Abstract: Lightweight concrete can be produced by replacing the normal aggregate with lightweight aggregate either partially or fully, depending upon the requirements of density and strength. The present study covers the influence of different aggregate curing conditions and admixtures on the strength of lightweight expanded clay aggregate concrete under normal curing and vacuum curing with and without addition of silica fume. The grade of the concrete is M40. The lightweight aggregate used is LECA, an expanded clay aggregate. Investigations were carried out up to a replacement of 50% of coarse aggregate. The workability and strength at different ages are presented.

Index Terms: Lightweight Expanded Clay Aggregate (LECA), Admixtures, Density, workability, Compressive strength

I. INTRODUCTION

Concrete is one of the most widely used construction material in modern constructions and infrastructure needs. It is used as a construction material because it can be moulded into any structural form and shape. The density of normal concrete ranges from 2200 to 2600 Kg/m³, self-weight occupies a very large load coming on the structures critically in cases such as weak soils and tall structures.

Lightweight concrete plays a major role in reducing the density of the concrete. It is used worldwide in many construction projects where soil is weak and heavy constructions are to be done, Lightweight concrete density varies from 300 to 1800 Kg/m³, LWC can be produced by using lightweight materials like Lightweight Expanded Clay Aggregate, Pumice stone, expanded shale, Perlite etc.

Structural lightweight aggregate can be produced naturally or from environmental waste. Use of these aggregates can reduce the density of concrete, the self-weight of the structure and it helps to construct larger precast unit.

The main objective of the present experimental study is to investigate the properties of lightweight expanded clay aggregate concrete (LECAC) under normal curing conditions and vacuum curing.

II. LITERATURE REVIEW

R.N.Rajprakash, A.Krishnamoorthi [1] studied the effect of partial replacement of coarse aggregate (Jelly) in concrete by Light weight coarse aggregate (LECA). They have partially replaced natural aggregates by using LECA by 20%, 40%, 60%, 80% and 100%. Compressive strength of 29.85 N/mm² at 20% LECA replacement for a water curing for a period of 28 days.

M.MAHDY [4] investigated the Mechanical properties, workability of lightweight concrete using LECA as lightweight aggregate. High strength concrete is achieved by treating LECA with Silica fume solution of different concentrations (10% & 20%) by weight of mixing water. Three silica fume levels of different percentage’s (5, 10, and 15 %) and two coarse to total aggregate content (0.48, 0.65) by volume were used. Results showed that use of cured LECA increased the compressive strength and flexural strength.

N.Sellakkannu and C.Tamilarasan [6] examined the properties of concrete which were determined by tests conducted on concrete such as Concrete Density, Porosity, Ultrasonic pulse velocity and Compressive & Split tensile strength. The test results and examination of the concrete samples using Optical Microscope shows that there is a strong bonding between the cement paste and LECA.

Serkan Subasi [12] studied the effect of fly ash in High strength light weight aggregate concrete produced with LECA. The Physical and Mechanical properties of the concrete were investigated. Concrete mixes with 350, 400 and 450 kg/m³ cement content and with 0%, 10%, 20% and 30% flyash as replacement of cement content were casted.

They found that Physical and Mechanical properties are enhanced by adding mineral admixtures, Ultrasonic pulse velocity is increased by 3%, Compressive strength is increased by 8%; and Split tensile strength is increased by 9% for the concretes with various cement contents.
III. EXPERIMENTAL STUDY

A. Materials

This section gives the details of the characteristics of the different materials used in this experimental study.

Cement

Cement is used as a binding material. In this experimental study Ordinary Portland Cement of Grade 53 is used. The cement is found to be conforming to various specifications of IS 12269-1987. The physical properties of cement are tested and the results are tabulated in the Table I as per IS 4031-1998.

| Test                      | Result      |
|---------------------------|-------------|
| Specific gravity          | 3.10        |
| Standard consistency      | 34%         |
| Initial setting time      | 45 minutes  |
| Final setting time        | 489 minutes |
| Bulk density              | 1440 kg/m³  |
| Fineness of cement        | 2.4 %       |

Aggregates

Aggregates are the inert granular materials such as sand, gravel, or crushed stone that are mixed along with water and Portland cement to make concrete. They are essential ingredients in making concrete.

