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Comparative Investigation of Some Mechanical Properties of Aggregates From Abakaliki And Auchi Areas

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***Abstract**: The utilization of crushed granite aggregate samples from different localities and regions (Abakaliki and Auchi) for concrete work is investigated in this work. Normal concrete is produced from different aggregates and this imparts different property to the resulting concrete. The most important property of concrete is its compressive strength. In this work, comparisons were made of the various properties of concrete made of crushed rock aggregates from four (4) sites in two different locations; two samples each from Abakaliki in Ebonyi state South-East geopolitical zone and Auchi in Edo state, South-South geopolitical zone of Nigeria respectively. The properties compared include workability, bulk density, specific gravity and their compressive strengths. Need was felt for this study as the major private and government constructions that are carried out in these geo-political zones of the quarry sites use any available stone within their reach. Aggregates of 20mm size were employed in the investigation. The mix ratio and water/cement ratio adopted for the study were 1:2:4 and 0.5 respectively. A total of twenty-four(24) concrete cubes (150mm x 150mm x 150mm) were cast of which three (3) cubes were crushed for each sample aggregate at maturity ages of 7 and 28 days. All cubes reached the target mean strength after 7 days of curing. The average 28 days strengths of the concretes on the average made with Auchi aggregates was found to be 8.9 percent higher than concrete made with Abakaliki aggregates*

***Keywords:-** Aggregate, Concrete, Compressive strength, Mechanical properties*

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I. Introduction

Concrete is a composite material which consists of fillers and binding material. The filler materials are fine and coarse aggregates and the binding material is cement paste (Mindness, et al, 2003). At the earlier stage of concrete development, it was believed that aggregates were chemically inert and held together by cement, but modern technology proves that aggregates exhibit chemical bond at the interface of aggregate and the paste. Aggregate is such important matter in concrete that mechanical properties and workability of concrete are directly affected by the properties of aggregates. Density of concrete is determined by the aggregate density. That is why the overall or mechanical properties of concrete depend on certain properties of aggregate like source of aggregates, normal, light or heavy weight aggregate, size of aggregate, shape of aggregate, crushing strength of aggregate, angularity index, surface texture, modulus of elasticity, bulk density, specific gravity, absorption and moisture content, bulking of aggregates, cleanliness, soundness of aggregates, thermal properties and grading of aggregates (Mindness et al., 2003). Moreover, interfacial transition zone (contact surface between aggregate and cement paste) plays an important role in strength and durability of concrete.

This work deals with the evaluation of the compressive strength of concrete produced with coarse aggregates from different locations, Auchi and Abakaliki. The coarse aggregates were gotten from Baba Rock and Setraco quarry sites located in Auchi and also from Chigbo and Diamond quarry sites located at Abakaliki. These samples from different locations are to be used, to determine their mechanical properties the fine aggregate was obtained from River Niger. Also preliminary laboratory investigations were conducted to ascertain the suitability of using the aggregate for construction work. Test which are to be conducted are sieve analysis, moisture content, bulk density, specific gravity and aggregate crushing value. The strength of concrete essentially depends on the integrity of the cement paste and the nature of the coarse aggregate.

II. Resarch Methdology

The materials used in the research were ordinary Portland cement from Dangote cement factory, portable tap water, and crushed stones from Abakaliki, Ebonyi State and Auchi, Edo State as well as river sand from River Niger, Anambra State.

3.1 Materials Used

The following materials were used for the tests:

1. **Cement**: Ordinary Portland Cement (OPC) locally available in Nigeria, Dangote Cement brand name in 50kg bag was used for the experiment.
2. **Water**: Portable water from material testing laboratory, Niger Construction Co Limited was used.
3. **Fine Aggregate**: Naturally occurring river sand was obtained from the banks of River Niger, Anambra State.
4. **Coarse Aggregate**: Crushed stones were obtained from Baba Rock quarry and Setraco quarry in Auchi, Edo State and Chigbo and Diamond quarries in Abakaliki, Ebonyi State.

