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Characteristics of Stone-Base Laterized Concretes

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ABSTRACT: Stone-base, a material often used for base construction in flexible pavements, have in recent studies been shown to be suitable as an all – in – concreting aggregate. This study investigated the crushing, flexural and split tensile strengths as well as other mechanical properties of stone-base laterized concretes (SBLC). Normal river sand fine aggregate was partially replaced by laterite while the coarse aggregate proportion was made of stone base. Concrete mixes containing 100%, 75%, 50%, 25% and 0% replacement (by weight) of river sand with laterite and stone base as coarse aggregate were prepared. The workability of all fresh concrete mixes was determined using the slump test. Observed slumps ranged between 20 and 70mm and the maximum crushing strength of 23.6N/mm^2 was produced by the specimen containing 25% laterite and 75% sand. All the strengths increased with the age of curing and the strengths were quite comparable with that of the control concrete which stood at 25.1N/mm^2. A maximum density of 2329kg/m^3 was recorded at 28 days curing. This density showed that stone-based laterized concretes are normal weight concretes and can be used for construction purposes.

KEYWORDS: Stone base, crushing strength, Laterized concrete, flexural strength, Split tensile strength.

1.0 INTRODUCTION

The provision of housing is governed by the need for shelter among other factors and according to Fitch and Branch (1960); the need for shelter must be met by materials that the environment can afford. Such materials must therefore be widely and readily available, economically appropriate to the environment, thermally efficient and socially acceptable. Besides, the building system derived from such materials must allow participation from the community and thereby improving the cash economy of that community. Materials that fit into these descriptions include lateritic soils used for replacing sand in concrete and stone-based aggregate which can replace the coarse granite in concrete. Knowledge of the structural characteristics and performance of concrete made with these materials is necessary for the accurate design of such structures. These and more necessitated this study. The use of stone base as coarse aggregate in laterized concrete can help positively in reducing the cost of concrete.
Concrete containing laterite soils are cheaper (Udoeyo and Iron, 2006) and would even be cheapest if the conventional coarse aggregate is replaced with stone base to have stone base laterized concrete (SBLC).

2.0 MATERIALS AND METHODS

2.1 Materials: Materials used included Portland limestone cement, sharp sand, laterite soil, stone base and water.

2.2 Cement: UNICEM brand of Portland limestone cement produced in Cross River State, Nigeria was used for the study. The cement conformed to the requirements of BS 12 and was safe kept to avoid dampness.

2.3 Sharp Sand: River sharp sand obtained from Ibagwa River, Akwa Ibom State, Nigeria was used for the study. The sand conformed to the standards recommended in BS 882: 1995: Part 1. The sand was a zone 2 aggregate and had a specific gravity of 2.66 and a maximum aggregate of 4.75mm.

2.4 Laterite soil: This fine aggregate was obtained from a borrow pit located at Akpasak Estate, Uyo, Nigeria. The laterite was treated in conformity to the requirements of BS 882: 1995: Part 1. It had a specific gravity of 2.53. The chemical constituents of the laterite as determined in the Ministry of Science and Technology laboratory, Akwa Ibom State are presented in Table 1.

2.5 Water: Potable tap water obtainable from the civil engineering laboratory, University of Uyo, Nigeria was used throughout the research experimentation. The water conformed to the requirements of BS 3148: 1975.

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2.6 Stone Base: this aggregate was obtained from a construction site where a 2.5km road dualization project was on going. The stone base was tested in conformity with BS 882: 1983.

3.0 METHODOLOGY

All the materials were graded according to the relevant standards and batching was done by weight throughout the experimentation. A prescribed mix of 1:2:4 proportions of cement: sand/laterite: stone base concrete was prepared for casting into the required specimens. Mixing of the batched materials were manually effected. The workability of the fresh concrete mix was determined using the slump test. The sharp sand portion was partially replaced with laterite in the percentages of 0, 25, 50, 75 and 100.

