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Strength of Laterite Rock Concrete

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Abstract This paper presents the results of laboratory tests conducted to investigate a concrete made with laterite rock coarse aggregates. The structural properties considered were strength and elasticity. Laterite concrete mix proportions of 1:3:6, 1:2:4 1:1½:3 by weight of cement, river sand and laterite rock respectively at varying water/cement ratios of 0.55-0.90 were used. The results established an optimum water/cement ratio of 0.75, 0.60 and 0.55; with characteristic strengths of 12.00N/mm^2,18.69N/mm^2 and 22.88N/mm^2 for mix 1:3:6, 1:2:4 1:1½:3 respectively. Flexural and splitting test results were about 6 - 21% of the compressive strength of the laterite rock concrete. The static modulus elasticity of laterite rock concrete is 22.72kN/mm².

Keywords: *strength, impact, workability, concrete, laterite rock*

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1. Introduction

Concrete today has assumed the position of the most widely used building material in the world. Concrete is classified in terms of the type and composition of aggregate used. Presently the crushed granite aggregate and river sand concrete system are generally regarded as the conventional concrete.

Aggregates occupy 60-80% of the volume of concrete and greatly influence its properties, mix proportions and economy. Thus any effort at reducing the cost of aggregate will have direct impact in reducing the cost of construction especially housing. In recognition of this, the BS 8500 (2002), BSEN 206-1 (2001) and B8110 (1997) encourage the use of non-conventional aggregate provided there are satisfactory data available on the properties of concrete made from them. There is therefore every incentive for research into alternative aggregates from cheaper source locally. Successful application of local aggregates will make housing cheaper, provide a source of revenue to the communities where it is found and jobs for the people and conserve fund on the equipment importation.

There is abundance of Lateritic materials all over the world, especially in tropical regions with high characteristic rainfall and persistently high temperatures. The typical regions of occurrence of laterite include India, Burma, Indonesia, Malaysia, Australia, Africa and interior parts of South America [17].

According to Maignien 1966, laterite is generally defined as a highly weathered material rich in secondary oxides of iron, aluminum or both. It is nearly devoid of bases and primary silicates but may contain large amounts of quartz and kaolinite. It is a group of mineral materials formed as the degradation products of certain igneous rocks and composed mainly of hydrated oxides of aluminum, iron and titanium $Al_2O_33H_{20}$ (gibsite), HF_e0_2 (geothite) FeO(OH) (Lepidocrocite) and Fe_2O_3 (hematite) [15].

An extensive area of Nigeria is covered with laterite materials in various weathered states, ranging from clay laterite, sandy laterite to rock laterite. In local construction practice, these materials are variously used mainly in blocks production, road fills and as fine or coarse aggregates in concrete production.

In view of its abundance and physical impurities, laterite rock aggregates represents a useful alternatives for crushed granite stones and river gravel in the production of concrete. However, there is dearth of reliable research information on the structural characteristics of laterite rock aggregate concrete.

Laterite rock occurs in the geological zone 2A in Nigeria. In this study and in line with general classification, concrete containing laterite rock aggregate sand and cement is referred to laterite rock concrete(LRC) This is in distinction from laterized concrete in which the fine aggregate in normal concrete is partially or wholly replaced by with laterite fines.

There is therefore the need to carry out a detailed study of these properties to ascertain its structural suitability, define the limits of its application and specify possible measures to be taken for an improved performance. The method adopted in this research was experimental through laboratory tests on fresh and hardened concrete.

2. Previous Studies

A number of studies had been carried out to determine the suitability of using laterite rock as an aggregate and obtain the engineering properties of the resulting concrete in its wet and hardened state. This includes the works of Akpokodje and Hudec [1], in which the specific gravity of laterite rock obtained from ten cities in Nigeria were investigated. In their work, they found out that their specific gravity varies from 2.95 – 3.47. Others are Udoeyo et al [21] reported a specific gravity of 2.51 for Owerri Laterite, Madu [12] reported a specific gravity of 2.62 – 2.90.

