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Comparative Study of the Crushing Strength of Concrete Made With Gutter Sand with That Made With River Sharp Sand

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Abstract

The need to search for alternative suitable materials for concrete in view of the rising cost of some of the conventional materials and the environmental impact of their continuous exploitation necessitated this research. Some of the sand deposited along our drainage paths, gutter, roadside and riverbanks could be gainfully used for concreting if sufficient data on their properties are available. They are relatively cheap and locally available. It is observed that within our local environment most people have already taken advantage of these materials for building construction. Investigation into the use of gutter sand as fine aggregate in concrete compared to river sand is presented in this study. Three different prescribed mix proportions of 1:1½:3, 1:2:4 and 1:3:6 concrete were prepared using river sand and gutter sand respectively at a water-cement ratio of 0.5. Cube crushing strengths were determined at 7, 14, and 28 days. Tests were also carried out on the aggregates to determine their particle size distribution and other properties while slump test was carried out on the fresh concretes to determine their workability. Results obtained indicated that the compressive strength of gutter sand concrete with the same cement content showed about 6% decrease when compared to the conventional river sand concrete. A cost analysis indicated that gutter sand concrete was 10% cheaper than river sand concrete of similar mix proportioning.

Keywords: Compressive strength, Fine aggregate, Gutter sand, prescribed mix, Workability.

1. Introduction

Concrete is a man-made composite with natural aggregates such as gravel, sand or crushed rock (Jackson and Dhir, 1996). Artificial aggregates for example blast furnace slag, expanded clay, broken bricks and steel shot are sometimes used where appropriate.

The other principal constituent of concrete is the binding medium used to bind the aggregate particles together to form a hard composite material. The most commonly used binding medium is the product formed by a chemical reaction between cement and water. Some other binders are used on a much smaller scale for special concretes in which the cement and water of normal concrete are replaced either wholly or partially. In its hardened state, concrete is a rock-like material with high compressive strength. By virtue of the ease with which fresh concrete in its plastic state may be moulded into virtually any shape, it may be used to advantage architecturally or solely for decorative purposes.

Of the constituents of concrete, aggregates forms about 75 percent of the volume and contribute greatly to the desirable qualities. Thus, the study of concrete properties includes the study of the constituent aggregate.

1.1 Statement of the Problem

The practice of civil engineering utilises concrete largely and the availability of concrete materials contributes in no small measure to the cost of concrete works in addition to other economic factors. The spiralling cost of the conventional concrete materials has made researchers look for cheap alternative materials which can be sourced locally within the immediate environment and have similar or superior properties to the conventional components. The most commonly used fine aggregate in Nigeria is river sand. Its cost is always on the increase. Gutter sand is sometimes used for block moulding. It is a product of the deposition or settlement of sand due to surface water runoff. It is mostly deposited naturally in drains and other low-lying areas. It is cheaper than river sand and is found in various locations in Nigeria. It can replace sand as a fine aggregate in concrete if test results are satisfactory.

1.2 Objective of Study

This study investigates and compares the workability, crushing strengths and water absorption properties of concretes made with gutter sand as fine aggregate and compare such properties with those of the normal river sand concrete. The cost of producing such concretes will also be ascertained.

It is hoped that the results of this work would provide vital information and data to government, corporate bodies and private individuals who seek for economical and technical alternative concrete materials for solving their housing problems. Engineers, architects, builders and other professionals may also have reasonable data for the design and construction of economical concrete structures using gutter sand as aggregate.

2. Literature Review

2.1 Concrete

Concrete is a synthetic construction material made by mixing appropriated proportions of fine aggregate (usually sand), coarse aggregate and water. The inherent characteristics of a concrete mix, whether in the fresh or hardened state depend on the proportions of the various constituents. Sinha and Roy (2001) stated that the overall proportion of the principal components is controlled by the requirements that:

a) When freshly mixed, the concrete must be workable or placeable;

b) When the mass has hardened, it attains the required strength and durability;

c) The cost of the final product must be the minimum with acceptable quality.

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Fresh concrete solidifies and hardens after mixing and placement due to a chemical reaction in which the water reacts with the cement and forms a compound, which binds the other components together to form a dense solid mass (Emmett and Gorse, 2005). This mass continues to harden overtime.

