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Evaluation of Partial Replacement of Laterite Soil with Granite Fine on the Creep of Laterized Concrete

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Abstract - The effect of partial replacement of lateritic soil with granite fine on the creep of laterized concrete was studied. The effect of water/cement ratio on the creep was also investigated. Besides, effect of water absorption properties of concrete on the creep of laterized concrete was also considered. Sieve analysis, slump, water absorption, and creep tests were performed on the samples. The results of the tests carried out on the specimens of varying granite fine and lateritic soil showed that the creep of laterized concrete increases with an increase in the percentage of laterite. Also, the creep increases as the water/cement ratio and slump increased. Water absorption of concrete increased with an increase in the laterite and thus increases the creep of laterized concrete. The maximum creep value obtained for the specimen with 100% granite fine was 0.333 x 10^{-3}.

Keywords: Creep, laterized, granite, concrete, slump

1. Introduction

In Nigeria, there are many building materials which are cheaper in cost and compare favourably in strength and durability to the commonly used ones. “One of such building materials is the lateritic soil. Lateritic soils are known to be readily available in large quantities all over the tropical region of the world. It is commonly used for residential buildings especially in the rural areas in Nigeria. The use of this material has not gained popularity in the urban area probably because of uncertainty in their strength characteristics. Another major hindrance to the use of the lateritic soil as a building material is the lack of accepted standard regarding the performance characteristics of the stabilized form of it, that is, landcrete”. Landcrete is a concrete in which the fine aggregate is lateritic soil. Concrete is a compound made from sand, gravel and cement. The cement is a mixture of various minerals which when mixed with water hydrate and rapidly become hard binding the sand and gravel into a solid mass. The properties of concrete depend on the quantities and qualities of its components.

Many investigations have been carried out on the use of laterite in building industries. Adepegba (2005), in his study of the effect of using laterite as fine aggregate, compared the properties of concrete made with regular aggregates with landcrete. “He concluded that sand could be replaced successfully with laterite in concrete. Nevil and Dowling (2009) have shown through investigation that the properties of lateritic soil that will influence its rate and ease of mixing includes its degree of finess, density, relative density, particle shape, chemical stability. Adekanye (2000) have shown that laterite can satisfactorily replace sand in mortars and concrete, and the strength comparable to standard mortar can be obtained easily”.

In another work on the factors affecting the strength and creep properties of laterized concrete, Lasisi and Osunade (2005) showed that an increased in cement content and a decrease in water/cement ratio result in significant increase in the compressive strength of laterite concretes.
To abolish the sceptical behaviour of people and to establish an acceptable standard engineering properties of lateritic soils as a building material, researchers have carried out various tests on the behaviour of the material. This paper, among others, is a part of such continuing effort in establishing an engineering basis for the use of lateritic soils in construction and concrete industries, especially in the urban areas of Nigeria where the use of lateritic soils now lacks credibility.

2. Materials and Methods

2.1 Materials collection

The materials used for the casting of the specimens were crushed granite (coarse aggregate), granite fine and laterite (fine aggregate), ordinary Portland cement and water. The granite fine was collected from Reynold Construction Company (RCC) quarry along Lagos – Ibadan road, the laterite was collected from a location (18.5 km from Ibadan) along Lagos – Ibadan expressway.

2.2 Sieve analysis

The particle size distribution of a soil is a major classification test and a knowledge of the distribution will also prove helpful in making a number of other engineering judgement about a soil and has many applications in Highway and Foundation Engineering. The soil sample that has been air dried was sieved down the range of appropriate BS test sieve and the amount retained by each sieve was recorded. The sieves should be well maintained and never overloaded since this can lead to the clogging of the mesh.

2.3 Batching and mixing of concrete

The batching was done by weight in order to eliminate errors due to variation in the proportion of voids contained in a specified volume. The mix proportion adopted was 1:2:4 by weight of cement, fine aggregate (granite fine and laterite) and coarse aggregate. The mixing of the materials was done by concrete mixer.