Coarse aggregate (Gravel)

In present experimental work coarse aggregate passing through 12mm IS sieve and retaining on 10mm IS sieve is used. Certain care is taken while choosing coarse aggregate and it is seen that it is free from impurities. Characteristic tests are conducted to find out the properties of the coarse aggregate and are tabulated in the Table II.

| Test                      | Result          |
|---------------------------|-----------------|
| Fineness modulus          | 6.41            |
| Specific gravity          | 2.43            |
| Bulk density              | 1420 kg/m³      |
| Water absorption          | 0.6 %           |

Coarse aggregate (LECA)

Lightweight expanded clay aggregate (LECA) is used as the lightweight aggregate which is of size 8 to 12mm. LECA is free from impurities. Characteristic tests are also performed on LECA and the results are tabulated in Table II.

| Test                      | Result          |
|---------------------------|-----------------|
| Fineness modulus          | 5.84            |
| Specific gravity          | 0.71            |
| Bulk density              | 410 kg/m³       |
| Water absorption          | 30 %            |

Fine aggregate

Fine aggregate used in this experimental work is locally available river sand, care is taken to see that the sand is free from impurities, waste stones and to remain clean. Sand used is confirming to the requirements of IS: 383-1970. Characteristic tests are conducted on fine aggregate and the properties of fine aggregate are tabulated in Table III.

| Test                      | Result          |
|---------------------------|-----------------|
| Fineness modulus          | 3.085           |
| Specific gravity          | 2.59            |
| Bulk density              | 1570 kg/m³      |
| Water absorption          | 1%              |

Mineral Admixture

Micro silica, as a replacement to the cement, is used as the mineral admixture in order to improve the strength of the lightweight concrete and also to avoid segregation of concrete.

Chemical Admixture

Admixtures, natural or manufactured chemicals, are added to the concrete before or during concrete mix. Admixtures are used in the tests have the qualities of air-entraining, water reducers, water reducing accelerators or retarders. Use of admixture will improve the workability of the concrete strength.

In the present study, CONPLAST SP 430 is used. It is used to improve the workability of the concrete and also specially formulated to give high water reductions upto 25% without loss of workability and also reduce permeability to give high quality concrete.

Water

Water is the most important ingredient of concrete which helps to bind the cement content and aggregates. Clean potable water is used for concrete mixes.

B. Mix Design

In the present study, the mix design of the Lightweight expanded clay aggregate concrete (LCEC) was done using the code IS:10262-2009 and IS:456-2000. In the coarse aggregate content of the mix, 50% of the normal aggregate is replaced with LECA to obtain lightweight concrete in the present studies. The chemical admixture i.e. SP 430 is used in order to improve workability and mineral admixture.
(Micro silica) is added in addition to cement in strength development of LECAC.

**Vacuum curing of Coarse aggregate (LECA)**

The amount of water absorbed by LECA while curing is less as it floats in the water. In order to improve the water absorption and fill the air voids, LECA is placed in the vacuum chamber and the moisture is removed by passing vacuum through the clay aggregate. This vacuum curing is done for 24 hours and the air voids present in the clay aggregate is filled with the water which results in the increase in the water absorption there by increasing the compressive strength of the LECA concrete.

**Casting of specimen**

The fresh concrete was casted using different water-cement ratio i.e. 0.35, 0.40, 0.45 and different super plasticizer dosage for each w/c ratio. For each mixture, cube cylinder and prism specimens of size 150x150x150mm, 150x300mm and 100x100x500mm were casted respectively. The composition of LWC mixtures are represented in Table IV.

**Curing of specimens**

All the casted concrete specimens were cured by placing the specimens in the curing tank containing water for a period of 28 days. The LECA was also cured using vacuum curing method by placing it in a vacuum chamber for 24 hours and then used in casting of LWC.

### IV. Experimental Methodology

The casted concrete specimens are tested as per standard testing procedures. The Experimental Results of the Lightweight expanded clay aggregate concrete such as Workability, Unit weight, water absorption of LECA, compressive strength, split tensile strength, Flexural strength of the LECA Concrete (LECAC50) is represented in this section.

#### A. Water absorption of LECA

The water absorption of LECA aggregate is found out by using water curing, vacuum curing. The results are given in table V.

#### B. Workability

The workability of the LECAC50 is measured by conducting the Slump cone test using standard Procedure prescribed in IS: 1199 - 1959 and given in Table VI.
C. Compressive Strength

Cubes of size 150x150x150mm were casted and allowed for curing in curing tank for 28 days and 56 days. And tested in Automatic compression testing machine of 2000KN capacity.

D. Flexural strength

Prisms of size 100x100x500mm were casted and allowed for curing in curing tank for a period of 28 days and tested in flexural testing machine.

E. Split tensile strength

Cylinders of size 150x300mm were casted and allowed for curing in curing tank for 28 days and tested in the

V. EXPERIMENTAL RESULTS

TABLE V. COMPARISON OF WATER ABSORPTION OF LECA

| Property                  | Normal LECA | Partially saturated surface dried LECA | Vacuum cured LECA |
|---------------------------|-------------|----------------------------------------|-------------------|
| Water absorption          | 0.85%       | 14%                                    | 75%               |

TABLE VI. WORKABILITY OF LECAC50

| Trial Mix No.                  | W/C ratio | Slump(mm) |
|-------------------------------|-----------|-----------|
| Partially Saturated Surface Dried LECA |           |           |
| M1                            | 60        |           |
| M2                            | 63        |           |
| M3                            | 78        |           |
| Partially Saturated Surface Dried LECA with Micro Silica | | |
| M4                            | 48        |           |
| M5                            | 52        |           |
| M6                            | 58        |           |
| Vacuum Cured LECA             |           |           |
| M1                            | 52        |           |
| M2                            | 69        |           |
| M3                            | 92        |           |
| Vacuum cured LECA with Micro Silica | | |
| M4                            | 46        |           |
| M5                            | 60        |           |
| M6                            | 95        |           |

The compressive strength of various proportions of LECAC50 for different curing periods such as 28 days and 56 days are analyzed. The results are tabulated in the Table VII. The split tensile and flexural strength results are tabulated in Table VIII, Table IX respectively.