Good quality concrete has many desirable properties that enhance its popularity as a major construction material. These properties include its economy especially when ingredients are readily available, durability and relatively low maintenance requirements. Concrete can be moulded into virtually any shape and size on site and has a potentially high compressive strength and can resist extreme conditions like fire, corrosion, etc. but concrete has a low tensile strength, low ductility, and is susceptible to cracking. Despite the limitations, concrete however remains the material of choice for many applications especially as research has facilitated mitigation of these weaknesses in concrete. Although all concrete properties are essential, two are however more recurring and critical for concrete works – workability and compressive strength (Jackson, N. et al, 1988).

2.2 Workability of Concrete

The workability of concrete is a measure used to determine the fluidity of concrete mix to be moulded into its required shape. It describes concrete consistency and homogeneity and is achieved with the ratio of water to cement, the cement content, physical characteristic of aggregate, the level of hydration and the material mix proportion (Nataraya and Reddy, 2007). Considerable improvement can be made in concrete workability by adding more water or by applying water-reducing admixtures to the mix. However, increasing the quantity of water leads to bleeding and segregation which results in poor quality concrete. Water-reducing admixtures on the other hand sustain workability with low water content (Aitin 1998). Workability of concrete can be measured by the slump-test, or the compacting factor test amongst others. The slump test is common in many construction sites due largely to its simple application (Lobo, C., 2005).

2.3 Related Works

Researches into concrete properties are wide and varied. Swany (2008) investigated the factors that can influence concrete strength made from washed laterite and stated that the deposition of fine laterite aggregate are more sharper than the river sand and at the same time it contain particles that can pass no 0.0212mm sieve. He concluded that the use of washed laterite in concrete is of two importances. Such concretes showed high slum performance, vast setting capacity and the residue is a good material for brick manufacturing.

Isang (2005) investigated the effect of washed laterite on the compressive strength of gravel based concrete, and reported that though the cost of washing the laterite is high; the strength of the washed laterite concretes is at the range of 90- 98% of that of normal concretes. Such concretes are also durable.

Adequate work has not been carried out to ascertain the suitability of gutter sand as a concrete aggregate. Its abundance has not been exploited hence this study.

3. Materials and Methods

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3.1 Materials

3.1.1 Cement

The popular UNICEM brand of Portland Limestone cement was used for this study. It was obtained in bags and stored in a good, smooth, clean and dry condition. The cement conformed to the requirements of BS12: 1991.

3.1.2 Gutter Sand

The natural occurring gutter sand was obtained from the drainage path along the University of Uyo main campus, Akwa Ibom State. The sand was stored in empty bags and transported to the laboratory. Its properties conformed to the requirements of BS 882: part 2: 1973.

3.1.3 River Sand

The river sand was obtained from Ibagwa in Abak L. G. A., Akwa Ibom State. It was stored in empty cement bags and transported to the laboratory where the practical was carried out. It conformed to the requirements of BS 882: part 2: 1973.

3.1.4 Gravel

Gravel was obtained from Ibiaku, Uruan L. G. A., Akwa Ibom State. The material was stored in empty cement bags and transported to the laboratory. Its physical properties conformed to the requirements of BS 882: part 2: 1973.

3.2 Tests Carried Out

Tests performed included Sieve analysis of the aggregates, workability test – slump test, crushing strength test and density test.

3.3 Manufacture of Crushing Test Specimens

3.3.1 Concrete Mix Proportions

The concrete mixes used for this research were 1:1½:3, 1:2:4 and 1:3: 6 at water cement ratio of 0.5 for each mix. The proportion represent cement, sand (gutter sand and river sand) and coarse aggregate respectively. Mixing was done manually. This was done in conformity with BS 1881: 1970 requirements.

3.3.3 Preparation of Crushing Test Cube

Nine concrete cubes of 150x 150 x 150mm each were made from each batch. The moulds were cleaned and oiled and then filled with concrete in three layers each layer being one-third the height of the mould. Each layer was evenly tamped 35 times across its section with a British standard tamping rod. The top was then levelled smooth and the cube labelled. Each cube was then placed in a damp place for about twenty-four hours. This test was conducted in conformity with BS 1881: Part 108: 1983. The specimens were carefully removed from the mould after twenty-four hours and then submerged in a curing bath containing clean water maintained at a temperature of between 20-300C until ready for testing. This was done in accordance to BS 1881: PART III: 1983.

