The Suitability of Using Laterite as Sole Fine Aggregate in Structural Concrete

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ABSTRACT
Sand has traditionally been used as fine aggregate in structural concrete. It is usually imported from relatively distant places at high costs, and this increases the overall cost of making concrete and of providing housing in various Nigerian communities. This study investigates the suitability of laterite as sole fine aggregate in place of sand, and specifically seeks to determine whether laterized concrete would satisfy the minimum compressive strength requirement of BS 8110 (1997) for use in reinforced concrete works, which is 25 N/mm^2. Potable water was used for this work and Ibeto brand of Ordinary Portland Cement was used as binder. Laterite was used as fine aggregate, while granite of 20 mm nominal size was used as coarse aggregate. Compressive cube strength and saturated surface dry (SSD) bulk density tests were conducted. Batching was by weight. Forty mix ratios of water: cement: laterite: granite were used. A total of 120 standard 150 mm concrete cubes were cast and cured for 28 days, then weighed and crushed. The results show that the average SSD density of the laterized concrete is approximately 22.81 KN/m^3, a value lower than the average value of 24KN/m^3 for traditional concrete. Also, a good number of the mix ratios had compressive cube strengths higher than the 25 N/mm^2 bench mark of BS 8110 (1997). Therefore, laterite could be used as sole fine aggregate for making structural concrete. Moreover, since laterized concrete has a lower unit weight than traditional concrete, it would be more suitable for use in communities with problematic soils that have poor bearing capacities.

Keywords: Bulk density, compressive strength, laterite, laterized concrete, traditional concrete, structural concrete.

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1 INTRODUCTION

Sand has traditionally been used as fine aggregate in structural concrete. The commonest types of sand used in this regard in various parts of Nigeria are river sand, erosion sand, and dune sand (dug-out sand). Unfortunately, these sand types are not readily available in many parts of the country, and could be rightly regarded as scarce material for concrete-making in those communities. Persons making concrete in such localities usually import sand from relatively distant places at high costs, and this increases the overall cost of making concrete and of providing housing for the people. Thus, there is an increasing need to source alternative locally-available materials that could serve as suitable replacement to sand as fine aggregate in concrete.

This study investigates the suitability of laterite as sole fine aggregate in place of sand. Laterite has the advantage of being readily available in most Nigerian communities. Besides being obtained intentionally in burrow pit excavations, it is also frequently obtained through various forms of excavations for substructure works, including excavations for foundations and septic tanks. However, unlike sand, laterite is a combination of different soil types, notably clay, sand, and silt. A good number of scholars have worked on laterite [1], [2], [3], [4] and established that, among other things, the presence of iron oxide accounts for its red colour. The presence of clay and silt particles in large quantities could make laterite fall short of the requirements of BS 882 [5] for high quality concrete. Thus, the suitability or otherwise of using laterite as sole replacement for sand in concrete would depend greatly on the proportion of these fine particles in the laterite. Many other scholars have carried out preliminary investigations on various aspects of laterized concrete and made findings that suggest the possibility of using laterite as replacement for sand in concrete [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25].

This study further seeks to determine whether laterite used as sole fine aggregate in concrete would satisfy the minimum compressive strength requirement of BS 8110 [26] for use in reinforced concrete works, which is 25 N/mm^2. The code also specifies that structural concrete should have a maximum water/cement ratio of 0.7 and a minimum cement content of 250 Kg/m^3. Since the unit weight of fresh normal weight concrete is about 24 KN/m^3 or 2449 Kg/m^3, the required cement content should be about 10.2% by weight.

