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The Effect of Replacement of River Sharp Sand with Quarry Fines on the Split Tensile Strength of Concrete

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ABSTRACT: Sharp sand, the normal fine aggregate in concrete is getting scarce daily because of the increase in construction activities in the country. Moreover, the cost of sand is so enormous to be afforded by the common citizens. The need to find readily available and good substitutes for sand becomes imminent. Quarry fines, a waste product generated in the stone quarrying industries has been found to serve as a good substitute for sand in concrete. The proper utilization of this waste material in concrete will seriously reduce the problem of managing this waste while at the same time helping in the reduction of the cost of concrete produced. This study investigated the effects of replacement of river sharp sand with quarry fines on the split tensile strength of concrete. It was observed that the split tensile strength kept increasing as the curing days increased and attained a maximum value of 2.66N/mm^2 at 75% sand replacement with quarry dust at 28 days age. At 100% quarry dust content, the 28th day split tensile strength reduced to 1.97N/mm^2 indicating a 26% reduction in strength.

KEYWORDS: Curing, Quarry fines, Utilization, Waste material, Split tensile strength,

1. INTRODUCTION

Concrete is regarded as the most widely used man-made material in the world, seconded only to water, a natural material (Nwofor, 2016). It is one of the most important construction materials, comparatively economical, easy to make, offering continuity and solidity and fast to bind with other materials. It is made up of cement, fine aggregate (sharp sand, quarry fines), coarse aggregate (crushed or uncrushed stones) and water in the proper proportions. The key to good quality concrete are the raw materials required to make the concrete. It has been shown that the strength of concrete depends mainly on the water-cement ratio, the slump, cement-aggregate ratio, the quality of cement, gradation of the aggregates and the efficiency of the curing technique (Nwofor, 2016). Also the specific gravity, particle size distribution, shape and surface texture of aggregates also have significant impact on the properties of wet and hardened concrete, while the mineralogical composition, toughness, elastic modulus generally account for significant impact on the hardened state of concrete. Concrete is basically of three types: light weight with density less than 19,200.00 kg/m^3, normal weight which is most common with density of about 24,000.00 kg/m^3 and heavy weight with density above 28,000.00 kg/m^3.There is high demand for concrete materials with the need for research into locally available substitutes for conventional concrete materials like river sand. Quarry fines have of recent been used to replace sand as fine aggregate in concrete.

1.1 Back Ground of Study

Another material used to replace sand as fine aggregate in concrete is quarry dust. Quarry dust is a fine material obtained from the crushing process during quarrying activity at the quarry site. In this study, quarry dust will be used to replace river-sand as a fine aggregate in concrete. Quarry dust has been in used for various activities in the construction industry such as road construction and manufacture of building materials such as bricks, tiles and autoclave blocks. Recent developments in the building construction industry in Calabar, Southern Nigeria have witnessed an increasing use of mixtures of lateritic sand and quarry dust to replace river sand in concrete productions without any reliable data on the appropriate use of these materials in structural elements of buildings. This is worrisome, given the history of building collapses in major cities of Nigeria and elsewhere. Information about strength properties of a material from which a load-bearing component is made is required by an engineer to complete the theoretical stress analysis of the component; tensile strengths are among some of the important properties to be considered. Quarry dust (QD) exist in abundance in most parts of Nigeria, and its incorporation in structural concrete will likely reduce the cost of building construction significantly. On the other hand, the use of this material would reduce environmental waste. These include: the environmental problems posed by the excessive mining of river sand, the conventional fine aggregate for concrete works in Nigeria and most parts of the world; and the environmental problems in quarry sites due to large heaps of quarry dust - the waste product of aggregate crushing process (Joseph *etal*, 2012).

River sand, which is one of concrete constituents has become very expensive and is also becoming scarce due to the depletion of river beds. Because of the scarcity, the cost of sand becomes enormous. This makes it necessary to source for alternative materials that are readily available and cheap to replace sand. Quarry Dust is a fine waste material and its utilization as sand replacement could perhaps have beneficial effects on the properties concrete.

