

Compressive Strength Study of Self-Curing Concrete Using Red Clay and Black Cotton Soil Lightweight Expanded Clay Aggregates (LECA)

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Abstract: *This study seeks to determine the effects of red clay and black cotton soil lightweight expanded clay aggregates (LECA), as a self-curing agent, on the compressive strength of self-curing concrete. Compressive strength test was done on 150x150x150 mm concrete cubes made of black cotton and red clay LECA. Concrete cubes of varying percentage of LECA content by weight of fine aggregates were cast and tested at 7, 14 and 28 days. For both red clay and black cotton soil LECA, the results showed that the compressive strength increases with increase percentage LECA content with maximum compressive strength being attained at 15% LECA content then decreases thereafter. The compressive strength of the concrete with 15% LECA content at 28th day was higher than the one with 0% LECA by around 18%. Incorporation of red clay and black cotton soil LECA as partial replacement of fine aggregate into self-curing concrete as a self-curing agent increases the compressive strength of concrete.*

Keywords: Red clay soil LECA, black cotton soil LECA, compressive strength, lightweight expanded clay aggregates

1. Introduction

Concrete is a man-made construction material consisting of binding material such as lime or cement, well graded fine and coarse aggregates, water and admixtures. Cement and water combines through hydration process forming a paste which coats the surface of fine and coarse aggregates and binds them together. For optimum hydration to be achieved, curing of concrete must be done. Curing is a process of maintaining the proper moisture content to promote optimum cement hydration. It results in gain in strength and hardness through chemical reaction between cement and water. This chemical reaction requires moisture, favorable temperature and time referred to as curing period. Conventionally, curing of concrete is done through various methods which include water curing, steam curing, curing by infra-red radiation, electrical curing [1].

With inadequate water for curing, chemical reaction will not proceed and the resulting concrete will not possess the desired strength and impermeability. Permeable concrete may allow the ingress of deleterious agents which can cause durability problem. In addition, early drying of concrete can cause micro-cracks or shrinkage cracks to develop on the surface of the concrete [2].

The conventional methods of curing have their shortcoming in practice. Water supply on the surface of vertical structural elements is still a technical problem and time allocated for curing eats into building time increasing costs and efforts [3]. Problem of scarcity of portable water is rising day by day all over the world. Arid and semi-arid areas in developing countries are always faced with scarcity of water. Thus conventional methods of curing may not work well in such areas because they require large amount of water.

Concrete curing techniques can be divided in to two categories, external curing which includes the conventional

techniques and internal curing also known as self-curing which is a technique which retains or provides additional moisture in concrete for effective hydration. Currently there are two methods available for self-curing of concrete. The first method is use of saturated porous lightweight aggregate as a self-curing agent which supplies an internal source of water to replace the water consumed by cement hydration. The second method uses membrane forming compound such as polymers as self-curing agents which reduces evaporation of water from the surface of concrete and also helps in water retention [4]- [5].

Numerous studies have been done on self-curing concrete using various materials as self-curing agents. The self-curing agents studied includes slag, pre-wetted lightweight aggregates, polymers, lightweight aggregates, silica fumes, limestone powder and clinkers, water soluble polyvinyl alcohol, polyethylene glycol, quartz powder, sodium lingo-sulphonate [2] [6]- [7].

Light expanded clay aggregates (LECA) consist of small, lightweight, bloated particles of burnt clay. Thousands of small, air-filled cavities of LECA give it its strength and thermal insulation properties. To manufacture LECA, plastic clay is extensively pretreated then heated and expanded in kiln. Thereafter the product is burned at about 1100°C to form the final LECA product. LECA has been used as part of fine and coarse aggregate and has been found to increase resistance to moisture change. Mechanical properties were improved when coarse aggregates were replaced by 40-60% by LECA as compared to conventional concrete [8].

Studies have been done on the use of LECA as part of fine aggregate and coarse aggregate in lightweight aggregates with the objective of determining its effect on the mechanical properties of concrete. Studies have shown that LECA improves the mechanical properties of porous asphalt [9].

LECA also improves the compressive strength of concrete when used as partial replacement of coarse aggregates [10].

The principal aim of this paper is to investigate the effects of black cotton and Red Clay LECA fine aggregate as a self-curing agent on the compressive strength of self-cured concrete when use as a partial replacement of fine aggregate. In in this paper, the experimental program, test results and discussion and conclusion has been dealt with.

2. Materials and specimen preparations

2.1 Materials

The following are the materials used in this study:

- Light expanded clay aggregates: made from red clay and black cotton soil.
- Water: portable water in the laboratory was used
- Fine aggregate: Normal river sand which conformed to BS 882 [11].
- Coarse aggregate: Crushed coarse aggregate of maximum size of 20mm, specific gravity of 2.6 conforming to BS 882[11].
- Cement: Local Portland pozzolana cement of grade 32.5 manufactured to Standard specification KS EAS 18-1: 2001 and classified as CEM IV/B-P 32.5 N Portland pozzolana cement.