2 MATERIALS AND METHODS

Potable water obtained from a public tap in Owerri, Imo state, was used for this work. Ibeto brand of Ordinary Portland Cement that conforms to BS 12 (1978) was used as binder. Laterite obtained from a burrow pit along Owerri-Okigwe road, Owerri, was used as fine aggregate. It had low clay and silt content and was free from physical organic substances. Granite of 20 mm nominal size obtained from a quarry in Umuchieze village, Abia State of Nigeria was used as coarse aggregate. The sieve analysis result for the laterite is as shown in table 1, with the grading curve shown in Fig. 1. It is interesting to note that except for some fractions of coarse aggregate retained on 10mm sieve size, the percentages passing the other sieve sizes, including the percentage of fine particles less than 0.15mm, are all within the grading limits for fine aggregate prescribed by both BS EN 882: 1992 and ASTM C 33-03. However, the fineness modulus of 1.86 indicates that the laterite as fine aggregate is skewed towards the smaller fractions than the large ones.

Compressive cube strength and saturated surface dry (SSD) bulk density tests were conducted in conformity with BS 1881: Part 115 (1986). Batching was by weight. Forty mix ratios of water: cement: laterite: granite were used. The Scheffe Simplex Optimization design method aimed at achieving the minimum target strength of 25N/mm^2 specified by BS 8110 (1997) was employed as a guide for choosing the mix ratios. The 40 mix ratios, shown in table 2, were selected within the bounds of two separate Scheffe's tetrahedrons whose vertices were respectively defined by mix ratios 1 to 4 and 21 to 24 in the table. Three standard 150mm x 150mm x 150mm concrete cubes were cast for each mix ratio, making a total of 120 cubes. These were cured for 28 days, then weighed and crushed to determine their compressive strength.

3 RESULTS AND DISCUSSIONS

The results of the compressive cube strength and saturated surface dry (SSD) density tests for all the forty mix ratios are as presented in table 4. The results show that the average SSD density of the laterized concrete (concrete with laterite as sole fine aggregate) is approximately 2328 Kg/m^3 or 22.81 KN/m^3. This value is reasonably lower than the average value of 24KN/m^3 for traditional concrete produced with cement, sand, and granite. Thus, laterized concrete would produce structural members with lower self-weight than traditional concrete. Also, a good number of the mix ratios had compressive cube strengths higher than or very close to the 25 N/mm^2 bench mark of BS 8110 (1997) as highlighted in table 3. Therefore, on the basis of compressive strength, concrete made with laterite as sole fine aggregate would be suitable for constructing reinforced concrete elements, provided a suitable mix ratio such as one of those with high strength in this table is used. It should also be noted that a good number of structural members such as columns and slabs under mild conditions of exposure in lightly-loaded structures typical of residential buildings frequently do not require very high values of concrete characteristic strength. CP 110: 1972 specified a minimum strength of 20 KN/mm^2 for such lightly loaded structural members. The use of laterized concrete would be especially suitable for the construction of such members.

4 CONCLUSIONS AND RECOMMENDATIONS

Laterite could be used as sole fine aggregate for making structural concrete. Such laterized concrete would be especially useful for concrete elements under mild conditions of exposure that are reasonably protected from the effects of harsh weather. We recommend using a combination of traditional concrete and laterized concrete for more sensitive structures; in which case traditional concrete could be used in casting members under moderate and harsher conditions of exposure such as foundations and other members in continuous contact with water, and laterized concrete used for members under mild conditions of exposure. Also, since laterized concrete has a lower unit weight than traditional concrete, it would be more suitable for use in Nigerian communities with problematic soils that have poor or unreliable bearing capacities. Moreover, the prevalence of laterite in most communities also means the use of laterized concrete would greatly contribute toward the provision of low cost housing units for the rapidly increasing populace in major urban cities such as Owerri in Imo State of Nigeria. The resultant burrow pits could be well utilized for sanitary landfills and recovered for other convenient uses at the maturation of the landfills.

