Study on the Suitability of Lateritic Rock as a Coarse Aggregate in Concrete

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Abstract- **This research investigates the suitability of lateritic rock as a coarse aggregate in concrete. Compressive strength tests of concrete samples were conducted using lateritic rock as a coarse aggregate in one sample and crushed granite as coarse aggregate in another sample serving as control. Two mix designs were used for both samples 1:2:4 and 1:3:6 ratio of cement, fine aggregate and coarse aggregate. Water cement ratio of 0.6 was used for both samples. The result of compressive strength has shown that lateritic rock aggregate used in the 1:2:4 and 1:3:6 mix ratios had average 20N/mm^2 and 18N/mm^2 compressive strengths respectively after 28 days of curing. The research has shown the suitability of lateritic rock as coarse aggregate in concrete production if properly washed and sieved to free it from dust and silt. It has also indicated that lateritic rock can be used as a cheaper coarse aggregate in concrete production to reduce the cost of building construction**.

Key Words: **Lateritic rock, Coarse Aggregate, Concrete, Compressive Strength**

I. INTRODUCTION

Granite rock is an important natural resource that is crushed to obtain coarse aggregate for concrete production and is an ideal material for construction works. Unfortunately not all places are blessed with granite rocks and granite rocks have to be transported over long distances to places of need. This cost of transportation significantly contributes to high cost of granite aggregate for construction works in such places and alternative construction material becomes imperative. Lateritic rock is widely used as substitute coarse aggregate in concrete production in areas lacking granite rocks for production of granite aggregate. Lateritic rock is a product of tropical weathering with reddish-brown or dark colour, with or without nodules or concretions and generally and not exclusively found below ferruginous crust or hard pan [1]. It is a highly weathered tropical rocky soil rich in secondary oxide of any combination of iron, Aluminium and Manganese [2]. The utilization of Lateritic rock helps in bringing down the cost of building construction significantly. Though it is widely used, there is need for adequate study on its suitability and reliability in building construction. This research presents a study on comparative performance of concrete made of granite aggregate and lateritic rock aggregate to ascertain the suitability of lateritic rock in concrete production.

II. MATERIAS AND METHODS

The materials used in this research include cement (Ordinary Portland Cement), fine aggregate, water (free from acid concentration and organic substances), lateritic rock and granite coarse aggregates. Lateritic rock is washed and sieved to free it from silts and dirt prior to its usage as aggregate in concrete. Concrete samples of 1:2:4 and 1:3:6 mix ratios of cement sand and aggregate respectively were prepared using lateritic rock aggregate and crushed granite aggregate to serve as control. Water cement ratio of 0.6 was used. Twelve specimen of concrete cubes of 150 mm x 150 mm dimensions were prepared for each of the mix ratios and used for compressive strength tests at 7, 14 and 28 days curing ages. Physical properties tests like sieve analysis, specific gravity, moisture content, bulk density were carried out to properly identify the fine and coarse aggregates in line with British Standard method [3][4].

III. RESULT AND DISCUSSION

Results of sieve analyses tests conducted to identify the aggregate samples are presented in Tables 1, Table 2 and Table 3 for fine aggregate, coarse granite aggregate and coarse lateritic rock aggregate respectively. The particle size distribution of 500 g of sand is given in Table 1. It shows a well graded with size ranging from 2.0 mm to 0.063 mm.

Table 1: Sieve Analysis test result of sand fine aggregate sample

Sieve Size	Mass Restrained (g)	Percentage Mass Retained (%)	Cumulative Percentage Retained (%)	100% Total Passing
2 mm	3	0.6	0.6	99.4
1.18mm	9	1.8	24.0	76.0
0.600 μm	154	30.8	33.2	66.8
0.425 μm	110	22.0	55.2	44.8
0.300 μm	102	20.4	75.6	24.4
0.212 μm	68	13.6	89.2	10.8
0.150 μm	29	5.8	95.0	5.0
0.63 μm	23	4.6	99.6	0.4
Pan	2	0.4	100.0	0
	500g			

Table 2 shows the result of sieve analysis for coarse granite aggregate in which 1000 g was the mass of the sample used. The sieve size ranged from 20mm to 5mm. Table 3 gives the sieve analysis result of lateritic rock aggregate. The size of sieve also ranged from 20mm to 5mm and 1000g was the mass of the sample used also.

