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Comparative Study of Cube and Cylinder Crushing Strengths of Laterized Concrete

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ABSTRACT: The non availability or shortage of river sand in some areas affects the concrete construction industry negatively. Hence there is need to find alternatives to river sand and one of the major materials locally available is lateritic soil commonly called laterite. It has been successfully used partially or wholly to replace sharp sand in concrete. This study investigated the relationship between the cube compressive strength and cylinder compressive strengths of laterized concretes made with various combinations of laterite and river sand. Laterized concretes of 1:1½:3 mix proportions were prepared with sand partially replaced with laterite at 0%, 20%, 40%, 50%, 60%, 80% and 100% at a water/cement ratio of 0.55. Granite of 20mm maximum size was the coarse aggregate used; batching was done by weight. A total of 84 cubes and 84 cylindrical specimens were prepared for testing after 3, 7, 21 and 28 days respectively. At each replacement level, the cube crushing strength as well as the cylinder crushing strength of the specimens was determined for proper comparison. At 7 days, the cylinder crushing strength was found to be 72% of the cube strength while for 14, 21 and 28 days they were 77%, 80% and 80% respectively.

1.0 INTRODUCTION

As the world population increases, the demand for housing and other infrastructures also increase. The demand for concrete and its constituents also increases. In Nigeria and most other countries, river sand is traditionally used as fine aggregate in concrete. The continuous mining of sand from our rivers has led to environmental degradation and unchecked depletion in its natural reserve. Hence, many sand mining sites have been closed because of the damage caused to the environment. This has led to scarcity of the product. Moreover, because of scarcity of the product, it is often transported from relatively distant places at high cost. The need for a readily available and economical alternative to sand becomes obvious. To solve this problem, several attempts have been made to either partially or completely replace river sand with other materials in concrete production. Such materials have included laterite and quarry dust.

Laterite is a mixture of clayey iron and aluminum oxides and hydroxides and it is abundantly available in tropical regions including Nigeria. Concrete containing laterites are termed laterized concrete. Researches on properties of laterized concrete have yielded positive results. Udoeyo et al (2006) investigated properties of concrete with partial and complete replacement of sand with laterite and observed that the workability of the resulting concrete was directly proportional to the percentage of laterite while compressive strength, split tensile strength, flexural strength and water absorption were inversely proportional to the percentage of laterite in the mix. Most of the investigations studied the compressive strengths of laterized concretes using cube specimens. Little or no effort has been made to investigate the compressive strengths of laterized concretes using cylindrical specimens. Moreover, attempts have not been made to compare strengths of cubes with those of cylindrical specimens to deduce if they follow patterns of other concretes. Eurocode specifies that the compressive strength of cylindrical specimens should be about 80% of that of the cube. This study attempted to determine strengths from both specimens and compared the two. It is believed that the findings of this study would be of immense guide to concreters using laterized concretes.

1.1 Aims and Objectives of the Study

The objectives of this study included the following;

- To determine the cube crushing strengths for laterized concretes at different percentages of laterite contents.
- To determine cylinder crushing strength for laterized concretes at different percentages of laterite contents.
- To compare the crushing strengths of laterized concrete cubes with those of cylinders at 3, 7, 14, 21 and 28 days respectively.
- To determine other properties of laterized concretes at the different replacement levels.

1.2 Significance of the study

Compressive strength is unarguably the most widely used strength parameter for concrete since concrete is good in compression and weak in tension. The study will enable concrete designers and users to appreciate the relationship between the cube and cylinder crushing strengths of laterized concretes in comparison to other standard concretes in case design is made using any specimen's strength. This will help in reducing the cost of concrete since laterite is easily available and affordable. The continuous exploitation of the sand resulting in environmental degradation will reduce.

2.0 LITERATURE REVIEW

The term "laterite" is used to describe a ferruginous, vesicular, unstratified and porous material with yellow ochre caused by its high iron content, occurring abundantly in Malabar, India (Osunade, 2002).

Ettu et al (2006) reported that a reasonable number of laterized concrete mix compositions met the minimum compressive strength of 25MPa for reinforced concrete as specified by BS 8110: 1997. It was also observed that the resulting concrete had an average density of 22.81kN/m^3 which was lower than 24kN/m^3, an average value for traditional concrete

Adepegba (1975) compared the strengths of normal concretes with those of laterized concretes and concluded that laterized concretes can be used as a structural material provided laterite content does not exceed 50%. According to Balogun and Adepegba (1982), the most suitable mix for structural applications is 1: 1½: 3 (Cement: sand/laterite : gravel) with a water-cement ratio of 0.65. Lasisi and Osunade (1984) established that the finer the grain size of lateritic soils, the higher the compressive strength of the concrete cubes made from such soils.

Osunade (1994) found out that increases in shear and tensile strengths of laterized concretes were obtained as the grain size range and curing ages increased. Also, greater values of shear and tensile strengths were obtained for rectangular specimens than those obtained for cylindrical ones

3.0 MATERIALS AND METHODS

3.1 Materials Used

Portland limestone cement of UNICEM brand sold in sealed 50kg bags was used. The cement was purchased in bags and transported to the laboratory. It was also protected from dampness to avoid lumps. The cement conformed to the requirements of BS 12: 1954 and NIS 444: 1988. Laterite, one of the two fine aggregates used for this research was obtained from a borrow pit in the Main campus, University of Uyo, Akwa Ibom State at a depth of 3.0 meters. It was treated in conformity with the requirements of BS 812-103.1:1985. The sharp sand was obtained from Ikpa River in Uyo, Akwa Ibom State, Nigeria and was treated in conformity with the requirements of BS 812-103.1:1985. It had a maximum particle size of 5mm. Natural crushed granite aggregate was used for this study. The material was obtained from Akamkpa quarry in Cross River State, Nigeria. It had a maximum size of 25mm and satisfied the requirements of BS 812-103.1:1985. Portable tap water supplied by the Civil Engineering laboratory, University of Uyo was used throughout the research experiments. The water conformed to BS3148.