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3.4 Testing of Test Cubes

The cubes were removed from the curing bath and their areas/volumes were determined. Each cube was weighed and hence its density determined. The cubes were each placed on the lower steel platen plate with both smooth surfaces facing bottom and top of the platen plates. The compressive load was applied at a constant rate of 4.5 to 9.0kN/sec until the specimen failed. The peak load at failure was read in kiloNewtons (kN). The crushing strength of each cube was thereafter determined using [1].

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

Where

P = peak load on cube (N)

fc = crushing strength (N/mm2)

A = cross sectional area of cube (mm2)

This was carried out in conformity to the BS 1881: Part 116: 1983 requirements.

3.5 Workability Test on Fresh Concrete

The slump test was used to evaluate the workability of each fresh concrete mix. This test was performed in accordance to BS 1881: Part 2: 1983. The slump cone was filled with fresh concrete in three layers, with each layer given 25 blows with the British standard tamping rod. The top layer was struck off level with the cone. The cone was gently lifted up at about two minutes. The fall in concrete level was measured by placing the cone at the same ground level with the concrete and the tamping rod was put at the top of the cone across the falling concrete. The difference in height was measured using a measuring tape and the value recorded.

3.6 Sieve Analysis on Aggregates

Sieve analysis of gutter sand, river sand and uncrushed gravel was carried out in accordance with the requirements of BS 812: Parts 182: 1975. This test was performed to determine the particle size distribution of the individual aggregates. The British Standard, BS 410 sieve was used to obtain the grading of the various aggregates. The results are presented in figs 4.1, 4.2 and 4.3 for gutter sand, river sand and gravel respectively.

4. Results and Discussion

4.1 Sieve Analysis Results

The results of sieve analysis carried out on the fine and coarse aggregates are presented in tables 4.1, and 4.2 for gutter sand and river sand, and coarse aggregates respectively. The particle size distribution curves for the three aggregates are also presented ad figs 4.1, and 4.2.

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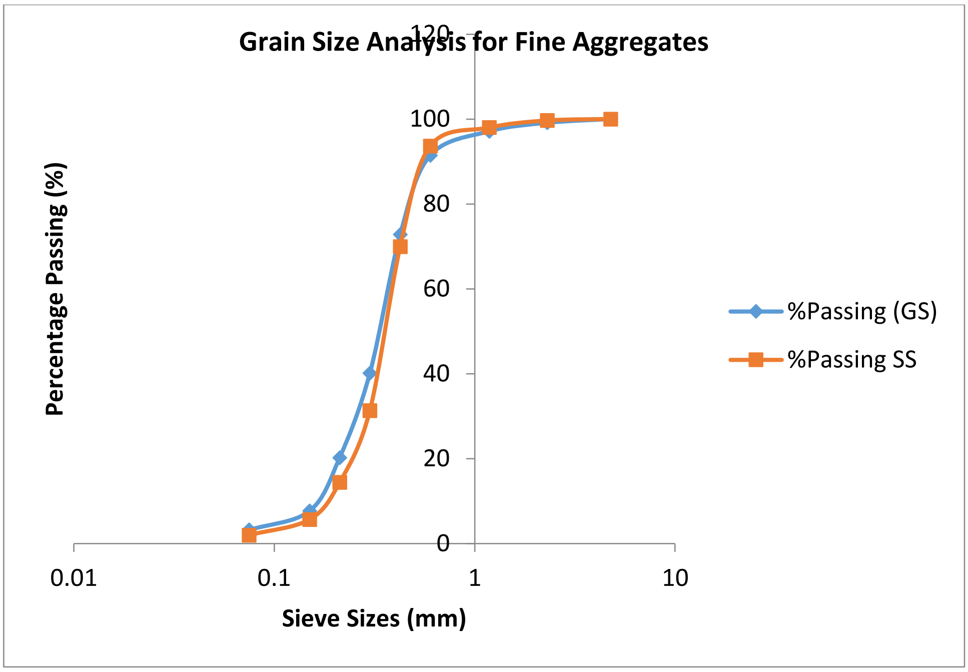

Fig. 4.1: Grain Size Analysis for Gutter Sand (GS) and River Sand (RS)

