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Effects of Black Cotton Soil and Red Clay SoilLightweight Expanded Clay Aggregates (LECA) on Water Absorption, Sorptivity and Mass Loss of Concrete

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Abstract: ***This study aims to evaluate the effects of black cotton and red clay lightweight expanded clay aggregates (LECA) on water absorption, sorptivity and mass loss of the concrete when used as self-curing agent in concrete. Concrete cubes of 150x150x150mm dimensions with varying percentages of LECA content by weight of fine aggregates were cast. The cast concrete cubes were used in determining the mass loss, sorptivity and water absorption of concrete. The results showed that the mass loss increases with increase in the percentage LECA content up to 15% LECA content then it starts decreasingnwith increase in the percentage of LECA content: at 15% LECA content, the mass loss was around 8%more than that of 0% LECA content. Water absorption decreases with increase of percentage LECA up to 10% and then thereafter increases with increase in percentage LECA content: at 10% LECA content, the water absorption of red clay LECA and black cotton LECAwere approximately 7% and 14% less than that of 0%LECA content respectively. At concrete age of 28 days, considering the least water absorption of 10 %LECA content, the water absorption of red clay LECAwas higher than that of Black cotton clay LECA by approximately 8%. Results also showed that Sorptivity increases with increase in percentage LECA content where sorptivity of concrete with Red Clay LECAwas higher than Black cotton LECA. Concrete with black cotton soil and red clay soil LECAcan be used in areas with limited exposure to water due to its high sorptivity. LECAcontent with respect to fine aggregate should be limited to 15% in order to achieve maximum mass loss.***

Keywords: Red clay soilLECA, black cotton soil LECA, water absorption, sorptivity, mass loss, density, lightweight expanded clay aggregates

1. Introduction

Movement of gases and liquids, from the surrounding environment, into the concrete causes physical and chemical reactions within its internal structure leading to concrete deterioration. With structures subject to cyclic wetting and drying regime, water absorption properties of concrete are responsible for ingress of contaminated water into the concrete which in turn affects the durability of concrete. Therefore, there is need to study water absorption characteristics of a concrete [1].

Water absorptionmeasures the extents to which the concrete is penetrated by water and other injurious agents; it is a good measure of the quality of near surface concrete which governs the durability of reinforcement. There are two major water absorption properties that are of importance to concrete quality, sorptivity and permeability. Sorptivity is the ability to absorb and transmit water through it by capillary suction while permeability is the measure of flow of water under pressure in a saturated porous medium [1].

Mass of concrete determines the overall self-weighta concrete structure. The more the mass, the larger the loads the larger the cross-section sizes of the members and the more the reinforcements. This increases the cost of construction which is a major challenge in developing countries.

Light expanded clay aggregates (LECA) consist of small, lightweight, bloated particles of burnt clay. Thousands of small, air-filled cavities of LECAcontributes to its higher water absorption properties.LECA,when used as part of fine and coarse aggregate, has been found to increase resistance to moisture ingress into the concrete. Mechanical properties of concretecan be improved when coarse aggregates were replacedLECA as compared to conventional concrete [2]

LECA has been studied as part of fine aggregate and course aggregate in lightweight aggregates with the objective of determining its effect on the mechanical properties of concrete. Studies shows that LECA improves the mechanical properties of porous asphalt. [3], and compressive strength of concrete when used as partial replacement of coarse aggregates [4].

Studies have been done on use of LECA as a self-curing agents in self-curing concrete.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 act as 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 thus helps in water retention[5-6].

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 [7-9].