3.2 Experimental Methods

Laterized concrete cubes and cylinders were prepared for compressive strength tests. Replacement of sharp sand with laterite fine aggregate was carried out at 0%, 20%, 40%, 50%, 60%, 80%, and 100% levels. The batching of concrete was done by weight and the different constituent materials were weighed based on the adopted mixes of 1:1½:3 and 1:2:4 respectively at water – cement ratio of 0.55. Three specimens were cast for each replacement level using cube and cylinder moulds. The specimens were demoulded after 24 hours and cured in a water bath until ready for test. Compressive strength results were taken after 3, 7, 14, 21 and 28 days of curing.

The tests conducted in the course of this study were:

(a) Sieve analysis test on all aggregates (in accordance with BS 882:1983)
(b) Specific gravity test on aggregates (in accordance with BS 882: Part 2:1983)
(c) Workability test on fresh concretes (in accordance with BS 1881:1970)
(d) Density test on concretes produced (in accordance with BS 1881:1970)
(e) Compressive strength test on concrete cubes and cylinders (in accordance with BS 1881: Part 4: 1970)
(f) Water absorption test on concrete specimens (in accordance with BS 1881:1970)

3.2.1 The compressive strength of the concrete was determined using equation [2].

$$f_c = P/A_c \quad [2$$

Where;

f_c = is the compressive strength in N/mm^2.

P = is the maximum load at failure in Newton.

A_c = is the cross sectional area of the cube.

4.0 RESULTS AND DISCUSSIONS

4.1 Properties of Materials Used

The laterite had a specific gravity of 2.53, while sand and coarse aggregate had 2.66 and 2.71 respectively. These values satisfy the conditions for use as aggregates as stipulated in BS 1377: Part 2:1990.

4.2 Sieve Analysis Result

The particle size distributions of the aggregates are presented on Tables 4.1, 4.2 and 4.3 for laterite, sand and coarse aggregate respectively. They are also plotted on Figures 4.1, 4.2 and 4.3 for the respective aggregates.

Table 4.1 Sieve Analysis for Laterite

Source:	University of Uyo permanent Campus			
Wt. Of Dry Sample:	1000g		Air dry Mc: 0.80%	
Wt. Of Washed Sample:	775.0g			
Sieve size (mm)	Weight Retained (g)	% Retained	Cum. % Retained	% Passing
4.75	0.00	0.00	0.00	100.00
3.35	0.00	0.00	0.00	100.00
2.36	0.00	0.00	0.00	100.00
1.18	49.50	4.99	4.99	95.01
0.85	64.20	6.47	11.46	88.54
0.60	146.80	14.80	26.26	73.74
0.425	239.00	24.09	50.35	49.65
0.25	188.60	19.01	69.36	30.64
0.15	67.80	6.83	76.19	23.81
0.075	13.70	1.38	77.58	22.42
Pan	5.60	0.56		