1.2 Objectives of the Study

This study will evaluate the effects of replacement of river sharp sand with quarry dust on the split tensile strength of concrete. The workability, density, and water absorption capacity of concrete containing quarry dust as fine aggregate will also be ascertained.

The findings of this study will be of immense help to engineers and construction firms wishing to utilize quarry dust in concrete production. It will also help in reducing the demand for sharp sand for concreting purposes. The study will also help in alleviating the problem of waste disposal encountered by the producers of quarry dust.

Split tensile strength is significantly used for plain concrete structures such as dam under earthquake excitations. Other structures which are designed based on bending strength e.g pavement slabs and airfield runways are subjected to tensile stresses.

2. LITERATURE REVIEW

2.1 Concrete with Quarry Dust as Fine Aggregate

Many attempts have been made to investigate the suitability of quarry dust as a replacement for sand in concrete. Gowrisanker (2016) carried out an experimental study on the variation in strength of concrete when replacing sand with quarry dust and cement with lime powder with replacement from 0% - 30%. From the test results, it was found that the maximum compressive strength and tensile strength was obtained at 30% replacement of quarry fines with sharp sand. They reported that quarry dust can be utilized as a good substitute for sharp sand. Mohankumar and Sudharsan (2017) studied the replacement of sand fine aggregate with quarry dust. The sharp sand was totally replaced with quarry dust. Krishnamoorthi and Mohankumar (2012) made preliminary studies on the strength properties of quarry dust based concrete. A trial mix design for M30 grade concrete and sand replaced at different percentages with quarry dust. They recommended a total replacement of sand with quarry dust. Allam (2016) studied the behaviour of M35 grade concrete having partial replacement of cement or sand with quarry waste. It concluded that the optimum percentage of concrete with granite fine powder was 60%. Anzar (2015) made a study on the suitability of quarry dust as sand replacing material and discovered that it improves the mechanical properties of concrete as well as its elastic modulus. The optimum compressive strength was achieved at a proportion of fine to coarse aggregates of 60:40. Agrawal (2017) made a study focusing on determining the suitability of using quarry dust as fine aggregate in traditional concrete. The compressive strength of concrete was determined after replacing sand with quarry dust at several ratios. The results of the study showed encouraging results for replacement of 50% of sand with quarry dust. Ukpata (2012) studied the compressive strength of concrete using lateritic sand and quarry dust at various combinations as fine aggregates. The results compared favourably with those of conventional concrete. The concrete was found to be suitable for use as structural members where lateritic sand did not exceed 50%.. Ilangovana (2008), studied the strength and durability properties of concrete containing quarry dust as fine aggregate and found that the compressive, flexural strength and durability studies of concrete made with quarry dust were nearly 10% more than the conventional concrete. Their workability results showed slump values ranging between 60-90mm and compacting factor 0.87 - 0.90 for grade 20 concrete. The range of 28 days compressive and flexural strengths for grade 20 concrete were found to be 23.7 - 34.50N/mm^2 and 3.45 - 6.40 N/mm^2 respectively.

Naushad (2014) observed that the escalating consumption of concrete as indicated by the steady rise of cement consumption has led to an increase in the world wide use of sand as fine aggregates. As a result of this, several developing countries like ours, have encountered some strain in the supply of natural sand to meet the increasing needs of infrastructural development in recent years. This situation has led to the increase in the price of sand and this translates directly to an increase in the cost of concrete. Large scale exploitation of river sand creates adverse environmental effects while the large scale exploitation of quarry dust will lead to the removal of environmental load and help reduce the effects posed by accumulation of this dust. Nowadays the natural river sand has become scarce and very costly. Quarry dust may be used in the place of river sand fully or partly if adequate data is available on its utilization.