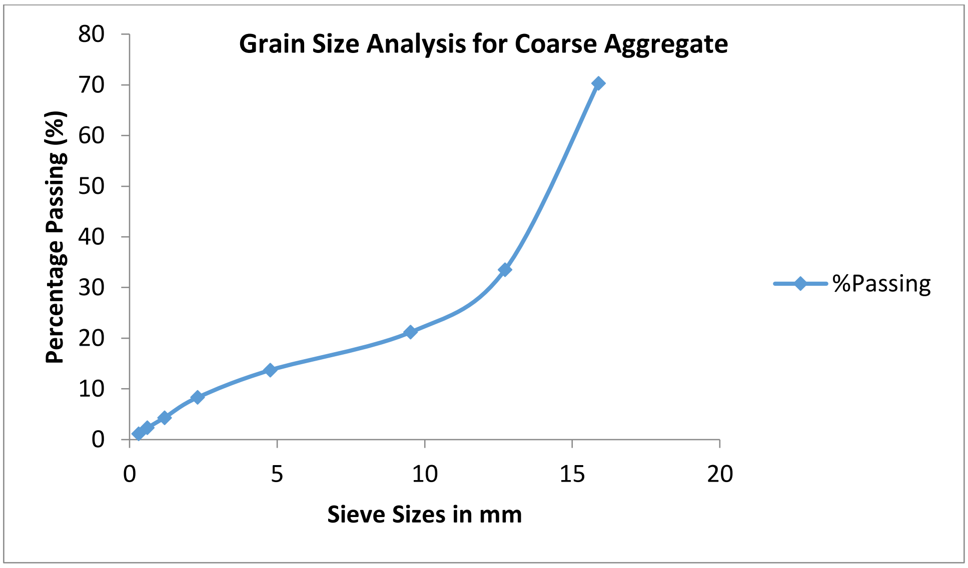

Fig. 4.2: Grain Size Analysis for Coarse aggregate

4.2 Fineness Modulus

From the results of the sieve analysis presented in Fig. 4.1and 4.2, the gutter sand had a fineness modulus of 2.72 while the river sand had a fineness modulus of 2.90. The fineness modulus of the gutter sand and river sand were less than the maximum value of 3.20 recommended for fine aggregate material in accordance with BS 822: Part 4: 1973, hence the gutter sand and river sand were suitable for use as fine aggregates. The fineness modulus of the uncrushed gravel was 6.45 also making it adequate for use as coarse aggregate.

4.3 Coefficient of Uniformity (Cu)

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From the particle size-grading curve, the coefficient of uniformity was 2.1 and 2.2 for river sand and gutter sand respectively. This shows that the gutter sand and river sand used were not very well graded but consisted of a uniform size of particles. Similarly, the coefficient of uniformity for the uncrushed gravel was 4.3. The value showed that the uncrushed gravel was very well-graded and suitable for use as coarse aggregate.

The aggregates were zoned based on the grading of the particle from the result of this work. It was observed that gutter sand aggregate was on zone 4 and river sand within zone 3 and 4 and coarse aggregate, which had a maximum size of 20mm diameter, was of zone 2. This was determined in accordance with BS 1881: Part 2: 1973.

4.4. Physical Properties of Materials Used.

The Physical Properties of the Materials Used in this study are presented in table 4.3.

Table 4.3: Physical Properties of Materials Used

Material	**Properties**	**Value**
Cement	Specific gravity	3.15
	Initial setting time	8 hours
	Final setting time	20 hours
River Sand	Specific gravity	2.64
	Coefficient of uniformity	2.10
	Fineness Modulus	2.90
Gutter Sand	Specific gravity	2.5
	Coefficient of uniformity	2.2
	Fineness Modulus	2.72
Coarse aggregate	Specific gravity	2.71
	Coefficient of uniformity	4.3
	Fineness Modulus	6.45

4.3 Slump Performance

The results of the slump performance for all the various mixes are summarized in table 4.4.