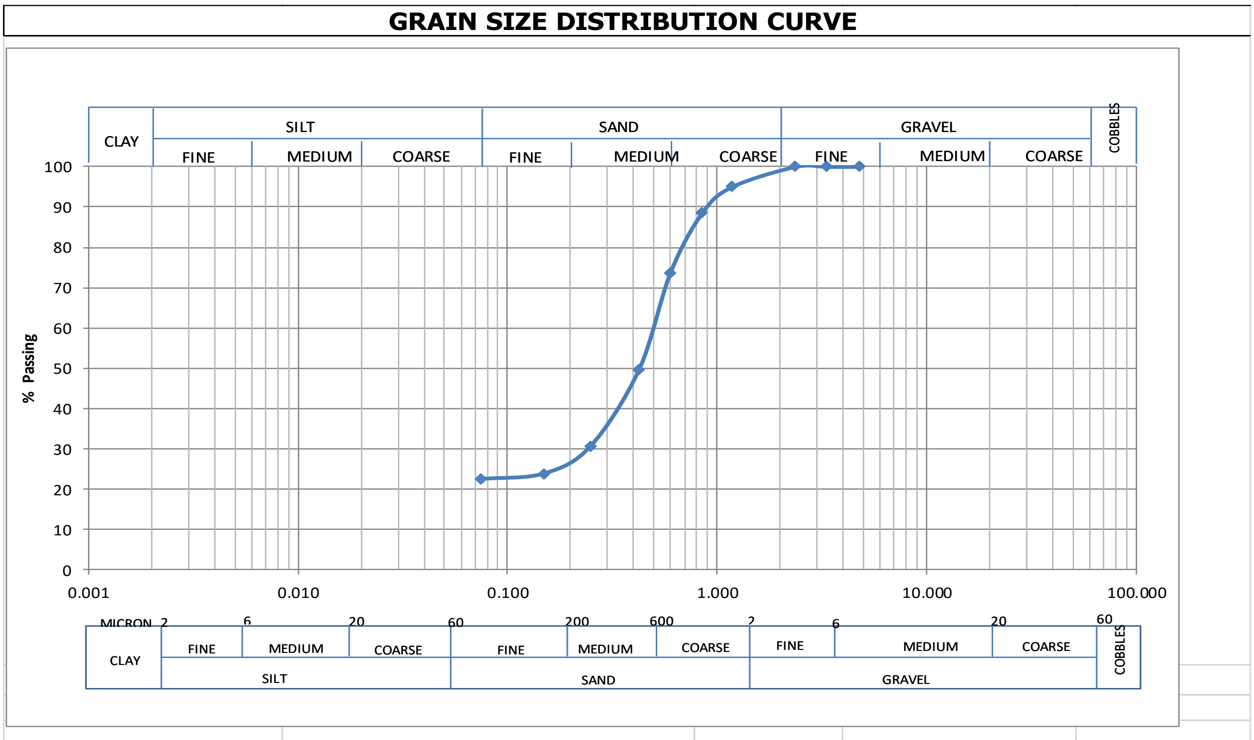

Fig 4.1 Grading Curve for Sieve Analysis of Laterite.

Table 4.2: Sieve Analysis for Sand

Source: University of Uyo permanent Campus				
Wt. Of Dry Sample: 1000g			Air dry Mc: 0.80%	
Wt. Of Washed Sample: 775.0g				
Sieve size (mm)	Weight Retained (g)	% Retained	Cum. % Retained	% Passing
4.75	4.50	0.46	0.46	99.54
3.35	3.80	0.38	0.84	99.62
2.36	13.20	1.33	2.17	98.28
1.18	54.10	5.46	7.64	92.82
0.85	55.60	5.62	13.25	87.20
0.60	114.10	11.52	24.78	75.68
0.425	189.20	19.11	43.89	56.57
0.25	251.10	25.36	69.25	31.21
0.15	120.00	12.12	81.37	19.09
0.075	30.70	3.10	84.47	15.99
Pan	4.40	0.44		

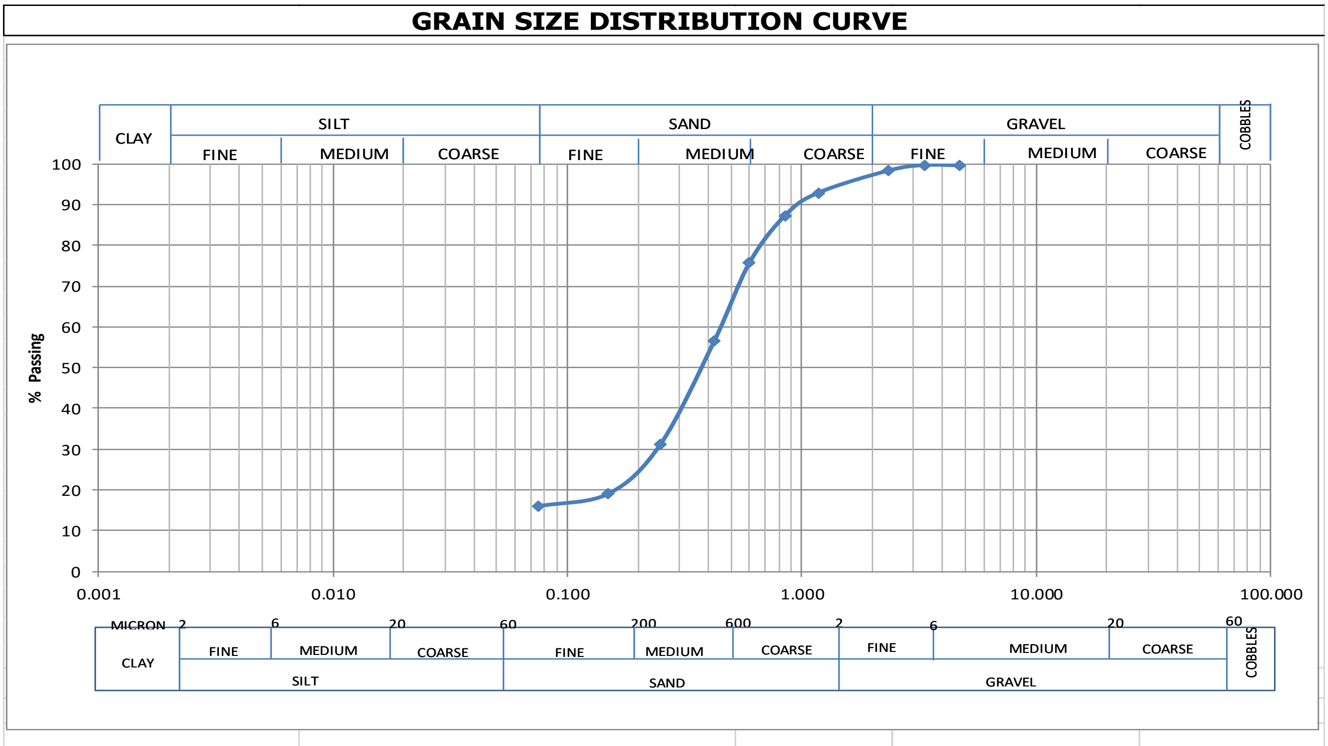

Fig 4.2 Grading Curve for the River Sand Used

Table 4.3 Sieve Analysis of Coarse Aggregate

Source: University of Uyo permanent Campus				
Wt. Of Dry Sample: 2000g			Air dry Mc: 0.80%	
Wt. Of Washed Sample: 775.0g				
Sieve size (mm)	Weight Retained (g)	% Retained	Cum. % Retained	% Passing
37.50	0.00	0.00	0.00	100.00
25.00	223.00	11.16	11.16	88.84
22.40	272.40	13.63	24.78	75.22
19.00	841.80	42.11	66.89	33.11
16.00	390.30	19.52	86.42	13.58
12.50	117.20	5.86	92.28	7.72
9.50	5.70	0.29	92.57	7.43
PAN	141.20	7.06		

