# Experimental Investigation on Lightweight Concrete Slabs

**J. Selwyn Babu, J. Rex**

***Abstract:** The popularity of Lightweight Concrete (LWC) is due to its least density factor and high insulation capability. Use of LWC can diminish the null load of structural members significantly. The rise in the price of civil construction materials, depletionand environmental exploitation has set an alarm for an alternative material. In this study, the normal coarse particulates (CA) was replaced by coconut shell (CS). Since specific gravity of both the materials is different the replacement was done on the volume basis. The properties of coconut shell material which is available in surplus amount and concrete ingredients were studied. Coconut Shell used in concrete has high effectuality on account of its flat surface on one side. In this paper, a study has been made on the flexural performance of lightweight concrete slabs. Slab specimens of size 1300 x 500 x 70mm were designed and casted for various replacement ratios (0%, 25%, 50%, 75% and 100%) of CS. Four point loading test was performed on slabs and parameters such as ultimate moment capacity, ductility factor, energy absorption, stiffness, and cracking pattern were observed.*

***Keywords:** Light weight Concrete, Coconut shell, CA Replacement, Four point Load Test.*

## I. INTRODUCTION

There has been a growing interest in the use of lightweight concrete (LWC) since it has moremerits over the conventional concrete which is obtained from natural particulates. This concretes densityusually ranges from 1400 to 2000 kg/m$^3$whereas for normal-weight concrete (NWC) it is 2400 kg/m$^3$. Eight out of the ten peak producers of Coconut are in the Asia Pacific region where India contributes to 75% of the world's coconut hub. The third major coconut producing nation India has a yearly production of 90% s from Southern India. The average yearly production of coconut is approximate around 15 billion nuts in India. Whenever lightweight particulates are abundantly available locally they can be used as a construction material which reduces the dead load of the structure. In recent years researchers are focussing on achieving a composite material with good durability, low density and high strength.

The demand for modern construction materials with lightweight particulate is growing due to the benefit that lesser density of materials used results in smaller cross section of structural elements and correspondingly the size of foundation is also considerably reduced.

Going forward,the mechanical behaviour of lightweight concrete prepared using coconut shell as partial and full replacement to normal coarse particulate was studied. The effect of lightweight concrete slabs the loss of strength of slabs due to usage of light weight particulates in the concretewould be useful for further research.

## II. MATERIALS USED

Conventionally usedordinary Portland Cement (OPC) of Grade 53 meeting the requirement to Indian Standard IS 12269 (1987) was used as binding material. River side sand confirming to IS 383 (1970) of zone III was used as the fine particulate for the experimental work. Normal stone particulate of maximum size not exceeding 20 mm was used as coarse particulate for concrete. Coconut shell (CS) from the nearby oil mills were collected and were well seasoned. The seasoned shells were crushed manually , sieved and collected. The water from the institute was used for preparing the concrete and curing.

## III. MIX PROPORTIONS

The mix design of lightweight concrete is generally recognized by employing trivial mixes (Shetty M S, 2005). Previously it was explored that the cement quantityranges between 285 and 510 kg/m$^3$ and the substitution of coarse particulate to CS have to be done on volumetric basis. An effort is made by manipulating a concrete mix for a 28 day distinctive compressive strength of 20 N/mm$^2$ as per IS 10262 (2009) and supplanting the coarse particulate with 25, 50, 75 & 100% of CS on volume basis. The particulars of the various mix proportions are given in Table 1. The proportional mixture was nominated as M0 for control concrete (no replacement of CS), M1, M2, M3 and M4 for 25, 50, 75 and 100% surrogates respectively. Due to elevated water absorption capability CS particulates were used in soaked surface dry (SSD) condition i.e., it was soaked in water for 24 hours and air dried before mixing.