Table 4.4: Workability Test Result for Gutter Sand Concrete – Slump Test

Mixed Ratio	Slump (mm) GSC	Slump (mm) RSC
1:1½:3	75	70
1:2:4	53	49
1:3:6	68	65

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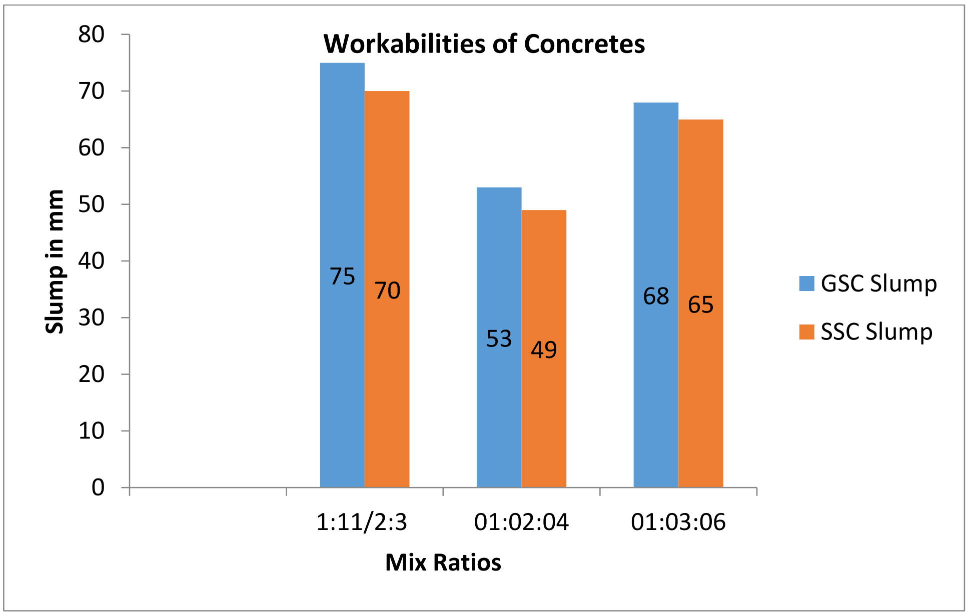
Table 4.1: Grain Size Analysis for Gutter Sand and River Sand		
B.S.Sieve	%Passing (GS)	%Passing RS
4.76	100.00	100.00
2.30	99.12	99.66
1.18	97.11	97.99
0.60	91.42	93.63
0.425	72.78	69.90
0.30	40.11	31.29
0.212	20.23	14.37
0.15	7.68	5.66
0.075	3.21	1.98

Table 4.2: Grain Size Analysis for Coarse Aggregate	
B.S.Sieve	%Passing
15.88	70.3
12.72	33.5
9.52	21.2
4.76	13.7
2.30	8.3
1.18	4.3
0.60	2.3
0.30	1.1



The slump performance of this concrete conformed to the basic requirements of BS 1881: Part 2: 1983. From the results of the slump tests presented in tables 4.5 and 4.6 above for gutter sand concrete and river sand concrete respectively, it was deduced that gutter sand concrete at a; the mix ratio was more workable than river sand concrete at the same water-cement ratio.

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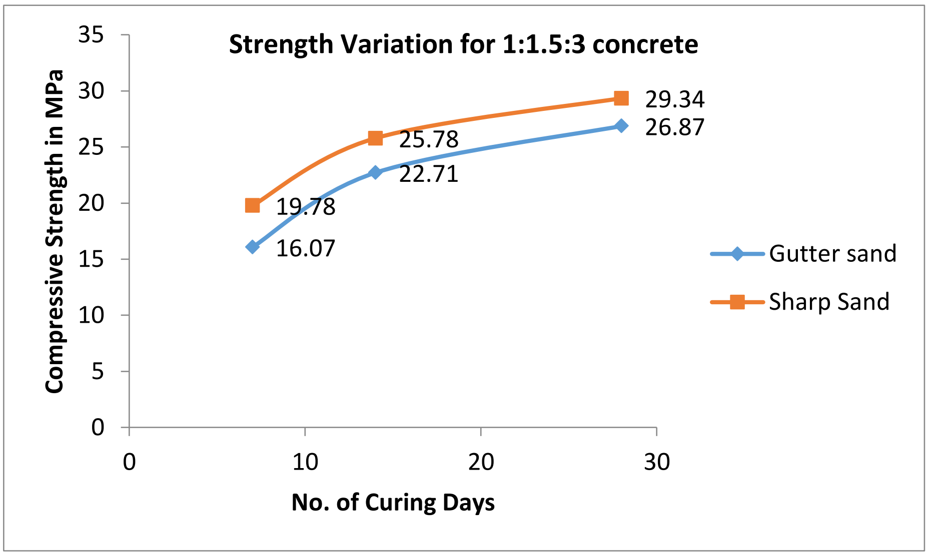
For that reason, it was observed that cubes made with gutter sand showed a smoother finished surface than that made from river sand concrete.