On water absorption Akpkodje and Hudec [1], Madu [12] and other gave a range of value between 3 to 9% which is higher than 0.5% for normal crush granite. They recommended that allowance should be made was water absorption of the coarse aggregate

In order to establish the relationship between the physical properties of laterite rock aggregates and the resultant strengths of concrete made from them, Akpokodje and Hudec [1] conducted Aggregate Crushing Value(ACV) and Loss Angelis Abrasion tests on laterite rock aggregates obtained from ten different locations in Nigeria. These tests gave values between 24 - 49% for the former and 4 - 19% for the later respectively. Madu [12] in his work obtained the values between 24 - 42% and 20 - 36% Aggregate Crushing Value (ACV) and Loss Angelis Abrasion respectively. These values are higher than the conventional granite with abrasion value between 17 and 20%, They concluded that concrete made from laterite aggregate may not suitable for abrasive environment.

Other physical properties investigated by Madu [12] are 10% fine test, flakiness, angularity number and organic impurities content. The values obtained from the above tests fall within acceptable specified limits. Akpokodje and Hudec [1], and Madu [12] concluded that the mineral composition is the major factor affecting the physical properties of laterite rock aggregates.

On concrete made from laterite rock concrete, Madu ([12] in his study on laterite concrete reported the workability of the range of 15 – 20mm, 25 – 30mm and 35-40mm for Nsukka laterite coarse aggregate. Akpkodje and Hudec [1] confirmed the relationship between the specific gravity of the aggregate and the density of concrete made from it. The obtained density of laterite rock concrete was varying from 2192 to 2472 kg/m^3.

Strength of concrete is commonly considered the most valuable property. It usually gives an overall picture of the quality of concrete because it is directly related to structure of the hardened cement paste.

Data obtained from various researchers showed that the locations from which laterite rocks were procured particularly the topography affect the strength properties. Akpkodje and Hudec [1] gave the strength of concrete made of laterite rock aggregate with aggregate/cement ratio of 2.20,water/cement ratio of 0.42 and coarse/fine aggregate ratio of 0.65.The laterite rock obtained from Nsukka – 34.344 MPa Enugu 42.10MPa, Wudil 30.56MPa,Bukuru 19.95 MPa, Okene 24,32 MPa Damaturu 23.45MPa all locations in Nigeria. Madu [12] gave a mean strength range 14.9-23.60Mpa for 1:2:4 mix and water/cent ratio of 0.55. While crushed granite gave 44.37 Mpa and concluded that concretionary laterite gravels possesses compressive strength that are comparable with concrete produced with granite crushed rock aggregates.

Many researchers have established a relationship between flexural strength and compressive strength of concrete. Among them are Sharad and Deepak [18]. They conducted study on concrete samples obtained from 41 construction sites where rigid pavements were being constructed in Indian. At each site has a target 28day compressive strength of 35N/mm^2 with minimum cement content, of 437 kg/m3 and at water cement ratio of concrete of 0.39. 150mm. x 150mm. x 150mm. cube samples and 150 x 150 x 700mm beam samples were taken for each day's concrete work. The results of the tests gave an average value of compressive strengths of 40.64 and that of the flexural value of 5.61 MPa. The average ratio of the flexural strength to the compressive strength gave 0.14.

A comparison of the ratio of the flexural strength to compressive strength of laterite rock concrete obtained by Raju and Ramakrishna [17] strength of concrete was 0.2 for the former and 0.1 for the later. These values are similar to what obtained from crushed stones as the control aggregate

Impact test demonstrates the relative brittleness, resilience, impact resistance and toughness of concrete and similar construction. It applies load repeatedly to the test specimen instead of making it to fail with one massive blow. A material with a high compressive strength can be very brittle and may easily fail due to impact, whereas a material which is more resilient but with less compressive strength can have a higher impact resistance [4].

Swamy and Jojagha [19] found that about 14% of all specimens tested broke into 2 pieces and 4 pieces whilst 72% of failure occurred by falling in 3 pieces and thus it was concluded that this pattern of failure appeared to be the predominant mode of failure of plain lightweight aggregate concrete specimens under the test conditions of their investigation.

Balogun and Oyekan [4] stated that the failure modes of a concrete under a repeatedly falling weight depends on a number of factors which include the following: The type of concrete specimen, the test boundary condition, the aggregate matrix bond strength, the aggregate strength and the matrix strength. They gave the results of impact test for different percentage of laterite content and the concrete matrix at 28 days. The results revealed that as the laterite content increases the impact strength reduces with a reduction in the compressive

In practice, the concrete modulus is usually not measured, but estimated from the concrete compressive strength, paste modulus E_p and aggregate modulus E_a, using a suitable empirical formula. Takafumi et al [20] developed an empirical equation for predicting the modulus of elasticity as a function of compressive strength and the concrete constituents in two phased macro philosophy. To achieve this more than 3000 data sets obtained by many investigators using various materials have been collected and analysed statistically. The compressive strengths of concretes considered range from 40 to 160 MPa. As a result, a practical and universal equation takes into consideration the types of aggregates and mineral admixtures were proposed.