**Table 1. Mix Proportions**

| Mix No | Mix Proportion (C:FA:CA:CS) | Cement Content (kg/m$^3$) | W/C ratio |
|---|---|---|---|
| M0 | 1:1.41:2.67<br>(2.67 = C.A) | 425 | 0.5 |
| M1 | 1:1.41:2:0.3<br>(2.3 = 2CA+ 0.3CS) | 425 | 0.5 |
| M2 | 1:1.41:1.33:0.61<br>(1.94 = 1.33CA + 0.61CS) | 425 | 0.5 |
| M3 | 1:1.41:0.67:0.91<br>(1.58 = 0.67CA + 0.91CS) | 425 | 0.5 |
| M4 | 1:1.41:0:1.21<br>(1.21 = CS) | 425 | 0.5 |

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*Test Specimens*

The flexural performance of the slabs, their size and the reinforcementunder a UDL. The dimension of the test sample was selected in order to achieve the requirements of the study with the smallest practical dimensions of specimen. 1300 X 500 X 70mm slabs were designated, which gave a center-to-center span of 1000mm. FourNos.of 8mm bars were placed in the slab with a 150mm center to center spacing. Six nos. of 6mm bars at 250mm spacingused as thedistribution reinforcement and with 20mmclear cover.

*Mixing, Casting, and Curing*

The base materials chosen as ingredients for the concrete block were assorted in an mixer of 0.5tonne capacity. The moulds were prepared and placed on the table vibrator and molten concrete mix was poured in two layers and vibrated to make a uniform mix. Three concrete cubes 150mm x 150mm, werecast to determine the compressive strength. The slabs and cubes were subjecting to curing with wet burlapfor 24 hours andprior to demoulding in the curing tanks for 28 days using wet gunny bags.

## IV. MECHANICAL PROPERTIES

Compression testing machine (CTM) of capacity 2000KN was used to test the specimens under continuous application of loadat the increase in a constant rate. While examining the specimens, precautions were taken to ensure the application axial loading. The compression test was in accordance withIS 516:1959 and IS 5816:1999 respectively.

**Table 2. Mechanical properties of concrete**

| Mix No. | Replacement of CA With CS | Compressive Strength (N/mm$^2$) |
|---|---|---|
| $M_0$ | 0% | 35.80 |
| $M_1$ | 25% | 26.43 |
| $M_2$ | 50% | 22.51 |
| $M_3$ | 75% | 18.82 |
| $M_4$ | 100% | 11.36 |

## V. EXPERIMENTAL PROGRAM

The experiments analysis focuses on the influence of coconut shell (CS) on flexural performance of simply supported (SS) one way slabs. The experimental program involves testing of 10 one-way slabs with end condition simply supported. Table 3 shows the details of test specimen planned in this study.

**Table 3. Details of Slab Specimen**

| Mix No. | Replacement of CA by CS | Slab Specimens |
|---|---|---|
| $SLM_0$ | 0% | 2 |
| $SLM_1$ | 25% | 2 |
| $SLM_2$ | 50% | 2 |
| $SLM_3$ | 75% | 2 |
| $SLM_4$ | 100% | 2 |

*Test procedure and instrumentation*

Lab test was conductedon an inflexiblerigid steel frame as shown in Figure 3 all the four edges are simply supported and a scientific dial gauge was placedcentrally at the bottom face of the block to record the corresponding deflections at various stage and to analyse cracking progress. A steel rectangular section of 20 mm thick was employed to transfer the load and both top and bottom sides were examined to study the sustained damage, such as yielding of reinforcement, punching failure surface and cracking pattern at Fig. 3. Testing of specimens under four point loading.The support distance in slab is 1m.