This study seeks to investigate the effect of black cotton soil and red clay soil LECA on water absorption, sorptivity and mass loss of concrete when used as a self-curing agent in self-curing concrete as 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 Preparation

2.1. Materials

In this study, the following materials were used:

- Cement: Local Portland pozzolana cement of 32.5 grade manufactured to Standard specification of Kenya Standards KS EAS 18-1: 2001 and classified as CEM IV/B-P 32.5 N Portland pozzolana cement.
- Light expanded clay aggregates: made from red clay and black cotton soil
- Water: portable water in the laboratory
- Fine aggregates: the river sand conforming to the requirements of BS 882[10].
- Coarse Aggregates: crushed stone coarse aggregate of maximum size of 20mm conforming to the requirements of BS 882[10]

2.2. Sample preparations

2.2.1.Light expanded clay aggregates (LECA)

The black cotton soil and red clay soil were separately mixed with 20% water by their respective weights and kneaded. Kneaded clay was then spread out into a thickness of 0.5 cm and cut into small pieces of 0.5 cm and left to dry to minimize moisture in order to avoid cracking bursting in the kiln. After drying, the pieces were then fed into the kiln where temperatures were steadily risen to 600^{o}C which burnt all the organic matter to create internal voids. The temperature was then raised to 960^{o}Cand remained constant for 3 hours for the pieces to sinter. 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.

2.3. Concrete mix design and mix preparation

Concrete mix design for class C30/20 was done by British mix design method [11]. This mix design was expected yield a concrete of 30 N/mm^2 compressive strength at the age of 28 days. Mix proportion obtain for the grade of concrete was 1:1.61:2.11:0.55 for cement, fine aggregate, coarse aggregate and water respectively.

Concrete preparation and mixing were done in accordance with the ratios determined from concrete mix design. In this research, the following seven batches of mix were prepared: one batch for control with 0% LECA content, three batches with 10%, 15% and 20 % of LECA content of red clay soil respectively and three batches with 10%, 15% and 20 % of LECAcontent of black cotton soil. Concrete cubes of 150x150x150 mm were used in this study. Percentage LECA content was by weight of the fine aggregate

3. Experimental Programme

The experimental programme entailed determination of water absorption, sorptivity and mass loss of concrete cubes made from the seven batches of the concrete cast. The cast cubes were cured in water for three days to minimize shrinkage cracks then left in open air but under a shade to avoid direct sunlight. The cubes were tested at 7and 28 days for density and water absorption and 28 days for sorptivity.

3.1. Determination of the mass loss

Cubes of 150x150x150 mm size were cast and cured and then mass measured at 7th and 28 days.This was done by measuring the mass of the concrete cubes from the seven batches at 7days and 28 days.

3.2. Determination of water absorption

The 150x150x150 mm cubes were oven dried for 24 hours at the temperature 105ºC ± 5ºC until the mass became constant and again weighed (W_1) and immersed in water for 72 hours before weighing(W_2) them again.

$$Water\ absorption = \frac{W_2 - W_1}{W_1} * 100 \quad (1)$$

3.3. Determining of Sorptivity

Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb water by capillarity. Sorptivity was determined by the measuring the capillary rise absorption rate. At 28 days, the cubes of 150x150x150 mm weredried in the oven at temperature of 105ºC ± 5ºC for 24 hours weighed (W_1) and then immersed in water so that 5mm height from the bottom of the cube was submerged in water. After 30 minutes, the specimens were then weighed in surface dry condition (W_2).

The cumulative water absorption (per unit area of inflow surface) increases as the square root of elapsed time (t). Therefore,

$$I = S.t^{\frac{1}{2}} hence\ S = \frac{I}{t^{\frac{1}{2}}} \quad (2)$$

Where;

S=Sorptivity in mm, t=elapsed time in mins, $I = \frac{\Delta w}{Ad}$, Δw =change in weight=W_2-W_1, W=Oven dry weight of cylinder in grams, W_2=weight of cylinder after 30 minutes capillary sunction of water in grams. A=surface area of the specimen through which water penetrated, d=density of water.

4. Results, Analysis and Discussion

4.1. Mass loss

As shown in Table1-2 and Figure 1-3, the mass loss increases with increase in the %LECA content until 15% LECA then it starts decreasing. At 15% LECA, the mass loss is around 8% more than mass loss at 0% LECA. The mass loss due to red clay is more or less the same as that due to Black cotton LECA.

