International Journal of Engineering and Emerging Scientific Discovery
ISSN: 2536-7250 (Print): 2536-7269 (Online)
Volume 9, Number 1, March 2024
http://www.casirmediapublishing.com

Performance of Concrete made with River Stones and Crushed Stones as Coarse Aggregates within Okene (LGA), Kogi State, Nigeria

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ABSTRACT

It is a common practice within Okene local government area (LGA) in Kogi State, Nigeria to use river stones as construction materials to provide sustainability and growth in the State. *A detail reports aimed at investigating* the performance of concrete made with crushed stone and locally sourced river stone as coarse aggregates for concrete productions. *The preliminary laboratory investigation was conducted to characterize the crushed stone and locally sourced river stone include the sieve test, physical properties, aggregate impact value and aggregate crushing value* were within the required specifications *to determine the sustainability of using coarse aggregates for construction work. A prescribed mix of 1:1.5:3 and 1:1:2,* cement, fine and coarse aggregates respectively with water cement ratio of 0.55 was adopted. The constituents were mixed manually and *cast into cubic mould size 150mm^3 for the compressive strength* while cylinder mould measuring 100mm diameter x 200mm long was used for *split tensile strength.* All the cube specimens *were demoulded after 24hours and cured by immersing in water for maturity of 7, 14 and 28days* respectively. It was observed that all the test results proved to have the required strength and also indicate that concrete produced with crushed stone has the maximum compacting factor and slump value. The optimum mean compressive strength and *split tensile strength* are 29.52N/mm^2 and 3.88N/mm^2 at designated mix for concrete made with crushed stone compared to river stone as 26.58N/mm^2 and 3.08N/mm^2 cured at 28days of testing respectively. The characteristics of the individual aggregate accounted for the variation in strength of the concrete. In conclusion, it's advisable to use both mix ratios for structural elements and the effect of any types of coarse aggregate on the concrete strength will be identified and also enable consumers to determine the type of aggregate to be designated for a specific concrete production.

Keywords: characterization, coarse aggregates, strength, consistency test and physical properties.

INTRODUCTION

Aggregate is one of the major construction engineering materials that have attracted the attention of researchers in recent years for many reasons. Aggregates are the mass of crushed stone, gravel, sand, etc. predominantly, composed of individual particles, but in some cases including clays and silts; that are used as filler in the production of mortar and concrete. Aggregate, part of which is course, is used primarily for the purpose of providing bulk to the concrete. As economical filler which is much cheaper than cement, maximum economy in the production of concrete can be obtained by using as much aggregate as possible. The combine aggregates generally occupy 60% to 75% of the concrete volume and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. The use of aggregate also considerably improves both the volume stability and the durability of the resulting concrete. The commonly held view that aggregate is a completely inert filler in concrete is not true, its physical characteristics and in some cases its chemical composition affect to a varying degree the properties of concrete in both its plastic and hardened state (Jackson, 1991) and (Murdock, 1979).

There has been a growing interest, especially in the developing countries, in the use of these locally sourced coarse aggregate materials in concrete production. The problem of lack of good crushed aggregates in some areas has been intensified by the increasing demand in concrete for regular construction purposes. The resulting effect has been a greater demand for alternative construction materials. This has adversely affected the cost of concrete materials, concrete production and construction generally. This problem is of great concern that some attempts have been made to either partially or completely replace crushed aggregates with other materials in concrete production.

Concrete is a composite construction material which will be a combination of cement, water, fine aggregate and coarse aggregate. Strength of concrete is commonly considered as most valuable property in Portland cement concrete and choice coarse aggregates. Although in many practical cases other characteristic such as durability and permeability may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hydrated cement paste. Moreover, the strength of concrete is almost invariably a vital element of structural design, (Neville, 2005).