3.1 Preparation and testing of crushing strength specimens: Seventy five stone base laterized concrete (SBLC) cubes (150 x 150 x 150mm size) were moulded; 15 at each of the replacement levels. Three cubes were tested each for crushing strengths at ages of 3 days, 7 days, 14 days, 21 days and 28 days. The steel cube moulds were properly oiled and cleaned before filling with concrete in three approximately equal layers. Each layer was rammed with 35 strokes of the steel rod and the final level was troweled smooth and labelled. The concrete cubes were then placed in a damp place for 24 hours after which they were demoulded and cured in accordance to BS 1883: Part 3. The digital compression machine was used for testing the cubes at a required curing age. The equipment recorded the ultimate load at failure as well as the crushing strength in N/mm^2. Equation 1 was also used to confirm the crushing strength computed.

$$f_c = P/A \qquad [1]$$

Where,

f_c = crushing strength in N/mm^2 ; P = Ultimate load at failure in kN; A = the cross sectional area of the cube in mm^2.

3.2 Preparation, Curing and Testing of Flexural Strength Test Beams

Flexural test beams were prepared in conformity with BS 1881: Part 108:1983 and BS1881: Part3: 1970 requirements. The mould used was 150 x 150 x 500mm beam size. After oiling the inside of the mould lightly with mineral oil, it was filled with the mixed concrete in three layers. Each layer was evenly rammed 150 strokes with a steel bar 380mm long weighing 1.8kg and having a ramming face 25mm square. The surface of the concrete was then towelled as smooth as practicable levelled with the top of the mould. Each beam was identified and kept in a damp environment for 24 hours before demoulding. After 24 hours the beams were removed from the mould and cured in a water bath for 28 days before testing.

Testing of flexural beams was carried out using CONTROLS testing machine in accordance to the requirements of BS1881: part118: 1983. The symmetrical two-point loading (at third points of the span) was adopted as shown in Fig.2 and Fig. 3. The beams were tested on their side in relation to the as-cast position. The load was applied without shock at a rate of increase in stress in the bottom fibre of about $12N/mm^2$ per minute. In all the specimens, fracture occurred within the middle one-third of the beam. The flexural strength (or modulus of rupture) was therefore calculated on the basis of ordinary elastic theory using eqn. 2 and recorded to the nearest $0.1N/mm^2$.

$$\mathbf{fs} = \frac{PL}{bd2} \ldots\ldots\ldots\ldots\ldots \qquad [2]$$

Where

fs is the flexural strength (N/mm^2); P is the maximum load at failure (N); L is the span of the beam specimen (mm); b is the breadth of the beam (mm) and d is the depth of the beam (mm).

3.3 Preparation and Testing of Split-Tensile Strength Test Cylinders

Split tensile strength test cylinders were prepared to conform to BS 1881: part 110: 1983 standards. Moulds used were of 150mm diameter and 300mm height. Each cylinder was cast, demoulded and cured in a manner similar to that applicable to the flexural beams except that each layer was rammed with 100 strokes of the punner. The split tensile cylinders are shown in plate 3.6b.

This test was performed as prescribed by BS1881: part117: 1983. After curing, the concrete cylinder was placed with its axis horizontal between the platens of the testing machine. In order to prevent very high local compressive stresses at the load lines, narrow strips of plywood were interposed between the specimen and the plates as shown in fig.3.2 and plate 3.9. The load was applied without shock and increased at a constant rate of stress of 0.02Mpa/s until failure took place and the concrete cylinder was split into two in the plane containing the vertical diameter of the specimen. The maximum load at failure was recorded and the tensile splitting strength was calculated and recorded to the nearest 0.05Mpa/s using the formula in equation 3. The CONTROLS digital testing equipment was used for this test.

$$f_{st} = 2P/\pi Ld \quad [3]$$

Where P = maximum load, L = length of the specimen, and d = diameter of the specimen.

4.0 RESULTS AND DISCUSSION

4.1 Properties of Materials Used: The properties of materials used in the study are summarized in Table 1.

Table 1: Physical Properties of Materials Used in the Study.

