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INFLUENCE OF MIX PROPORTION ON WORKABILITY OF LATERIZED CONCRETE

***Muhammad, A., Abejide, O. S. and Kaura, J. M.**

Civil Engineering Department, Ahmadu Bello University Zaria, Kaduna Nigeria

*Corresponding authors' email: 7588umar@gmail.com

ABSTRACT

The increase in infrastructural development in the tropic has led to high demand for concrete production. Consequently, its constituents became very scarce and costly, especially the naturally occurring constituents. Laterite as an abundant naturally occurring material in the tropics is only put in use as filling material or in road construction. This study presents the determination of influence of nominal mix proportion (1:2:4, 1:1.5:3 and 1:1:2) at a constant water cement ratio of 0.5 with laterite fully replacing sand (fine aggregate). 72 numbers of cubes of size 100 mm were prepared for the different concretes, while 12 numbers were cast for each mix proportion and cured in the curing tank at 3, 7, 14, 28 days. Though the laterite was found to be a normal weight aggregate, it was also identified as A – 7 – 6, medium plastic clayey and porous material, with a specific gravity of 2.59. For the fresh concrete, the slump value and degree of workability were obtained using the Vee-bee consistometer and slump tests in both laterite and conventional concrete in all the three mix proportions (1:2:4 : 0.5, 1 : 1.5 : 3 : 0.5, 1 : 1 : 2 : 0.5). The Vee bee second for the mix proportions (1:2:4 , 1:1.5:3 and 1:1:2) are 13:18 , 09:44 and 6.0 for the conventional concrete while 14:47 , 12: 41 and 9:30 for Laterized concrete.

Keywords: conventional concrete, hydrometer analysis, laterized concrete, slump, vee bee consistometer

INTRODUCTION

Concrete is the most commonly used construction material in the world. This material is made from the mixture of binding material (usually cement), fine aggregate, coarse aggregate, water and sometimes, admixtures, all in suitable proportions. Conventionally, concrete is a site-made material unlike other materials of construction and as such can vary to a great extent in its quality, properties and performance in the fresh and hardened state, due to the use of natural materials, except cement, which is an artificial material (Busch *et al*., 2022). The properties of concrete may also vary according to its production process and its constituents. The increasing demand for the usage of huge quantities of concrete for construction, leads to an increase in the cost of the binding materials and depletion of natural resources, such as aggregates, which in turn increases the cost of concrete.

In ordinary structural concrete, the aggregates (fine and coarse) occupy about 70-75% of the concrete volume, which makes them have a pronounced influence on the properties of fresh and hardened concrete (Sangeetha *et al*., 2021). Laterite has the advantage of being readily available in most tropical communities. Besides being obtained intentionally in borrow pits excavation, it is frequently obtained through various forms of excavation for structural works, including excavation for foundations and septic tanks (Kaze *et al*., 2021). Laterite is used in making kutcha houses and huts, found in villages.

Laterite concrete or lateritic concrete is a concrete in which laterite replaces aggregates. In recent time, researchers' efforts have been directed towards determining, as well as, improving some physical and engineering properties of lateritic soil (Awoyera *et al*., 2018). Several investigations have been conducted on the effective structural application of lateritic soil as a component in concrete (Awoyera *et al.*, 2017; Musbau *et al*., 2021; Yaragal *et al.*, 2019). It has also been found that laterite concrete has similarities with conventional concrete in some properties. Laterite concrete will be especially useful for concrete elements under mild conditions of exposure that are reasonably protected from the effect of harsh weather. Abhijet *et al*. (2017)

Laterized concrete is a concrete in which laterite either partially or wholly replaces conventional aggregate in the production of concrete. Several investigations have been conducted on the effective structural application of lateritic soil as a component of concrete (Osunade *et al.*, 1990). Laterite used in concrete can either be gravelly and sandy laterite (stable) or silty and clayey (unstable). Laterite can enhance properties of concrete depending on the laterite and also the blended material, (Shuaibu *et al.*, 2014). In their study, Shuaibu *et al.*, (2014) concluded that laterized concrete has proved to possess structural properties, though laterite soil has been seen to yield less workable concrete. A study by Samuel and Osadola (2019), shows that workability of concrete is reduced with increasing content of laterite. This is due to the high content of laterite. Hence, superplasticizer dosage increases considerably at laterite content greater than 40%. Falade (1994) in his study examines the variation of workability and characteristic strength of laterized concrete, with varying water/ cement ratio and mix proportion using 7 and 28 days curing.