Extensive investigation findings have promoted the use of locally-available materials to reduce the cost of infrastructure systems and thereby making building affordable to the middle and low-class residents. Hence, any advocacy for completely new or blended materials should be tested both structurally and mechanically to ascertain the short-time and longtime behaviors. This will certainly help to establish a well-define boundary or clearly spelt out limitation especially when local code of practice for design, construction and workmanship is yet to be published for Engineers and builders. Past researches (Ede, 2011) and (Amobi, 2006) all identified substandard materials (especially poor quality concrete) among other factors as the leading causes of building collapse in Nigeria. The increasing population and development rate in Kogi State has influenced the rapid construction of buildings in all corners of Okene LGA. It is a common practice within Okene environs to use river stones as construction materials as sustainability in the State. Moreover, one-third of the volume of concrete is occupied by coarse aggregate and any variations in coarse aggregate types can affect its strength and properties and it becomes important to investigate the quality of the coarse aggregates performances on structural elements. This study aimed to reduced concreting cost, encourage, investigate the properties characterization and the strength performance of concrete made with crushed stones and local river stones within Okene local government area (LGA), Kogi State, Nigeria.

RELEVANT LITERATURES

Abdullahi, (2012): Concluded in his study that the concrete made from river gravel has the highest workability followed by crushed quartzite and crushed granite aggregates. The compressive strength was noted highest value with concrete made from quartzite aggregate followed by river gravel and then granite aggregate. The compressive strength models were proposed as a function of age at curing and he advised to concrete practitioners to use the aggregate made from quartzite for concrete work. Beshr et al, (2003): Studied the effect of coarse aggregate quality on the mechanical properties of high strength concrete. They considered the effects of four types of aggregates namely calcareous, dolomitic, quarzitic limestone and steel slag on the compressive and tensile strength, and elastic modulus of strength of concrete. The researchers concluded that the highest and lowest compressive strength was obtained in the concrete specimens prepared with steel slag and calcareous limestone aggregates respectively. Similarly, the split tensile strength of steel slag aggregate concrete was the highest, followed by that of dolomitic and quarzitic limestone aggregate concretes. The type of coarse aggregate also influences the modulus of elasticity of concrete.

Ajagbe & Tijani, (2018): Found in their study is that among twelve samples only five mixtures had above the minimum cube compressive strength of 25N/mm^2 and they recommended these samples for the construction of the reinforced load-bearing building structural members. Other three mixtures had above the compressive strength of 20N/mm^2 and recommended for the use in plain concrete construction while the remaining four mixtures had their compressive strength between 19.3N/mm^2 and 17.9N/mm^2. Finally, they concluded that the compressive strength depends on aggregate source. Bamibgoye et al., (2016b): Conducted test on the particle size distribution analysis, slump test and compressive strength on hardened concrete in exploiting economics of gravel as a substitute to granite in concrete production. They found out that higher composition of gravel significantly improves concretes' consistency property while greater proportions of granite do significantly enhance compressive strength.

Ke-Ru et al., (2001): Carried out tests to study the effect of the coarse aggregate type on the compressive strength, splitting tensile strength, fracture energy characteristic length and elastic modulus of concrete produced at different strength levels with 28-day target compressive strength of 30, 60 and 90 N/mm^2 respectively. Concretes considered in their paper were produced using crushed quartzite, crushed granite, limestone and marble coarse aggregates. The results show that the strength, stiffness, and fracture energy of concrete of a given water – cement ratio (w/c) depend on the type of aggregate, especially for high strength concrete. It is suggested that high – strength concrete with lower brittleness can be made by selecting high – strength aggregate with low brittleness.

