An Experimental Study on Internal Curing of Concrete Using Light Expanded Clay Aggregate

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***Abstract*— as water is becoming a scarce material day-by-day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. Keeping importance to this, an attempt has been made to develop self-curing concrete by using Light Expanded Clay Aggregate (LECA). In this experimental investigation the strength characteristics of Normal Strength Concrete cast with the self-curing agent LECA have been studied and compared with the corresponding conventionally cured concrete. IS method of mix design was adopted, for the normal strength internal curing concrete of grade M30 grade of concrete is design on trial and error basis. For producing internal-curing concrete replacements of 5%, 10%, 15% and 20% of LECA by weight of aggregate was used and tested. It was observed that after implementation of new technique the water consumption for curing was significantly reduced by 100% for 5% and 10% replacements.**

***Keywords*— Light Expanded Clay Aggregate (LECA), Curing**

I. INTRODUCTION

Concrete is a composite material composed of gravels or crushed stones (coarse aggregate), sand (fine aggregate) and hydrated cement (binder). Concrete is the most widely used construction material in the world. It is used in many different structures such as dam, pavement, building frame or bridge. Water is a necessary component of the cement hydration reaction. The hydration reaction is responsible for the conversion of the gray cement powder into the binding cement paste which gives concrete its strength. It is well known in concrete construction that a 'proper curing period' is essential at early ages to enable the concrete to gain strength.

A. Internal Curing

The American Concrete Institute (ACI) defined internal curing in its ACI Terminology Guide as “supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-wetted lightweight aggregates, that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation (American Concrete Institute, 2010).” While external curing water is applied at the surface and its depth of penetration is influenced by the quality of the concrete, internal curing enables the water to be distributed more equally throughout the cross section. In our research we have used expanded clay shale (LWA) as replacement for coarse aggregates in 5%, 15%, and 20 %.

B. Aggregate Replacement Methodology

Lightweight aggregate batched at a high degree of absorbed water may be substituted for normal weight aggregates to provide “internal curing” in concrete containing a high volume of cementitious materials. High cementitious concretes are vulnerable to self-desiccation and early-age cracking, and benefit significantly from the slowly released internal moisture. Experience has shown that high strength concrete is not necessarily high performance concrete and that high performance concrete need not necessarily be high strength. A frequent, unintended consequence of high strength concrete is early-age cracking. Blending lightweight aggregate containing absorbed water is significantly helpful for concretes made with a low ratio of water-to- cementitious material or concretes containing high volumes of supplementary cementitious materials that are sensitive to curing procedures. This process is often referred to as water entrainment. Time dependent improvement in the quality of concrete containing pre-wetted lightweight aggregate is greater than with normal weight aggregate.

II. REVIEW OF LITERATURE

Bentz.,(2008) has studied that the substitution of light weight aggregate (LWA) sand for a portion of the normal weight sand to provide internal curing for a mortar is examined with respect to its influence on ITZ percolation and chloride ingress. Experimental measurements of chloride ion penetration depths are combined with computer modeling of the ITZ percolation and random walk diffusion simulations to determine the magnitude of the reduced diffusivity provided in a mortar with IC vs. one with only normal weight sand. In his study, for a mixture of sands that is 31% LWA and 69% normal weight sand by volume, the chloride ion diffusivity is estimated to be reduced by 25% or more, based on the measured penetration depths

Khokrin.,(1973) discussed the unique physical characteristics of rotary kiln expanded slate lightweight aggregate for producing high performance and high strength lightweight concrete. The compressive strength, elastic modulus, splitting tensile strength, specific creep, and other properties of lightweight concrete are significantly affected by the structural properties of the lightweight aggregate used. Concrete production, transportation, pumping and placing are also affected.

Ryan, et. al., (2009) has indicated that while internal curing may have been originally developed to reduce autogenous shrinkage and mitigate early-age cracking in high performance concretes, its application has far-reaching consequences for the performance of concrete throughout its lifetime By providing an on-demand source of extra water, internal curing can improve the slump retention, workability and finishability of fresh concrete and reduce deformations and cracking due to plastic, autogenous and drying shrinkage.

