Experimental Investigation on Structural Lightweight Concrete Using Expanded Clay Aggregates

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ABSTRACT: Conventional concrete has a large self-weight, which is one of its downsides. In the past, there have been several efforts to make concrete lighter and more efficient as a building material. In this work, we try to figure out how different amounts of light expandable clay aggregates (LECA)—25, 50, 75, and 100% by weight—affect the strength qualities of modified M20 grade concrete. Several tests are performed on the modified concrete after 28 days, including compressive strength, split tensile strength, flexural strength, modulus of elasticity, and in-plane shear strength by mode-II fracture test. The results of these tests are then compared. The outcomes are seen as quite acceptable.

Keywords: LECA(light weight Expandable Clay Aggregate), , compressive strength, split tensile strength, modulus of elasticity, flexure, In-plane shear strength

1. INTRODUCTION:

The dead weight acting on buildings becomes crucial when structures are developed in poor soils, and there are great benefits in lowering the density of concrete. Concrete created using natural aggregates often has a higher density, which is problematic. The creation of artificial surfaces that are both lightweight and durable has received more focus in recent years. Materials that have the same characteristics as aggregates found in nature. There are many benefits of using lightweight aggregate in oncrete. Among them, you may find the following: (a) Less dead load means smaller footings and a lighter, more compact top structure. Cement amount and reinforcing might both be reduced as a consequence of this. (b) More compact and lightweight pre-cast elements necessitating less bulky and costly transportation and handling machinery. (c) Lessening the dimensions of columns, slabs, and beams to make more room. (d) Thermally efficient. (e) Fire resistance is improved.

LECA, short for lightweight expandable clay aggregate, is made by rotating kiln heating clay particles to 1200 °C. The many air gaps both within and between the aggregates are responsible for LECA's light weight. Depending on the size of the particles, the density of aggregates may vary between 380 and 710 kg/m^3. With a value between 0.09 and 0.101, it provides excellent thermal insulation. In addition to being fireproof and insulating, it can withstand both acidic and basic liquids. Road building, floor and roof slopes, sewage systems, water purification systems, prefabricated panels and slabs, and many other applications make use of LECA. Reduced demand for natural aggregates, which are becoming more rare, is a direct result of LECA's use. In comparison to natural aggregates, LECA is easier to transport due to its low weight.

2. REVIEW OF LITERATURE

T. Parhizkar, et.al (2011) [1] reported the results of an experiment that examined the characteristics of lightweight aggregate concretes including volcanic pumice. In order to achieve this goal, two types of lightweight concrete were constructed and their physical/mechanical properties and durability were tested. One kind of concrete was lightweight coarse with natural fine particles, while the other was lightweight coarse and fine aggregates concrete. Drying shrinkage, compressive strength, and tensile strength all found that these lightweight concretes fulfilled the structural lightweight concrete standards.

Sivakumar & B. Kameshwari (2014) [2] the findings of an ongoing experiment to create lightweight concrete using mineral additives such as fly ash, bottom ash, and light expanded clay aggregate were detailed in a paper. Experiments were conducted on concrete mix M20 to determine the optimal dosage of mineral admixtures for compressive strength, flexural strength, and split tensile strength. Cement was replaced with fly ash, fine aggregate with bottom ash, and coarse aggregate with light expanded clay aggregate at rates of 5%, 10%, 15%, 20%, 25%, 30%, and 35% in each mix. The results were evaluated after 7, 28, and 56 days.

V. Swamynath & K. Muthumani (2017) [3] gave structural lightweight concrete a comprehensive overview. The building method used will determine the lightweight aggregates to be used. There are a variety of structural, non-structural, and infill uses for lightweight aggregate.

Prakash Desai, et.al [4] arrived at double central notched specimen geometry which fails in predominant Mode-II failure; they also made finite element analysis to arrive at stress intensity factor. Using this DCN geometry lot of experimental investigation using cement paste, mortar, and plain concrete was done.

Swamy R.N& Lambert G.H (1984) [5] researched lightweight aggregates and shown that, with the addition of certain chemical and mineral admixtures, lightweight concrete has the same load-bearing capacity as conventional concrete and a much higher thermal efficiency.

T. Sonia and R. Subhashini [6] I studied the mechanical properties of lightweight concrete M25 mixes with different percentages of natural aggregate and fly ash replacement. The mixes included varying amounts of fly ash (15%) and cement (20%). The optimal ratio was 15% fly ash to 40% natural aggregate and LECA (40%).

Objectives of the study

1. Determining solution to avoid rapid depletion of natural resources used in construction industry by using alternate aggregates.
2. By replacing coarse aggregate in concrete with light weight aggregate to produce light weight concrete.