2.2 Specimen preparations

2.2.1 Light expanded clay aggregates (LECA)

LECA was made from red clay and black cotton soil. The clay was mixed with 20% water by weight of soil and kneaded then was spread out into a thickness of 0.5 cm and cut into small pieces of about 0.5 cm. The pieces were left to dry till they were non-sticky but still soft. The pieces are then stirred on an abrasive sieve to decrease their flakiness. The modified aggregate was then dried to reduce moisture in order to minimize cracking and bursting once in the furnace. After drying the molded aggregates were then fed into the surface where temperatures were steadily risen to about 600°C and all organic matter burnt beginning the process of internal void creation. The temperature was then raised to 950°C for the sintering process to begin. The temperature was then left stable at around 960°C for a period of 3 hours. The LECA was then slowly cooled to avoid crumbling to room temperature from where it was then soaked for 48 hours in water to acquire saturated surface dry conditions.

2.2.2 Concrete mix design and mix preparation

Concrete mix design was done for class C30/20 by British mix design method. This mix design was expected yield concrete having 30 N/mm² compressive strength at the 28

days. Mix proportion obtain for the grade of concrete was 1:1.61:2.11:0.55

3. Experimental Programme

The experimental programme entailed the determination of compressive strength of concrete cubes of seven batches of the concrete cast. Concrete preparation and mixing were done in accordance with the ratios determined from concrete mix design. The following seven batches of mixes were prepared: one batch for control with 0% LECA, three batches with 10%, 15% and 20 % of LECA of red clay soil and three batches with 10%, 15% and 20 % of LECA of black cotton soil.

For each batch, nine compression tests cubes 150x150x150 mm cast for this study, a total of 56 cubes were cast. The cast cubes were cured in water for three days to minimize shrinkage cracks then left in open air under a shade to avoid direct sunlight. The cubes were tested at 7, 14 and 28 days and the compressive strength determined.

4. Test Results and Discussions

4.1 Compressive strength test

The compressive strength results were as shown in Table 1. From Figure 1-2, the compressive strength increase with increase LECA content with maximum compressive strength being achieved at 15% LECA for both red clay and black cotton soil. Thereafter, the compressive strength decrease with increase in LECA content. The compressive strength of the concrete with LECA was higher than the one with 0% LECA, control (Table 1). At 28 days, the compressive strength of concrete with 15 % LECA was around 18% more than the one without LECA. There is insignificant difference in compressive strength and its development between Black cotton and red clay soil LECA as it can be seen in Figure 3. The high values of compressive strength can be attributed to the three days' water immersion curing. From other related studies done before [12-13], initial four days curing was sufficient to develop compressive strength higher or same as the one cured for 28 days when tested at 28 day

Table1: Compressive strength results

Batch	% LECA	Compressive strength, N/mm ²		
		7 days	14 days	28 days
Control	0%	19.3	24.6	28.8
Red clay soil	10%	20.4	25.7	31
	15%	22.4	27.3	34.1
	20%	20.6	26.4	32.1
Black cotton soil	10%	19.5	24.8	31.3
	15%	21.5	27.3	33.5
	20%	20	26.6	33