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Table 1. Result of sieve analysis for laterite
Fineness modulus = 1.86

Sieve size (mm)	Mass retained (g)	Percentage retained	Cumulative % retained	Percentage Passing
10	6.94	1.40	1.40	98.60
5	0.68	o.14	1.54	98.46
2.36	6.25	1.27	2.81	97.19
1.18	23.09	4.69	7.50	92.50
0.6	91.64	18.60	26.10	73.90
0.3	173.83	35.29	61.39	38.61
0.15	118.34	24.03	85.42	14.58
< 0.15 (Pan)	71.86	14.58	--	
Total	492.63		186.16	

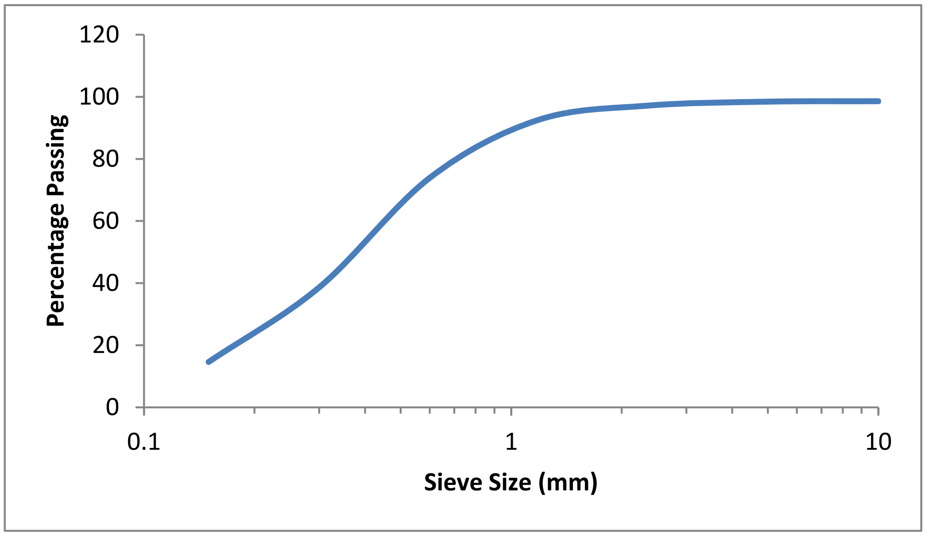

Fig. 1: Grading curve for laterite

Table 2. Mix ratios used for this work

S / N	Water	Cement	Laterite	Granite	S / N	Water	Cement	Laterite	Granite
N1	0.5	1	1	1	N21	0.6	1	1.35	1.65
N2	0.55	1	2	1.5	N22	0.75	1	1.8	2.2
N3	0.65	1	1.5	2	N23	0.7	1	2.25	2.75
N4	0.6	1	1.5	1.5	N24	0.55	1	2.71	3.3
N5	0.525	1	1.25	1.5	N25	0.675	1	1.575	1.925
N6	0.575	1	1.5	1.25	N26	0.65	1	1.8	2.2
N7	0.55	1	1.25	1.25	N27	0.575	1	2.03	2.475
N8	0.6	1	1.75	1.75	N28	0.725	1	2.025	2.475
N9	0.575	1	1.5	1.75	N29	0.65	1	2.255	2.75
N10	0.625	1	1.75	1.5	N30	0.625	1	2.48	2.25
N11	0.575	1	1.5	1.75	N31	0.64	1	2.2085	2.695
N12	0.595	1	1.6	1.5	N32	0.636	1	2.299	2.805
N13	0.565	1	1.4	1.35	N33	0.645	1	2.118	2.805
N14	0.345	1	1.65	1. 5	N34	0.65	1	2.0275	2.475
N15	0.573	1	1.5	1.525	N35	0.62	1	1.983	2.42
N16	0.578	1	1.53	1.59	N36	0.66	1	1.982	2.42
N17	0.58	1	1.54	1.57	N37	0.659	1	2.0818	2.54
N18	0.576	1	1.505	1.43	N38	0.7	1	2.08	2.54
N19	0.572	1	1.52	1.54	N39	0.6515	1	1.9592	2.3925
N20	0.55	1	1.375	1.375	N40	0.676	1	1.909	2.332