3. MATERIALS USED

The following materials were used for preparing the concrete mix.

1. ACC cement of 53 grade
2. Fine aggregate i.e sand
3. Coarse aggregate
4. Light expandable clay aggregates (LECA)
5. Water

3.1 Cement: ACC 53 grade cement with specific gravity 3.26 was used as binder.

3.2 Light Expandable clay aggregates: LECA is an acronym term for (Light Expandable Clay Aggregate) which is produced in rotary kiln at about 1200 degree centigrade. The base material is plastic clay which is extensively pre heated. Light Expandable Clay Aggregate is procured from Nexcus Buildcon Solution, India.

Specific gravity	:	1.18
Aggregate Size mm	:	10-12 mm
Bulk Density	:	645 kg/m^3
Shape	:	Round pellets

3.3 Water: This experimental inquiry has made use of the local drinking water, which is devoid of acids, pollutants, suspended sediments, etc.

4. Casting of specimens:

Using the ISI approach, which yields a mix percentage of 1:1.58:2.88 with a water-cement ratio of 0.50, the M20 concrete mix was created. The experimental program began with cleaning and brushing all inside sides of steel moulds measuring 150x150x150 mm using machine oil. This would make it easier to remove the specimens subsequently. The mixture began with cement, fine and coarse aggregate, and different ratios of Light Expandable Clay. A thorough hand-mixing of all of them was performed. Three standard 150X150X150 mm cube specimens and twelve DCN specimens were cast with aggregate replacements of LECA varying in percentages from 0% to 100%. Six cylinders were cast with the same mixes; three of these cylinders were used to determine the split tensile strength and the other three for the compressive strength. Furthermore, in order to determine the flexural strength, three batches of 500mm X 100mm X 100mm beams were cast for each mix. A total of three layers of concrete were poured into the moulds, and to prevent honeycombing, each layer was crushed with a tamping rod 25 times. After filling the moulds to capacity, the specimens were placed on the table vibrator. All specimens and other castings were subjected to a steady vibration for 7 seconds. After three hours of meticulous casting, the steel plates that had formed the notches were gently and neatly removed. After 28 days of curing, the specimens were removed from water and let to dry for a few hours in the shade.

5. Testing of specimens

5.1. Compressive strength of cubes: By dividing the force taken by the specimen by its cross-sectional area, the compressive strength of cubes was determined. Table 1 shows the compressive strength values at various percentages of LECA substitution, while Figure 2 shows the same data graphically.

5.2 Flexural Strength: One way to evaluate the concrete's tensile strength is by looking at its flexural strength. How well an unreinforced concrete beam can withstand bending before giving way is what this metric measures. We used the industry-standard two-point loading procedure to measure the flexural strength. The flexural strength was determined in this investigation using three 100x100x500 mm beams.

5.3 Cylinder Compression Test: The cylindrical specimens were tested by carefully positioning them vertically between the compressive plates of the 3000KN digital compression testing equipment, ensuring that their axis remained parallel to the ground. The plates and the cylinder were separated by narrow strips of plywood, which served as packing material. These strips were then compressed to absorb the stress.

5.4 Cylinder Split tensile Test: This test used a 3000KN digital compression testing equipment, which required the cylindrical specimens to be held horizontally with their axis parallel to the plates that apply compression. The plates and the cylinder were separated by narrow strips of plywood, which served as packing material. These strips were then compressed to absorb the stress. A constant force was exerted on the cylinder until it broke.

5.5 Modulus of elasticity: The theoretical modulus of elasticity was calculated using IS code formula.

$E=5000*\sqrt{f_{ck}}$ [9] Where,

f_{ck} = Characteristic Compressive strength of concrete in N/ mm^2 The modulus of elasticity values were also calculated from the other empirical formula suggested by Takafumi[10] for light weight concrete.

$$E=k_1k_2*1.486*10^{-3}*f_{ck}{}^{1/3}*\gamma^2$$

Where f_{ck} = Compressive strength in N/mm^2, γ = Density in Kg/m^3, K_1 =0.95 (correction factor corresponding to coarse aggregate), K_2 =1.026, (correction factor corresponding to mineral admixtures).

The values of the modulus of Elasticity are tabulated in table 5 and values are graphically presented in figure 5.

