Concrete is designed for SF1 which range between 550mm to 650 mm. Due to higher percentage replacement of natural coarse aggregates by LECA in the mix SCLWC75 and SCLWC100, slump flow diameter falls below the range and its variation is shown in the Fig. 9and for T500 all the mixes ranges between 2s and 5s and satisfies the filling ability of concrete and passing ability of concrete is also satisfied by V- Funnels tests ranges between 5 sand 8s.

B. *Effect of LECA in Hardened properties of concrete*

Among all SCLWC mixes, an increase in light weight aggregates (LECA) resulted in a decrease in mechanical strength and is shown in Fig. 10 a, 10 band 10 c and also decreases in densities when the percentage of LWA is increased. Due to higher water absorption rate of 19.04 %, Lightweight Expanded Clay Aggregates hold the water inside the pores for a prolonged time for internal curing, so that there will be a decrease in strength at initial stage [6].

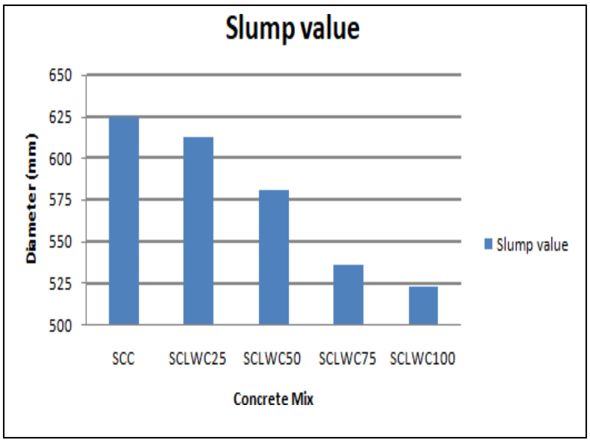


Fig.9. Effect of LECA in Slump Flow Test.

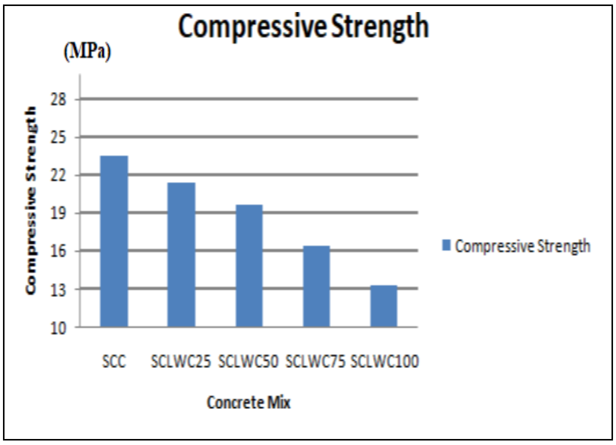


Fig. 10 a. Compressive Strength Test Results.

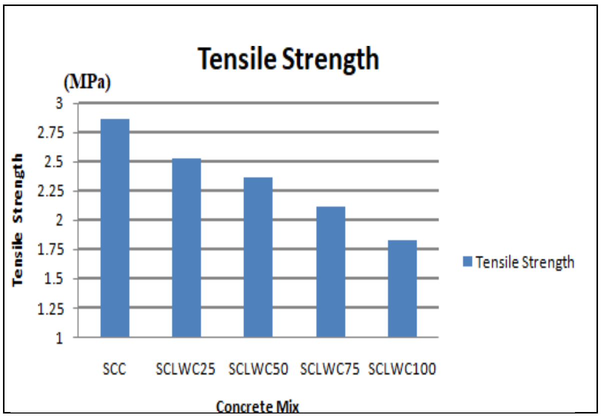


Fig. 10 b. Split Tensile Strength Test Results.