MATERIALS AND METHODS

Materials

The fine aggregate used in this research was river sand free from impurities and silt according to specifications. The coarse aggregates like; river stones were sourced locally from Okene local government area in Kogi State and the sourced aggregates were bagged and transported to the federal polytechnic Ado-Ekiti State, Nigeria. Crushed stones was procured from quarry and sieved through the sieve sizes 20mm to 4.75mm respectively. Dangote ordinary Portland cement 42.5N to BS EN 197-1: 2011 brand was sourced from a local distributor in Ado Ekiti State and of current supply, free-contamination and it was used as binder. It specific gravity and unit weight of cement is 3.15 and 1440 kg/m^3 respectively. Portable water free from all suspended particles and chemical substances from Civil Engineering Concrete Laboratory at Federal Polytechnic Ado- Ekiti State was used for both mixing and curing of concretes cast are in accordance with BS EN 1008: 2002.

Methods

Characterization of Coarse Aggregates

The research was to characterized the physical property of coarse aggregates and evaluate the concrete using two different coarse aggregates for the concrete productions. The physical and mechanical properties like; Sieve analysis to determine size distribution and specific gravity that will help in the determination of mix design. Water absorption capacity, moisture contents and bulk density of coarse aggregates properties and aggregate strength characteristics, eg Aggregate crushing values and impact values as presented in Table 1. All were experimented in Civil Engineering Laboratory, Federal Polytechnic Ado-Ekiti State.

The test results revealed that aggregates specific gravity are 2.47and 2.66. It is show that crushed stone has highest value and these matched a previous finding by (Reddy et al., 2015) and (Lay, 2009). From the experiment, the bulk densities were founded as 1547kg/m^3 and 1660kg/m^3 respectively as relate to a study finished by (Ajagbe &Tijani, 2018) as 1530kg/m^3 to 1622kg/m^3. It can be observed that the river stone has absorb more water than the other as calculated and the values of water absorption capacity of the coarse aggregates are 1.28% and 0.9% respectively. (Neville & Brooks, 2010) writes the value of should not greater than 2% if exceed soundness test is required. Crushed stones were higher in the results obtained from the experiment like; moisture content, impact value and aggregate crushing values and all fall within the range of the recommended value which make them suitable for concreting works.

Table 1: The Characterization of coarse aggregates used.

Materials test				
Property	**River stone**	**Crushed stone**	**Permissible limits**	**Assess Code**
Max. size (mm)	10-35	5-20	0	Nil
Specific gravity	2.47	2.66	2.4 min	ASTM C127. 1993
Bulk density Kg/m^3	1547	1660	1200min.	ASTM C127. 1993
Absorption capacity %	1.28	0.9	0.5 - 3	ASTM C127. 1993
Moisture content %	1.25	1.09	3	BS 812: Part 109: 1990
Impact value %	12	18	25 - 30	BS 812: Part 112: 1990
Crushed value %	21	27	45max	BS 812 Part 110: 1990

Gradation (Sieve Analysis)

Sieve analysis helps to determine the particle size distribution of aggregates and in this study crushed stone and locally sourced river stones were tested using the mechanical sieve shaker. The materials retained on each sieve was weighed and the various masses were recorded as shown in Table: 2. It is discovered that none of the aggregates sizes were retained on sieve sizes 30.5mm and 25mm indicating that the maximum size of all the aggregates is less than 35mm. According to the results of sieve analysis, using specified guideline BS: 812 part 2, (1995), only river stone has maximum aggregate size greater in size for 25mm. These aggregates therefore fall within the limits specified for structural concrete.

Table 2: The sieve analysis results for coarse aggregates used

Sieve Size (mm)	**% Passing**	**% Passing**	**Limit as per IS:383-1970**
	River stone	**Crushed stone**	
30.50	100.00	100	100
25.00	95.82	100	95-100
19.50	47.77	96.76	85-100
12.50	13.65	32.32	-
9.50	1.65	16.76	0-20

6.30	0.12	1.24	-
4.75	0.02	0.06	0-5
Receiver	0.00	0.00	-

Green Concrete Preparation

The entire process of mixing of all the constituents was achieved my hand mixing. 36-specimens were cast using two nominal mix ratio of 1:1.5:3 and 1:1:2 and the ingredients employed were batched by weight with constant water-cement ratio of 0.55 in the production of concrete. The binder cement (grade 42.5) manufactured by Dangote group of company complying with BS 12 1991 was used. The sharp sand used was obtained from Ado environ, All the aforementioned were used as constant parameters for all the samples. The concrete constituent materials were calculated based on absolute volume method of mix design. The green concrete produced was used to established the compaction factor test, slump test and cast specimens which was cured for both Compressive strength and Split tensile strength at maturity of 7, 14 and 28days.