ZHENG Jian-jun and ZHOU Xin-zhu [22] developed a numerical method that can predict the elastic modulus of three-phase concrete made with two different aggregates. In this method, the mesostructure of concrete is simulated and the lattice type model is modified to take into account the mechanical properties of the cement paste, ITZ, and fine and coarse aggregates of concrete. The finite element method is then employed for analysing the stress and strain in concrete and therefore determining its elastic modulus. Finally, the developed numerical method was verified by comparison with the experimental results obtained from the research literature given less than 10% error.

Pintea and Traian [16] conducted an experiment on conventional crushed granite concrete to calculate the Secant Modulus of Elasticity in full accordance with the articles from the German standard DIN 1048-5:1991. Test specimens were concrete cylinders 150 mm in diameter with a height of 300 mm, and complied with EN 12390-3 with concrete strength class C40/50. The average value of the Secant Modulus of Elasticity of 33878 N/mm2 for the specimen tested at the age 28 days was very close to correspondent value of 31400 N/mm2 obtained from DIN, 1045-1:2008-08 standard.

3. Materials and Methods

The materials (laterite rock and sand) were air dried in the open laboratory. The laterite was first crushed or ground and then passed through a set of sieves. The proportion passing through sieve (20mm) and retained on sieve (5mm) was used for all experiments, uniformly medium gravel while the sand passing 2mm and retained in 150μm

The water used was fit for drinking conforming to BS3148 (1970).

The cement used was the ordinary Portland cement produced by Dangote Cement Company conforming to EN 196-1:1987; 196-6:1989.

The specific gravity test of the sample was carried using a mechanical shaker in accordance with BS 812: 1995, Part 6 (A).

Plate 1. Mechanical shaker for Gs test

3.1. Workability Tests

The workability tests on freshly mixed concrete were carried out using the slump test in accordance with ASTMC 143 – 90a and BS 1881: Part 102:1983. The compacting factor test was carried out in accordance with BS1881 part 103; 1993 and ACI 211, 3-75 (Revised 1987) (Re-approved 1992).

The freshly mixed concrete batched by weight for mix proportions 1:3:6; 1:2:4 and 1:1½:3 with water/cement ratios 0.70, 0.75, 0.80, 0.85, 0.96, 0.60, 0.70, 0.80, 0.85, 0.9 and 0.50, 0.55, 0.60, 0.65, 0.70 respectively

3.2. Strength Properties

3.2.1. Compressive Strength

Compressive strengths for the mixes were carried out in accordance with BSEN206 2001: part 3. Total numbers 108 cubes were cast for this test. From the results of the cube tests, 1:3:6 mix proportion was considered not fit for a structural concrete and was no longer used in the remaining experiments.

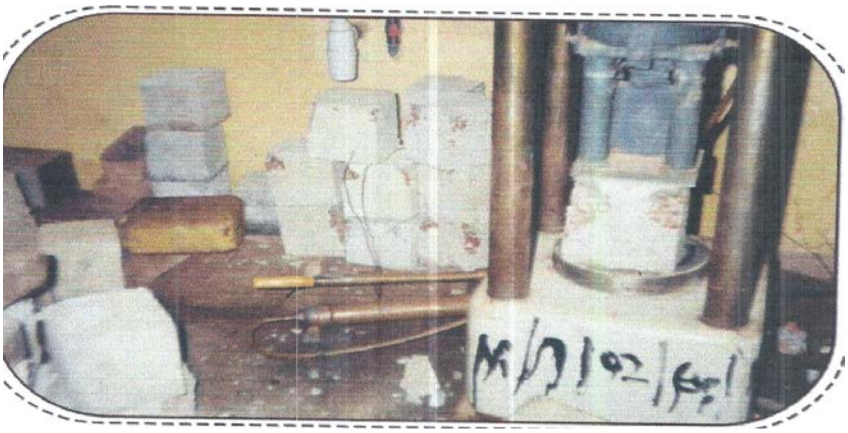

Plate 2. Manual compression test machine

3.2.2. Beam Flexural Test

This was carried out on beams of size 100 x 100 x 500mm in accordance with ASTM C293. The beam specimens were prepared using a steel beam mould and cured for 28 days for each mix of 1:2:4 and 1:1:½:3 for different water/cement ratios. The beam was then placed on 25mm diameter bars at 50mm from both edges and loaded on third-span point through a spreader bar as shown in Fig.1. The load was applied gradually at 120kNmm^{-1} loading rate. The flexural tensile strength f_r was then calculated by the standard formular in equation 1