III. MATERIALS AND METHODOLOGY

The materials used for making internally cured concrete specimens are:

- Cement
- Coarse aggregate
- Fine aggregate
- Water
- Pre-wetted LECA

A. Light Expanded Clay Aggregate (LECA)

Lightweight expanded clay aggregate (LECA) or expanded clay is a light weight aggregate made by heating clay to around 1,200 °C (2,190 °F) in a rotary clin. The base material is plastic clay which is extensively pre-treated and then heated and expanded in a rotary klin at about 1100ºC to form finished LECA product. LECA consists of small, lightweight, bloated particles of burnt clay. The yielding gases expand the clay by thusands of small bubbles forming during heating producing a honeycomb structure. LECA has an approximately round or potato shape due to circular movement in the kiln, and is available in different sizes and densities. LECA is used to make lightweight concrete products and other uses. LECA is imported in india by GBC INDIA.

LECA (Fig 1) was developed about 1917 in Kansas City, Missouri , to the production in a rotary kiln of a patented expanded aggregate known as Haydite which was used in the construction of USS Selma, an ocean-going ship launched in 1919. Following in the USA was the development of a series of aggregates known as Gravelite, Perlite, Rocklite, etc. In Europe, LECA commenced in Denmark, Germany, Holland (Netherlands), UK and Middle East.

Fig. 1Example of LECA

B. Pre-wetted LECA

Light expanded clay aggregate (LECA) is dipped in water for 24 hours. This pre-wetted LECA is used for casting cubes. Here pre-wetted LECA is used as a partial replacement of coarse aggregate by 5%, 10%, 15% and 20%. These pre-wetted lightweight aggregate stores water in it and act as a reservoir which will be able to release water whenever the concrete requires.

C. Batching of Concrete

It is the process of measuring the concrete mix ingredients and introducing them in to mixture. Batching is done by weighing rather than by volume. Here cement, fine aggregate, coarse aggregate and LECA are measured and batched. Water is measured in volumetric quantity as 1 litre = 1Kg. Here two type of concrete mixing is done. First one, adding same amount of water as per design. Second one, by reducing the amount of water that is absorbed by pre-wetted LECA.

D. Mixing of Concrete

Mixing concrete is simply defined as the complete blending of the materials which are required for the production of homogenous concrete. In this project we have done machine mixing. The cement, fine aggregate, coarse aggregate and pre-wetted LECA are loaded into mixer and water is added.

E. Casting

Moulds were cleaned and fitted, further the inner surface of the mould was oiled. The fresh concrete was casted into the specimen using tamping rod with three layers of compaction. The operation of placing and compaction are independent and are carried out simultaneously. Mould is compacted using vibrator.

F. Curing

The specimen were cured under two different conditions such as water curing and air curing at ambient temperature. Specimen are kept for curing for s7 and 28 days. For water curing, after 24 hours, the specimens are marked and removed from the moulds and immediately submerged in clean, fresh water and kept there until taken out just prior to test. The water or solution in which the specimens are submerged are renewed every seven days and is maintained at a temperature of 27° ± 2°C. Hydration of cement is not a momentary action but a process continuing for long time. Of course the rate of hydration is fast to start with, but continues over a very long time at a decreasing rate. The quantity of the product of hydration and consequently the amount of gel formed depends on the extent of hydration.

IV. EXPERIMENTAL RESULTS

A. Tests on Cement

To achieve a good quality and high strength concrete, it is necessary that the ingredients constituting the concrete should also be of good quality. Hence, before using in the mix the testing of these ingredients of various properties is required, to ensure their quality. Table I shows the test results on cement.

TABLE I
PROPERTIES OF CEMENT

SL No	Description	Value
1	The specific gravity of cement	3.16
2	Initial setting time of cement	30 minutes
3	Final setting time of cement	236 nutes

B. Tests on Fine Aggregate

Sand used in the present investigation conforms to IS: 2368-1968 specifications. Figure I and Table II shows sieve analysis of sand and typical properties respectively.