This study investigates the influence of mix proportion on workability of laterized concrete at a fixed water / cement ratio of 0.5, using the mix proportion 1: 2 :4, 1: 1.5 : 3 and 1 : 1 : 2. The fine aggregate (River sand) was fully (100%) replaced with a lateritic material, of medium plastic clayey type (A- 7- 6). Different properties of laterite concrete have been considered at different stages with far reaching recommendation in favour of laterite as suitable for use in construction industry (Ukpata *et al*., 2012).

Adepegba (1975) was identified as the first to study the effect of using laterite as a fine aggregate in cement for the production of concrete. Adepegba (1977) also carried out further research comparing the resistance in high temperature, modulus of elasticity and compressive and tensile strengths of laterite concrete mixes (1:2:4, 1:1.5:3 and 1:1:2 by weight) to that of normal concrete. He concluded that for high workability with only 25% of sand in concrete could be substituted with laterite as fine aggregates, while the mix ratio should be 1:1.5:3 and with a water/cement ratio of 0.65.

Laterite is a tropical soil that is available in the tropics and in many parts of Africa, Asia and America (Adepegba, 1975). Its neglect as an engineering material is linked to the uncertainty in its strength and other structural characteristics, such as creep, shrinkage and long-term durability (Kaze et *al.*, 2021). According to Metekong *et al*. (2021), laterite is a highly weathered material rich in secondary oxides of iron, aluminium or both. It is nearly devoid of base and primary silicate, but may contain large amounts of quartz and kaolinite. It varies in colour from white to dark reddish. The change in colour of the material indicates the degree of its maturity, which depends largely on the concentration of iron oxides.

Laterite is composed of both cohesionless and cohesive soil portions; in which the cohesionless portion consist of gravels, sand and silt, while the cohesive portion consists of the fine particles usually as silt and clay. The material behaves in a unique way with some laterite changing colour when exposed to humidity variation. Hence, some components are referred to as stable; these are gravely and sandy, while, silty and clayey are referred to as unstable. The stability in this sense is based on their ability to withstand variation in terms of moisture without significant change in its properties, which is of course fundamental in material for building construction (Riggassi, 1995)

MATERIAL AND METHODS

Materials

Fine Aggregate

Two different materials were used as fine aggregates in this research work. For the production of conventional concrete, clean river sand having a fineness modulus of 2.96 a specific gravity of 2.56, a density and water absorption percentage of 1600 kg/m^{3}and 7.13% obtained in Samaru Zaria, Nigeria was used. For production of laterized concrete, laterite soil obtained from a borrow pit along Shika-Samaru Road Zaria, Nigeria was used. The laterite soil is naturally reddish brown in colour. It was classified under the unified soil classification as A- 7 – 6 (high plasticity clay soil) with a specific gravity, and a fineness modulus of 2.56 and 1.65 respectively.

Coarse aggregates

The coarse aggregate is crushed granite rock with a maximum aggregate size of 20mm. It was obtained from a quarry site in Zaria. It was ensured that the material is clean and free from deleterious substances and was prepared and tested in accordance with BS 812-103-1 (2016) and BS 812-103-2 (2016). It was identified as a normal weight aggregate having a density and specific gravity of 1450kg/m^2 and 2.6, respectively. The particle size distribution calculation reveals it to be having a fineness modulus of 2.58.

Cement

The cement used is a brand of Portland limestone cement. The conformity of this cement was assessed using BS EN 197-1 (2019).

Water

The water used for the test was collected from a tap in the concrete and soil laboratory of the Civil Engineering Department, Ahmadu Bello University, Zaria. This water is portable and fit for drinking.

Methods

Test on Aggregate

The characteristic of the lateritic material was obtained through performing the following test on a collected portion of the laterite. Below are the different tests performed.

i. Particle size distribution (sieve analysis and hydrometer test).
ii. Atterberg Limit test.
iii. Specific gravity test.

i. Particle size distribution

The particle size distribution (PSD) analysis for the river sand (conventional) and coarse aggregates was determined through the dry sieve method in accordance with standards BS 812-103-2 (2016). Since the lateritic material, contains substantial quantity of tiny materials (< 0.0045), the wet method of sieving was performed on the coarser portion, while hydrometer test was performed on the finer portion, which the material that passes the No 200 (0.0725mm). The result is reported graphically on a semi log graph.

ii. Atterberg Limit test

The lateritic material that passes through the sieve 425mm (No. 36) was used for Atterberg limit test. It was carried out in accordance with BS 1377 : (1990.). It is also important in determining and classifying the fine grained material.