$$f_r = \frac{PL}{b^2 d} \quad (1)$$

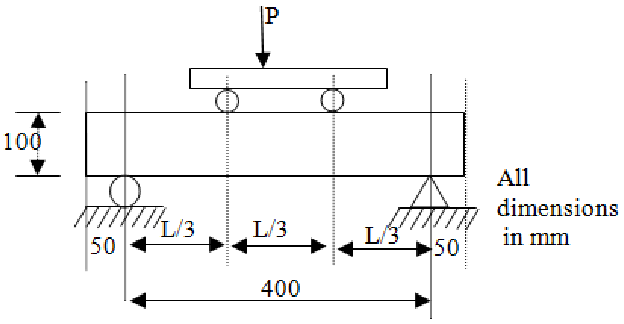

Figure 1. Third point loaded system

Where P is the applied load, L, b and d are the span, width and depth of the beam

3.2.3. Splitting Tensile Test

A total of 6 samples were tested, 3 for each mix proportion. The splitting test for this research was carried out using a cylindrical specimen of diameter of a 150mm and 300mn depth. The cylindrical specimen was supported longitudinally using 25mm loading strip running longitudinally on the top of the specimen on top of the beam. The load was applied gradually at 120kNmm^{-}1 loading rate. This was carried out in accordance with ASTM C496. The splitting tensile strength was then calculated from equation 2

$$f_t = \frac{2P}{\pi l D} \quad (2)$$

Where P is the applied load, L and D are the length and diameter of the cylinder

3.2.4. Impact Test

The method of test used for impact resistance determination is the drop hammer test recommended by the ACI committee 544. The tests were conducted by dropping a 4.5kg hammer repeatedly from a height of 450mm off to a hardened steel ball resting on a cylindrical specimen 152.5mm diameter and 63.5mm height. The test was carried out on the concrete specimen at the ages of 7, 14, 21 and 28 days. Two samples were tested for each age and mix. The number of blows resulting in the total crushing was recorded. The impact resistance of the material was taken as the number of blows required for the first visible crack to appear on the test specimen. The results are presented in Appendix 2.

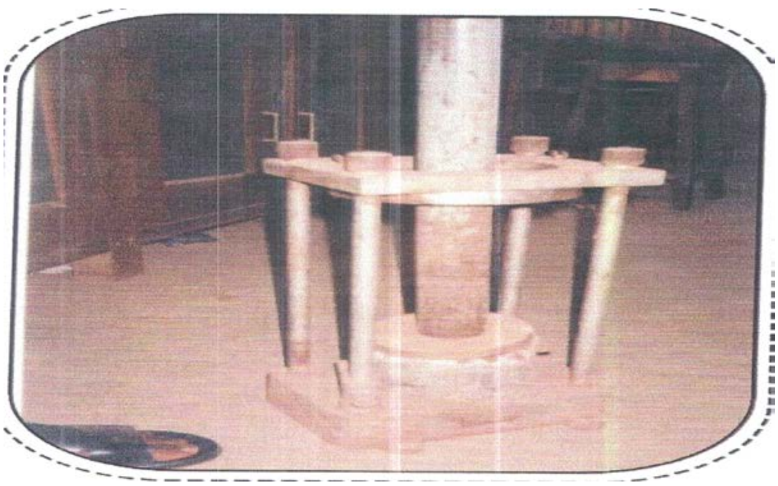

Plate 3. Impact test equipment

3.2.5. Determination 0f Static Modulus of Elasticity

This test was carried out in accordance with BS 1881: Part 121:1983.Three a cylindrical mould 150mm ϕ and 300min depth from 1:1½:3 mix was used for the test. Strain gauges were attached to the specimen with the use of rapid setting and set hard adhesive. The test specimens were placed with the measuring instruments or fixing points attached axially, centrally in the machine. The basic stress of 0.5N/mm^2 (σ_b) was then applied and the strain gauge readings recorded. The stress was increased steadily at a constant rate within the range 0.6 ± 0.4 N/mm^2/s) until the stress equal to one-third of the compressive strength of the concrete (σ_a = f_c/3) is reached. The loads on the specimen were increased at the specified rate, until failure of the specimen occurs. The static modulus of elasticity E_C was calculated from the relation in equation 3.

