Study of degradation of elastic modulus of light weight concrete

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Abstract. Light weight concrete can be defined as a concrete with low density and thermal conductivity. In this study, less density up to 1908 kg/m³, was achieved using light weight coconut shell aggregates. Conventional concrete was cast using natural aggregates and its density was found to be 2376 kg/m³. The cubes of 150 x 150 x 150 mm size were cast and tested for moist curing period of 7, 14 and 28 days. After confirming the characteristic compressive strength, cylinders specimens (CC, CS10, CS20, CS30) of size 150 x 300 mm were cast and cured. Cured specimens were tested for stress-strain behavior in the CTM and the Young's modulus were calculated. All the combinations resulted in light weight concrete with density around 1900 kg/m³ and degradation of Youngs Modulus is negligible for all the mixes.

Keywords: Cement, coarse aggregate, coconut shell, M-Sand, compressive strength and elastic modulus.

1. Introduction
1.1 General
The present conditions in construction cannot be imagined without concrete. Concrete has become so important that, it is the second most consumed material in the world after water. The major constituents of concrete being the aggregates play a crucial role in the strength attainment. The aggregate occupy about 70% of the concrete's volume which is divided into 25% of fine aggregate and 40% of coarse aggregate. Hence concrete has high density it results in huge self-weight, along with various external loads. Light weight concrete produced by replacing the coarse aggregate, using no fines and air entrainment concepts can be used for its versatility. Though it has been providing low density, it has not been much effective in terms of compressive strength and durability aspects.

Light weight structural concrete possesses the following characteristics which are most suitable for the structural performance: (i) Improved thermal properties. (ii) Reduction in dead loads making savings in foundation and reinforcement. (iii) Reduction in transporting and handling pre-cast units on site etc. All the above characteristics make light weight structural concrete the best choice among the other types.

For structural applications, concrete strength must be greater than 17 MPa. Light weight concrete has better insulation against heat and sound. Because of light weight they are also suitable for earthquake proof structures. Elastic modulus of the light weight concrete may be less than normal weight concrete.

Mahmoud Lasheemand AmrShaat [1] has compared the structural behaviour of light weight concrete slabs with that of the conventional concrete slabs. It was found that light weight slabs showed yielding and ultimate strengths almost equal to conventional concrete slabs. The findings of the study shows
that the effective slab width for ultimate limit state calculations should be different from that used for serviceability limit states. The elastic modulus of light weight concrete is found to be less than that of normal weight concrete. Khandaker M. Anwar Hossain [2] concentrated on workability, strength and durability properties of pumice based light weight aggregate concrete. The cement being replaced with volcanic ash. It was concluded that blended cement based light weight concrete has showed reduced shrinkage and high thermal resistance. Husain Al-Khaiat[3] studied the characteristics of light weight concrete and normal weight concrete in both hot dry and hot humid coastal conditions. It was found that light weight concrete has quick initial setting phase compared to normal weight concrete. Apekshakanojia and Sarvesh [4] studied about the performance of coconut shell as coarse aggregate in concrete. The experiment for compressive strength has been carried out and found that the 7 day strength for light weight concrete has been reducing drastically on increase in the percentage of replaced coconut. An optimum percentage of 30% has been decided in order to achieve a moderate strength in comparison with conventional concrete. Sherif Yehia [5] concentrated on strength and micro structural characteristics of light weight concrete. It was found that 20% of partial replacement of coarse aggregate with light weight aggregate decrease the compressive strength. It was concluded that addition of mineral admixtures would enhance the strength properties.

1.2 Research Significance

From the earlier studies it was concluded that waste coconut shell could be effectively used for replacing the conventional aggregates. The present study focuses on the density, compressive strength and elastic modulus of the light weight concrete. Partial replacement of coarse aggregate with waste coconut shell at different proportions namely 10%, 20% and 30% was concentrated.

2. Materials used

Ordinary Portland cement of grade 53, Potable water, M-sand, coarse aggregates and coconut shell were used as constituents of concrete. Waste coconut shell has been used as a partial replacement of conventional coarse aggregate.

2.1 Cement

Ordinary portland cement (Dalmia) of grade 53 procured from local suppliers was used for the investigation. The cement being a binder material helps to bind the fine and coarse aggregate together and also filling the voids between aggregates. Cement had a specific gravity of 3.1 with consistency 31% and setting time as 32 minutes [6].

2.2 Fine aggregate

M-sand has been used as fine aggregate. The fineness modulus and specific gravity are 4 and 2.65 respectively confirming to zone-II as per IS :383-1970. [7]

2.3 Coarse aggregate

Crushed coarse aggregate of size 20mm were collected from local quarries. The aggregates have been tested as per IS: 2386 (part 1)-1963[8] and surface quality description of the aggregate are classified as per IS:383-1970. The gradation of the coarse aggregate (CA) and coconut shell (CS) is shown in Figure1.