2.4 Slump test

The slump test was prescribed by BS1881, Part 102. "A frustum of a cone, 300 mm high was used as a mould. It was placed on a smooth surface with the smaller opening at the top and filled with concrete in three layers. Each layer was tamped 25 times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface was stripped off by means of hand trowel. The mould was firmly held against its base during the entire operation." This was facilitated by foot rest brazed to the ground. When filling was completed, the cone was immediately slowly lifted and unsupported concrete slumped. The decrease in height of the slumped concrete was measured.

2.5 Water absorption test

The test was carried out according to the requirements of BS 1881, Part 122. The tests samples were dried to about 100 to 110oC and immersed in water at room temperature for 24 hours, the test samples were removed and air dried for about 10 minutes before the weights were measured, the initial weights were observed before immersing the test samples into water. The moisture content (in percentage) was derived using equation 1.

$$W = \frac{F-L}{L} X 100 \qquad (1)$$

Where W = Moisture content, %
F = Final weight after immersion in water for 24 hours, kg
L = Initial weight before immersion in water for 24 hours, kg

2.6 Creep test

When the specimens attained the desired curing age, the specimens were removed from curing tank between 1-1.5 hours before the test. "The specimens to be tested for creep were carefully and accurately positioned. The specimens were loaded axially. The dial gauge was used to record the deformation. The load was applied instantaneously and held constant while the deformation was monitored as a function of time on the dial gauge". There was a creep at high rate which later slow down gradually until there was no appreciable deformation being indicated by the dial gauge. However, the load was left for some hours before unloading it.

3. Results and Discussion

3.1 Sieve analysis

The result of sieve analysis is illustrated in Figure 1. From the curve, it can be deduced that, the value of d_{60} and d_{10} is 0.80 and 0.15 respectively. Diameter which 60% and 10% of the soil grain are smaller than is called d_{60} and d_{10} respectively. The effective size is also refer to as d_{10}. In view of this, the effective size of the soil sample is 0.15 mm. Besides, uniformity coefficient, U which is the ratio of d_{60} to d_{10} is 5.33. Since the value of uniformity coefficient, U is greater than 5, the soil is well graded which implies that the soil has ample quantities of all the various particle sizes.

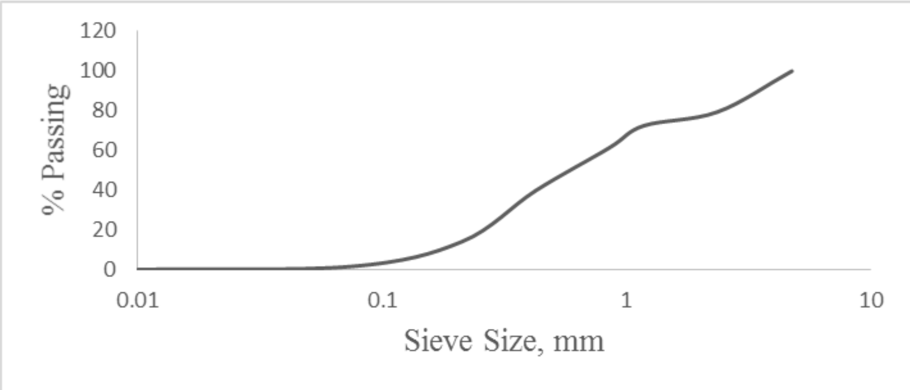

Figure 1: Particle size distribution

3.2 Workability of concrete

The slump test primarily measures the consistency of concrete and is suitable for detecting changes in workability. "A concrete which can be readily compacted is said to be workable i.e an increase in the water content or deficiency in the proportion of fine aggregates results in an increase in slump (Mehta, 2004). The results of the slump test carried out are shown in Table 1. The slump for the samples ranges from 18.0 to 0.0". This shows that only specimens with 100% granite fine and 0% laterite show no slump. Specimens made of 20%, 10%, 0% granite fine and 80%, 90%, 100% laterite show low slump while other specimens indicated very low slump.

Table 1: Composition of the specimens, water/cement ratio and slump

% composition granite fine	% composition granite fine	Water/cement ratio	Slump (mm)
100	0	0.600	0.00
90	10	0.613	4.50
80	20	0.620	7.00
70	30	0.628	9.00
60	40	0.638	11.00
50	50	0.650	12.00
40	60	0.663	12.50
30	70	0.670	14.00
20	80	0.683	15.00
10	90	0.700	16.50
0	100	0.720	18.00

3.3 Water absorption

The permeability of concrete is of prime importance since it determines the amount of protection against corrosion to the underlying reinforcement from the penetration of foreign materials like chlorides. Penetration of concrete by some chemical materials in solution has adverse effect on its durability, for instance when calcium hydroxide is being leached out or an attack by chlorides and sulphates takes place.