$$E_c = \left[\frac{\sigma_a - \sigma_b}{\varepsilon_a - \varepsilon_b} \right] \quad (3)$$

4. Results and Discussion

4.1. Specific Gravity

Specific gravity is critical information for the Hot Mix Asphalt Design Engineer. The value is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). In Portland cement concrete the specific gravity of the aggregates is used in calculating the percentage of voids and the solid volume of aggregates in computations of yield. The absorption is important in determining the net water-cement ratio in the concrete mix. Knowing the specific gravity of aggregates is also critical to the construction of water filtration systems, slope stabilization projects, railway bedding and many other applications. The results obtained from the specific gravity yielded a specific gravity of 2.79 which falls within the values for normal weight aggregates.

4.2. Workability:

Workability is the ease with which freshly mixed concrete can be placed, compacted and finished without segregation [2]. It is the amount of useful internal work necessary to produce fully compacted concrete [3,9]. Workability test results are presented in Appendix 1, while the plot of the slump and compacting factor versus the water/cement ratio are shown in Figure 2. The plots reveal that the workability of laterite rock concrete increases with the increase in water/cement ratio for all the mixes tested. The workability test results show that the laterite rock concrete can be graded under S2 using the European classification ENV 206: 1992 having the slump of 50-90mm. By TRRL classification, this workability with compacting factor of 0.92 and slump of 50-100mm can be described as medium.

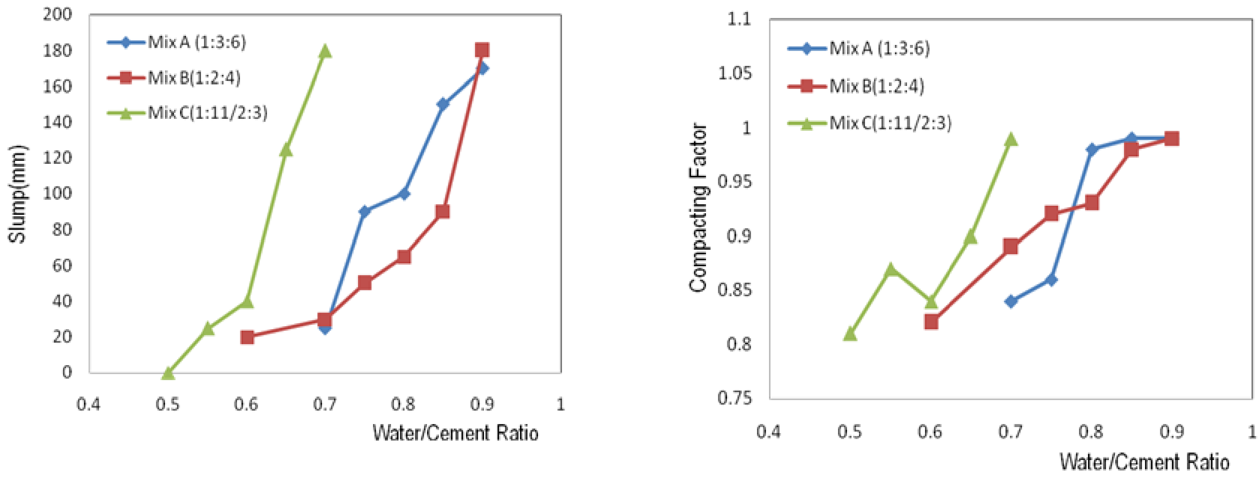

Figure 2. Variation of slump and compacting factor with water/cement ratio and

4.3. Compressive Strength

Compressive strength is generally considered to be the most important mechanical property of concrete. The result from the cube tests are presented in Table 1. The calculated characteristic strength of the concrete gives f_{cu} values of 12.6N/mm² for 1:3:6, 18.2N/mm² for 1:2:4 and 25.2N/mm² for 1:1½:3 at water/cement ratio of 0.75, 0.60 and 0.55 respectively as shown in Table 1. The results show that the ratio 1:3:6 possesses no significant strength to be considered a structural concrete. The relationship between compressive strength and age is shown in Figure.3. The growth pattern of strength is non- linear for the entire test from 7 to 21 days while there is little significant growth in strength between 21 and 28 days.