iii. Specific gravity test

The specific gravity was conducted in accordance with BS EN 1097- 3 (2020). The test was conducted on the fine and coarse aggregates. The specific gravity is of importance in the calculation of aggregates quantity for any given concrete mix, as expressed in Equation (1)

$$Specific\ Gravity\ (Gs) = \frac{B}{(P + B - P_S)} \quad (1)$$

$Where\ B = Quantity\ of\ material, sand\ or\ gravel$

$P = Gas\ Jar + Water$

$P_s = Gas\ Jar + Water + Material$

iv. Water Absorption of Aggregate:

The test was done in accordance with BS EN 1097-6 (2020). The equation below is used to determine the percentage of water content in a given aggregate.

$$Absorption\ (\%) = \frac{W_B - W_A}{W_A} \times 100 \quad (2)$$

$W_A = Dry\ weight\ of\ aggregate$

$W_B = Weight\ of\ aggregate\ after\ immersed\ in\ water$

Preparation of concrete constituent

The laterite material was sieved and that portion that passes the No. 4 sieve (sieve 4.75mm) and retained on the sieve No. 300 (sieve 0.15mm) was used as the fine aggregate in the production of laterized concrete. The coarse aggregate (clean and free from deleterious substance) used in the study was a crushed granite of nominal size 20mm.

Mix proportion

This involves selecting and estimating the proper quantity of ingredients that will be used to achieve the required strength. The following calculation was used for the proportioning.

Water cement ratio = 0.5

Size of conventional concrete/laterite concrete cube used for the test is 100mm x 100mm x 100mm

Therefore, volume of one cube = 0.001m^3

For a concrete mix prepared using a mix ratio of 1:2:4, determination of quantity of materials using absolute volume method can be obtained thus:

Let:C = Cement content (Specific gravity = 3.15),
L = Laterite content (Specific gravity = 2.56)
Q = Coarse aggregate content (Specific gravity =2.6)
W = Water

$\therefore \quad L = 2C$

$Q = 4C$

$$\frac{0.5C}{1000} + \frac{C}{1000 \times 3.15} + \frac{2C}{1000 \times 2.56} + \frac{4C}{1000 \times 2.6} = 1m^3$$

$Hence, C = 322.58kg$

Volume of 1 cube of laterite concrete = 0.001m^2

∴ 12 No of cubes were cast for each mix

Thus, volume of 12 no. cubes = 0.001 x 12 = 0.012m^3

But 1m^3 contained 322.58kg of cement

Hence, 0.012m^3 contained 3.87kg of cement

Add 10% waste = 0.387 + 3.87 = 4.26kg

∴ 0.012m^3 of laterite concrete contained 4.26kg of cement
The quantity of the materials required to cast 12 nos. cubes of size 100mm x 100mm x 100mm are:
Cement = 4.26kg
Laterite = 8.52kg
Coarse aggregate = 17.04kg
Water = 2.13kg
The above calculation was repeated for the remaining mix proportion.

Concrete Batching and Mixing.

Three (3) mixes 1:2:4, 1: 1.5:3 and 1: 1: 2 at a constant water cement ratio of 0.5 were adopted in the study. Batching of constituents for both conventional and laterized concrete was achieved by weight using the Avery weighing scale. Mixing was done by hand on a flat, clean non porous metal plate. It begins by mixing the spread fine aggregate with cement thoroughly in their dry state until a uniform colour is observed. The already batched coarse aggregate was later added to the mixture and mixes continued. The prescribed amount of water, according to the water-cement ratio of 0.5 was then added periodically and the mixing process continued until a homogenous mixture was obtained. The process was repeated for all the mix. Workability test was carried out on both laterized and conventional fresh concrete.

Workability Test

The workability for both conventional and laterized fresh concrete was determined by performing slump and vee bee consistometer tests on the fresh mix concrete.

Slump test

This test was performed in accordance with BS EN 12350 – 2 : (2019)

Vee bee Consistometer

The test was carried out in accordance with BS EN 12350 – 3 : (2019)

RESULT AND DISCUSSION

Result

Particle Size Distribution (Sieve Analysis of Coarse and Fine Aggregate)

The particle size distribution result of fine and coarse aggregates presented in Figure 1 shows that both river sand (conventional aggregate) and the coarse aggregate are well-graded material. The gradation profile shows a fair representation of aggregate sizes in both types of aggregate. The result shows that the fine (river sand) aggregate is a Zone 2 aggregate having a fineness modulus of 2.96 a Coefficient of Curvature (Cc) and Uniformity coefficient of 5.3 and 1.0 respectively. The coarse aggregate having the maximum aggregate size of 25mm has coefficient of curvature of 1.4.