Table 2: Sieve analysis result of crushed granite coarse aggregate sample

Sieve Size	Mass of Restrained (g)	Total Mass Retained (g)	Percentage Retained	100% Total Passing
20mm	105	10.5	10.5	89.5
14mm	290	29.0	39.5	60.5
10mm	234	23.4	62.9	37.1
6.3mm	277	27.7	90.6	9.4
5mm	65	6.5	97.1	2.9
pan	29	2.9	100.0	0
	1000g			

Table 3: Sieve Analysis result of Lateritic rock (Coarse Aggregate)

Sieve Size	Mass Restrained (g)	Total Mass Retained (g)	Percentage Retained	100% Total Passing
20mm	21	2.1	2.1	97.9
14mm	164	16.4	18.5	81.5
10mm	410	41.0	59.5	40.5
6.3mm	368	36.8	96.3	37.0
5mm	28	2.8	99.1	0.9
pan	9	0.9	100.0	0
	1000g			

The surface moisture test is expressed as a percentage of the weight of the saturated and surface dry aggregate. Moisture content test was conducted on coarse aggregate made of lateritic rock. The sample was weighed and oven dried for 24 hours at 50 ^{0}C before being weighed again to obtain the moisture content in line with British standard [5]. The result indicated an average value of 7.47 % water content.

Specific gravity test was conducted on all the samples of fine and coarse aggregates (crushed granite and lateritic rock) as presented in Table 4. The result of the test has shown that lateritic rock aggregate has a lower value of specific gravity.

Table 4: Result of Specific gravity test on aggregate samples

Specimen	Specific gravity
Fine aggregate	2.55
Granite Aggregate	2.65
Lateritic rock Aggregate	2.23

The two mix ratios of 1:2:4 and 1:3:6 were chosen to obtain the ideal mix proportion of lateritic rock. Water/cement ratio of 0.6 was used for all the samples. Slump test was carried out to measure the workability of the mixes and the result shows that the lateritic rock samples of 1:3:6 mix ratio has slump value of 40 mm while control mix has a slump of 25 mm for the same mix ratio. For 1:2:4 lateritic rock sample has a slump of 30 mm while control has a slump of 27 mm. Slump values of 0-25 mm is classified as very low workability, slump of 25 mm – 50 mm is low workability, slump value of 25 mm – 100 mm is medium workability, while 100 mm – 175 mm has high workability [6] . Therefore, Lateritic rock aggregate can be said to have higher water absorption and a workability value ranging from low (for 1:2:4 mix ratio) to medium (for 1:3:6 mix ratio).

The freshly prepared concrete mix was poured into 150 mm x 150 mm moulds and compacted using tamping rod for 25 times to achieve proper compaction. It was allowed to set for 24 hours before the cubes were removed and submerged in water filled curing tank and allowed to cure for seven days (7), fourteen days (14), twenty one days (21) and twenty eight days (28).The cubes were removed from the curing tank and wiped clean of water and allowed to dry in the air for about fifteen minutes. It was weighted in order to calculate the saturated density. Compressive strength test was conducted on the cured concrete cubes in line with british standard method [7] to know their cube crushing strength. After seven days of curing, the cubes were crushed using compressive strength testing machine. Sixteen cubes were tested; three cubes of 1:2:4 mix ratio having lateritic rock as coarse aggregate, three cubes of 1:2:4 mix ratio having crushed granite as coarse aggregate and three cubes of 1:3:6 mix ratio having crushed coarse aggregate. The same procedure was repeated after 14 days, 21 days and 28 days curing periods. This is done to obtain progressive records of strength development by the cubes and obtain ideal curing period of concrete made of lateritic rock aggregate.

Table 5 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:2:4 mix ratio after 7 days curing. Table 6 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:3:6 mix ratio after 7 days curing. Table 7 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:2:4 mix ratio after 14 days curing.

Table 5: Average compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:2:4 after 7 days curing.

Mix ratio 1:2:4	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.6	2.26	245	10.3
Crushed granite concrete				
	8.3	2.45	341	15.2

Table 8 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:3:6 mix ratio after 14

days curing. Table 9 shows compressive strength test result of lateritic rock concrete and granite concrete of 1:2:4 mix ratio after 21 days curing while Table 10 shows compressive strength test result of lateritic rock concrete and granite concrete of 1:3:6 mix ratio after 7 days curing. Finally Table 11 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:2:4 mix ratio after 28 days curing and Table 12 provides compressive strength test result of lateritic rock concrete and granite concrete of 1:3:6 mix ratio after 7 days curing.

Table 6: Average compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:3:6 after 7 days curing.

Mix ratio 1:3:6	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.5	2.2	207	9.2
Crushed granite concrete				
	8.25	2.44	243	10.9

Table 7: Average compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:2:4 after 14 days curing.

Mix ratio 1:2:4	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.44	2.2	365	16.3
Crushed granite concrete				
	8.23	2.44	487	21.7

Table 8: Average compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:3:6 after 14 days curing.

Mix ratio 1:3:6	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.1	2.26	216	12.1
Crushed granite concrete				
	8.19	2.43	408	18.2

Table 9: Average Compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:2:4 after 21 days curing.