2.2 Negative Effects of River Sand Mining

For thousands of years, sand has been used in the construction of roads and buildings. Today, demand for sand continues to increase. Excessive sand mining causes the degradation of rivers. Sand mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive stream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river. Sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire stream bed to degrade to the depth of excavation. Sand mining generates extra vehicle traffic, which negatively impairs the environment. Where access roads cross riparian areas, the local environment may be impacted. Sand mining can have other costly effects beyond the immediate mine sites. Many hectares of fertile streamside land are lost annually, as well as valuable timber resources and wildlife habitats in the riparian areas. Degraded stream habitats result in lots of fisheries productivity, biodiversity, and recreational potential. Severely degraded channels may lower land and aesthetic values (Sennag 2018)

2.3 Tensile Strength of Concrete

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature hence, it is not expected to resist the direct tension; this cause the concrete to develop cracks when tensile force exceeds its tensile strength. Therefore it is necessary to determine the tensile strength of concrete, to determine the load at which the concrete member may crack. The cracking is a form of tension failure .Furthermore, splitting tensile strength test on concrete is a method to determine the tensile strength of concrete (Katz, 2003).

3. RESEARCH MATERIALS AND METHODS

3.1 Research Materials

Materials used in this study include the following;

3.1.1 Cement: Dangote Portland cement was used for this research process. The Portland cement conformed to BS12:Part3: 1978 requirements. The cement was well protected from dampness to avoid lumps. Cement was purchased and taken to the laboratory in sealed 50kg bags.

3.1.2 River Sharp Sand: Sufficient quantity of sharp sand was obtained and spread out for a few days in the laboratory before use to dry, removing dampness in order to maintain consistent weights when batching. Sieving analysis was conducted on the sharp sand to determine the particle size distribution of aggregates according to BS 882: Part 103.

3.1.3 Quarry Fine: Quarry fine was also used as fine aggregate to replace sand. It was obtained from a dealers dump site at Udo Udoma Avenue, Uyo, Akwa Ibom state in bags and transported to the laboratory.

3.1.4 Coarse Aggregate:

Coarse aggregate of 20mm maximum size was used for this research work. It was purchased from a dealer along Udo Udoma Avenue, Uyo. It was sieved and the particles size distribution computed.

3.1.5 Water:

Portable tap water suitable for domestic consumption was be used throughout the research experiments. Water is important in starting the reaction between cement and other constituent materials. The binding property of cement cannot take effect without water. The water will conform to BS31480.

3.2 Research Methods

The following tests were performed in the course of this study:

3.2.1 Sieve Analysis:

Sieve analysis was done by passing the dried aggregate through a series of standard test sieves beginning with the one sufficiently coarse to pass all the material. The test conformed to the requirements of BS 410: 1976. Having completed the sieving, the weights of aggregate retained in each sieve in turn were recorded. The weights and percentages of aggregate passing each test sieve were then computed. The results of sieve analysis were represented graphically in charts known as grading curves/charts.

3.2.2 Specific Gravity Test: This test was carried out to determine the specific gravities of all the soil samples.

3.2.3 Slump Test: The concrete slump test is an empirical test that measures the workability of fresh concrete. . The slump of each batch of concrete was tested using a 300mm high slump cone. The mixed concrete was put into the slump cone in 3 layers with each layer stroked 25 times. When the strokes were completed a trowel was used to level the top of the cone. The cone was lifted upwards and the difference between the height of the slump cone and top of the subsided concrete gave the slump of the mixture.

3.2.4 Compacting factor test: The compacting factor was obtained by passing the mix through an arranged system where the mix falls through the apparatus and is compacted by gravity as it falls from one level to another, the surface is leveled and the weights taken. Then the mix was further compacted in a vibrating table, the vibrated mix was filled in the cylinder and leveled, the new weight taken and the compaction factor obtained as the ratio of the weight of the non-compacted mix to the compacted weight of the same sample.

3.2.5 Casting of cylinder: The specimens were cast in an iron moulds, 150mm x 300mm in shape. This conforms to the specifications of ASTM C496 - Standard Test Method of Cylinder Concrete Specimen. The moulds surfaces was cleaned and oiled the moulds were then assembled. After assembling the mould was filled with concrete in three approximately equal layers. Each layer was stroked with a 16mm tamping rod for 25 times. This was done to ensure a symmetrical concrete distribution within the mould. Finally the excess concrete was scrapped off the top surface. The concrete was kept in a moist condition for 24 hours before demoulding.

3.2.6 Curing: after 24 hours the cylinder was removed and the resulting concrete was cured in a water bath till the age of testing.

