Study of Light Weight Geopolymer Concrete using LECA

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Abstract - Geopolymer concrete is being studied extensively and found as a greener alternative to Portland cement concrete. No cement is used in geopolymers concrete; instead GGBS and alkaline solution with a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) are used to make the binder necessary to manufacture the concrete. The high self-weight of normal concrete can be reduced by using low density concrete, which obviously reduces the size of the sectional elements, foundation size, and thereby cost of construction. In the present study, it is aimed to produce lightweight geopolymer concrete by partial replacement of normal weight aggregates with LECA. This aims to investigate on concrete mix M25 by the effect of partially and fully replacement of the coarse aggregate by LECA with various percentages such as 0%, 40%, 60%, 80% and 100%. Fresh properties of lightweight geopolymer concrete are studied by conducting slump cone test. Hardened properties of geopolymer concrete are assessed by conducting compressive strength test on specimens subjected to 28 days ambient curing.

***Key Words*:** light weight aggregate, geopolymer concrete, alkaline solution, sodium hydroxide(NaOH), sodium silicate(Na2SiO3), LICA

1. INTRODUCTION

Concrete is the most often used material in construction besides wood. Concrete which is a main building material is broadly used in the construction of infrastructures such as buildings, bridges, highways, dams, and others facilities. The increasing of the human population leads to the increasing the demand for the building constructions. Geopolymer is a new inorganic polymeric material that has undergone a marked development in the past years. The geopolymer activates the sodium hydroxide produced alumina-silicate components which was found to be as an alternative binder to the OPC. Geopolymer is formed from the reaction of a source material that is rich in silica and alumina with alkaline liquid. Geopolymerisation involves a heterogeneous chemical reaction between alkali metal silicate solutions and solid aluminosilicate oxides at highly alkaline conditions and mild temperatures yielding amorphous to semi crystalline polymeric structures, which consist of Si–O–Si and Si–O–Al bonds. LECA is a special type of clay pelletized and fired in a rotary kiln at a very high temperature (with grains size 4–10 mm). Lightweight concrete expanded clay aggregates exhibit particular properties: favorable thermal and acoustic behavior provided by the volume of voids, although with low mechanical strength. For structural use, it is normal to incorporate ordinary aggregates in the concrete mix to achieve adequate mechanical strength. With the increasing use of lightweight concrete with expanded clay aggregates in precast products for construction, there is a need for a better understanding of for the properties of these concretes in order to more effectively design and optimize the characteristics of these products.

2. OBJECTIVE

To investigates the mechanical properties of light weight Geopolymer concrete produced by replacing normal coarse aggregate by Light weight expanded clay aggregates (LECA). The influence of different proportions of replacements of LECA with coarse aggregate is to be analyzed.

3. MATERIALS

3.1 Ground granulated blast furnace slag (GGBS)

Ground-granulated blast-furnace slag is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground-granulated blast-furnace slag is highly cementitious and high in CSH(Calcium silicate hydrates) which is strength enhancing compound which increases the strength, durability and appearance of the concrete.

3.2 Sodium hydroxide

Generally the sodium hydroxide is available in solid state in the form of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. In this investigation the sodium hydroxide pellets are used. Sodium hydroxide solutions were prepared with concentration of 14M.

3.3 Sodium silicate

Sodium silicate is also known as water glass or liquid glass is available in liquid (gel) form. As per the manufacture, silicates are supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of Geopolymer Concrete. Sodium silicate gel is added to sodium hydroxide solution of desired concentration, this alkaline solution (NaOH solution and Na_2SiO_3) prepared 24 hours prior to preparation of concrete.

3.4 Fine aggregate

Fine aggregates or sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. Sands that have been stored out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in size of grains. Usually commercial sand dunes originally formed by the action of winds. According to the Indian standards natural sand is a form of silica (SiO2) that has maximum particle size of 4.75mm and it was used as fine aggregate. The minimum particle size of fine aggregate is 0.075mm. It is formed by decomposition of sand stones due to various weathering actions. Fine aggregate prevents shrinkage of the mortar and concrete. Fine aggregate is an inert or chemically inactive material, most ofwhich passes through a 4.75mm IS sieve and contains no more than 5 percent of coarser material. It may be classified as follows:

3.4.1 **Natural sand**: fine aggregate that results from the natural disintegration of rocks and has been deposited by streams or glacial agencies.
3.4.2 **Crushed stone sand**: fine aggregate produced by crushing hard stone.
3.4.3 **Crushed gravel sand**: fine aggregate produced by crushing natural gravel.

It reduces the porosity of the final mass and considerably increases its strength. Usually, natural river sand is used as a fine aggregate. However, at places, where natural sand is not available economically, finely crushed stone may be used as a fine aggregate.