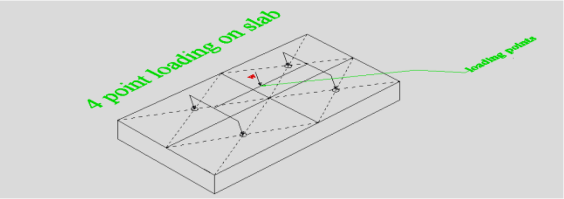

**Figure 1. Load Pattern on Slab**

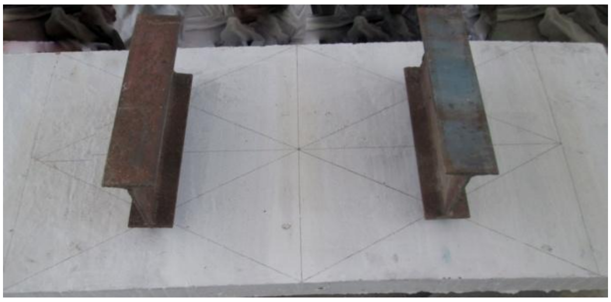

**Figure 2. Four Point Load Distribution**

**Figure 3. Loading Set up for Simply Supported Slab**

## VI. DISCUSSION ON TEST RESULTS

In this Analysisof the load versus middle deflection curves the flexural collapse is characterized by a smooth diminution of the carrying load with cumulative displacement. Flexural collapse is measured to take place in slabs in which the majority of the reinforcement yields before punching occurs and at the same time, the slabs show evidence of huge deflection prior to failure. Flexure failure was defined when an unexpected decrease of the load carrying capacity occurs at summit load (nearly vertical branch of the load deflection curve).Cracking and failure patterns were alsoused to sort out the failure nature. Slabs were measured to fall short in flexure and diagonal cracks extending from the middle of the patch area followed by flexural punching failure occurred as lateral crack at the out surfacesof area, followed by streak cracks extending from the flat area of stability of resistance. The failure was progressive with the rupture of bottom reinforced layer. Punching failure occurred at four point loading test as the load fell abruptly and was released completely.

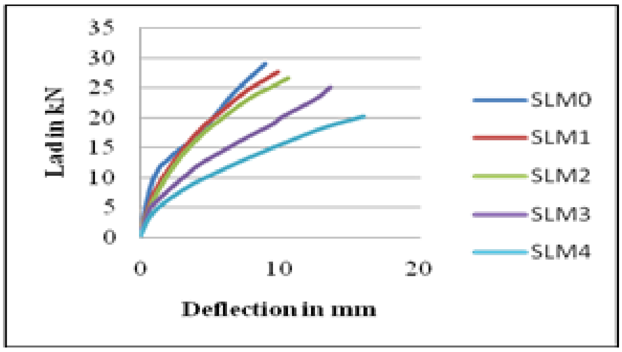

**Figure 4. Load Vs. deflection curves**

## VII. LOAD DEFLECTION RESPONSE

The central deflections are given in Table 4. Thecentral Load Vs. deflection response from the values in in table 4are projected in Figure 4, where the central deflections analogous to first crackload of SLM$_1$ to SLM$_4$ decreases in the series of 9 to 45%, when compared with control slab specimens and the central deflections corresponding to ultimate load of SLM$_1$ to SLM$_4$increases in the range of 10 to 78%,when analysed with control specimens. From the above observations it is clear thatsimilar trend is observed at first crack and ultimate failure stages. But, pace of reduction of deflections at first crack stage is more when compared to ultimate stage. At the firstcracking stage, rate of decrease of deflections are more due to presence of old mortar over the CS, but at ultimate point the rate of reduction of deflections are fewer due to the contribution of steel bars.

**Table 4: Maximum central deflection at first crack load and at ultimate load**

| Slab No. | FIRST CRACKing LOAD (kN) | Deflection at initial cracking load(mm) | Ultimate load (kN) | Deflection at critical crack load (mm) |
|---|---|---|---|---|
| SLM$_0$ | 14 | 2.44 | 29 | 8.95 |
| SLM$_1$ | 12 | 2.23 | 27 | 9.85 |
| SLM$_2$ | 9 | 1.62 | 26 | 10.55 |
| SLM$_3$ | 7 | 1.57 | 25 | 13.57 |
| SLM$_4$ | 5 | 1.35 | 20 | 15.95 |

*Stiffness*

From the curvature path of load to deflection curve, two values of the stiffness of the tested slabs have been obtained. The stiffness values are shown in Table 5. This indicates that stiffness decreases as the percentage of CA with CSreplacement upsurges. Stiffness degradation is the proportional ratio between the ultimate stiffness to the un-cracked stiffness. As the stiffness degradation decreases, the specimen shows higher ductility.