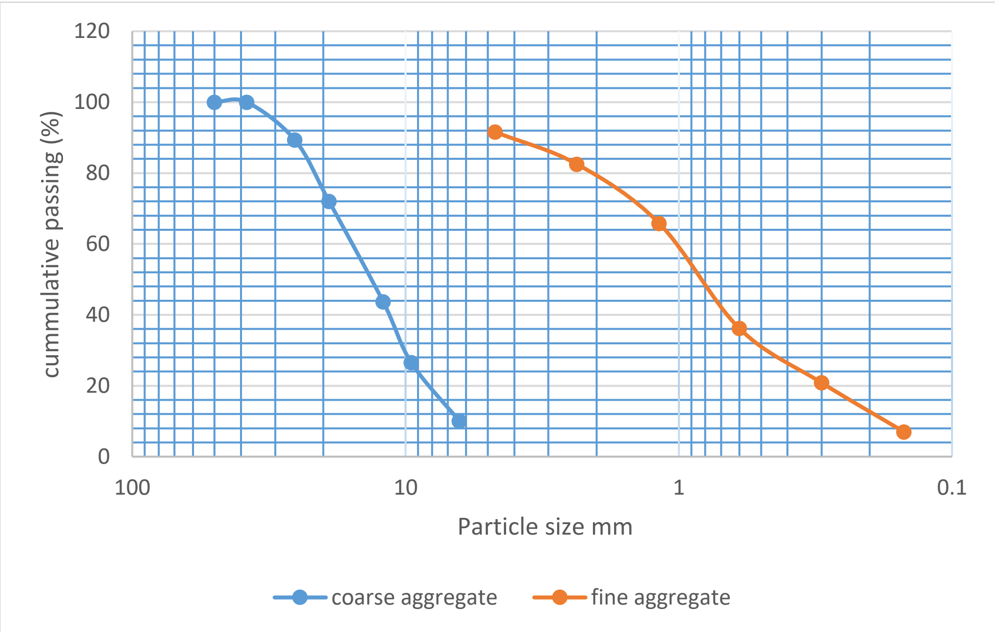

Figure 1: Particle Size Distribution Curve of Fine Aggregate and Coarse aggregate.

Particle Size Distribution (Sieve Analysis and Hydrometer analysis on Laterite Material)

The sieve analysis performed on the lateritic material reveals it to contain larger amounts of clay with about 70% of it particles cumulatively passing BS No.200 (0.075 mm). Figure 2 shows the particle size distribution curve (Sieve and Hydrometer Analysis) of the lateritic material.

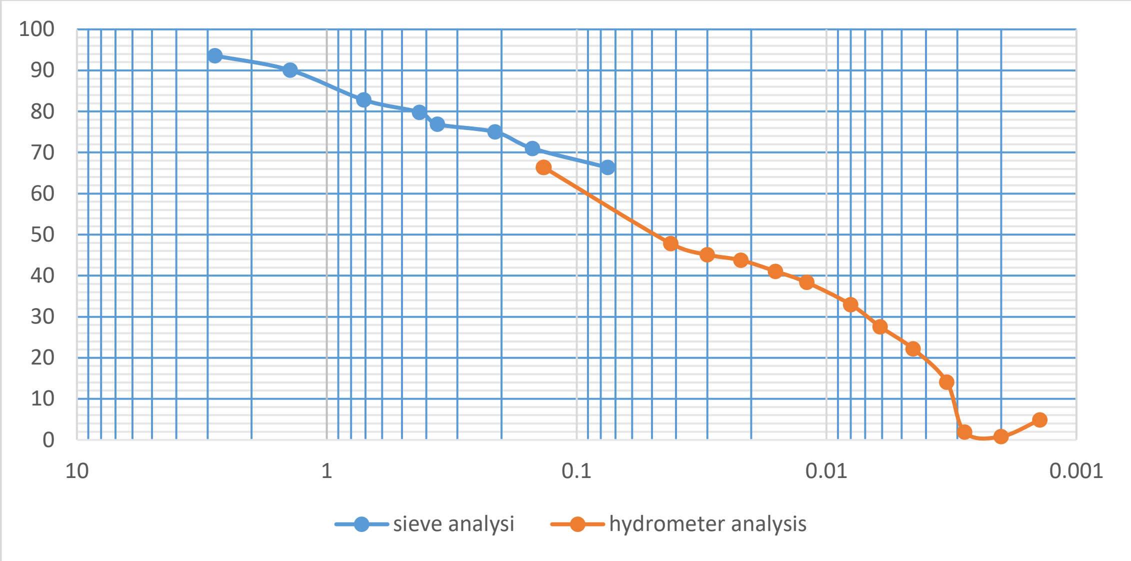

Figure 2: Particle Size Distribution Curve of Laterite Material.