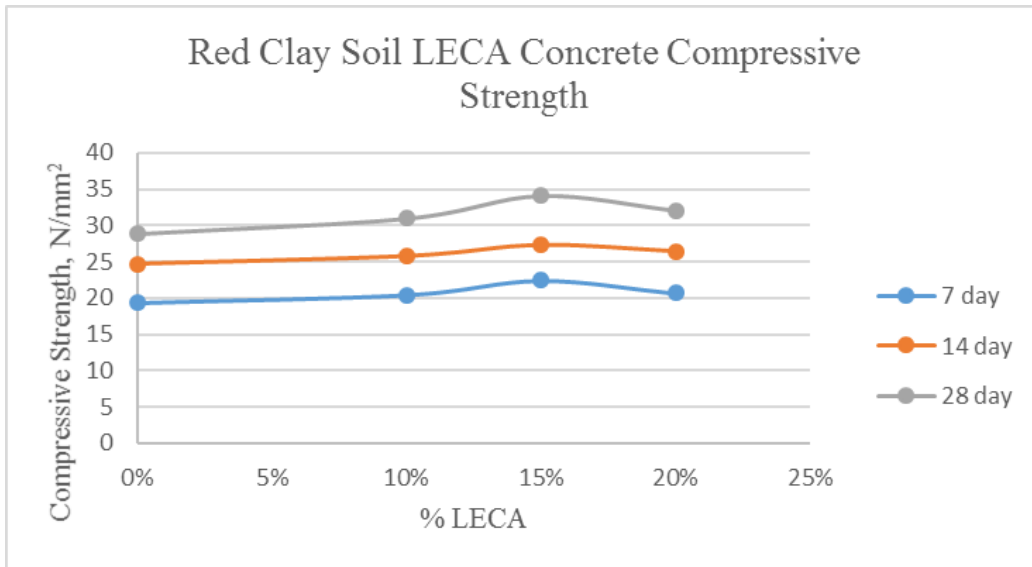


Figure 1: Compressive strength of red clay soil LECA concrete

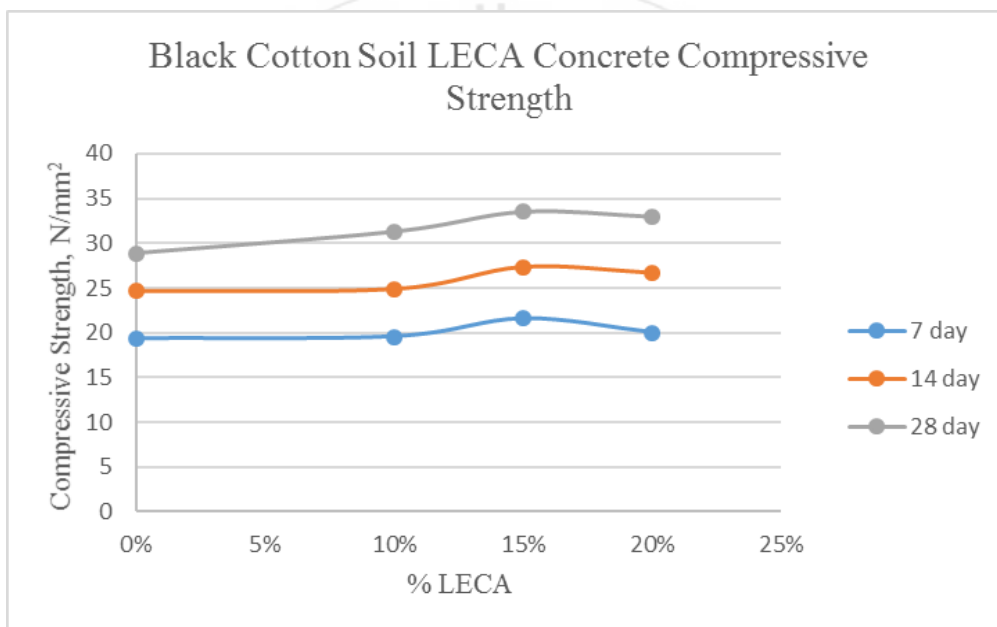


Figure 2: Compressive strength of black cotton soil LECA concrete

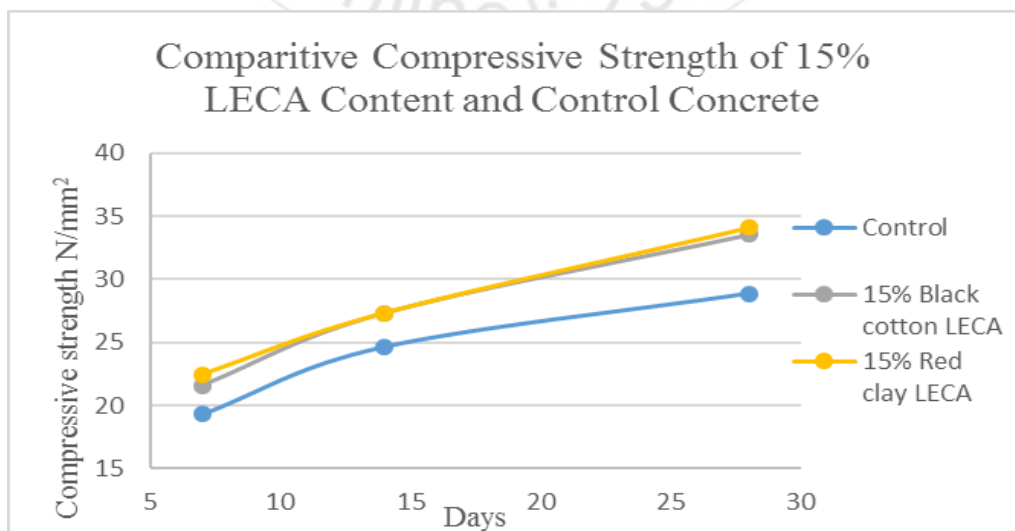


Figure 3: Compressive strength of control and 15 % black cotton soil and red clay LECA content concrete

5. Conclusion

The objective of this study was to investigate the effects of black cotton and Red Clay LECA fine aggregate as a self-curing agent on the compressive strength of self-curing concrete. Basing on the experimental results, the following conclusions were drawn from the study:

- The compressive strength of concrete increases with increase black cotton and red clay soil LECA content up to 15% but thereafter it reduces.
- Addition of LECA as fine aggregate to concrete increases compressive strength.
- Maximum compressive strength is achieved when 15% of fine aggregate was replaced with LECA
- The compressive strength concrete with black cotton and red clay soil LECA is more or less the same.
- More studies should be done to determine the maximum LECA content with that will give minimum shrinkage cracks when no external curing is done.

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