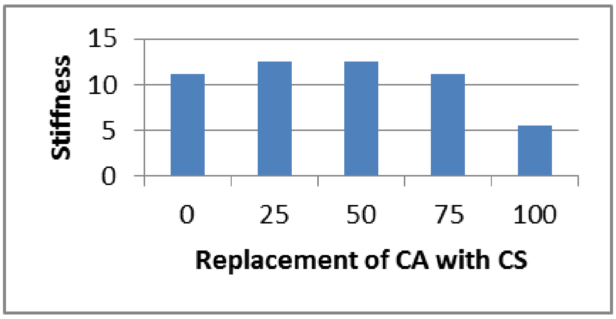

**Figure 5.Effect of percentage replacement of CA with CS on Stiffness of simply supported(SS) slab specimens**

**Table 5. Stiffness**

| NOMENCLATURE OF SLAB SPECIMEN | STIFFNESS (kN/mm) |
|---|---|
| SLM$_0$ | 11.17 |
| SLM$_1$ | 12.47 |
| SLM$_2$ | 12.52 |
| SLM$_3$ | 11.10 |
| SLM$_4$ | 5.52 |

## VIII. ENERGY ABSORPTION

The absorption of energy is explained and the corresponding calculations made from the actual test consequences, and are tabulated in Table 6 and Fig and clearly show the increase in the energy absorption.

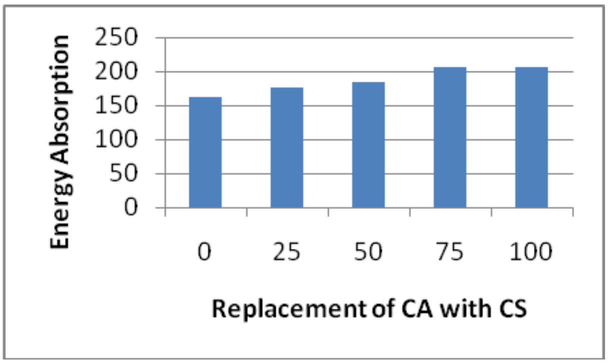

**Figure 6. Effect of percentage replacement of CA with CS on Energy absorption of simply supported slab specimens**

**Table 6. Energy Absorption**

| NOMENCLATURE OF SLAB SPECIMEN | ENERGY ABSORPTION (kNmm) |
|---|---|
| SLM$_0$ | 162.11 |
| SLM$_1$ | 176.32 |
| SLM$_2$ | 183.63 |
| SLM$_3$ | 205.07 |
| SLM$_4$ | 205.62 |

*DUCTILITY FACTOR*

Ductility factor is the represented as the fraction of total deformation at maximum load to the elastic limit deformation. The values estimated from the results are shown in Table 7 and Fig7 clearly shows the increase in the ductility. Hence it has been established that as the infusion percentage of coconut shell upsurges, the energy captivation also increases.

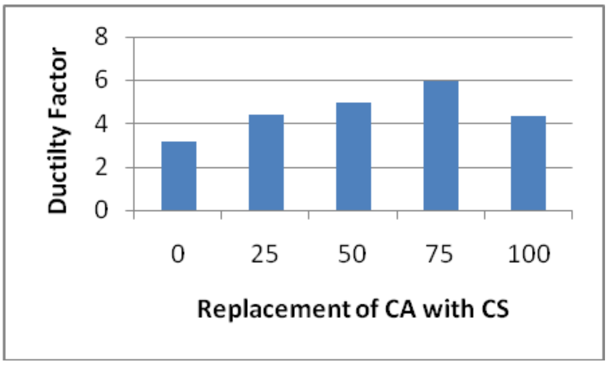

**Figure 7. Effect of percentage replacement of CA with CS on Ductility Factor of simply supported slab specimens**

**Table 7. Ductility Factor**

| NOMENCLATURE OF SLAB SPECIMEN | DUCTILITY FACTOR |
|---|---|
| $SLM_0$ | 3.14 |
| $SLM_1$ | 4.42 |
| $SLM_2$ | 4.95 |
| $SLM_3$ | 5.97 |
| $SLM_4$ | 4.36 |