3.2 Equipment/Apparatus

The apparatus and equipment used in this work are shown in plates 1 to 7








1. The compressive 2. Concrete Mould 3. Sieve Sample 4. Electronic 4. Manual 2. Oven 7. Specific testing machineWeighing Machine Compressive Machine Gravity bottle

3.3 Methods

The following tests were carried out

1. Sieve Analysis 2. Bulk Density 3. Specific Gravity 4. Aggregate Crushing Value (ACV) 5. Slump Test
1. Compressive Strength Test and Slump test

3.3.1 Sieve Analysis: Sieve analysis (using BS 410:1986), was carried out on the crushed stones to obtain a uniform grade size of 20mm that was used. The aggregates were washed and oven dried before passing it through the various sieves. The arrangement of sieves was from 50mm on top to 12.5mm at the bottom. Shaking was done manually.

3.3.2 Bulk Density: The test was done in accordance with procedures prescribed in BS 812: Part 2(1975). British Standard (BS 812) has specified the degree of compaction. These are:

1. Loose (Un-compacted)
2. Compacted

The test was carried out by using metal cylinder having prescribed depth and diameter and the bulk density is to be determined depending on the maximum size of aggregates and the degree of compaction.

Loose Bulk density was determined by filling the container with dried aggregates until it overflows from the container. The top surface of the container was leveled by rolling the rod on it. After that, the weight of the aggregate mass that is inside the container was divided by the volume of the container. This will give you the bulk density of the loose aggregates.

Compacted Bulk Density was determined by filling the container in three layers and each layer was tamped with a 16mm diameter rounded nosed rod. After filling in three layers, the top surface was leveled and compacted bulk density was evaluated by using the same expression as for loose bulk density. The weight of the aggregates mass that are inside the container was divided by the volume of the container to give the bulk density of compacted aggregates.

3.3.3Specific Gravity: The apparent specific gravity test was carried out in accordance with the procedures in BS 812: Part 2(1975).

$$S.G = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.1$$

Where; W_1= weight of empty flask W_2= weight of flask + sample W_3= weight of flask + sample + water W_4 = weight of flask + water

Table 3.1: Specific Gravity For Both Diamond And Chigbo Quarries In Abakaliki

sample l.d	specific gravity	average s.g
Diamond Quarry	2.614	2.660
Chigbo Quarry	2.705	

Table 3.2: Specific Gravity For Both Setraco And Baba Rock In Auchi

Sample I.D	Specific Gravity	Average S.G
Setraco Quarry	2.668	2.681
Baba Rock Quarry	2.694	

3.3.4 Aggregates Crushing Value test: The Aggregates Crushing Value Test according to BS 812:110 describes a method to determine the aggregate crushing value (ACV) which gives a relative measure of the crushing resistant of aggregate under an increasing compressive load. The method is applicable to aggregates passing a 14.0mm test sieve and retained on a 10.0mm test sieve.

An aggregate specimen was compacted into a steel cylinder fitted with a no-friction. The specimen is then loaded via the plunger. The load crushes the aggregate to an extent depending on the crushing resistant of the material. It is measured by a sieving test on the crushed specimen and it is a measure of the aggregate crushing value (ACV).

A compression testing machine of 500/600kN capacity, a suitable steel cylinder and plunger are required to perform this type of test see plate 7 below.

3.3.5 Batching of Concrete: Metal moulds measuring (150mm x 150mm x 150mm) were used to mold the concrete cubes. A total of 48 cubes were prepared with mix ratio of 1:2:4 and w/c ratio of 0.5. The samples were tested at the ages of 7, 14, 21 and 28 days respectively.

The mixing of concrete was done manually. Different constituent materials were measured and weighed after which the proper mixture took place in the following order.