Material	Property	Value
Laterized Concrete	Workability	20 – 35mm
	Density	2164 – 2329kg/m^3
Laterite	Specific gravity	2.53
	Coefficient of Curvature	1.07
	Uniformity Coefficient	2.40
	Chemical constituents:	
	SiO_2	49.5%
	Fe_2O_3	30.61%
	MnO	10.32%
	Al_2O_3	3.61%
	P_2O_5	1.34%
	TiO_2	1.11%
	K_2O	0.14%
	CuO	0.14%
Sand	Specific gravity	2.66
	Coefficient of Curvature	1.14
	Uniformity Coefficient	3.5
Stone base	Specific gravity	2.56
	Coefficient of Curvature	1.33
	Uniformity Coefficient	3.00
Cement	Specific gravity	3.15
	Initial setting time	148 minutes
	Final setting time	215 minutes
	Unit weight	1440 kg/m^3
	Consistency	32%
	Soundness	0.58mm

4.2 Grading of Aggregates: The results of the sieve analysis of the aggregates are presented on Tables 2, 3 and 4 for laterite, sand and stone base respectively. Same results are plotted in Figures 2, 3, and 4 respectively. From the results, the laterite had a wide distribution of particles ranging from 0.075mm to 2.36mm in diameter, a uniform coefficient (Cu) of 2.4 and a coefficient of curvature of (Cc) of 1.07 thus the laterite was well graded.

The results also showed that the sand had particles that ranged from 0.15mm to 4.75mm, a uniformity coefficient of 3.5 and a coefficient of curvature of 1.14. The sand was also well graded.

The stone base particles ranged from 4.75mm to 63mm. Its uniformity coefficient and coefficient of curvature were 3.0 and 1.33 respectively. According to Smith (1970), the stone base was well graded since its coefficient of curvature falls between 1 and 3.

Table 2. Grain Size Analysis for Laterite Used

Sieve size (mm)	Weight retained (g)	% Weight retained	Cumm. % retained	% Passing
9.5	0.00	0.00	0.0	100.0
4.75	0.00	0.00	0.0	100.0
3.35	0.00	0.00	0.0	100.0
2.36	0.02	1.29	1.3	98.7
1.18	0.12	7.86	9.2	90.9
0.85	0.17	10.70	19.9	80.2

0.60	0.37	23.71	43.6	56.4
0.40	0.42	27.32	70.9	29.1
0.25	0.28	17.91	88.8	11.2
0.15	0.14	9.28	98.1	1.9
0.075	0.02	1.42	99.5	0.5
<0.075	0.01	0.52	100.0	0.0
Total	1.55			

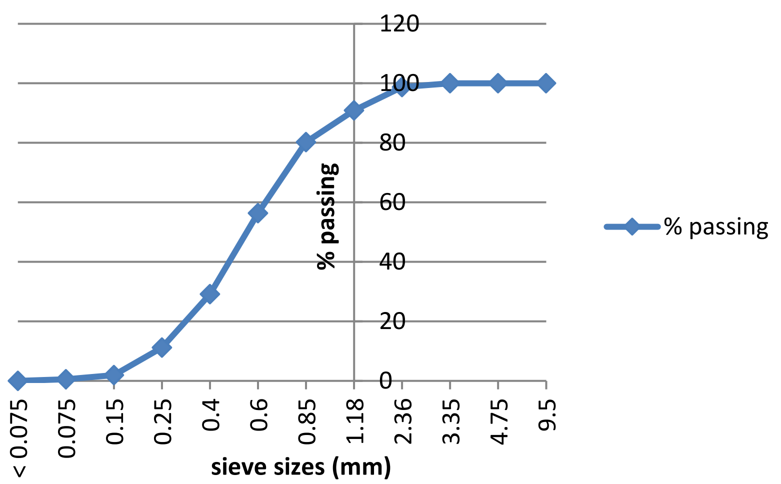

Fig. 2: Grading Curve for Laterite Used

Table 3. Grain Size Analysis for Sand Used

Sieve size (mm)	Weight retained (g)	% Weight retained	Cumm. % retained	% Passing
4.75	0.0265	2.782	2.8	97.2
2.36	0.0305	3.202	6.0	94.0
1.18	0.1210	12.703	18.7	81.3
0.60	0.2380	24.987	43.7	56.3
0.30	0.3670	38.530	82.2	17.8
0.15	0.1530	16.063	98.3	1.7
Pan	0.0165	1.732	100.0	0.0