Atterberg limit test
The lateritic material that passed through the sieve 4.25mm (No. 36) was used for Atterberg limit tests. The results reveal the material to have liquid limit, plastic limit and plasticity index of 48%, 19.28% and 28.72% respectively. Also the laterite material is found to be a clayey soil of medium plasticity. Based on Unified Soil Classification system (USCS) and AASHTO, it is identified as CL and A – 7 – 6 (clayey soil).

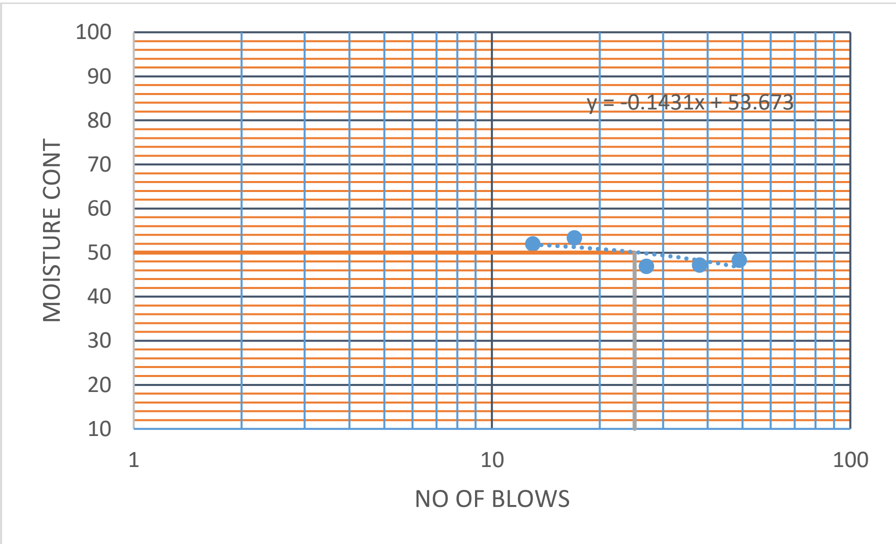

Figure 3: Liquid limit chart

Table 1: Atterberg limits of laterite material

Atterberg limit	Test Value (%)
Plastic limit	19.28
Liquid limit	48.00
Plasticity index	28.72

***Specific* Gravity (Relative Density)**
The specific gravity of a material is considered to be an indication of the material's strength or quality. Low specific gravity generally indicates porous, weak and absorptive material where as high specific gravity indicates material of good quality. From the test results, the coarse aggregate, fine aggregate and laterite have specific gravities of 2.6, 2.79 and 2.56 respectively. All values obtained fall within the range prescribed by ASTM C127 (2015) and ASTM C128 (2015).

Result for Cement test
All conformity tests carried out on the cement are to BS EN 196:3 (2016). These tests include consistency, setting time and soundness tests. Table 2 shows that the cement meets the requirements of a Portland Limestone cement set out in BS EN 196:3 (2016).

Table 2: Results of Conformity tests on Cement

S/No.	Test on Cement	Test Value	Code limits	Remark
1.	Consistency	30%	26 – 33%	Okay
2.	Setting times (Initial)	98 mins	≥45 mins	Okay
3.	Setting times (Final)	162 mins	≤600 mins	Okay
4.	Soundness	3 mm	≤10 mm	Okay