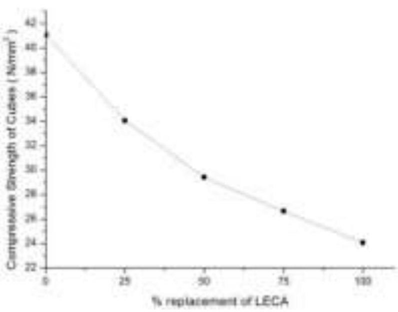
5.6 Mode II fracture test: In order to evaluate DCN specimens measuring 150x150x150mm, notches were inserted into one third of the middle area of the casting process. The DCN cubes underwent a Mode II fracture test on a computerised compression testing equipment with a load capacity of 3000KN. A loading rate of 0.5 KN/sec is being applied. Table 8 displays the outcomes of the tests, and figure 6 provides a visual representation of the data. In order to ensure that the central one third of the structure could be punched or sheared through along the notches when the load was applied, steel supports with a square cross section were placed at the bottom of the notches and a uniform distribution of weight was applied over that area.

5.6.1 In-Plane shear strength: The in plane strength of modified concrete was calculated using the formula

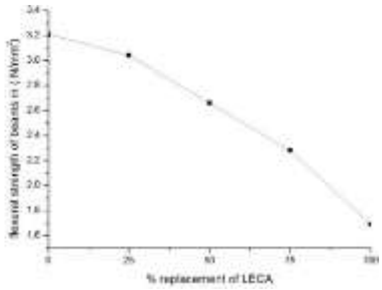
In plane shear strength = P/2*d(d-a) N/mm^2
Where P= Ultimate load in mode-II shear
d= size of the cube = 150mm
a= depth of notch in mm

The values of plane shear strength of modified concrete for various a/w ratios in mode-II shear are presented in Table 9 and values are presented graphically in figure 7.

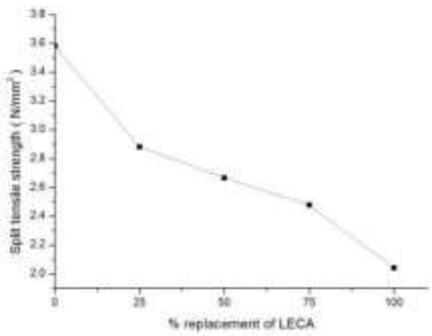
6. RESULTS and ANALYSIS



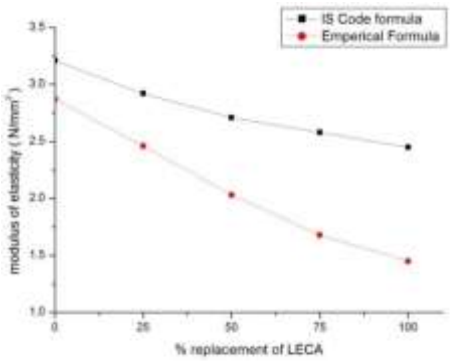
Compressive strength of cubes



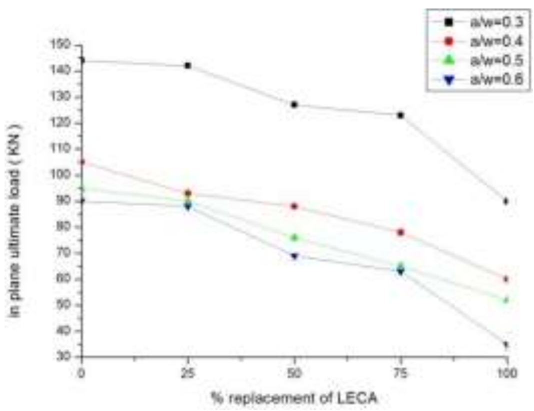
Flexural strength of beams



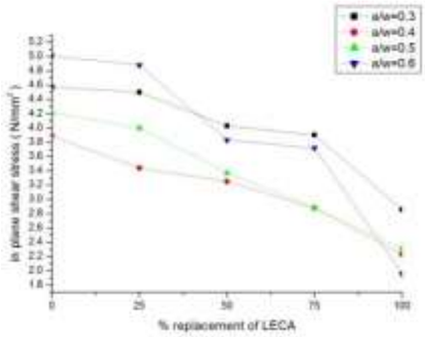
Split tensile strength of cylinder



Modulus of elasticity



Super imposed loads for different a/w ratios



In plane shear stress for different a/w ratios

7. CONCLUSIONS

1. The target mean strength of M_{20} concrete is 26.60 N/ mm^2. From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Light Expandable Clay aggregate is 24.06 N/ mm^2 which is slightly nearer to the target mean strength of M_{20} concrete and in a similar case it can be observed that compressive strength of 26.64 N/mm^2 is achieved even with 75% replacement of natural aggregate with LECA which is nearer to the target mean strength of M_{20} concrete.
2. From the test results it can be observed that flexural strength, split tensile strength and density decreases with increase in replacement level of LECA.
3. From the analysis of test results it is observed that in plane shear stress decreases with increase in replacement level of LECA.
4. The light weight concrete prepared by 100% Light expandable Clay Aggregate as coarse aggregate is in no way inferior to the natural aggregate.

8. REFERENCES

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