The penetration depends on the absorption and permeability of concrete. A concrete which readily absorbs water is susceptible to deterioration and hence the resistance to chemical attack may improve by reduced absorption (Sakr, 2006). Table 2 shows that the water absorption of concrete is increased with an increase in the laterite while the water absorption of concrete is reduced with a decrease in the content of granite fine.

Table 2: Water absorption result

% composition granite fine	% composition granite fine	Moisture content, %
100	0	0.84
90	10	1.32
80	20	1.69
70	30	2.20
60	40	2.71
50	50	3.10
40	60	3.63
30	70	4.16
20	80	4.71
10	90	5.14
0	100	5.73

3.4 Effect of decreasing percentage composition of granite fine on the creep of laterized concrete

From creep results, it was observed that the creep increases as the percentage composition of granite fine decreases. For instance, the maximum creep value obtained for the specimen with 100% granite fine was 0.333 x 10-3, when the granite fine was decreased to 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10% and 0% the maximum creep obtained were 1.013, 2.46, 3.567, 3.947, 4.627, 7.107, 8.42, 10.4, 10.407, and 10.433 respectively. The results show that while concrete with high percentage of granite fine (70% and above) can undergo elastic and plastic deformation (which is allowed for recovery when unloaded) concrete with high percentage of laterite (70% and above) can only undergo plastic deformation. It could be observed that specimens with higher percentage of laterite cannot experience cyclic loading while those with little laterite could.

There was a sharp measure of creep upon sudden loading of the specimens. "After this sudden rise in the creep of the specimens, there was a gradual increase in the creep until it has reached an asymptotic level which is indicated by no appreciable movement of the dial gauge. Upon sudden unloading of the specimen (for 100%, 90%, 80% and 70% granite fine), there was a sudden change in the reading obtained on the dial gauge. This is a measure of instantaneous recovery (Sata *et al.*, 2007). This was followed by a gradual fall in the reading and this is termed the creep recovery. However, as the percentages of granite fine fell below 70% the specimen did not undergo recovery as shown in Figure 2. It was also observed that laterized concrete undergo plastic and elastic deformation. The plastic deformation is the deformation of the laterized concrete that remains permanent, it does not allow for any recovery. The deformation under plastic continue until there was a failure as indicated in Figure 2". As the amount of laterite increases however, the specimens experience more plastic deformation rather than elastic type. The elastic deformation on the other hand is the deformation that tends to bring the specimens to their original length. It is the elastic deformation that is responsible for the recovery of the specimens when relieved of their loads.