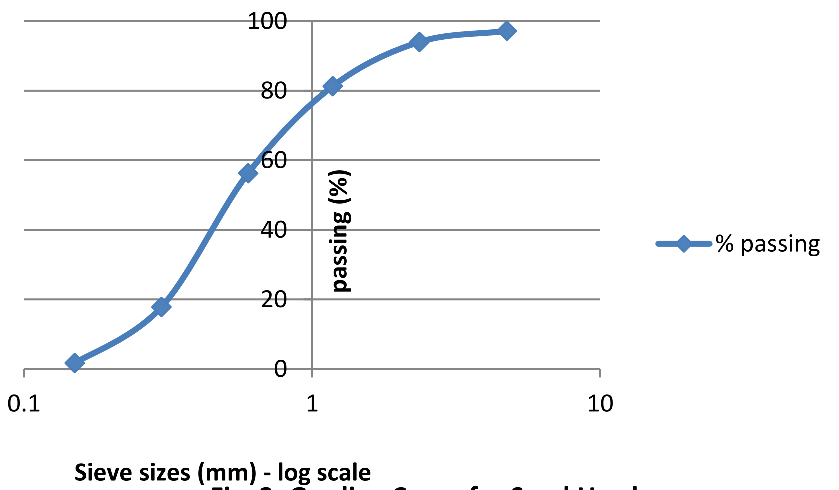

Fig. 3: Grading Curve for Sand Used

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Table 4. Grain Size Analysis for Stone base Used

Sieve size (mm)	Weight retained (g)	% Weight retained	Cumm. % retained	% Passing
80	0.00	0.00	0.0	100.0
63	0.25	3.45	3.5	96.6
50	0.33	4.57	8.0	92.0
40	0.30	4.22	12.2	87.7
25	0.46	6.42	18.7	81.3
20	0.97	13.61	32.3	67.7
16	1.01	14.15	46.4	53.6
12.5	0.10	14.00	60.4	39.6
10	0.79	11.11	71.5	28.5
6.3	0.65	9.08	80.6	19.4
4.75	0.70	9.85	90.5	9.5
<0.075	0.68	9.54	100.0	0.0
Total	7.11			

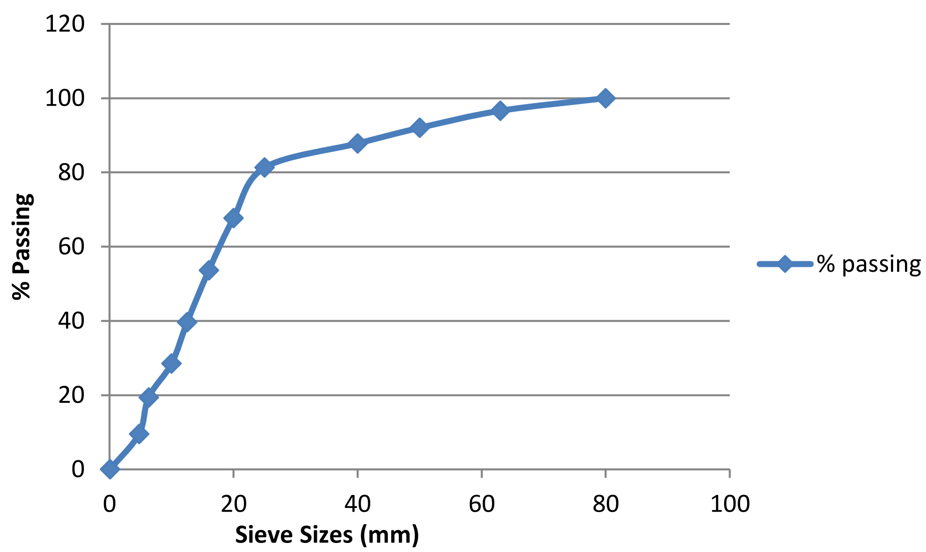

Fig. 4: Grain Size Analysis for Stone Base Used

4.2 Workability of Stone Base Laterized Concrete

The workability test results are presented on Table 5 and Figure 5. The slumps ranged between 20 and 70mm and were all true slumps. At the water cement ratio of 0.5 that was maintained throughout all the mixes, the concretes were moderately quite workable. From the results, it was observed that the slump increased as the laterite content increased. This may be attributed to the fact that the increase in laterite content also led to increase in the quantity of fines in the mix thereby influencing the fluidity of the mix.