Mix ratio 1:2:4	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.36	2.19	309	17.7
Crushed granite concrete				
	8.15	2.42	537	23.8

Table 10: Average compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:3:6 after 21 days curing.

Mix ratio 1:3:6	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.3	2.16	368	16.4
Crushed granite concrete				
	8.2	2.42	480	21.4

Table 11: The compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:2:4 after 28 days curing.

Mix ratio 1:2:4	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.4	2.20	447	19.9
Crushed granite concrete				
	8.2	2.43	603	26.8

Table 12: The compressive strength test result of lateritic rock concrete and crushed granite concrete in mix proportion of 1:3:6 after 28 days curing.

Mix ratio 1:3:6	Weight in air (kg)	Maximum load (kN)	Density (kg/m^3)	Compressive strength (N/mm^2)
Lateritic rock concrete				
	7.5	2.18	422	18.8
Crushed granite concrete				
	8.32	2.47	520	23.2

Table 13: Summary of compressive strength test of concrete cube samples

Mix ratio	Curing Age (days)	Average Compressive strength (N/mm^2)
Crushed granite concrete		
1:2:4	7	15.2
	14	21.7
	21	23.8
	28	26.8
1:3:6	7	10.9
	14	18.2
	21	21.4
	28	23.2
lateritic aggregate concrete		
1:2:4	7	10.3
	14	16.3
	21	17.7
	28	20
1:3:6	7	9.2
	14	12.1
	21	16.4
	28	18.8

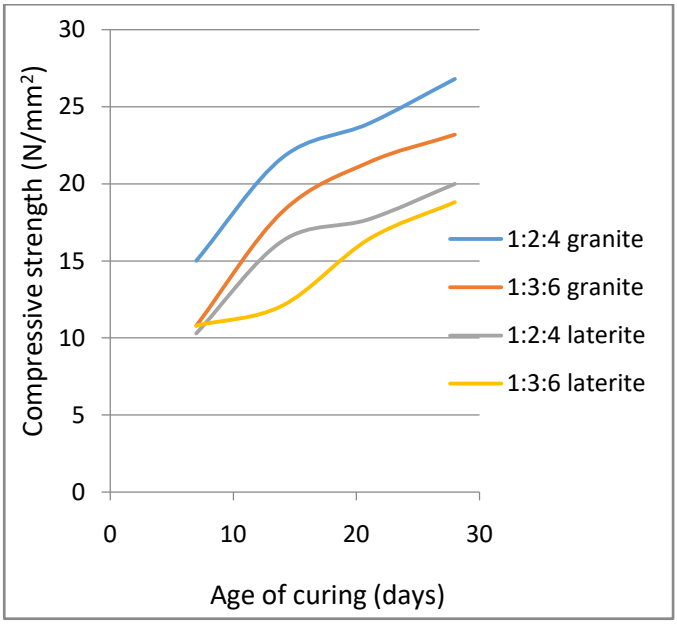

Figure 1: Compressive strength test results of concrete samples made with crushed granite and lateritic rock

Table 13 and Figure 1 provide summary of compressive strength results obtained based on tests carried out in this research. It is observed that lateritic rock concrete has average compressive strength of 20 N/mm^2 for 1:2:4 mix ratio and 28 days curing in comparison to 26.8 N/mm^2 obtained from granite rock concrete. This indicates that lateritic rock is a suitable material for concrete production. For 1:3:6 mix ratio, lateritic rock concrete has average compressive strength of 18.8 N/mm^2 in comparison to 23.2 N/mm^2 obtained for granite rock concrete.

1:2:4, the granite concrete (23.63 N/mm^2) and lateritic rock concrete (17.3 N/mm^2) for 21 day curing. Also, in 14 days curing, the granite concrete gives more strength (17.05 N/mm^2) than the lateritic rock concrete (11.48N/mm^2) in the mix proportion of 1:3:6. Also, in 1:2:4 the granite concrete is 16.10N/mm^2.For seven days curing, the granite concrete gives more strength (10.5N/mm^2) than lateritic rock concrete (7.08N/mm^2) in the mix proportion 1:3:6. In the mix proportion 1:2:4, the granite concrete is (14.65N/mm^2) and lateritic rock concrete (9.65N/mm^2).

IV. CONCLUSION AND RECOMMENDATION

The average compressive strength of 20 N/mm^2 obtained from lateritic rock concrete is an encouraging result. This indicates that lateritic rock can be used as aggregate in concrete production of 20 N/mm^2 target strength. This research recommends the use of cleaned lateritic rock as coarse aggregate in concrete production for 1:2:4 and 1:3:6 nominal mix ratio of cement fine aggregate and coarse aggregate respectively. This will bring significant cost savings in concrete production especially in areas with paucity of granite rocks.

Further study on the use of cement admixtures to increase the strength of lateritic concrete is recommended.

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