3.2.7 Split tensile strength test: After curing the cubes for the specified period, the cylinder was removed and wiped to remove surface moisture in readiness for split tensile test. The cylinder was tested according to ASTM C496 requirements.

The splitting tensile strength was calculated using eqn 1:

$$T = 2P/\pi LD \quad \text{..............................[1]}$$

Where:

T= Splitting tensile strength, MPa

P= Maximum applied load indicated by the testing machine, N

D= Diameter of the specimen, mm

L= Length of the specimen, mm

4. RESULTS AND DISCUSSION

4.1 Properties of Materials Used: The physical properties of the materials used in this research work are summarized in Table 4.1.

Table 4.1: Properties of Materials used.

Materials	Properties	Values
Sharp sand	Specific gravity	2.61
	Coefficient of curvature(Cc)	1.05
	Uniformity Coefficient (Cu)	2.81
Quarry dust	Specific gravity	2.86
	Coefficient of curvature(Cc)	0.71
	Uniformity Coefficient (Cu)	3.60
Coarse aggregate	Specific gravity	2.56
	Coefficient of curvature(Cc)	1.03
	Uniformity Coefficient (Cu)	1.80

Table 4.2: Slump, Compacting factor and Water absorption values for every mix

Percentage replacement		Slump (mm)	Compacting factor	Water absorption (%)	28^{th} day Density (kg/m^3)
Sharp Sand	Quarry Dust				
100%	0%	48	1.88	0.74	2546
75%	25%	36	2.18	0.76	2561
50%	50%	21	2.60	0.76	2570
25%	75%	10	2.92	0.83	2593
0%	100%	0	3.75	0.94	2296

4.1.1 Specific Gravity of Samples

The quarry dust used had a specific gravity of 2.86 while the sharp sand had a specific gravity of 2.61. Moreover, the coarse aggregate had a specific gravity of 2.56.

4.1.2 Particle Distribution of the Aggregates

The results of the grain size analysis for sand, quarry dust and coarse granite are presented in Figures 4.1, 4.2, and 4.4 respectively. Figure 4.3 presents a plot of both fine aggregates to show their variability. From the results obtained, the sharp sand had a particle size ranging between 4.75mm and 0.075mm with 3.85% of the aggregate being retained in the 4.75mm sieve and 0.38% retained in the 0.075mm sieve, a Uniform Coefficient (Cu) of 2.66 and a Coefficient of curvature (Cc) of 1.32 , thus the sand is well graded. The quarry dust had a particle size ranging between 4.75mm and 0.075mm, a Uniform Coefficient (Cu) of 3.71 and a Coefficient of Curvature (Cc) of 0.71. The coarse aggregate contained particle sizes ranging from 19.00mm to 4.75mm, and has a Uniform Coefficient (Cu) of 1.8 and a Coefficient of Curvature (Cc) of 1.058. Sieve analysis for fine and coarse aggregates was conducted in conformity to BS 882:1992.