It can be concluded that the strength age relationship of the laterite rock concrete bear a close resemblance with the general trends associated with the conventional granite rock concrete [14].

Table 1. Compressive Strengths.

Mix proportion	Water/cement ratio	Age / strength.			
		7 days	14 days	21days	28days
1:3:6	0.75	5.67	9.72	12.1	12.6
1:2:4	0.6	9.46	14.01	17.47	18.2
1:1½:3	0.55	12.60	22.43	23.44	25.2

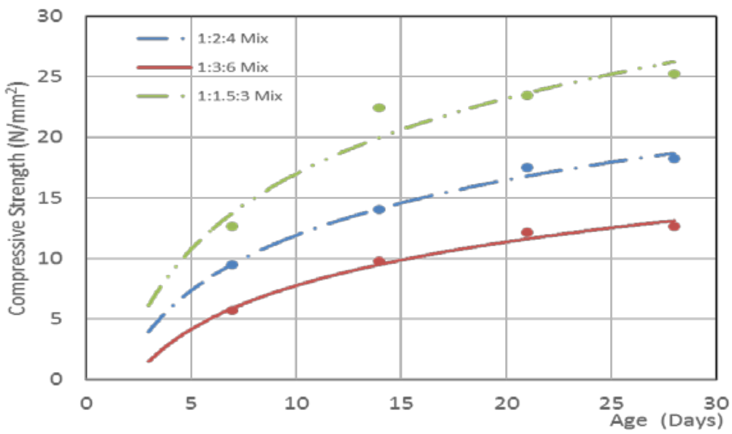

Figure 3. Variation of compressive strength with age

4.4. Flexural and Tensile Strengths

The tensile and flexural strengths are important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, strength in tension is of interest in unreinforced concrete structures, such as dams, under earthquake conditions. Other structures, such as highway and airfield pavements, are designed on the basis of flexural strength, which involves strength in tension. The determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. In Table 2, the tensile and flexural strengths are strongly affected by the compressive strength of the concrete. These strengths increase with increasing compressive strength. The result is in agreement with various researchers such as Gupta et al [11] and Raju and Ramakrishna [17].

Table 2. Results of strength test (tensile and flexural strengths)

Mix proportion	Water/Cement ratio	Compressive strength N/mm^2	Flexural strength N/mm^2	Tensile strength N/mm^2	Strength Ratios		
					f_t/f_c	f_f/f_c	f_f/f_t
1:3:6	0.75	12.60	1.64	1.51	0.12	0.13	1.09
1:2:4	0.6	19.11	2.98	1.62	0.08	0.16	1.84
1:1½:3	0.55	24.67	3.28	1.92.	0.08	0.13	1.71

4.5. Impact Test

Impact properties of concrete are of interest where there is the possibility of the impact loading in the foreseeable service life of a concrete structure such as missile impact, gas explosions, construction accidents, vehicle impacts and pile driving. The presence of various types of microcracks and air voids in concrete system and pores in the hardened cement paste component in concrete are weak zones which could initiate the growth of cracks, lowering impact strength. The Laterite Rock Concrete gives a 28 day impact value of 44 which is higher than the impact value of 3 for laterized concrete and 23 for conventional concrete tested by Balogun and Oyekan [4]. A plot of impact resistance against age at loading is shown in Figure 4

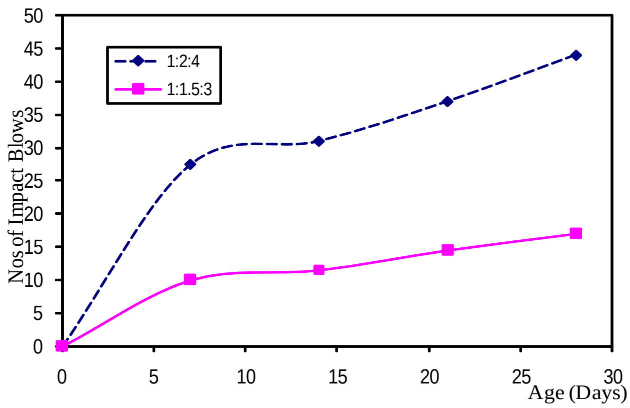

Figure 4. Relationship between impact resistance and age

4.6. Static Modulus of Elasticity

According to Neville [14], that, in the two phase models of a concrete structure, the value of the elastic modulus of concrete is influenced by the modulus of the aggregates and its volumetric proportion. The plot of the result of stress strain characteristics of 150mm diameter and 300minm depth made with of the laterite rock concrete of mix proportion 1:1½:3 at optimum water/cement ratio is presented in Figure 5.The values of the static modulus of elasticity in compression determined at 30% of failure stress. The result shows that the static modulus elasticity of the laterite rock concrete is approximately 22.72kN/mm². This value is little less than the modulus of elasticity of normal concrete (24kN/mm²). The ultimate compressive strain value from test is found to be 0.0015. This value is lower than that of the conventional concrete (0.0035).