2.4 Coconut shell aggregate

The waste coconut shell were collected from the nearby oil mill factories and hotels. The crushed coconut shells are as shown in Figure 2. The properties of the coconut shell and coarse aggregate were shown in table 1.

| S.No | Property           | Coconut shell | Coarse aggregate |
|------|--------------------|---------------|------------------|
| 1    | Specific Gravity   | 2.65          | 2.66             |
| 2    | Water Absorption   | 18.68%        | 0.49%            |
| S.No | Property          | Coconut shell                                   | Coarse aggregate |
|------|------------------|------------------------------------------------|------------------|
| 3    | Surface Texture  | Smooth inner surface and rough outer surface   | Rough            |
| 4    | Shape            | Flaky                                          | Angular          |
| 5    | Impact Value     | 26.54%                                         | 20.13%           |
| 6    | Crushing Value   | 18.03%                                         | 22.86%           |

Figure 1. Fineness modulus of coarse aggregate and coconut shell.

2.5 Methodology
Mix proportion arrived for M40 concrete was 1 : 1.46 : 2.54 with W/C ratio 0.4 [9]. Total of 36 cube specimens (150 mm x 150 mm x150 mm) were cast for checking the compressive strength at 7, 14 and 28 days of moist curing. Prior to curing the cubes were tested till failure Compression Testing Machine (CTM) of 3000 kN capacity. For all the combinations the cylinder specimens (150 mm x 300 mm) were cast to test for stress-strain characteristics. The compressometer was fitted to the cylinders to pick the decrease in length for each load increment. Deflection at interval 5 kN load was recorded. Figure 3 shows the cast specimens Figure 4 shows the elastic modulus test on cylinders and Figure 5 shows the compressive test on cube specimen.

Figure 2. Crushed coconut shell.

Figure 3. Cast specimens.
3. Results & Discussion
Conventional concrete was partially replaced for coarse aggregate with coconut shell aggregate. The density, compressive strength and elastic modulus are compared.

3.1 Fresh concrete properties
Coconut shell aggregate concrete M40 grade has better workability because of smooth measures. The demould weight density for conventional concrete for different curing period are compared in Table 2. The demould density after 28 days of moist curing are as shown in Table 3. The increase in percentage replacement shows a gradual decrease in density of specimens.

### Table 2. Properties of conventional concrete

| ID | Density (kg/m³) |
|----|-----------------|
| CC7 | 2257.03 |
| CC14 | 2269.62 |
| CC28 | 2376.29 |

### Table 3. Properties of coconut shell concrete

| ID | Density (kg/m³) |
|----|-----------------|
| CS10 | 2133.33 |
| CS20 | 2068.14 |
| CS30 | 1985.18 |

3.2 Hardened concrete properties
The strength properties like compressive strength and elastic modulus of coconut shell concrete was carried out for CC, CS10, CS20 and CS30 coconut shell aggregate concrete.

#### 3.2.1 Compressive strengths

Average compressive test results of the specimens are as shown in Table 4. The test specimen is shown in Figure 4. Even though the replacement resulted in decrease in target strength, the values are nearing 40 MPa.

### Table 4 - Compressive strengths of conventional and coconut shell concrete [10]

| Type of concrete | % of replacement | Compressive strength(N/mm²) |
|-----------------|-----------------|-----------------------------|
| CC              | 0               | 46.37                       |
| CS10            | 10              | 39.58                       |
| CS20            | 20              | 35.20                       |
| CS30            | 30              | 33.84                       |

#### 3.2.2 Elasticity modulus of coconut shell concrete

The compressive test was carried out confirming to [10], to obtain the stress strain curve and modulus of elasticity of concrete. Stress strain behaviour for CS10, CS20 and CS30 are compared in Figure 6. The standard value for M40 concrete is $3 \times 10^4$ MPa. The elastic modulus of the specimens are displayed in Table 5. Comparison shows that there is no major degradation of elastic modulus for lightweight concrete specimens.
Table 5 - Elastic modulus of coconut shell concrete [10]

| % Replacement | Young’s Modulus (MPa) |
|---------------|------------------------|
| CS10          | $4 \times 10^4$         |
| CS20          | $3 \times 10^4$         |
| CS30          | $2.5 \times 10^4$       |

Figure 6: Comparison of stress-strain curves.

4. Conclusion
Convention concrete is partially replaced for coarse aggregate using waste coconut shell. Studies has been carried out to check the light weight density achieved and to analyse the compressive and elastic modulus of the coconut shell based light weight concrete.

From the test results the following conclusions have been summarized:
1. The coconut shell replaced cube with 30% replacement (CS30) has achieved the optimum light weight density of 1908 Kg/m³.
2. Compressive strength for cube specimen with 20% replacement (CS20) was restoring the strength to that of design strength.
3. Compressive strength could be enhanced with usage of both mineral and chemical admixtures.
4. The degradation of Young’s modulus for all the specimens was negligible compared to the standard value for conventional concrete.

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