Table 5. Workability of SBLC

Combination (%)		Slump (mm)
Sand	Laterite	
0	100	70
25	75	60
50	50	30
75	25	25
100	0	20

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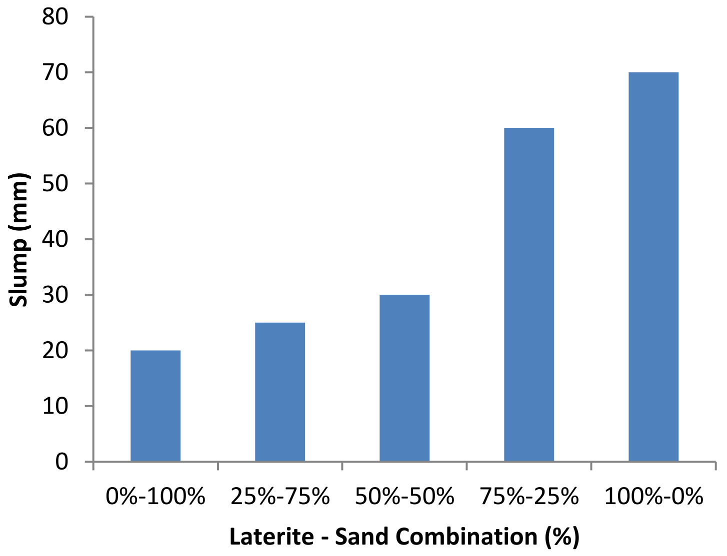

Fig. 5: Slump Test Results (mm)

4.3 Crushing Strength of SBLC:

The averages of the crushing strengths of three replicate samples of stone base laterized concrete cubes obtained from this study are presented in Table 6. Figure 6a shows the variation of the crushing strength with days of curing while Fig. 6b shows the variation of the strength with the laterite content in the mix. From the test results, the crushing strength of stone base laterized concrete increases with age and decreases with increase in the percentage of laterite content. Stone base laterized concrete with 25% laterite and 75% sand attained strength of 23.6N/mm^2 which is 10% lower than the design strength of 25N/mm^2 at 28 days curing. With 100% laterite content, strength of 20.5 N/mm^2 was achievable. This strength is 20% percent lower than the 25N/mm^2 produce by the control mix. However, such strength is still useful for structural concrete construction. For 50 – 50 laterite – sand SBLC, strength of 23.2N/mm^2 was achieved. This strength is quite close to that of the control mix and can comfortably be used for structural constructions. SBLC follows the same trend maintained by other concretes at different ages of curing.

Table 6. Summary of the Crushing Strengths of Stone Base Laterized Concretes

% Combination		Crushing Strength (N/mm^2)				
Sand	Laterite	3 days	7 days	14 days	21 days	28 days
100	0	7.2 ± 0.27	15.1 ± 0.32	20.5 ± 0.70	23.2 ± 0.55	25.1 ± 0.51
75	25	6.8 ± 0.08	11.7 ± 0.35	18.9 ± 0.27	22.1 ± 0.61	23.6 ± 0.61
50	50	6.5 ± 0.18	11.1 ±0.10	17.1 ± 0.52	20.8 ± 0.43	23.2 ± 0.66
25	75	6.3 ± 0.10	8.3 ± 0.42	14.3 ± 0.71	20.3 ± 0.51	22.4 ± 0.59
0	100	5.6 ± 0.15	7.5 ± 0.15	13.7 ± 0.50	19.6 ± 0.53	20.5 ± 0.38

4.4 Flexural Stength of SBLC: The average flexural strengths of SBLC obtained from this study are presented in Table 7a and Figures 7a and 7b. The same trend followed when considering the crushing strengths are equally maintained here. The flexural strengths increased with increase in the age of curing and also decreased as the laterite contents increased. The flexural strengths ranged between 3.33 – 3.93N/mm^2 at 28 days.