TABLE VII. COMPRESSIVE STRENGTH OF LECAC50

| LECA TYPE                              | Mix | Compressive strength (MPa) | % increase in strength |
|----------------------------------------|-----|---------------------------|-----------------------|
| Partially Saturated Surface Dried LECA | M1  | 33.40                      | 35.82                 | 5.13%                 |
|                                        | M2  | 29.59                      | 31.09                 | 5.06%                 |
|                                        | M3  | 27.30                      | 28.54                 | 4.54%                 |
| Partially Saturated Surface Dried LECA with Micro Silica | | | | |
|                                        | M4  | 36.20                      | 37.92                 | 4.75%                 |
|                                        | M5  | 31.92                      | 33.21                 | 4.04%                 |
|                                        | M6  | 29.86                      | 31.04                 | 3.95%                 |
| Vacuum Cured LECA                      | M1  | 36.95                      | 39.62                 | 7.22%                 |
|                                        | M2  | 32.84                      | 34.87                 | 6.18%                 |
|                                        | M3  | 29.36                      | 31.11                 | 5.98%                 |
| Vacuum cured LECA with Micro Silica    | M4  | 39.94                      | 43.21                 | 8.18%                 |
|                                        | M5  | 35.14                      | 37.74                 | 7.39%                 |
|                                        | M6  | 32.79                      | 34.95                 | 6.58%                 |
TABLE VIII.
SPLIT TENSILE STRENGTH OF LECAC50

| Design Mix No. | Split tensile strength (MPa) | With Microsilica | Without Microsilica |
|----------------|------------------------------|------------------|--------------------|
| M1             | 8.4                          | 7.2              |
| M2             | 8.7                          | 7.7              |
| M3             | 9.9                          | 8.4              |

TABLE IX.
FLEXURAL STRENGTH OF LECAC50

| Design Mix No. | Flexural strength (MPa) | With Microsilica | Without Microsilica |
|----------------|-------------------------|------------------|--------------------|
| M1             | 6.24                    | 6.15             |
| M2             | 6.20                    | 6.02             |
| M3             | 5.93                    | 5.79             |

Figure 9. Comparison of compressive strength for LECAC40 and LECAC50 Mix at age of 28 days

Figure 10. Compressive Strength of LECAC50 Trial Mixes for different W/C ratio and chemical admixture dosage

Figure 11. Variation of compressive strength of LECAC50 mix with Partially saturated surface dried LECA with and without addition of 10% Microsilica at age of 28 days

Figure 12. Variation of compressive strength of LECAC50 with Partially saturated surface dried LECA and vacuum cured LECA at age of 28 days

Figure 13. Variation of compressive strength development of LECAC50

Figure 14. Variation of Split tensile strength of LECAC50

Figure 15. Variation of Flexural strength of LECAC50
VI. CONCLUSIONS

The following conclusions are drawn from the Experimental Investigation:

- The unit weight of LECAC50 mix was found to be in the range of 1700 Kg/m$^3$ to 1780 Kg/m$^3$ which was less than the conventional concrete density.
- The addition of Conplast SP 430 to the LECAC50 improved its workability & strength. The optimum dosage of chemical admixture obtained for water-cement ratios 0.35, 0.40, and 0.45 are 1.5%, 1%, and 1% respectively.
- The addition of conplast SP 430 exhibits increase in the compressive strength by 6.13% for LECAC50.
- The vacuum cured LECA has a water absorption of 75%, whereas the water absorption of partially saturated surface dried LECA for 1 day is 15%, which shows an increase in water absorption with vacuum curing.
- The compressive strength of LECAC50 with vacuum cured LECA increased by 9.83% compared to partially saturated surface dried LECA.
- The addition of 10% Microsilica to LECAC50 with partially saturated surface dried LECA improved the compressive strength by 8%.
- The addition of 10% Microsilica to LECAC50 with vacuum cured LECA increased the compressive strength by 10.33%.
- The addition of 10% Microsilica has shown improvement in Split tensile strength and flexural strength of LECAC50.
- The development of compressive strength of LECAC50 at age of 56 days with vacuum cured LECA is increased compared to the partially saturated surface dried LECA as Micro silica reacts with the water available in the pores of the vacuum cured LECA.

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