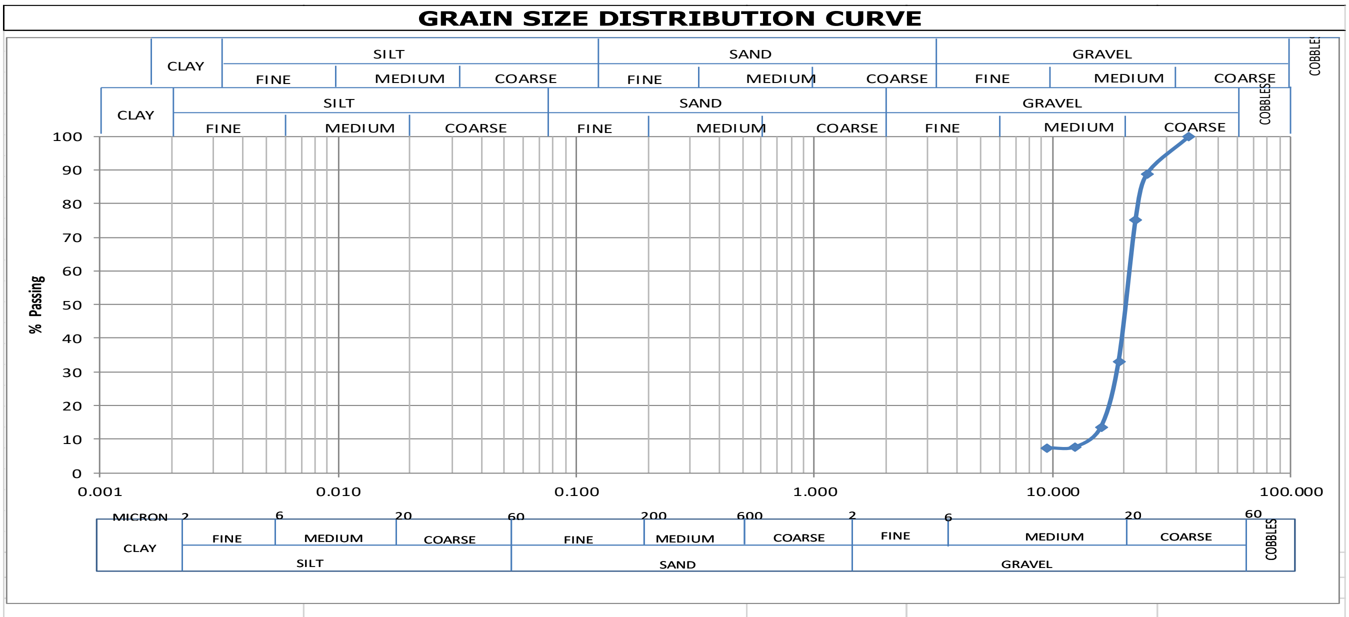

Fig 4.3: Grading Curve for Coarse Aggregate size 25mm

4.3 Workability (Slump Test)

The results of the workability test using the slump experiments are shown on Table 4.4 and Figure 4.4. Laterized concretes containing 0% of laterite exhibited 165mm slump as against 10mm for that containing 100% laterite. Generally the slump (that is workability) reduced as the percentage of laterite increased.

Table 4.4: Slump Test Results

Combination		Slump (mm)
Laterite	Sand	
0%	100%	165
20%	80%	95
40%	60%	42
50%	50%	34
60%	40%	30
80%	20%	15
100%	0%	10