## IX. CRACKING INCORPORATED FAILURE PATTERNS

The top view image of the sample subjected to is portrayed in Figure 7. The concluding cracking patterns of the $SLM_0$, $SLM_1$, $SLM_2$, $SLM_3$, $SLM_4$ slabs are presented in Figures 9 to 18. It is analysed that the cracks progressing on the bottom face of the slab are radial, penetratinginitiallyfrom the loading point and flowing through the corners. A rectangular punch is found surrounding the four point load occur on top surface and also seen reflected on bottom face with an enlarged area, clearly classifying the wave form type cracks depending on the replacement percentage of CA with CScertain disparities in the amount and positioning of cracks and the edge of the failure wave form at the bottom were marked. Careful inspection publicized that the bottom edge decreases as the replacement percentage of CA with CS increases.The overall cracking progressionexistsindistinguishably for all the operated specimens.

**Figure 8.Simply supported block specimens postFailure**

### 1. BOTTOM SURFACE CRACKS

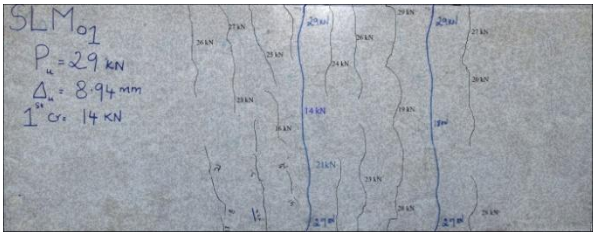

**Fig.9 Cracking pattern of $SLM_{01}$**

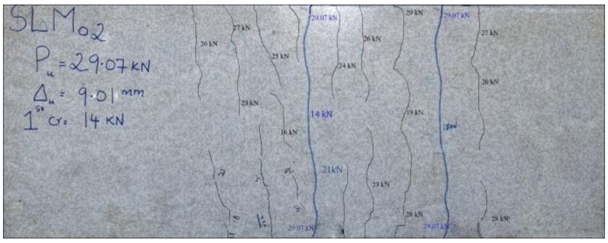

**Fig.10 Cracking patternof $SLM_{02}$**

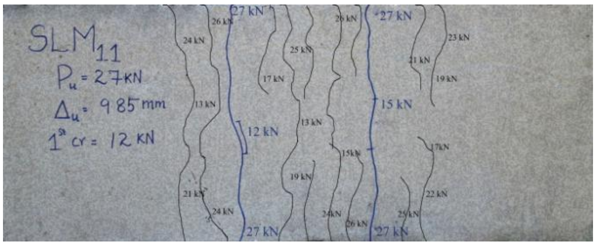

**Fig.11 Cracking pattern of $SLM_{11}$**

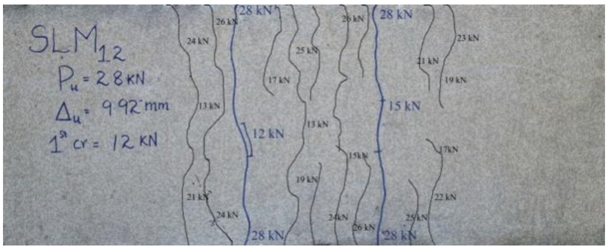

**Fig.12 Cracking pattern of $SLM_{12}$**

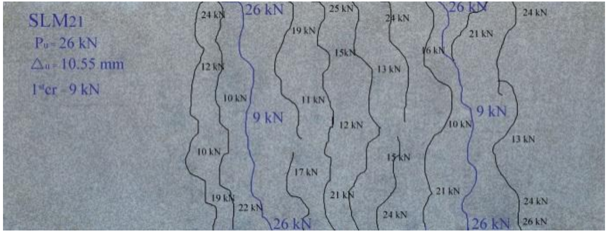

**Fig.13 Cracking pattern of SLM21**

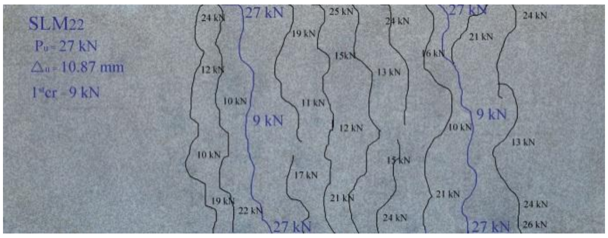

**Fig.14 Cracking pattern of $SLM_{22}$**

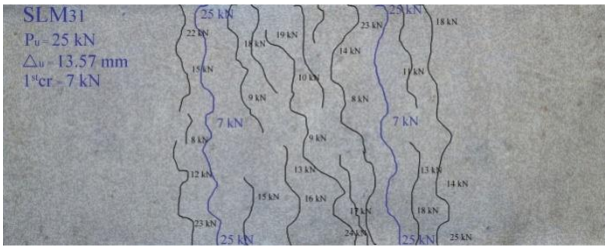

Fig.15 Cracking pattern of $SLM_{31}$

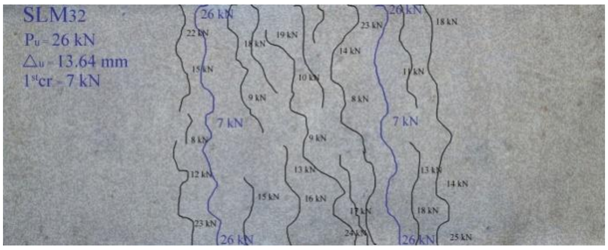

Fig.16 Cracking pattern of $SLM_{32}$

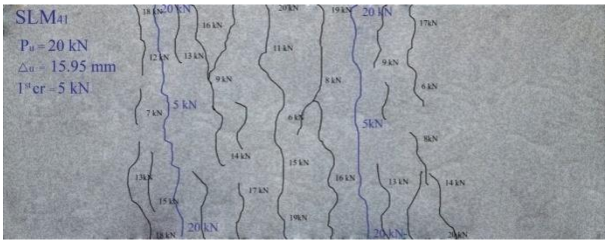

Fig.17 Cracking pattern of $SLM_{41}$

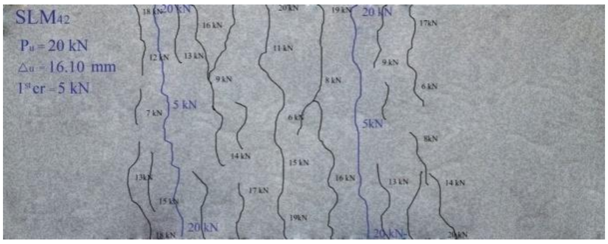

Fig.18 Cracking pattern of $SLM_{42}$