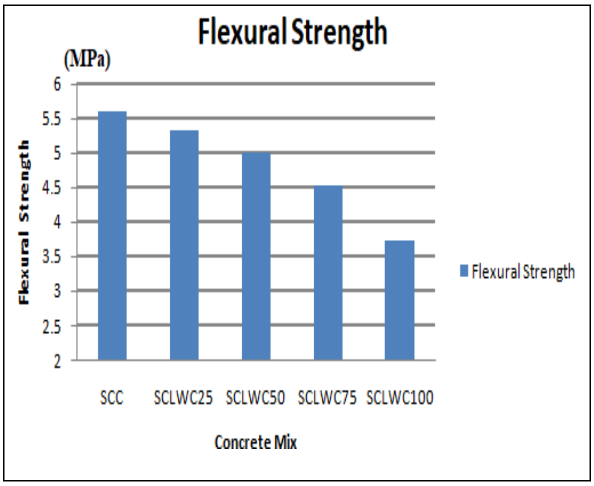


Fig. 10 c. Flexural Strength Test Results.

CONCLUSIONS

The present experiment study serves as a basis in developing and promoting the use of Self Compacting Lightweight Aggregates within India. All SCLWC mixes were compared with SCC based on their fresh and hardened properties. The observations made in the present study are:-

- The increase in Lightweight Expanded Clay Aggregates had a detrimental impact on the mechanical strength of SCLWC. This effect was more significant for lower density concrete mixes such as SCLWC75 and SCLWC100.
- The increase in powder content helps to improve over all stability and segregation resistance of SCLWC.
- SCLWC75 and SCLWC100 showed a decrease in compressive strength by 30% and 40% respectively.
- SCLWC25 and SCLWC50 are good at fresh and hardened properties comparatively. The density of SCLWC25 and SCLWC50 are comparatively lesser than SCC, hence it decreases the self-weight of structure and also reduces the deflection.
- LECA has more water absorption rate, so SCLWC increase the internal curing rate for a prolonged time.

REFERENCES

1. ROBERT M. BROOKS, 2009. Soil stabilization with flyash and rice husk ash. International Journal of Research and Reviews in Applied Sciences, 1(3), 209-217
2. D. D.AMAN, G. AYTAC: Public Green Space and Disaster Relief: the Scope for Effective Policies in Istanbul. In JOURNAL OF ENVIRONMENTAL PROTECTION AND ECOLOGY 19(3), 1047 (2018).
3. YI CAI, BIN SHI, CHARLES W.W. NG, CHAO-SHENG TANG, 2006. Effect of polypropylene fibre and lime admixture on engineering properties of clayey soil. Engineering Geology 87, 230–240
4. A. SECO, F. RAMÍREZ, L. MIQUELEIZ, B. GARCÍA, 2011. Stabilization of expansive soils for use in construction. Applied Clay Science 51, 348–352
5. LAVANYA PRABHA, S., GOPALAKRISHNAN, M., NEELAMEGAM, M.: Development of high-strength nano-cementitious composites using copper slag, ACI Materials Journal, 2020, 117(4), pp. 37–46.
6. SUNDARABALAN, BALASUBRAMANIAN, SHANMUGAM, P., & AHN, Y. H.: Modeling the underwater light field fluctuations in coastal oceanic waters: Validation with experimental data. Ocean Science Journal. https://doi.org/10.1007/s12601-016-0007-y
7. MOHAN, A , VIJAYAN, D.S. , REVATHY, J., PARTHIBAN, D., VARATHARAJAN, R.: Evaluation of the impact of thermal performance on various building bricks and blocks: A review, Environmental Technology and Innovation, 2021, 23, 101577(2021)
8. GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S. (2020). Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In Journal of Environmental Protection and Ecology (Vol. 21, Issue 6, pp. 2153–2163).
9. LAVANYA PRABHA, S., DATTATREYA, J.K., NEELAMEGAM, M., SESHAGIRI RAO, M.V., Investigation of bolted RPC plate under direct tension, Journal of Structural Engineering (Madras), 2009, 36(5), pp. 333–341
10. MOHAN, A., TABISH HAYAT, M.: Characterization of mechanical properties by preferential supplant of cement with GGBS and silica fume in concrete, Materials Today: Proceedings, 2020, 43, pp. 1179–1189.
11. DHARMAR, S., GOPALAKRISHNAN, R., MOHAN, A.: Environmental effect of denitrification of structural glass by coating TiO2, Materials Today: Proceedings, 2020, 45, pp. 6454–6458
12. PRABHA, S.L., SURENDAR, M., NEELAMEGAM, M.: Experimental investigation of eco-friendly mortar using industrial wastes ,Journal of Green Engineering, 2019, 9(4), pp. 626–637