Testing on Concrete

Testing the properties of fresh and hardened of concrete is a significant part of assessing or evaluating an existing structure's safety and physical conditions before modifications. For this research progress, testing on fresh and hardened of concrete with destructive or nondestructive is often the only acceptable way to resolve quality issues encountered during construction. The fresh concretes were tested on consistency and hardened concretes were tested for both the compressive strength and split tensile strength.

Slump Test

Concrete slump test as outlined in [BS EN 12350-2: 2009], is a test for evaluating the workability of fresh concrete. Two processes which are batching and mixing for river stone and crushed stone must be carried out before the slump test can be accomplished. Batching by volume was considered for the mix ratios 1:1.5:3 and 1:1:2. The coarse aggregates and cement were mixed with portable water. The slump test procedure entails the following steps: Three layers of concrete were poured into the cone, each compacted with 25 tamps of tamping rod. The concrete was now allowed to droop under its own weight while the cone was steadily raised, using the upturned cone and slump rod as a guide, and the slump was then measured

Compressive Strength Test

The compressive strength was determined in accordance with BS 1881: Parts 108, 116: 1983 using $150mm^3$ cubes. The specimens were cast in steel moulds for concrete made with river stone and crushed stone and tested for each mix proportion. The moulds were base-clamped together, oiled and filled in layers of approximately 3-compacted layer with 25 strokes each to entrap the air. The moulds were removed after 24hrs and immersed in water tank to cure for maturity of 7, 14 and 28days. Three trial were examined from each aggregate sample and tested as specified by BS 1881: Part 116: 1983. The cube was placed with the cast faces in contact with the platens of the testing machine, i.e. the position of the cubes as tested was at right angles to the position as cast using Unit Test Scientific (UTS) crushing machine.

Split Tensile Strength Test

In the splitting tensile test, 36- cylindrical concrete of size 200mm x 100mm was cast for concrete made with river stone and crushed stone, de-moulded after 24hurs and immersed in water to cured at 7, 14 and 28days. The specimens were placed with its axis horizontal, between platens of a testing machine, and the load was increased until failure took place by splitting in the plane containing the vertical diameter of the specimens. This is prescribed by BS 1881: Part 117: 1983; ASTM C 496 – 90 as similar test.

RESULTS AND DISCUSSIONS

The compacting factor test and slump test results of concrete produced with crushed stone and river stone are shown in Table 3. River stone had higher a compacting factor of 0.98% and 1.06% whiles that of crushed stone was 0.92% and 0.88% for nominal mix ratios of 1:1.5:3 and 1:1:2. The average slump for crushed stone was found to be 22.10mm and 27.41mm of the same mix ratios compared 2009.to river stone which 34.43mm and 36mm which indicated that the smaller the aggregates size, the higher the quality consistency. The slump tests were carried out in accordance with BS EN 12350-2.

Table 3: Compacting factor and slump test results of concrete

Coarse Aggregate Type	Mix Ratio	Compacting Factor (%)	Average Slump Values (mm)
River stone	1:1.5:3	0.98	34.43
Crushed stone		0.92	22.10
River stone	1:1:2	1.06	36.00
Crushed stone		0.88	27.41

Compressive strength and Split Tensile Strength Relation

Table 4 and Table 5: Demonstration the summary of mean compressive strength and split tensile strength of concrete with nominal mix ratios of 1:1.5.3 and 1:1:2 for concrete produced with river and crushed stones at maturity of 7, 14, and 28days respectively. All tests were performed in accordance to BS 1881: Part 116 and 117, 1983.