Table 7. Summary of the Flexural Strengths of Stone Base Laterized Concretes

% Combination		Flexural Strength (N/mm^2)				
Sand	Laterite	3 days	7 days	14 days	21 days	28 days
100	0w	3.40 ± 0.01	3.62 ± 0.02	3.66 ± 0.01	3.71 ± 0.03	3.93 ± 0.00
75	25	3.23 ± 0.00	3.55 ± 0.03	3.60 ± 0.01	3.68 ± 0.00	3.87 ± 0.03
50	50	3.15 ± 0.02	3.28 ± 0.01	3.30 ± 0.03	3.39 ± 0.00	3.58 ± 0.00
25	75	2.84 ± 0.00	3.13 ± 0.01	3.27 ± 0.00	3.35 ± 0.02	3.30 ± 0.03
0	100	2.48 ± 0.03	2.91 ± 0.03	3.20 ± 0.00	3.28 ± 0.01	3.33 ± 0.02

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4.5 Split Tensile Strength Of SBLC: The average split tensile strengths of SBLC obtained in this study are presented in Table8 and Figures 8a and 8b. The results showed that the splitting strength increased with the age of concrete and reached a maximum value of 3.12N/mm^2 at 28 days of curing for the combination that contained no laterite (control samples). The 28th day splitting strength for the combination with 100% laterite stood at 2.61N/mm^2. This shows a 16.3% reduction in the splitting strength. A 50/50 sand/laterite SBLC had a splitting tensile strength of 2.73N/mm^2. This indicates a 12.5% reduction in the strength. Moreover, the split tensile strengths as observed from Fig. 8b also show decrease with increase in the percentage of laterite.

Table 8. Summary of the Split tensile Strengths of Stone Base Laterized Concretes

% Combination		Split tensile Strength (N/mm^2)				
Sand	Laterite	3 days	7 days	14 days	21 days	28 days
100	0	1.59 ± 0.03	2.42 ± 0.01	2.46 ± 0.02	2.67 ± 0.02	3.12 ± 0.03
75	25	1.23 ± 0.02	2.35 ± 0.02	2.39 ± 0.00	2.62 ± 0.02	2.91 ± 0.01
50	50	1.21 ± 0.01	1.99 ±0.00	2.36 ± 0.01	2.51 ± 0.03	2.73 ± 0.00
25	75	1.19 ± 0.00	1.56 ± 0.05	2.14 ± 0.03	2.47 ± 0.01	2.69 ± 0.01
0	100	1.14 ± 0.02	1.41 ± 0.01	2.07 ± 0.03	2.42 ± 0.03	2.61 ± 0.02

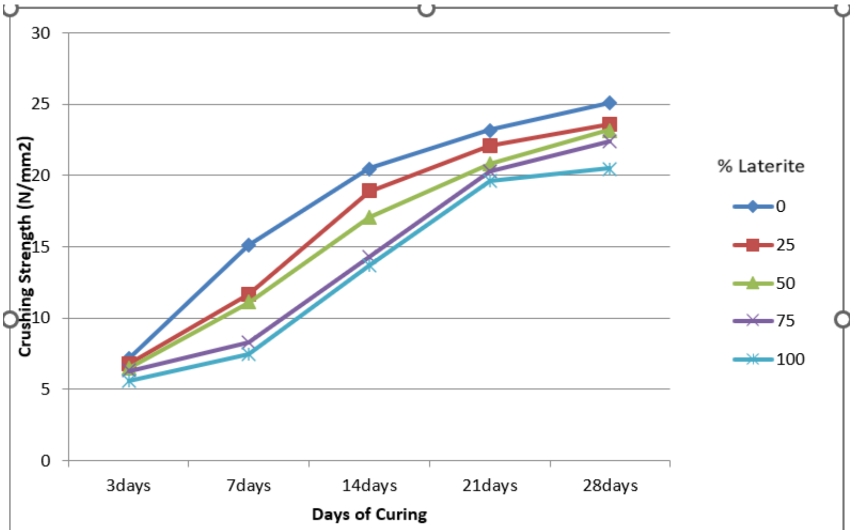

Fig. 6a: Crushing Strength of Stone Based Laterized Concrete.