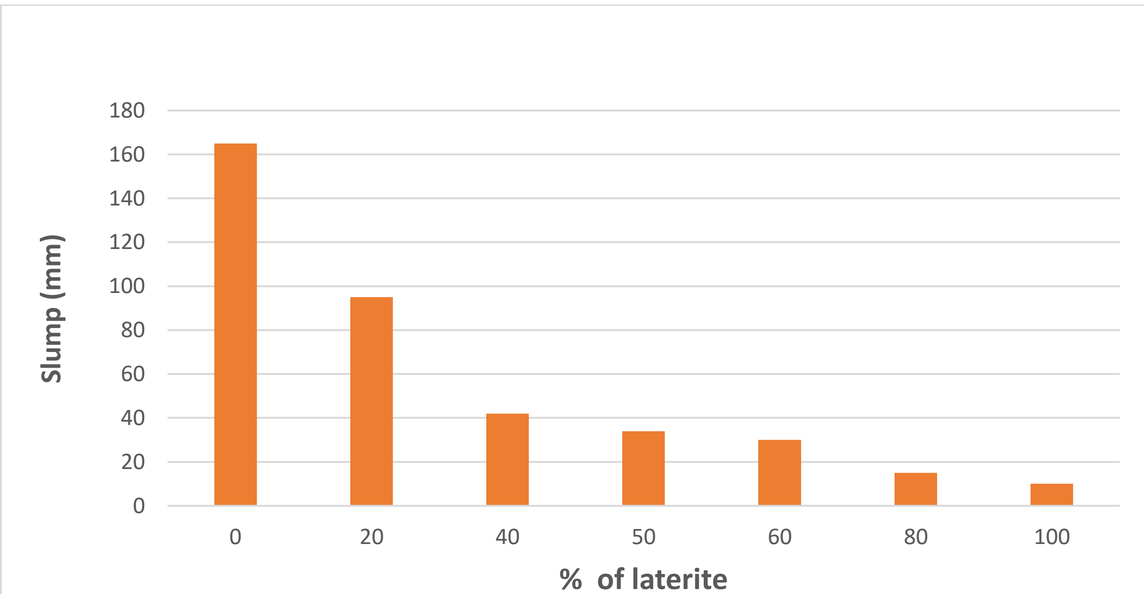

Fig. 4.4: Slump test results

4.4 Density of Normal Laterized Concrete

Table 4.5 shows the range of densities of the laterized concretes used in this experimentation. The densities between 2401kg/m^3 and 2470kg/m^3 indicating that the laterized concretes used were normal weight concretes.

Table 4.5: Average 28th Day Densities of Laterized Concretes Used

Combination		
Laterite	Sand	Density (kg/m^3)
0%	100%	2401
20%	80%	2427
40%	60%	2423
50%	50%	2432
60%	40%	2402
80%	20%	2452
100%	0%	2470

4.5 Compressive Strengths of Laterized Concrete Cubes and Cylinders

The Compressive strengths of the laterized concrete cubes and cylindrical specimens studied are presented on Table 4.6 and Figures 4.4 to 4.8.

Table 4.6: Compressive Strengths of Cube and Cylinder Specimens

Combination		Curing Days	Cube Strength N/mm^2	Cylinder Strength N/mm^2	Cube/Cylinder Strength Ratio
Laterite	Sand	3	10.5	9.1 ± 0.15	0.86
		7	22.7 ± 0.10	16.5 ± 0.40	0.73
0%	100%	14	23.4 ± 0.15	18.2 ± 0.45	0.77
		21	25.8 ± 0.10	21.6 ± 0.20	0.84
		28	26.2 ± 0.17	22.2 ± 0.11	0.85
20%	80%	3	10.9 ± 0.10	6.9 ± 0.10	0.63
		7	20.6 ± 0.49	15.6 ± 0.57	0.76
		14	22.7 ± 0.35	16.9 ± 0.15	0.74
		21	24.6 ± 0.32	17.8 ± 0.37	0.72
		28	26.6 ± 0.35	18.2 ± 0.16	0.68
40%	60%	3	9.3 ± 0.15	6.5 ± 0.10	0.70
		7	20.9 ± 0.10	14.4 ± 0.32	0.69
		14	21.8 ± 0.50	15.7 ± 0.50	0.72
		21	23.5 ± 0.10	16.5 ± 0.31	0.70
		28	26.3 ± 0.15	17.2 ± 0.20	0.65
50%	50%	3	8.5 ± 0.20	6.5 ± 0.15	0.76
		7	20.2 ± 0.25	13.2 ± 0.60	0.65
		14	20.8 ± 0.26	14.1 ± 0.50	0.68
		21	22.6 ± 0.60	16.1 ± 0.32	0.71
		28	23.5 ± 0.15	17. 1 ± 0.26	0.73
60%	40%	3	9.0 ± 0.10	6.1 ± 0.30	0.68
		7	17.8 ± 0.05	12.8 ± 0.99	0.72
		14	19.7 ± 0.11	13.9 ± 0.60	0.71
		21	22.7 ± 0.32	14.2 ± 0.15	0.63
		28	23.7 ± 0.05	15.3 ± 0.25	0.65
80%	20%	3	8.4 ± 0.15	5.4 ± 0.20	0.64
		7	18.3 ± 0.25	10.7 ± 0.46	0.58
		14	20.3 ± 0.26	12.6 ± 0.58	0.62

		21	20.8 ± 0.10	13.7 ± 0.52	0.66
		28	21.1 ± 0.10	14.3 ± 0.16	0.68
100%	0%	3	6.9 ± 0.25	4.9 ± 0.20	0.71
		7	14.7 ± 0.10	9.0 ± 0.63	0.61
		14	14.9 ± 0.10	8.6 ± 0.30	0.58
		21	16.1 ± 0.20	8.5 ± 0.50	0.53
		28	17.2 ± 0.10	8.8 ± 0.35	0.51