Table 4: Compressive strength and split tensile strength for concrete with river stone

Trials	Curing (Days)	Mix Ratio	Split Tensile Strength (N/mm^2)	Mean Split Tensile Strength (N/mm^2)	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
S11	7	1:1.5:3	1.15	1.18	13.13	13.60
S12			1.18		14.01	
S13			1.21		13.66	
S21		1:1:2	1.22	1.23	14.15	14.15
S22			1.24		14.17	
S23			1.23		14.12	
S31	14	1:1.5:3	2.21	2.21	15.87	16.02
S32			2.23		16.09	
S33			2.18		16.11	
S41		1:1:2	2.22	2.24	18.13	18.14
S42			2.24		18.16	
S43			2.36		18.14	
S51	28	1:1.5:3	3.07	3.05	22.73	22.95
S52			3.03		22.88	
S53			3.05		23.24	
S61		1:1:2	3.05	3.08	26.56	26.58
S62			3.08		26.58	
S63			3.11		26.61	

Table 5: Compressive strength and split tensile strength for concrete with Crushed stones.

Trials	Curing (Days)	Mix Ratio	Split Tensile Strength (N/mm^2)	Mean Split Tensile Strength (N/mm^2)	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
T11	7	1:1.5:3	1.28	1.26	15.16	15.08
T12			1.28		15.13	
T13			1.21		14.97	
T21		1:1:2	1.29	1.32	17.08	16.86
T22			1.34		16.88	
T23			1.32		16.63	
T31	14	1:1.5:3	2.26	2.28	19.66	19.83
T32			2.29		19.78	
T33			2.26		20.06	
T41		1:1:2	2.24	2.27	21.56	21.73
T42			2.27		22.05	
T43			2.31		21.58	
T51	28	1:1.5:3	3.41	3.44	25.14	24.88
T52			3.38		24.87	
T53			3.53		24.63	
T61		1:1:2	3.46	3.48	29.53	29.52
T62			3.45		30.11	
T63			3.51		29.51	

Compressive Strength

From fig.1 and 2, the compressive strength of concrete produced with river and crushed stones at mix ratio 1:1:2 offer the optimum compressive strength at all cured periods of 7, 14 and 28days when compared with mix ratio1:1.5:3. It was observed that the mean compressive strength of river and crushed stones used as coarse aggregates are 22.95 and 24.88N/mm^2 for designated mix ratio1:1.5:3 while that of mix ratio 1:1:2 has strength 26.58 and 29.52N/mm^2 as cured at

28days regime respectively. Satisfactory relate to (Ajagbe & Tijani, 2018) investigated and found that the compressive strength of concrete made with different coarse aggregates from different sources are range from 17.9N/mm^2 to 29.43N/mm^2 at 28days.