Influence of mix proportion on workability of fresh concrete

Laterized concrete has been known to exhibit nearly zero slumps in the absence of superplasticizers. The workability test result is shown in Table 3. Regardless of the kind of aggregate (fine aggregate) used; the workability of the fresh concrete was observed to be influenced by the mix proportion at the fixed water cement ratio. This is seen in the result obtained from Slump and Vee bee Consistometer tests performed on both laterized and conventional concrete. Both laterized and conventional concrete shows same trend in degree of workability in all the mix ratio (1: 2 : 4 , 1 : 1.5 : 3, and 1 :1 : 2) at constant water cement ratio of 0.5. At minimum mix proportion (1: 2 : 4 : 0.5 , 1 : 1.5 : 3 : 0.5) the fresh concrete exhibit a nearly zero slump, this agrees with previous findings of (Ukpata *et al*. 2012). They shows that with over 70% of laterite content substituting the River sand in mix proportion 1:1.5:3 the slump is virtually zero. While a true slump was observed with mix proportion 1 : 1 : 2 : 0.5 in both type of concrete. Despite that grading of aggregate has a vital role on concrete workability, especially the percentage passing (15 to 30 %) the No 50 (0.3mm) sieve the influence of mix proportion is more pronounced in both concrete. This could be attributed to aggregate / cement ratio in each mix for both the concrete. As the aggregate cement ratio decreases a more workable concrete is produced. This also agrees with Falade's (1994) findings, that workability decrease with increase in lateritic / cement ratio. The time (vee bee seconds) required for the concrete to be remoulded and take the shape of a cylinder is delayed in laterized concrete than in conventional concrete (Figure 3) , even though timing was within same limit (degree of workability).

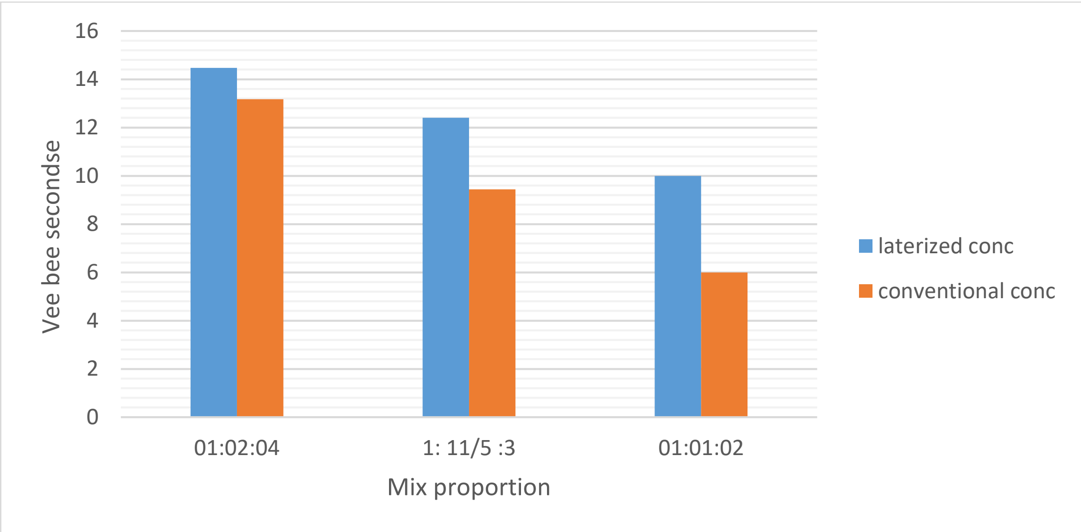

Figure 3: Relationship Between Vee bee sec. and Mix Proportions

Table 3: Slump and Vee Bee (seconds) for Conventional Concrete

Mix proportion	Slum (mm)	Vee Bee (seconds)	Degree of workability
1: 2 : 4 : 0.5	0	13:18	Very low workability
1: 1.5 : 3 : 0.5	0	09 : 44	Low workability
1: 1 : 2 : 0.5	80	6:0	Medium workability

Table 4: Slump and Vee Bee (seconds) for Laterized Concrete

Mix proportion	Slum (mm)	Vee Bee (seconds)	Degree of workability
1: 2 : 4 : 0.5	0	14:47	Very low workability
1: 1.5 : 3 : 0.5	0	12 : 41	Very low workability
1: 1 : 2 : 0.5	7.5	9 : 30	Medium workability

CONCLUSION

The lateritic material used in the study was found to contain large amount of clayey material and is identified under AASHTO and USCS as A – 7 – 6 and CL (clayey of medium plastic). It has a specific gravity which falls within the requirement set by ASTM C127 (2015) and ASTM C128 (2015). By using laterite with the above characteristic fully replacing the fine aggregate (river sand) to produced concrete at fixed water / cement ratio of 0.5, the workability follows the same trend as the conventional concrete. when the mix proportion is improved (aggregate cement ratio decreases), a more workable laterized concrete was obtained. The Degree of workability seems to be better and optimum in concrete with mix proportion 1: 1:2:0.5, and is hence recommended laterized structural concrete mixes.

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