3.5 Coarse aggregate

Coarse aggregate consists of naturally occurring materials such as gravel, or it results from the crushing of parent rock, to include natural rock, slags, expanded clays and shales (lightweight aggregates), and other approved inert materials with similar characteristics, having hard, strong, and durable particles, conforming to the specific requirements of this section. According to the Indian standards, crushed angular aggregate passes through 20mm IS sieve and entirely retains 10mm IS sieve.

3.6 Light expanded clay aggregate

It is the special type of aggregate which are formed by pyroclastic process in rotary kiln at 1,200 °C (2,190 °F) very high temperature. Since it is exposed to high temperature, the organic compounds burn, as a result the pellets expand & form a honeycombed structure. Whereas the outside surface of each granule melts and is sintered. The resulting ceramic pellets are lightweight, porous and have a high crushing resistance. It is environmental friendly, entirely a natural product incorporating same benefits as tile in brick form. LECA is non-destructible, noncombustible & impervious to attack by dry-rot, wet-rot & insects.

4. MIX PROPORTION

The mix design has been made for M25 grade conventional concrete and light weight concrete use of code IS 10262- 1982, IS 456-2000 recommended. The water cement ratio (W/C) was kept constant at approximately 0.48 for all mixes, the percentage like 20%, 40%, 60%, 80 and 100% incorporation was used as partial and full replacement of natural coarse.

5. CURING

The specimens of LWGPC are kept for ambient curing for period of 28 days. Since there is a delay in setting time of GPC, all the specimens are given three days rest period before they are demoulded and kept for ambient curing. During the rest period the specimens along with the mould were kept in sunlight to facilitate demoulding easily. The specimens are demoulded after three days of rest period.

Table -1 : Specific Gravity

Materials	**Specific Gravity**
LECA	0.56
M-sand	2.66
Sodium Silicate	1.61
Sodium Hydroxide	1.29
Coarse Aggregate	2.72
GGBS	2.85

Table -2 : Mix Proportion

Mix	**GGBS (Kg/m^3)**	**M-sand (Kg/m^3)**	**CA (Kg/m^3)**	**NaOH (Kg/m^3)**	**Na2SiO3 (Kg/m^3)**	**LECA (Kg/m^3)**
LECA 0	400	770	1182	80	120	0
LECA 40	400	770	709	80	120	97.6
LECA 60	400	770	473	80	120	146.5
LECA 80	400	770	237	80	120	195
LECA 100	400	770	0	80	120	244

After analyzing the Specific gravity of the raw materials, the mix design for the preparation of different proportions of LECA on replacing the coarse aggregate accordingly. The mix design results are shown in Table –I. The amount of materials in Kg/m^3 to be taken for the preparation of specimen is given in this Table –I. With the help of this table the specimens are casted and cured for 28 days for the analysis of compressive strength.

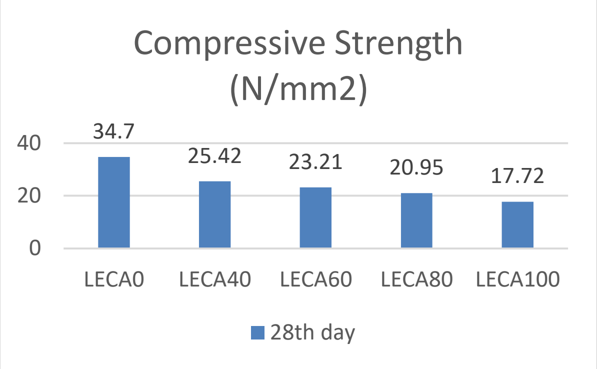
6. COMPRESSIVE STRENGTH RESULT

Compressive strength results of 25.42 N/mm^2, 23.21 N/mm^2 for LECA40 & LECA60 respectively these replacement percentage due to made up light weight concrete with densities varying from 1400- 2000kg/m3. This mix can also be used for structural purposes.

Table -3 : Compressive Strength Result

LECA %	**SPECIMEN 1 (N/mm^2)**	**SPECIMEN 2 (N/mm^2)**	**SPECIMEN 3 (N/mm^2)**	**AVERAGE RESULT (N/mm^2)**
LECA0	32.9	36.5	34.7	34.7
LECA40	26.15	26.11	24	25.42
LECA60	21.37	23.71	24.54	23.21
LECA80	20.51	20.13	22.21	20.95
LECA100	17.85	19.20	16.11	17.72

Chart : Compressive Strength of specimen after 28 days



7. CONCLUSION

Based on the experimental results of this study the following conclusion can be drawn.

1. The density of concrete is found to decrease with the increase in percentage replacement of normal aggregate by Light Expanded Clay Aggregate.
2. Compressive Strength of concrete is found to decrease from 34.70 to 17.72 N/mm^2 with increase in LECA content from 0% to 100%
3. The LECA concretes when replaced with 40% and 60% of coarse aggregates shown better results, when compared to conventional concrete.
4. Hence the strength obtained from the LWGPC is comparable with the M30 to M20 grade concrete, these LWGPC can be used effectively for strength purposes on structural purpose of concrete where the weight of the structure can be reduced at the same time.

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