Table 4. Values of compressive cube strength (CCS) and saturated surface dry (SSD) density for the forty mixes

Mix No	Water	Cement	Laterite	Granite	Cement Content (%)	Compressive cube strength (N/mm²)	Saturated surface dry density (Kg/m³)
N1	0.5	1	1	1	29	21.48	2348
N2	0.55	1	2	1.5	20	13.63	2304
N3	0.65	1	1.5	2	19	14.96	2336
N4	0.6	1	1.5	1.5	22	18.07	2338
N5	0.525	1	1.25	1.5	23	19.85	2305
N6	0.575	1	1.5	1.25	23	21.18	2323
N7	0.55	1	1.25	1.25	25	25.04	2278
N8	0.6	1	1.75	1.75	20	16.3	2322
N9	0.575	1	1.5	1.75	21	20.74	2338
N10	0.625	1	1.75	1.5	21	20.59	2294
N11	0.575	1	1.5	1.75	21	21.48	2388
N12	0.595	1	1.6	1.5	21	26.96	2292
N13	0.565	1	1.4	1.35	23	24.44	2271
N14	0.345	1	1.65	1. 5	22	4.44	2195
N15	0.573	1	1.5	1.525	22	25.48	2409
N16	0.578	1	1.53	1.59	21	23.26	2380
N17	0.58	1	1.54	1.57	21	23.41	2387
N18	0.576	1	1.505	1.43	22	24.3	2361
N19	0.572	1	1.52	1.54	22	26.45	2407
N20	0.55	1	1.375	1.375	23	26.89	2283
N21	0.6	1	1.35	1.65	21.74	30.66	2348
N22	0.75	1	1.8	2.2	17.39	23.41	2304
N23	0.7	1	2.25	2.75	14.93	22.54	2326
N24	0.55	1	2.71	3.3	13.23	8.89	2338
N25	0.675	1	1.575	1.925	19.32	26.37	2305
N26	0.65	1	1.8	2.2	17.7	17.78	2323
N27	0.575	1	2.03	2.475	16.45	24.89	2278
N28	0.725	1	2.025	2.475	16.06	23.26	2323
N29	0.65	1	2.255	2.75	15.03	20.74	2338
N30	0.625	1	2.48	2.25	15.74	20.66	2293
N31	0.64	1	2.2085	2.695	15.28	20.53	2389
N32	0.636	1	2.299	2.805	14.84	19.82	2292
N33	0.645	1	2.118	2.805	15.23	19.93	2270
N34	0.65	1	2.0275	2.475	16.25	22.13	2196
N35	0.62	1	1.983	2.42	16.6	22.49	2410
N36	0.66	1	1.982	2.42	16.5	22.41	2380
N37	0.659	1	2.0818	2.54	15.92	22.3	2387
N38	0.7	1	2.08	2.54	15.82	24.89	2362
N39	0.6515	1	1.9592	2.3925	16.66	21.4	2407
N40	0.676	1	1.909	2.332	16.9	22.17	2284

Table 3. Mixes with strengths higher than or very close to 25 N/mm^2

Mix ratio	Compressive cube strength
0.55 : 1 : 1.375 : 1.375	26.89 N/mm^2
0.55 : 1 : 1.25 : 1.25	25.04 N/mm^2
0.595 : 1 : 1.6 : 1.5	26.96 N/mm^2
0.5725 : 1 : 1.5 : 1.525	25.48 N/mm^2
0.5755 : 1 : 1.52 : 1.54	26.45 N/mm^2
0.6 : 1 : 1.35 : 1.65	30.66 N/mm^2
0.675 : 1 : 1.575 : 1.925	26.37 N/mm^2
0.565 : 1 : 1.4 : 1.35	24.44 N/mm^2
0.70 : 1 : 2.08 : 2.54	24.89 N/mm^2