- Cement was mixed with fine aggregate on a water tight none absorbent platform until the mixture was thoroughly blended.
- Coarse aggregates were added and mixed properly until it was uniformly distributed throughout the batch.
- Water was added and mixed until the concrete appears to be homogenous and of the desired consistency.

3.4 Slump Test

The workability of a concrete can be measured by the concrete slump test. A simplistic measure of the plasticity of a fresh batch of concrete following the ASTMC 143 test standards was made.

The slump was measured by filling “ABRAMS Cone” with a sample of fresh batch of concrete. The cone was placed with the wide end down onto a level, non-absorptive surface. It was then filled in three layers of equal volume, with each layer tampered with a steel rod to consolidate the layer in 25 numbers of times. The cone was carefully lifted and the enclosed material slumps a certain amount due to gravity.

The slump was measured with a rule calibrated in cm and values recorded. This was done in accordance to BS 1881: Part 102(1983) and BS 1881: Part 108 (1983).

3.5 Curing[2]:

The test specimens were stored at the damped corner of the laboratory for 24 hours and after this period the specimens were removed from the molds and kept submerged in clear fresh water until taken out prior to test.

Curing of the cubes was done according to BS 1881: Part 111 (1983). The concretes were tested for compressive strength at the ages of 7, 14, 21 and 28 days.

3.6 Testing of Concrete Specimens:

The testing was done in accordance with BS 1881: Part 116(1983) and BS 1881 : Part 117 (1983). The cube samples after being dried were weighed and placed between hardened steel bearing plates on a universal compression machine (see plate 4 above).

III. Results

4.1 Sieve Analysis Results

Table 4.1: Sieve Analysis of All Coarse Aggregate Samples

Sieve size (mm)	Setraco quarry Auchi Percentage passing	Babarock quarry auchi Percentage passing	Chigbo quarry abakaliki Percentage passing	Diamond quarry abakaliki Percentage passing
50	100	100	100	100
37.5	80	92	78	96
25	70	80	65	85
19	50	65	40	70
12.5	20	20	30	27
9.5	15	15	22	20
4.75	2	1	5	2

2	0	0	1	1

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould (a)	7.154	7.133	7.128
Wt of mould (b)	1.192	1.192	1.192
Wt of sample (a-b)	5.962	5.941	5.936
Volume of mould (cm^3) (c) (15.0x15.0x15.0) cm^3	4050	4050	4050
Bulk density (g/cm^3) (a-b)/c	1.472	1.467	1.466
Average bulk density (g/cm^3)	1.468		

Table 4.3: Uncompacted bulk density for Baba Rock Quarry (Auchi)