## X. CONCLUSION

The outcome of the experimental procedures substantiates that thefollowing conclusions seem to be valid.

1) By increasing the coconut shell percentage the cube compressive strength can be decreased.
2) The ultimate cubical compressive strength of coconut shell infused concrete (replacing of natural coarse particulate with coconut shell from 25% to 100%) is in the range of 26.43 to 11.36N/mm$^2$, for natural coarse particulate concrete the cube compressive strength is 35.8N/mm$^2$.
3) For slabs with natural CA the first crack load was experienced at 14kN. For slabs with CS it varies from 14 to 5kN for 25 to 100% replacement respectively. The first crack load was 14.28 to 64.29% less compared to normal particulate slabs.
4) For normal coarse particulate slabs the ultimate load is obtained at 29kN, whereas for CS replaced slabs the range is from 29 to 20 kN. The decrease in range is observed as 6.89 to 31.03% for 25 to 100% replacements respectively.
5) Under punching shear it was identified that the increase in the percentage of CS replacement decreases the stiffness and stiffness degradation.
6) The ductility of lightweight concrete block is usually greater than the normal weight concrete block. In CS replaced concrete slabs the ductility factor increased from 29.47 to 75.37% for 25 to 100% replacement respectively.
7) The energy absorption of CS concrete slab specimens increases from 8.77 to 26.84% for 25 to 100% replacement.
8) It is concluded that, when the natural coarse particulate is replaced up to 50% with CS the resulting CS concrete represent same behaviour like the natural coarse particulate concrete in terms of the flexural properties studied in this investigation.
9) These facts justify the effects on usage of these concrete, which can contribute to the waste disposal and assures a green environment.

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