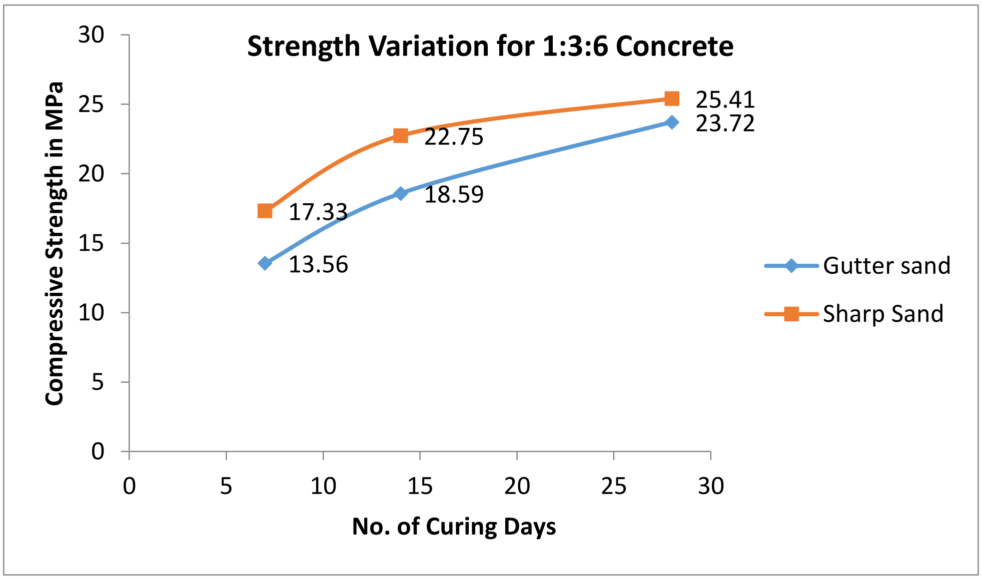
4.4 Compressive Strength of Test Cubes

The results of the compressive strength tests are presented in table 4.5.

Table 4.5: Crushing Strength of Test Cube

Concrete mix	Gutter sand concrete (GSC)		
	7th day	14th day	28th day
1:1½:3	16.07 ± 0.31	22.71 ± 0.45	26.87 ± 0.46
1:2:4	14.74 ± 0.21	21.11 ± 0.22	24.84 ± 0.28
1:3:6	13.56 ± 0.02	18.59 ± 0.34	23.72 ± 0.44
	River sand concrete (RSC)		
1:1½:3	19.78 ± 0.22	25.78 ± 0.44	29.34 ± 0.56
1:2:4	18.44 ± 0.45	24.28± 0.31	27.26 ± 0.46
1:3:6	17.33 ± 0.42	22.75 ± 0.34	25.41 ± 0.46





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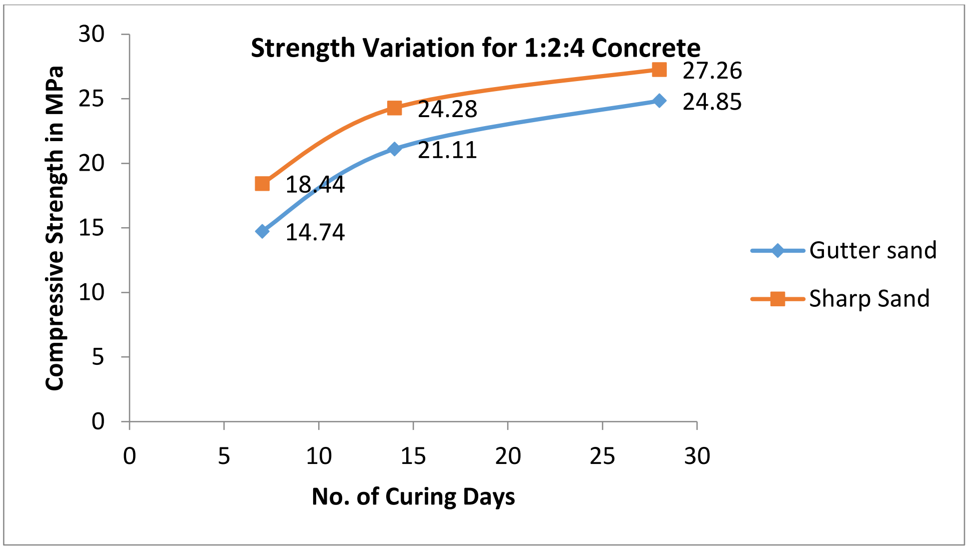