From the Figure 1 and 3, for 15% LECA content, the mass loss at 7 days is more than that of 28 days, but more than 15% LECA content, the 7days'mass loss is less than that of 28 days. This can be attributed to the increase of weight of water present in the concrete due increase in water content.

Table 1: Mass loss, water absorption and sorptivity results for Red Clay soil LECA

Batch	Sorptivity mm/min$^{0.5}$ (x10^{-5})	Water Absorption, %		Cube Mass, kg	
	28 days	7 days	28 days	7 days	28 days
Control	4.05	2.47	1.98	8.6	8.65
Red10%	6.5	2.17	1.85	8.13	8.25
Red15%	8.93	2.29	1.95	8.05	7.8
Red 20%	12.98	2.78	2.26	8.3	7.95

Table 2: Mass loss, water absorption and sorptivity results for Black Cotton Soil LECA

Batch	Sorptivity, mm/min$^{0.5}$ (x10^{-5})	Water Absorption, %		Cube Mass, kg	
	28 days	7 days	28 days	7 days	28 days
Control	4.05	2.47	1.98	8.6	8.65
Black 10%	4.87	2.15	1.70	8.13	8.25
Black 15%	7.30	2.38	1.79	8.05	7.9
Black 20%	9.73	2.65	2.28	8.3	7.9

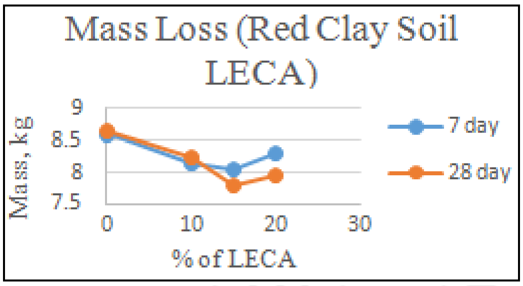

Figure 1: Mass loss for concrete with Red Clay Soil LECA

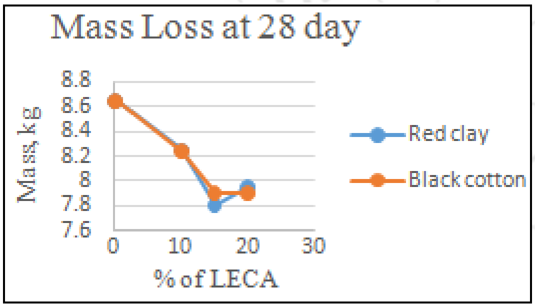

Figure 2: Mass loss for concrete with Red Clay Soil and Black Cotton soil LECA

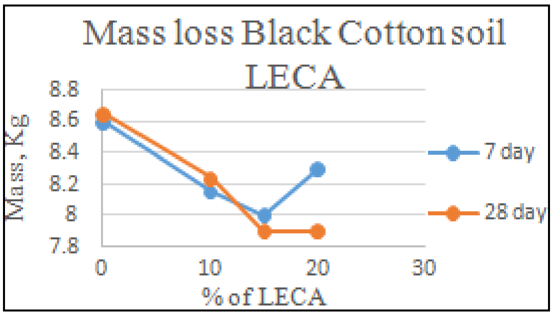

Figure 3: Mass loss for concrete with Black Cotton SoilLECA

4.2. Water absorption

From Table 1-2 and Figure 4-6, the water absorption at 7days is higher than 28 days by a range of 17%-24% for Red clay LECA contents and 16-32% for black cotton LECA contents. The water absorption decrease with increase of %LECA content upto 10%LECAcontent and then increase with increase in % LECA thereafter. At 10% LECA, the water absorption was around 7% for red clay soil LECA and 14% of black cotton soil LECA less than that 0%LECA content.