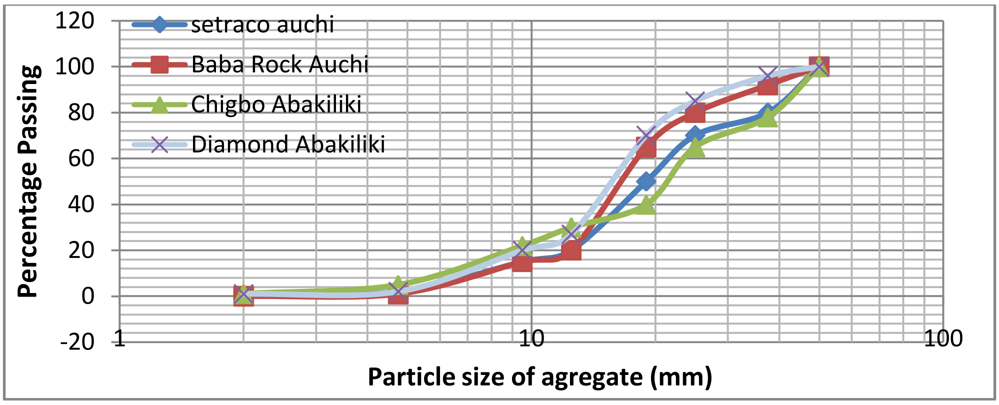

Fig 4.2a Particle Size Distribution for Fine Aggregate

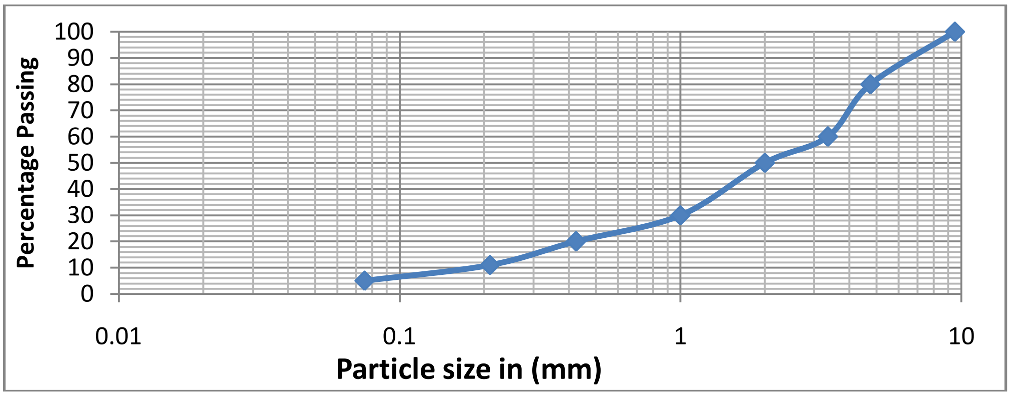

Fig 4.2b Bulk Density Test Results

Table 4.4: Compacted bulk density for Baba Rock Quarry (Auchi).

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	8.139	8.159	8.211
Wt of mould	1.192	1.192	1.192
Wt of sample	6.947	6.967	7.019
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.715	1.720	1.733
Average bulk density (g/cm^3)	1.723		

Table 4.5 Uncompacted bulk density for Setraco Quarry (Auchi)

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	7.530	7.529	7.572
Wt of mould	1.192	1.192	1.192
Wt of sample	6.330	6.337	6.380
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.563	1.565	1.575
Average bulk density (g/cm^3)	1.568		

Table 4.6: Compacted bulk density for Setraco Quarry (Auchi)

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	8.346	8.557	8.236
Wt of mould	1.192	1.192	1.192
Wt of sample	7.154	7.365	7.044
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.766	1.819	1.739
Average bulk density (g/cm^3)	1.775		

Table 4.10: Uncompacted bulk density for Chigbo Quarry (Abakaliki).

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	7.052	7.060	7.202
Wt of mould	1.192	1.192	1.192
Wt of sample	5.860	5.868	6.010
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.447	1.449	1.484
Average bulk density (g/cm^3)	1.460		

Table 4.11: Compacted bulk density for Chigbo Quarry (Abakaliki)

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	8.412	8.214	7.999
Wt of mould	1.192	1.192	1.192
Wt of sample	7.220	7.022	6.807
Volume of mould (cm3)	4050	4050	4050
Bulk density (g/cm3)	1.783	1.734	1.681
Average bulk density (g/cm3)	1.733		

Table 4.12: Uncompacted bulk density Diamond Quarry (Abakaliki)

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	6.987	7.084	7.031
Wt of mould	1.192	1.192	1.192
Wt of sample	5.795	5.892	5.839
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.431	1.455	1.442
Average bulk density (g/cm^3)	1.443		

Table 4.13: Compacted bulk density for Diamond Quarry (Abakaliki)

Sample	1 (kg)	2(kg)	3(kg)
Wt of sample + mould	8.241	8.341	7.994
Wt of mould	1.192	1.192	1.192
Wt of sample	7.049	7.149	6.802
Volume of mould (cm^3)	4050	4050	4050
Bulk density (g/cm^3)	1.740	1.765	1.680
Average bulk density (g/cm^3)	1.728		

AV.Sp. Gravity = 2.715%

Table 4.17: Specific Gravity of Baba Rock Quarry (Auchi)