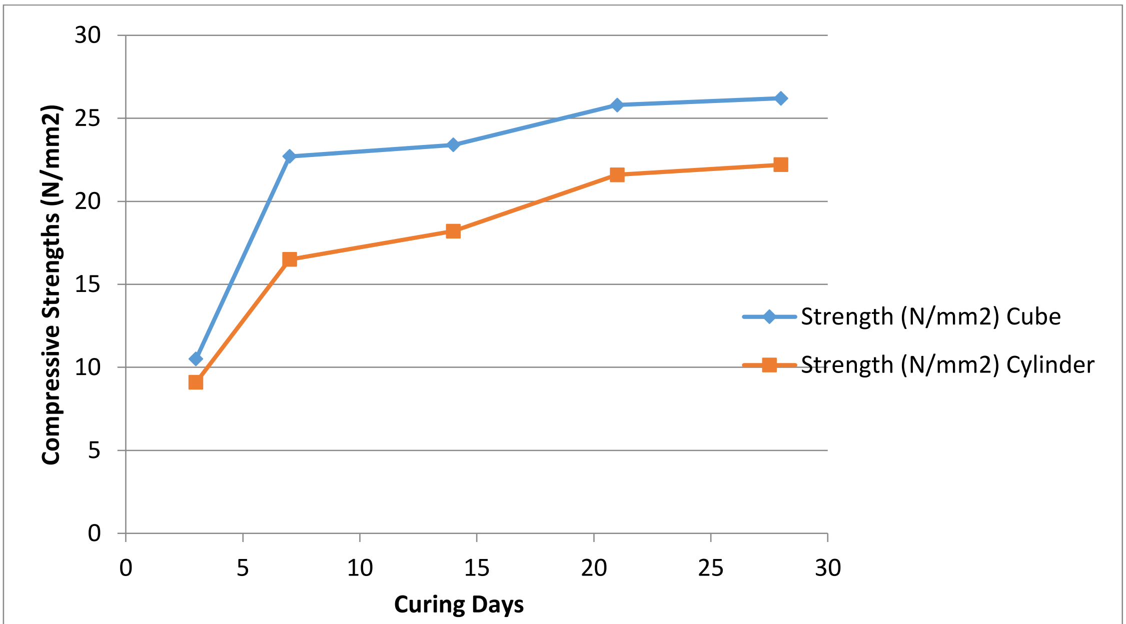

Fig. 4.4: Cube and Cylinder Strengths at 0% Lat / 100% Sand

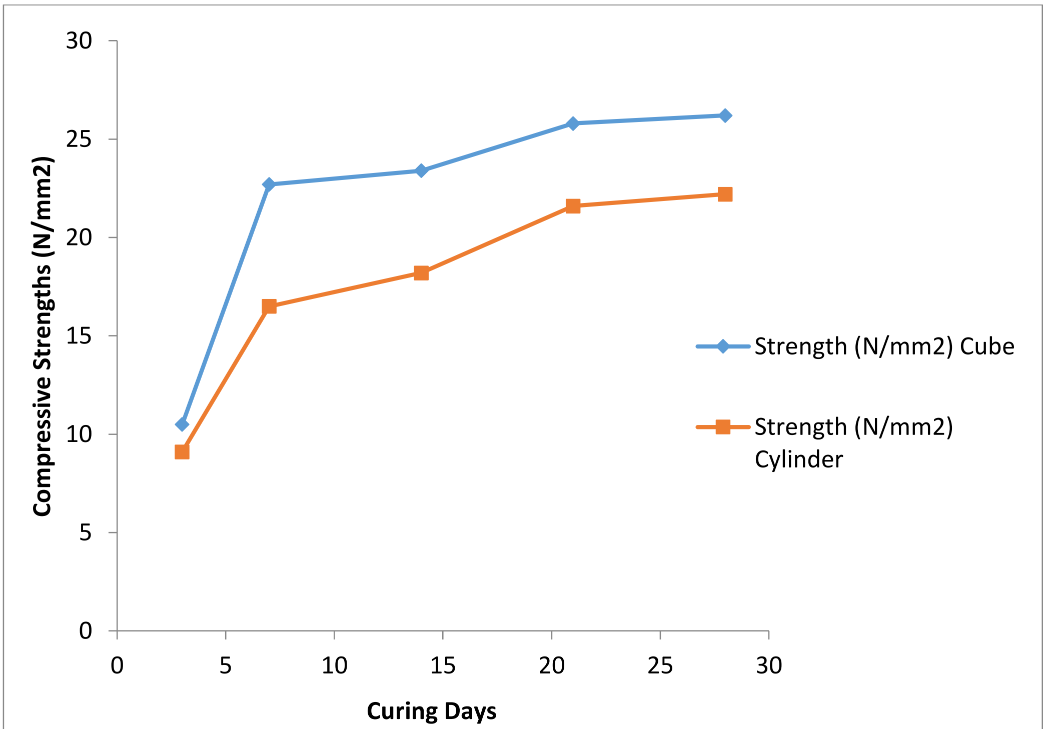

Fig. 4.4: Cube and Cylinder Strengths at 0% Lat / 100% Sand

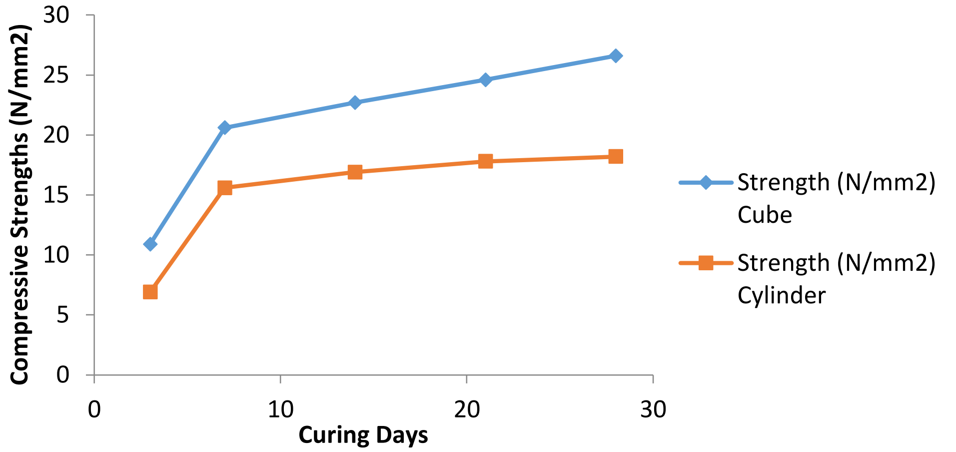

Fig. 4.5: Cube and Cylinder Strengths at 20% Lat/ 80% Sand

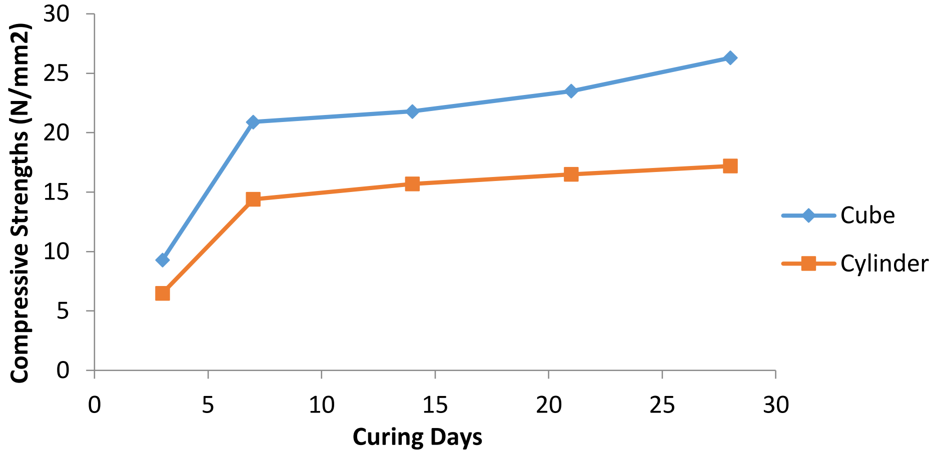

Fig. 4.6: Cube and Cylinder Strengths at 40% Lat/ 60% Sand

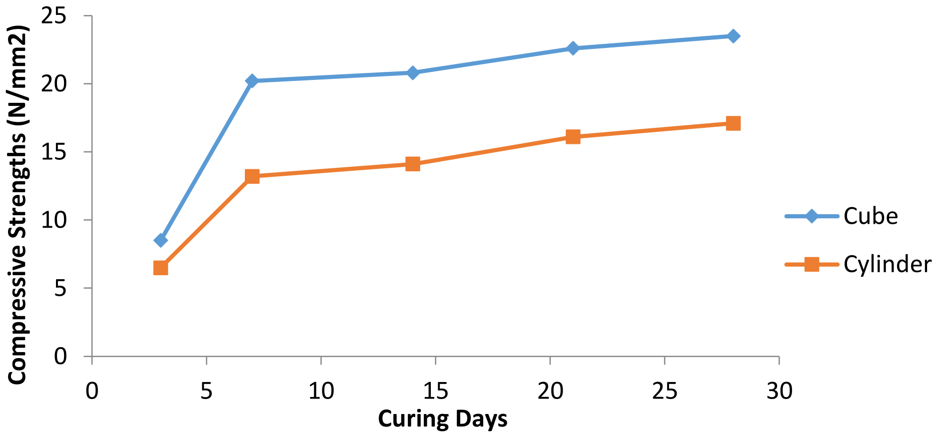

Fig. 4.7: Cube and Cylinder Strengths at 50% Lat/ 50% Sand

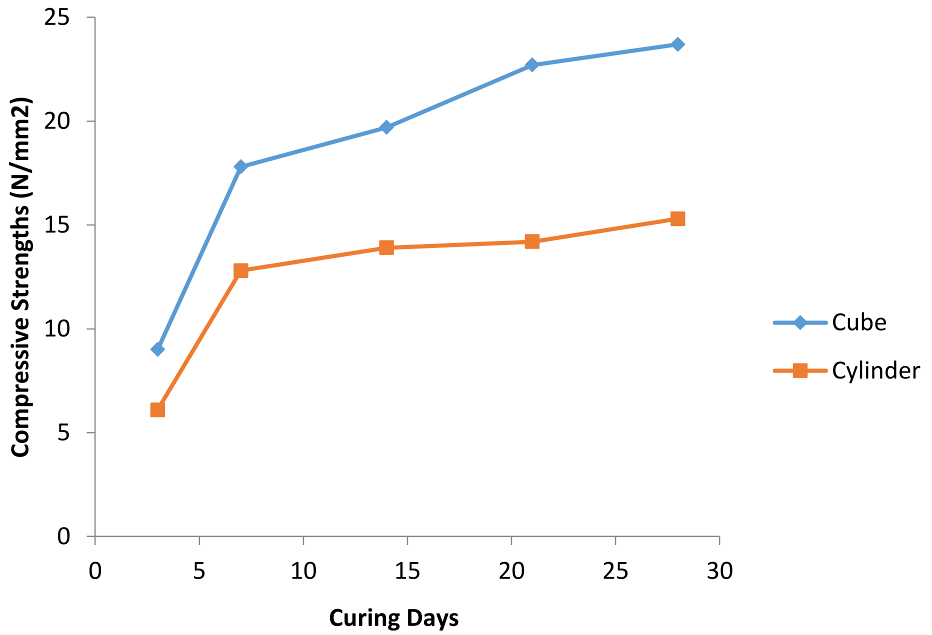

Fig. 4.8: Cube and Cylinder Strengths at 60% Lat/ 40% Sand

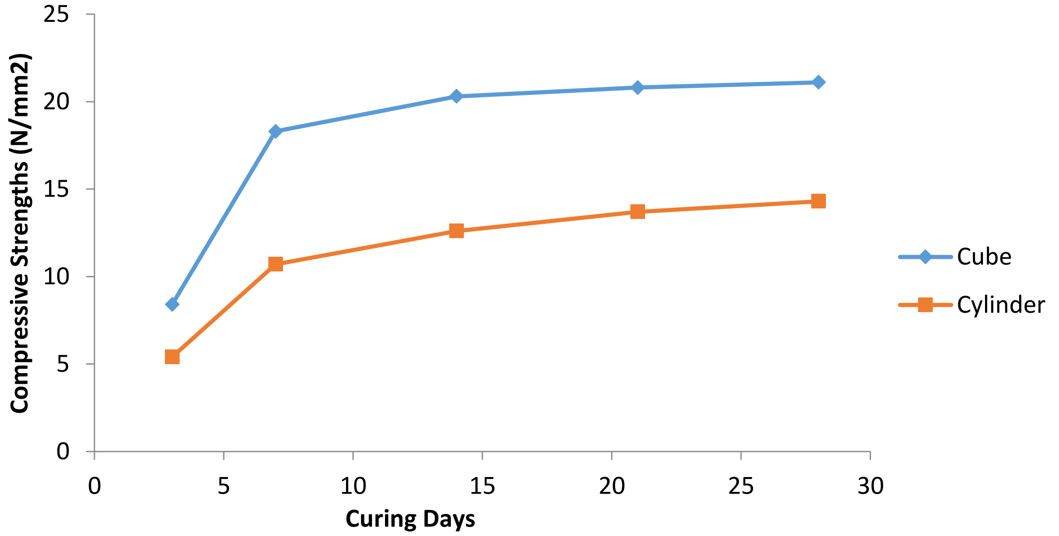

Fig. 4.9: Cube and Cylinder Strebgths at 80% Lat/ 20% Sand

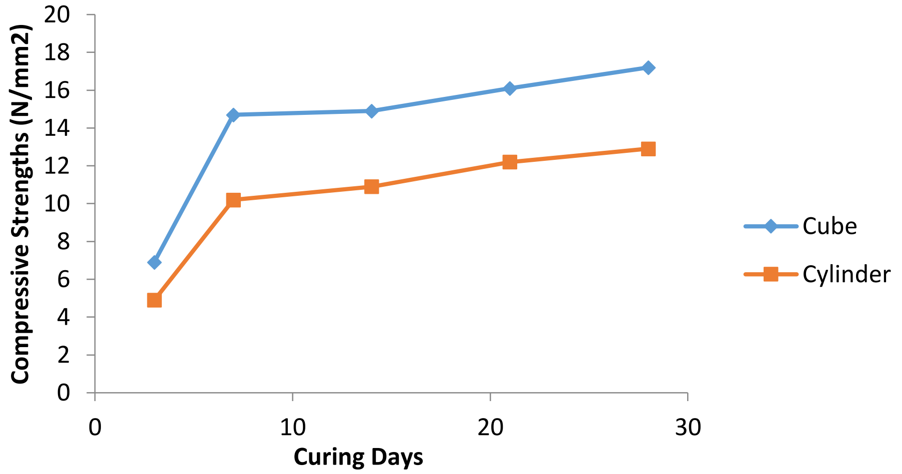

Fig. 4.10: Cube and Cylinder Strengths at 100% Lat/ 0% Sand

At 3 days curing for all the combinations of laterite and sand, the cylinder specimens had strengths 68% that of the cube. Similarly the respective percentages for 7 days, 14 