Figure 6 shows that the water absorption for black cotton LECAwas higher than that of red clay LECA. At 28 day, considering the least water absorption of 10 %LECA content, the red clay LECA is higher than that of Black cotton clay LECA by around 8%

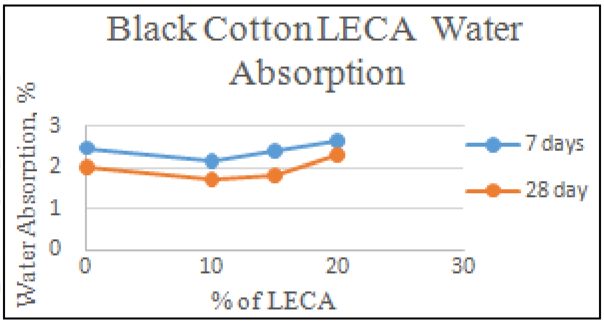

Figure 4: Water Absorption for Black Cotton Soil LECA concrete

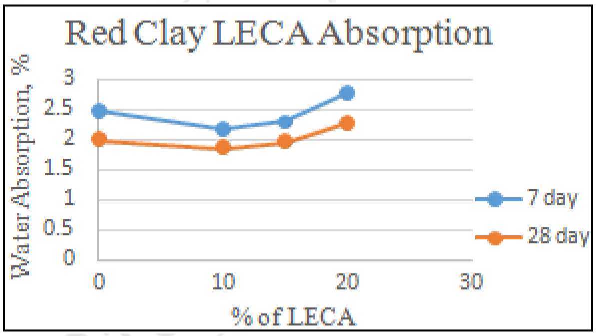

Figure 5: Water Absorption for Red Clay Soil LECA concrete

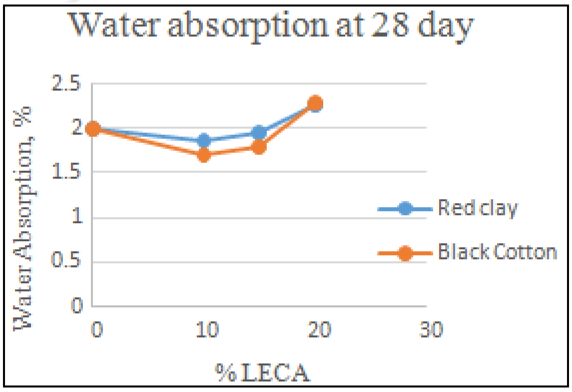

Figure 6: Water Absorption for LECA concrete

4.3 Sorptivity

From Table 1-2, and Figure 7, sorptivity increases with increase in % LECA content. The sorptivity of concrete cubes with Red Clay LECA is higher than Black cotton LECA.

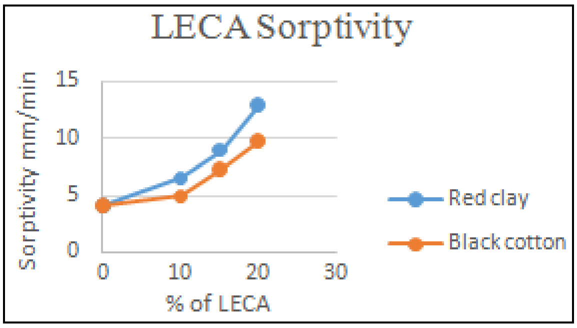

Figure 7: Water Absorption for LECA concrete

5. Conclusion

The objective of this study was to investigate the effects of black cotton and Red Clay soil LECA fine aggregate as a self-curing agent on the mass loss, water absorption and sorptivity of self-curing concrete. From the experimental results, the following conclusion were drawn from the study:

- Use of black cotton and red clay soil LECA as a fine aggregate reduces the mass of the concrete.
- The water absorption decrease with increase of Red clay and Black cotton soil %LECA content up to 10% and then increase with increase in % LECA content
- The water absorption for red clay LECA is higher than that of black cotton LECA.
- Sorptivity increases with increase in LECA content.
- The sorptivity of concrete cubes with Red Clay LECA is higher than Black cotton LECA.

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