Sample	1 (kg)	2(kg)
W1	0.516	0.516
W2	1.557	1.557
W3	1.039	1.111
W4	1.885	1.928
Specific gravity	2.708%	2.679%

AV. Sp. Gravity = 2.694%

Table 4.18: Specific gravity of Setraco Quarry (Auchi)

Readings	Sample	
	1(kg)	2(kg)
Wt of empty flaskW1	0.516	0.516
Wt of flask and sample W2	1.557	1.557
Wt of flask, sample and water W3	1.097	1.111
Wt of flask and water, W4	1.907	1.928
Specific gravity	2.643%	2.692%

$$\textbf{S.G} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

AV. Sp. Gravity = 2.668%

Table 4.19: Specific Gravity of Chigbo Quarry (Abakaliki)

Readings	Sample	
	1 (kg)	2(kg)
Wt of empty flaskW1	0.516	0.516
Wt of flask and sample W2	1.557	1.557
Wt of flask, sample and water W3	0.997	1.052
Wt of flask and water, W4	1.860	1.895
Specific gravity	2.702%	2.707%

$$\textbf{S.G} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

AV. Sp. Gravity = 2.705%

Table 4.20: Specific Gravity of Diamond Quarry (Abakaliki)

Readings	Sample	
	1 (kg)	2(kg)
Wt of empty flaskW1	0.516	0.516
Wt of flask and sample W2	1.557	1.557
Wt of flask, sample and water W3	1.142	1.144
Wt of flask and water, W4	1.946	1.944
Specific gravity	2.641%	2.586%

$$\textbf{S.G} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

AV. Sp. Gravity = 2.614%

1.3 Aggregates Crushing Value

Table 4.21: Aggregates Crushing Values of the Samples

Site location	Baba Rock Quarry (Auchi)	SetracoQuarry (Auchi)	Diamond Quarry (Abakaliki)	Chigbo Quarry (Abakaliki)
Weight of sample	2.7kg	2.7kg	2.7kg	2.7kg
Crushing load	372KN	372KN	372KN	372KN
Weight Passing 14mm sieve	0.583kg	0.562kg	0.959kg	0.422kg
Weight Retained On sieve 10mm	2.111kg	1.432kg	1.728kg	2.272kg
Weight of crushed Sample passing 2.36mm sieve	0.515	0.578	0734	0695
Aggregate Crushing Value (%)	19	21	27	25

Aggregate crushing value = (B/A) x 100%

A = weight of aggregate sample tested B = weight of crushed aggregate passing through a 2.36mm sieve

Fig 4.22 Crushing Strength Of Concrete Made With Setraco Aggregate Auchi

Mix Ratio 1:2:4; W/C Ratio = 0.5; Slump = 4.8cm

Sample	Weight of cube (g)	Concrete density(g/cm^3)	7days strength (N/mm^2)	28 days strength (N/mm^2)
A	7959	2.35	13.77	20.82
B	7992	2.36	16.00	22.14
Average	7975.5	2.355	14.89	21.48

Fig 4.23 Crushing Strength Of Concrete Made With Baba Rock Aggregate Auchi

Mix Ratio 1:2:4; W/C Ratio = 0.5; Slump = 5.2cm

Sample	Weight of cube (g)	Concrete density(g/cm^3)	7days strength (N/mm^2)	28 days strength (N/mm^2)
A	7853	2.32	13.7	21.26
B	8153	2.42	17.3	23.9
Average	8003	2.37	15.5	22.58

Fig 4.24 Crushing Strength of Concrete Made With Diamond Aggregate Abakiliki
Mix Ratio 1:2:4; W/C Ratio = 0.5; Slump = 5cm

Sample	Weight of cube (g)	Concrete density(g/cm$^{3)}$	7days strength (N/mm^2)	28 days strength (N/mm^2)
A	8172	2.42	12.00	19.04
B	8003	2.37	9.33	21,26
Average	8087.5	2.395	10.665	20.15