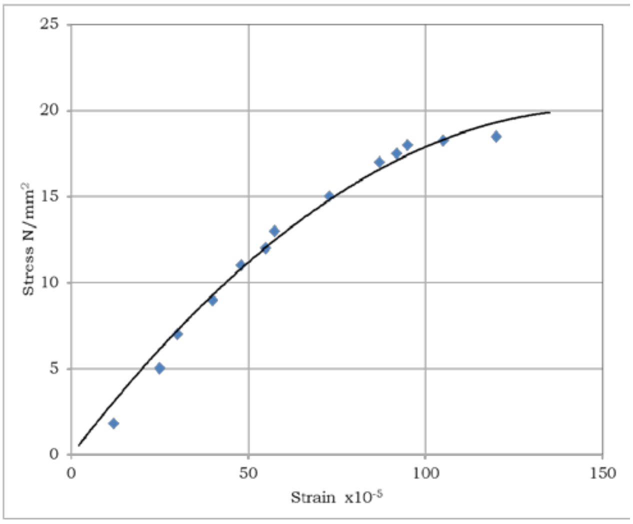

Figure 5. Stress-Strain Relationship of Laterite Rock Concrete

5. Conclusions

Laterite rocks possess a number of good qualities that justify its suitability for making a durable and good structural concrete.

On the basis of tests, observations and analysis carried out in this study, it can be concluded that

a The laterite rock concrete has an average density ranging between 2200kg/m^3 and 2300kg/m^3 therefore fall within the classification of a dense concrete

b The slump and workability of the laterite rock concrete corresponding to that of a structural concrete. Its workability falls within the range of 50 – 100mm and hence its classified as medium.

c It has an appreciable characteristic strength of 19.11kN/m^2 for 1:2:4 at w/c of 0.60 and 24.67N/mm^2 at w/c of 0.55 for 1:1½:3. It is therefore classified as a structural concrete

d It has impact energy of 874.07Nmm and impact strength of 109.90 KN/m^2. These values are higher than that for granite concrete

e Its impact resistance capacity makes it suitable for floors subjected to impact loads

f Flexural and splitting test results were about 8 - 16% of the compressive strength of the laterite rock concrete.
g The static modulus elasticity of the laterite rock concrete is approximately 22.72kN/mm².

6. Recommendation

The above conclusions confirm the suitability of the laterite rock concrete for shortterm structural applications. In other to exploit this abundant material to its fullest, further studies recommended on its durability and longterm resistance.

References

[1] Akpokpodje, E.G; Hudec P. (1992) *Properties of concretionary Laterite gravel concrete*. Bulletin of the International Association of Engineering Geology. No. 46 Paris 1992 Pp. 45-50.

[2] American Concrete Institute (1994) Cement Terminology Manual of Concrete Practice Part 1: Materials and general properties of concrete pp. 68, AC1116R-90 (Detroit Michigan, 1994).

[3] American Society for Testing and Materials (1993) Terminology Relating to Concrete and Concrete Aggregates. ASTMC 125-93.

[4] Balogun L. A. and Oyekan G. L. (1997) *Resistance of Laterized Concrete to impact*. Proceedings of the international conference on structural engineering and modeling (SEAM) Kumasi Ghana 1997, pp. 285-295.

[5] British Standard Institution (1993a) Specification for aggregates from natural sources for concrete, London, BS 882:1992.

[6] British Standard Institution (1995) Testing Aggregates BS 812.

[7] British Standard Institution (1997) Code of Practice for the Structural Use of Concrete BS8110 London England 1997.

[8] British Standard Institution (2002) Method of Specifying and Guidance to specifying BS8500 complementary to BSEN 206-1 London England.

[9] British Standard Institution (2001) Test for Fresh Concrete BSEN12350 Part 2 2001 English version of Euro code.

[10] Ephraim M. E., Rowland-Lato E. O (2015). Compressive Strength of Concrete Made with Quarry Rock Dust and Washed 10mm Washed Gravel as Aggregates. American Journal of Engineering, Technology and Society. 2(2): 26-34.