days, 21 days and 28 days were 77, 69, 70, and 80. These indicated that for laterized concretes the cylinder specimens have strengths lower than the cube specimens. BS 8110 stipulates that the cylinder strength should be about 80% of the cube strength. The cylinder strengths of the laterized concrete studied at 14, 21, and 28 conformed to this.

Additionally, the cube-to-cylinder strength ratio was found to be higher for the samples at 14 and 21 days, compared to those at 7 and 28 days. This suggests that the concrete samples gained strength during the intermediate curing period, but not as much during the earlier or later stages of the curing process. The exact reasons for this behavior are not entirely clear and may be influenced by a range of factors such as the mix design, curing conditions, and testing protocols.

Moreover, cylinder/cube strengths were higher for the samples at 14, 21, and 28 days compared to those at 7 days. This suggests that the concrete samples gained more strength during the later stages of the curing process.

5.1 CONCLUSION AND RECOMMENDATION

The following conclusion has been made from this study:

1. There is decrease in the workability of concrete as the percentage of laterite increase hence laterized concretes require increased water – cement ratio.
2. Compressive strength increased with curing age for both cube and cylinder specimens.
3. The maximum compressive strength was obtained at 25% replacement of sand with laterite.
4. Compressive strength decreases with increase in the laterite content.
5. The compressive strengths of cube specimens were higher than those of cylinder at all replacement levels.
6. The ratio of cylinder to cube compressive strengths ranged between 0.65 and 0.8.

5.2 RECOMMENDATION

A ratio of 1:1½:3 concrete is recommended for laterized concretes meant for structural purposes and the percentage replacement of sand with laterite should not exceed 50%.

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