Fig 4.25 Crushing Strength of Concrete Made With Chigbo Aggregate Abakiliki
Mix Ratio 1:2:4; W/C Ratio = 0.5; Slump = 4.5cm

Sample	Weight of cube (g)	Concrete density(g/cm$^{3)}$	7days strength (N/mm^2)	28 days strength (N/mm^2)
A	8043	2.38	10.22	20.44
B	7884	2.34	11.55	20.00
Average	7963.5	2.36	10.9	20.15

Table 4.26 Summary of properties evaluated

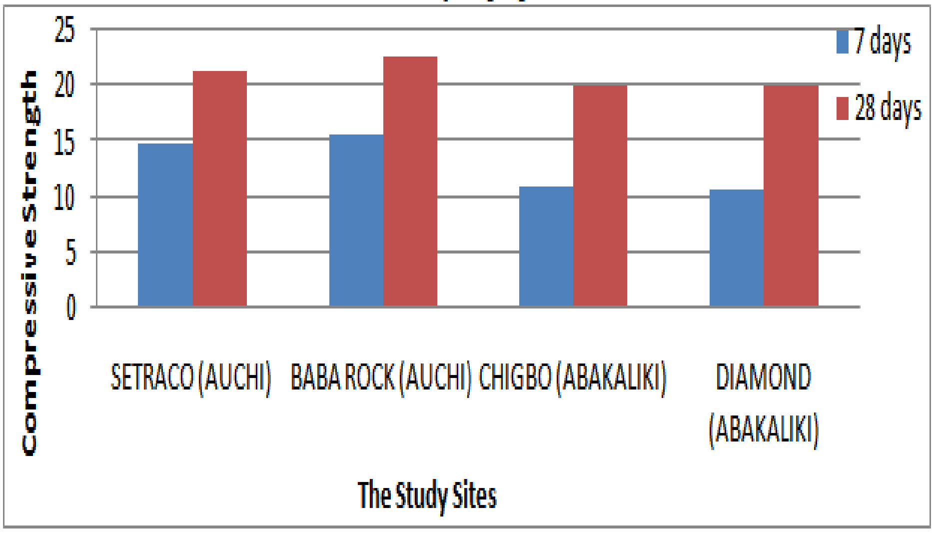

Fig 4.3 Aggregate crushing value of a sample

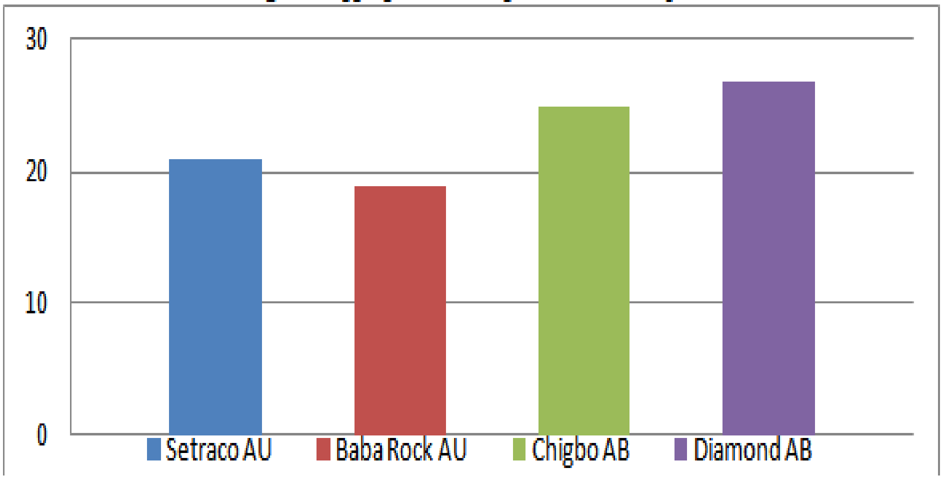

Fig.4.4: Compressive Strength of Concrete Using Aggregate from Various Sources

V. Discussions, Conclusions And Recommendations

5.1.1 Grading

Fig 4.2 obtained in the sieve analysis for fine aggregate shows that 22% of the River Niger sand used for the purpose of this project work is gravel, and 75% of it, is sand while 3% of the sample is silt. Also the sieve analysis conducted on the coarse aggregate obtained from Chigbo quarry and Diamond quarry all in Abakaliki are 100%