[11] Gupta B.L, Gupta Amit (2004) *Concrete Technology* Standard Publishers New Delhi, India.

[12] Madu R. M. (1980) *The Performance of Laterite Stones as Concrete Aggregates and Road Chipping.* Materials and Structures Vol. 13 Number 6 Nov. 1980.

[13] Muhit I.B, Haque S. & Rabiul A. M. (2013). Influence of crushed coarse aggregates on properties of concrete. American Journal of Civil Engineering and Architecture, 1 (5) 103-106.

[14] Neville A.M. (1996) *Properties of Concrete* 4th edition ELBS Longman London

[15] Osunade J. A Lasisi F. (1997) *Effect of Sizes and Types of Coarse Aggregates on the Tensile Strength of Laterized Concrete.* Proceedings of the Structural Engineering Analysis and Modeling conference (SEAM 4) Kumas Ghana.

[16] Pintea, A. & Traian, O. (2012). Elastic deformation of concrete. Determination of secant modulus of elasticity in compression. Acta Technica Napocensis: Civil Engineering & Architecture 55 (2) 189-204.

[17] Raju Krishna N. Ramakrishna R. (2006) *Properties of Laterite Aggregate concrete* Materials and Structures. Vol. 5 available online Aug. 11-2006.

[18] Sharad Y. M. & Deepak D. N. (2012). Studies on correlation between flexural strength and compressive strength of concrete. The Indian Concrete Journal.1, 1-6.

[19] Swamy, R. N. and Jojagha A. H. (1982) *Impact Resistance of Steel Fibre Reinforced Lightweight Concrete.* The international Journal of Cement Composites and lightweight concrete, Vol. 4, pp. 208-220.

[20] Takafumi, N., Fuminori, T., Kamran, M. N., Bernardino, M. C.& Alessandro, P. F. (2009). A practical equation for elastic modulus of concrete. ACI Structural Journal. 106.690-696.

[21] Udoeyo, Felix, F. Udeme H. Iron and Obasi Odim (2006) *Strength performance of laterized concrete.* Construction and building materials Vol. 20, issue 10 Dec. 2006 pp. 1057-1062.

[22] Zheng Jian-Jun†, Zhou Xin-Zhu (2006) A Numerical Method for Predicting the Elastic Modulus of Concrete Made with Two Different Aggregates. Journal of Zhejiang University Science A ISSN 1009-3095 (Print); ISSN 1862-1775.

APPENDIX 1

Workability Test Result.

Mix proper.	Water/Cement Ratio	Slump	Compacting factor.
1:3:6	07	25mm	0.89
	0.75	90mm	0.86
	0.80	100mm	0.98
	0.85	150mm	0.99
	0.90	170mm	0.99
1:2:4	0.6	20mm	0.82
	0.70	30mm	0.89
	0.75	50mm	0.92
	0.80	65mm	0.93
	0.85	90mm	0.98
	0.90	180mm	0.99
1:1½:3	0.50	0.00	0.81
	0.55	25mm	0.87
	0.60	40mm	0.84
	0.65	125mm	0.90
	0.70	180mm	0.99

APPENDIX 2

Impact Test Result

Age	Mix proportion	No of blows		Average impact Resistance
		Crack	crushing	
7 days	1:2:4	27	38	27.5
		28	33	
		9	11	
	1:1½:3	11	12	10
14 days	1:2:4	30	32	31
		32	38	
		10	15	
	1:1½:3	13	17	11.5
21 days	1:2:4	38	46	37
		36	45	
		14	18	
	1:1½:3	15	20	14.5
28 days	1:2:4	43	48	44
		45	51	
		16	25	
	1:1½:3	18	28	17

Impact energy $= mgh$ eqn 4.4

Impact strength $\frac{F}{A}$ eqn 4.5

Impact Calculations for 1:2:4

Age (Days)	Density kg/m^3	Compressive strength N/mm^2	No of blows	Impact energy J	Impact force dissipated N	Impact strength N/mm^2	Impact Strength KN/m^2
7	2279.26	12.60	27.5	546.00	1213.98	0.068	68.68
14	2271.74	15.45	31.0	615.82	1368.50	0.077	77.43
21	2236.94	18.68	37.0	735.01	1633.37	0.092	92.42
28	2210.55	19.11	44.0	874.07	1942.38	0.110	109.90