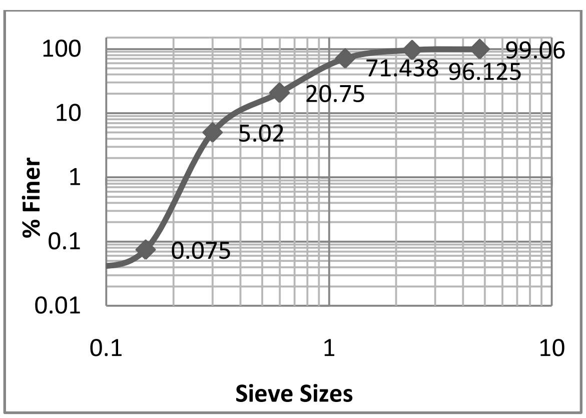

Figure I: Sieve Analysis of Fine Aggregate

TABLE II

PROPERTIES OF FINE AGGREGATE

SL No	Description	Value
1	The specific gravity of Fine Aggregate	2.53
2	Fineness Modulus	3.7
3	Water Absorption	20.12

C. Tests on Coarse Aggregate

Crushed stone of fraction 20mm down size retained on IS: 480 sieves have been used. Table III shows properties of Coarse aggregate

TABLE III

PROPERTIES OF COARSE AGGREGATE

SL No	Description	Value
1	The specific gravity of Fine Aggregate	2.53

D. Tests on Coarse Aggregate

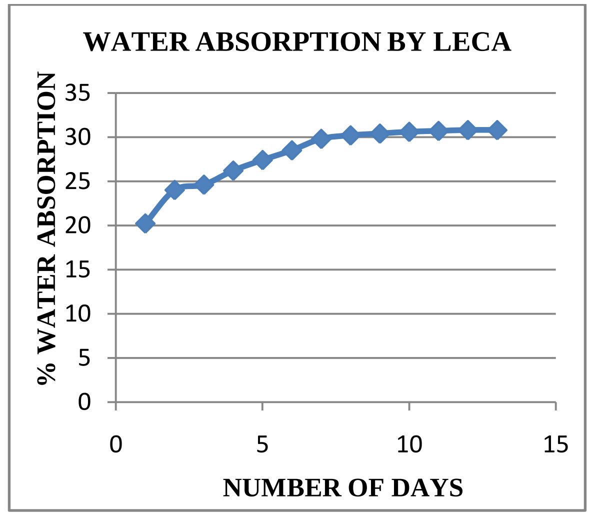

Figure II: Compressive Strength V/S Number of Days without Curing

TABLE IV

PROPERTIES OF LECA

SL No	Description	Value
1	The specific gravity of LECA	1.64
2	Moisture Content	0
3	Water Absorption	20.2%

E. Mix Design

TABLE II

MIX DESIGN

SL No	Trial Mix
1	1 : 1.74 : 2.84
2	1 : 2.02 : 3.3

F. Tests on Concrete

The basic test on concrete as per the Indian standard code was conducted to study the behavior of the concrete. The compression test on cube specimens, flexure strength test and split tensile test were conducted as per IS: 516-1959(reaffirmed 1999).

TABLE II

MIX DESIGN

% Replacement By LECA	With Curing	Without Curing	Degree Of Workability
5	28	28	Medium
10	32	32	Medium
15	37	37	Medium
20	40	40	Medium

G. Compressive Strength of Cubes

Totally 204 cubes manufactured casted and compressive strength was measured under two different types of curing i.e. water curing and air curing at ambient room temperature after 7 and 28 days. Figure III, Figure IV and Figure V shows variation of compressive strength with age of internally cured concrete over water curing and air curing at ambient room temperature respectively.