gravel as shown Fig 4.2 and that of Setraco quarry and Baba rock quarry all in Auchi are equally 100% gravel from the sieve analysis result shown in Fig 4.2.

5.1.2 Bulk Density for Aggregates

From table 4.26 it can be seen that the values of aggregate bulk densities obtained from the uncompacted bulk density are lower than the compacted bulk density values for all aggregates. The result obtained show that Setraco quarry has the highest bulk density value for compacted bulk density. This is followed by Chigbo quarry, followed by Diamond quarry and lastly Baba rock quarry. The uncompacted bulk density Setraco has the higher bulk density value followed by Baba rock quarry, followed by Chigbo quarry while lastly is Diamond quarry coarse aggregate.

5:1:3 Aggregates Crushing Value

Table 4.21 shows the result of aggregate crushing value test conducted on the coarse aggregate from Chigbo and Diamond quarries from Abakaliki, also on Setraco and Baba rock quarries from Auchi. Coarse aggregate under compaction and passing through sieve size 3.36mm are not the same. From the result obtained, it shows that Baba rock quarry in Auchi has 19% of crushed aggregates that passed through sieve 3.36mm while Setraco quarry Auchi aggregates recorded 21%. Chigbo quarry and Diamond quarry aggregates both from Abakaliki recorded 25% and 27% respectively. Therefore Baba rock has a better aggregates crushing value due to the mass of sample retained after crushing and that passing through the sieve of 3.36mm.Followed by Setraco quarry in Auchi, and Diamond quarry in Abakaliki, and lastly is Chigbo quarry in Abakaliki.

5.1.4 Compressive Strength of concrete.

Table 4.26 and Fig 4.4 shows that concrete made with aggregates obtained from Abakaliki (Chigbo and Diamond quarries) recorded a compressive strength of $10.9N/mm^2$ and $10.6N/mm^2$ respectively on the 7^{th} day. However the concrete made with aggregates from both chigbo and diamond quarry both in Abakaliki both recorded a compressive strength of $20.15N/mm^2$ on the 28^{th} day. The compressive strength of concrete made both aggregates from Abakaliki recorded 52.6% of the 28^{th} day strength of the seventh day for diamond quarry and 54.09% for chigbo quarry. On the other hand, concrete made with aggregates from Baba rock Auchi $15.6N/mm^2$ compressive strength on the 7^{th} day and $22.58N/mm^2$ on the 28^{th} day and hence 69.08% of its 28^{th} day strength was attained on the 7^{th} day. Setraco quarry in Auchi recorded $14.89N/mm^2$ on the 7^{th} day and $21.48N/mm^2$ on 28^{th} day attaining 69.32% of the 28 day strength on the 7^{th} day

Therefore, when obtaining the strength of concretes for better quality, aggregates from Auchi should be selected

5.2 Conclusion

The following conclusions are made:

Aggregates from Auchi may be employed for concrete work in places where concrete practitioners have variety of choice available following the fact that sample from Abakaliki shows the least strength development at all ages while the highest compressive strength was achieved from concrete gotten from Baba rock, followed by concrete from Setraco all in Auchi.

5.3 Recommendations

1) The investigation should be extended to cover the chemical compositions of crushed stones.
2) The effect of shape of aggregates, texture, porosity, packing should be considered in determining the compressive strength of concrete
3) Further investigations should be made with variation of mix design and water/cement ratio.

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