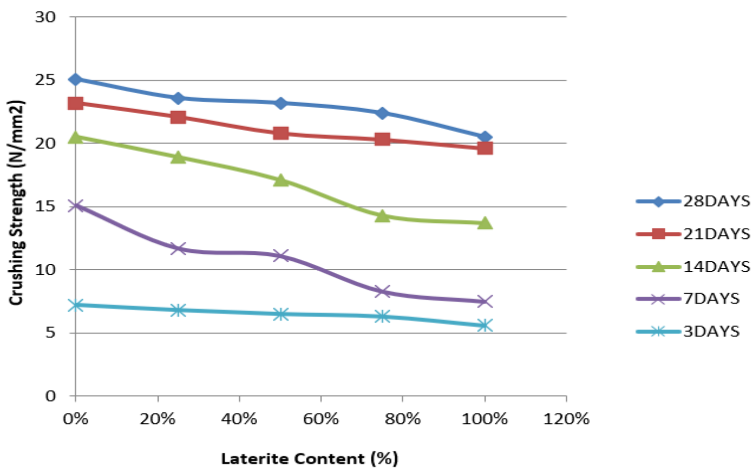

Fig. 6b: Variation of Crushing Strength with Laterite Content

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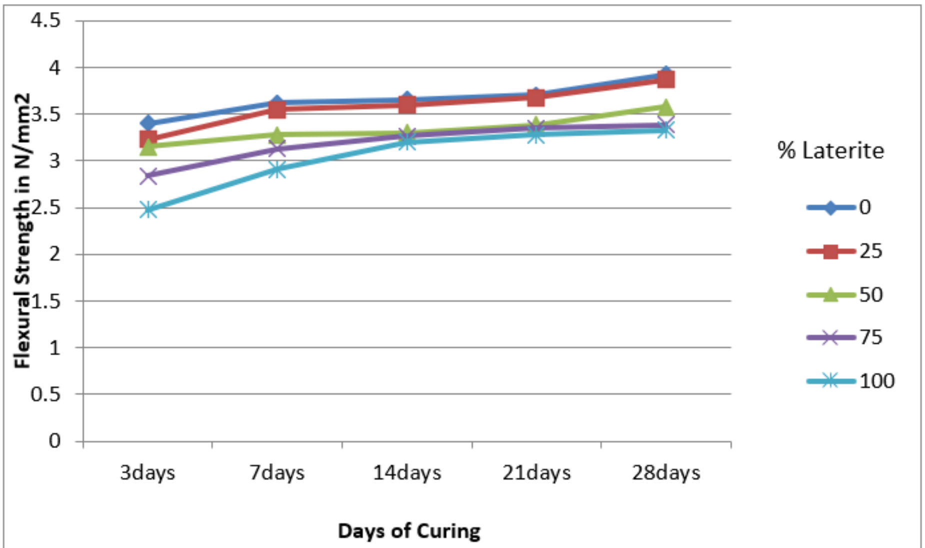