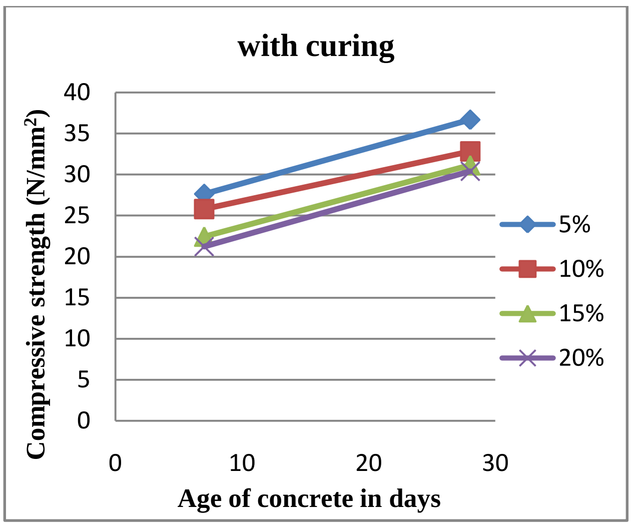

Figure III: Compressive Strength V/S Number of Days with Curing

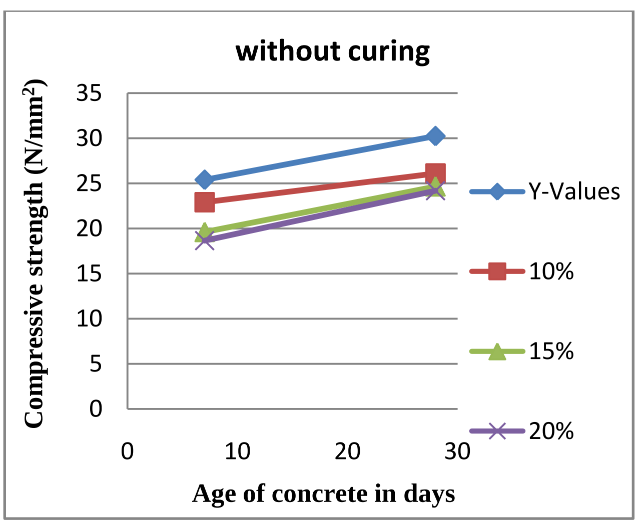

Figure IV: Compressive Strength V/S Number of Days without Curing

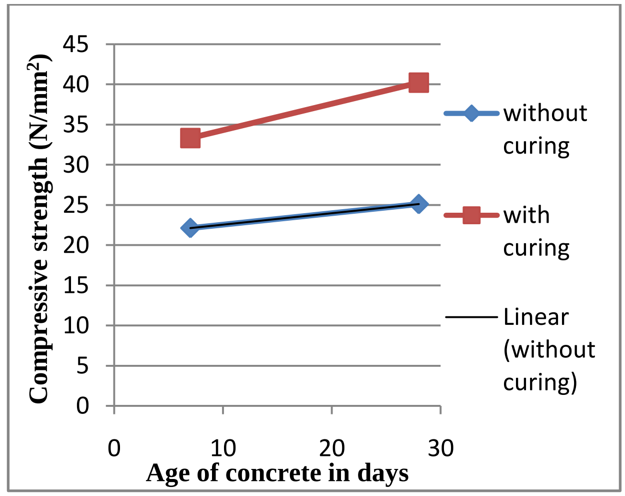

Figure V: Compressive Strength V/S Number of Days for Normal Concrete

V. CONCLUSIONS

- The conventional curing requires more water for curing. Therefore in areas having water scarcity problems, internal curing technique can be used.
- Coarse aggregate can be partially replaced by LECA up to 5%, 10%, 15% and 20%. Beyond 5% replacement poor compressive strength is achieved.
- Compressive strength of concrete made using LECA is somewhat same as normal M30 grade concrete.
- There is no significant change in compressive strength of with curing concrete and without curing concrete using LECA
- The compressive strength of normal M30 grade concrete is 40.22 N/mm² whereas the compressive strength achieved by internally cured concrete is 36.66N/mm² replacing coarse aggregate with LECA by 5%.
- The compressive strength of normal M30 grade concrete without curing is 33.33 N/mm² whereas the compressive strength achieved by internally cured concrete is 30.23N/mm² replacing coarse aggregate with LECA by 5%.

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