A careful inspection of the results in table 4.5 revealed the possibility of attaining higher compressive strengths for gutter sand concretes of 1:1½:3, 1:2:4, and 1:3:6 at the same water-cement ratio of 0.5. The result showed that 1: 1½: 3 gutter sand concrete attained 26.87 N/mm2 at 28 days while 1:1½:3 river sand concrete attained 29.34 N/mm2 at the same age. The strengths compared favourably having only about a nine percent difference. For another mix ratio, the strengths still maintained a small percentage difference.

4.5 Cost Analysis

The cost analysis for this work using current market prices is summarized in tables 4.6 and 4.7 for gutter sand concrete and river sand concrete respectively.

Table 4.8: Market Value of Constituent

Material	**Qty**	**Unit**	**Cost (#)**	**Unit Cost (#)**
Cement	50	Kg	4,000.00	80.00
River Sand	5000	Kg	14,000.00	2.80
Gutter Sand	5000	Kg	6,000.00	1.20
Uncrushed aggregate	1000	Kg	8,000.00	8.00
Water	20	Litre	10.00	0.50

Table 4.6: Cost of Gutter sand concrete Per Cubic Meter

Mix Ratio	Water	Cement (#)	Gutter sand (#)	Gravel (#)	Total (#)
1:1½:3	100.50	32,240.00	726.00	9,680.00	42,746.50
1:2:4	87.50	27,600.00	828.00	10,480.00	38,995.50
1:3:6	57.50	18,400.00	829.20	11,048.00	30,334.70

Table 4.7: Cost of River sand concrete Per Cubic Meter

Mix Ratio	Water	Cement (#)	River sand (#)	Gravel (#)	Total (#)
1:1½:3	100.50	32,240.00	1,694.00	9,680.00	43,714.50
1:2:4	87.50	27,600.00	1,932.00	10,480.00	40,099.50
1:3:6	57.50	18,400.00	1,934.80	11,048.00	31,440.30

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Table 4.9: Quantities of constituent materials Per Cubic Meter of concrete

Mix Ratio	W/C Ratio	Cement (kg)	River sand (kg)	Gutter sand (kg)	Gravel (kg)	Water (kg)
1:1½:3	0.5	403	605	605	1210	201
1:2:4	0.5	345	690	690	1380	175
1:3:6	0.5	230	691	691	1381	115

The cost analysis indicated that:

The cost of river sand concrete of 1:1½:3, 1:2:4, and 1:3:6 mixes were two percent (2%), three percent 3%, and four percent (4%) higher than those of gutter sand concrete of the same proportions.

5. Conclusion

Using a mix ratio of 1:1½:3 at water/cement ratio of 0.5, a mean compressive strength value of 26.37N/mm2 was obtained for gutter sand concrete while the conventional river sand concrete attained 29.4N/mm2 compressive strength at 28 days. 1:2:4 gutter sand concrete at a water/cement ratio of 0.5 attained a mean compressive strength of 24.85 N/mm2 while river sand concrete of the same mix yielded 27.26N/mm2 compressive strength at 28 days.

Moreover, using a mix ratio of 1:3:6, with a water/cement ratio of 0.5, a mean 28th-day compressive strength of 23.72 N/mm2 was attained for gutter sand concrete while river sand concrete attained 25.4N/mm2 strength at the same age. The strengths are quite comparable with no significant differences. Gutter sand concrete was more workable than the river sand concrete. It was also 10% cheaper than the river sand concrete. Builders, architects and civil engineers engaged in construction should use gutter sand concrete as it attained strengths comparable with those of the conventional concrete.

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