Fig. 7a: Flexural Strength of Stone Base Laterized Concrete

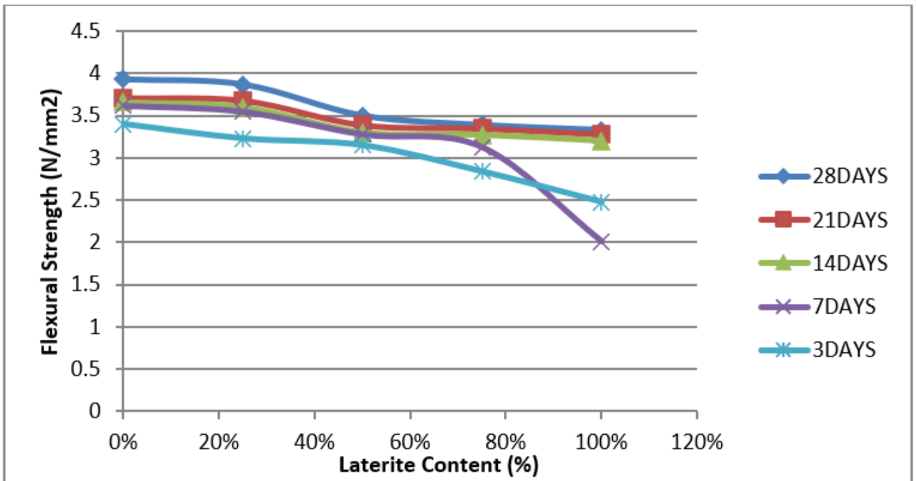

Fig. 7b: Variation of Flexural Strength with Laterite Content

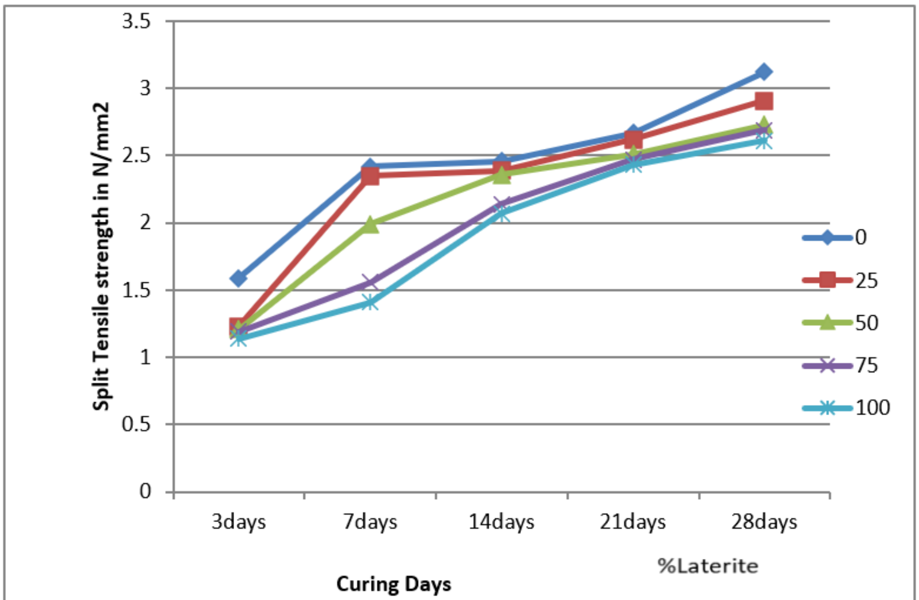

Fig. 8a: Split Tensile Strength of Stone Base Laterized Concrete

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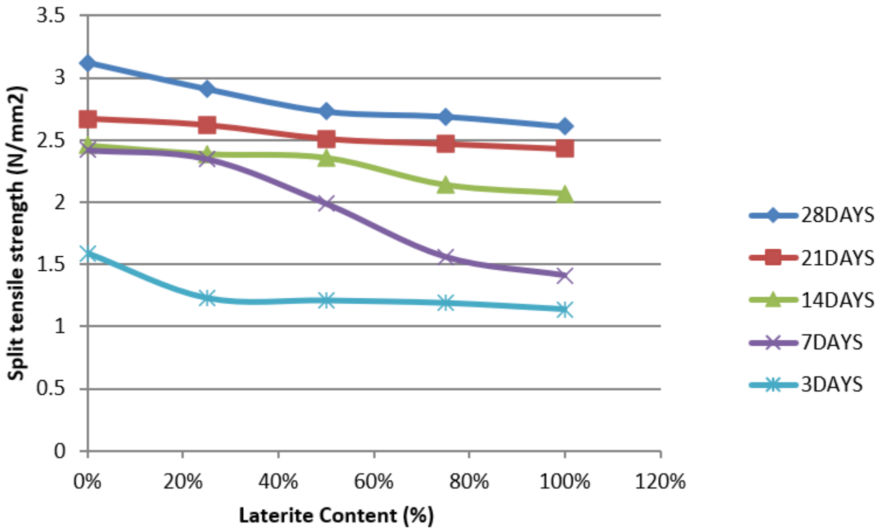

Fig. 8b: Variation of Split Tensile Strength with Laterite Content

5.0 CONCLUSION

Fresh stone base laterized concretes are very workable and all produced true slumps.

The crushing strength, flexural strength and split tensile strengths of stone base laterized concretes increase with the age of curing.

The strengths reduce with increase in the percentage of laterite in the mix.

Stone base laterized concretes have strengths that compare favourably with those of normal concretes and can be used for structural purposes.

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