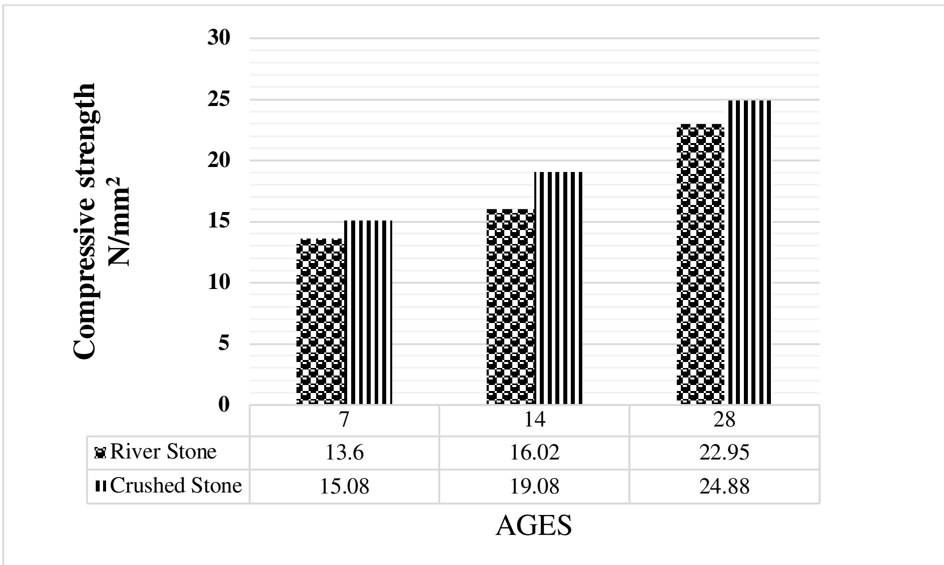

Figure 1: Graphical presentation of mix ratio 1:1.5:3 for mean compressive strength of concrete mixed with river and crushed stones.

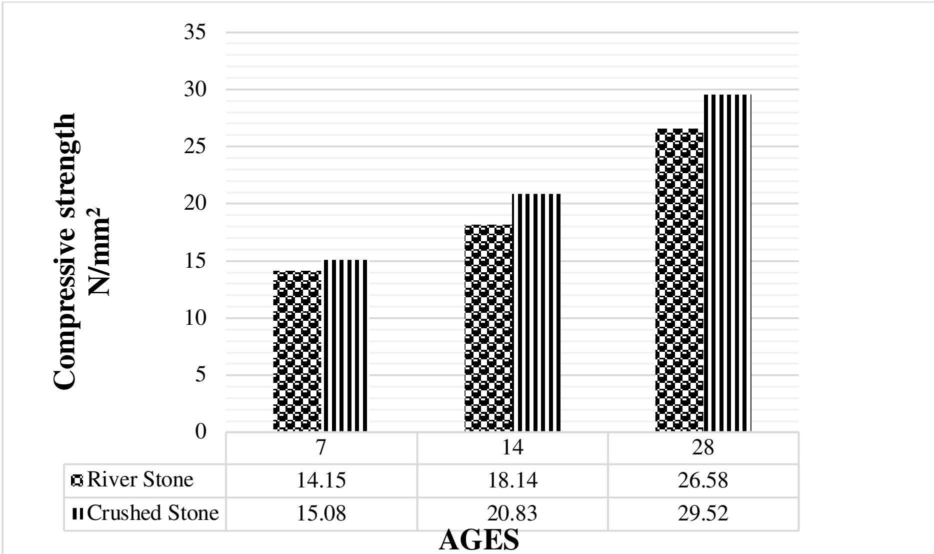

Figure 2: Graphical presentation of mix ratio 1:1:2 for mean compressive strength of concrete mixed river and crushed stones.

Split Tensile Strength

Fig. 3 and 4 characterized the results of concrete cured at 7, 14 and 28days, thus indicate the mean split tensile strength for designated mix ratio 1:1:2 to have the highest strength of 3.88N/mm^2 compared to mix ratio 1:1.5:3 as 3.44N/mm^2 for crushed stone concrete cured at 28days as respectively. The optimal strength was however closer to findings of Sallal et al., 2018 and Ali et al., 2018 which established their conclusions on the results between 1.85 and 4.96 N/mm^2 cured at 28days using different coarse aggregate type, content and distinct constituents.