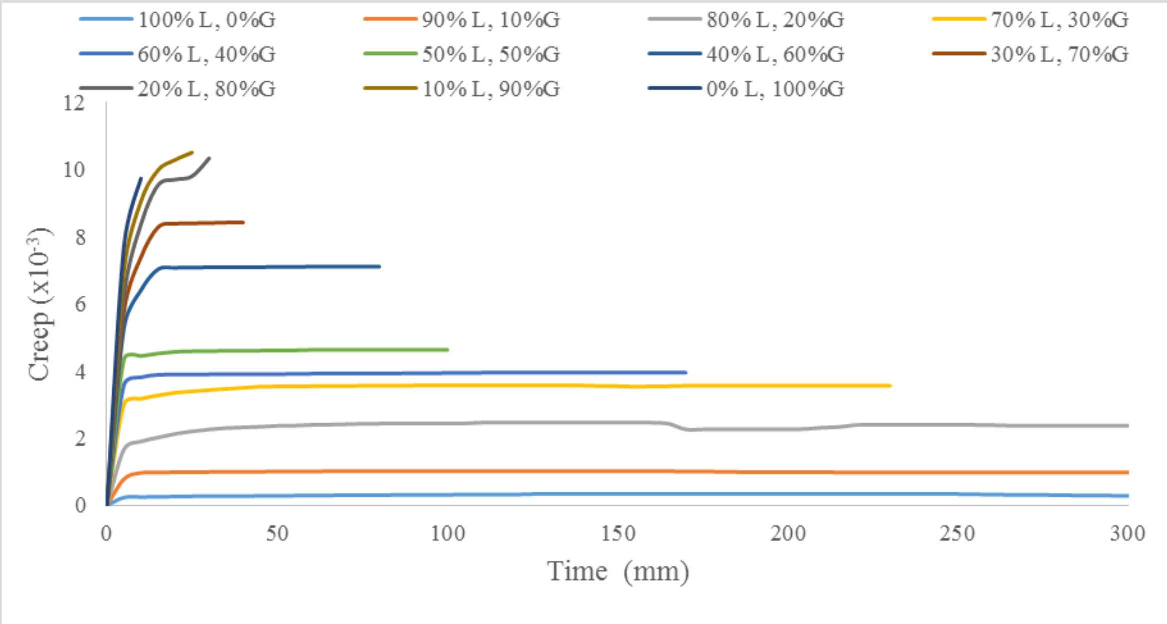

Figure 2: The creep curve

3.5 Effect of water/cement ratio on the creep of laterized concrete

It was observed that as the percentage of laterite increases, more water is required to obtain a mix of approximately the same workability. "The increased water requirement increases the water/cement ratio and the slump. Table 1 shows that as the quantity of laterite increases from 0% to 100%, the water/cement ratio increased from 0.6, 0.613, 0.62, 0.628, 0.638, 0.65, 0.663, 0.67, 0.683, 0.7, and up to 0.72 respectively. This shows that laterite has higher tendency to absorb water than granite fine, this more water absorbed affect the cement paste, which in turn, affect the creep of the laterized concrete". As more water is present in the cement paste, the strength is reduced and a higher creep obtained when loaded. Thus as the percentage of laterite increased, more water was added and the specimen experienced greater creep.

Neville (2006) showed that the part of the concrete that experience creep is the cement part and that creep is related to the internal movement of the absorbed water or intercrystalline water. These facts explain why more water is required for specimens with higher percentage of laterite and why the creep of such specimens were higher. The lateritic content of such specimen absorbed more water than those with higher granite fine content. The absorbed water (and the intercrystalline water) moved as the specimens were loaded and thus experience greater creep. Because the creep of the specimens depend on the lateritic cement paste and this cement paste depend largely on water/ cement ratio, the creep of laterized concrete is affected by the water/ cement ratio.

By the nature of laterite, more water is required for specimens with higher laterite content to obtain the same workability. This explains why there was a sharp measure of creep upon sudden loading, as the laterized cement paste started to adjust itself, it forced the absorbed water to move. The absorbed water is not easily moveable because it is electro chemically bonded to the laterite particles and as the cement paste forces this water to move, there was a turbulence that resulted in the sharp creep recorded on the dial gauge. However, after the initial movement, the measure creep increased at a decreasing rate, bringing the value to asymptotic level.

4. Conclusion

The effect of partial replacement of lateritic soil with granite fine and the effect of water/cement ratio on the creep of laterized concrete have been investigated. The creep of laterized concrete increased as the percentage composition of laterite increased while that of granite fine decreased. Besides, as the slump increased with the increase in percentage of lateritic content and with a reduction in the percentage content of granite fine, the creep also increased. Creep is known to have adverse effect on the stability of structures due to increase in deformation. The deformation in concrete with higher percentage of laterite (greater than 30%) is rapid and thus, undesirable for structures that are subjected to a high deformable load. Concrete with high percentage of laterite should not be used in structures that may experience a cyclic (or dynamic) loading. In reinforced concrete, creep results in a gradual transfer of load from the concrete to the reinforcement. This could be too rapid and catastrophic in nature when concrete with higher percentage of laterite is used.

As the percentage of laterite increased with a decrease in granite fine, plastic deformation increased and specimen recovery decreased. Water absorption of concrete increased with an increase in the laterite while it reduced with a decrease in the content of granite fine. Penetration of concrete by some chemical materials in solution has adverse effect on its durability. The penetration depends on the absorption and permeability of concrete. A concrete which readily absorbs water is susceptible to deterioration and hence, the resistance to chemical attack can be improved by reduced absorption.

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