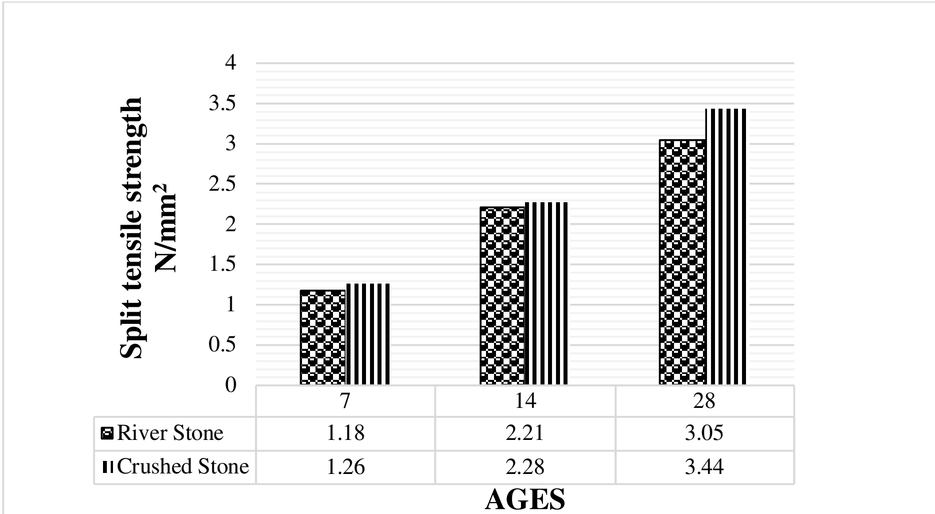

Figure 3: Graphical presentation of mix ratio 1:1.5:3 for mean split tensile strength of concrete mixed with river and crushed stones.

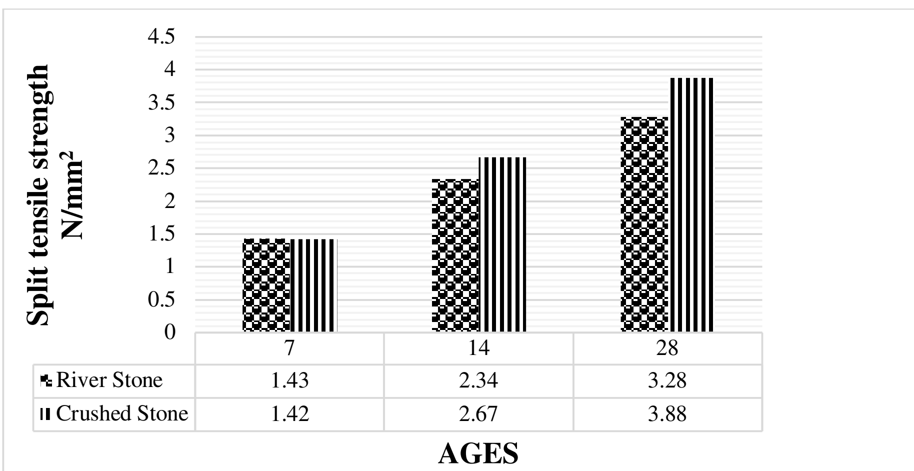

Figure 4: Graphical presentation of mix ratio 1:1:2 for mean split tensile strength of concrete mixed with river and crushed stones.

CONCLUSIONS AND RECORMENDATION

The following conclusions proffered based upon laboratory experimental program conducted to on both coarse aggregates;

i. The characterization of physical properties of the coarse aggregates are within the permissible limits specified by standard codes and specifications.
ii. The compacting factor and slump values of designated mixes provided acceptable percentage of consistency due to high surface area of the coarse aggregates that required more water to produce concrete.
iii. Concrete made with crushed stone established the highest mean compressive strength as 29.52N/mm^2 for mix ratio 1:1:2 while that of river stone as 26.58N/mm^2 for concrete cured at 28days of testing. This shows that both aggregates (crushed stone and river stone) could meet the targeted concrete grade M20 and M25.
iv. The study shows the slight variations for strength generated for crushed stone on split tensile strength as 3.88N/mm^2 and 3.44N/mm^2 compared to that of river stone as 3.05N/mm^2 and 3.08N/mm^2 cured at 28days of testing.
v. Decisively, both mix ratios established good strength performances that were suitable for structural applications.

These properties of concrete (consistency measured, compressive and split tensile strengths) made with the river and crushed stones as coarse aggregates depict strength that is acceptable. Therefore, the performance of the aggregates was satisfied and recommended to be used for high strength concrete works.

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