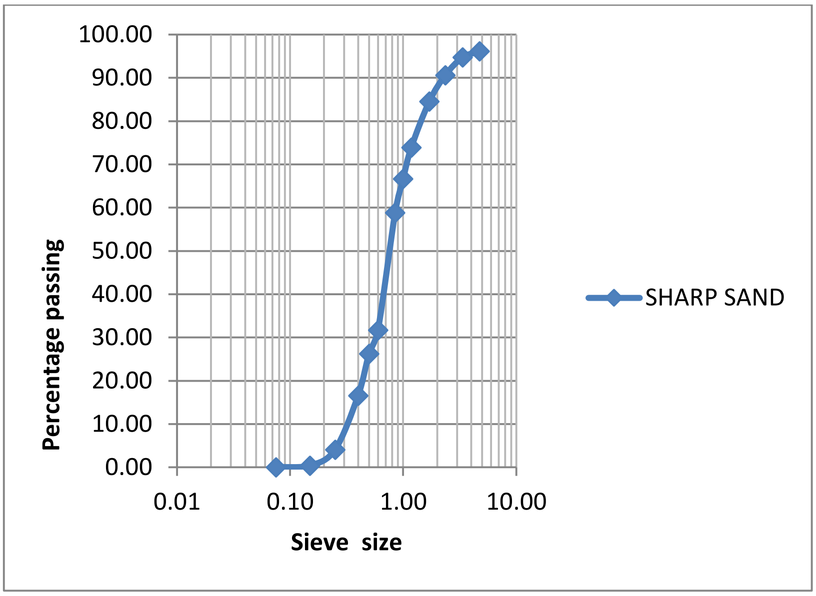

Figure 4.1: Graph Showing Sieve Analysis of Sharp Sand

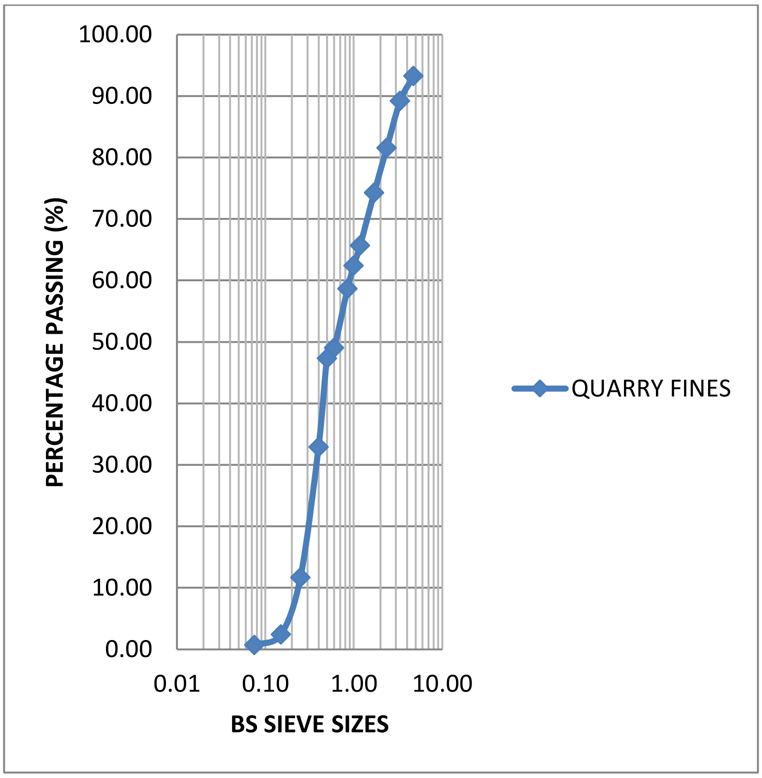

Figure 4.2: Graph Showing Sieve Analysis of Quarry Fines

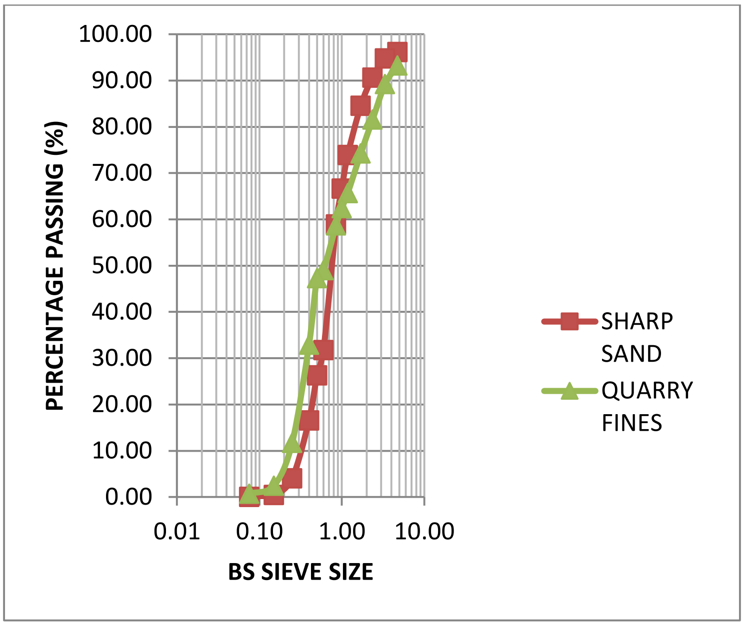

Figure 4.3: Combined Graph Showing Sieve Analysis of All Fines Aggregate

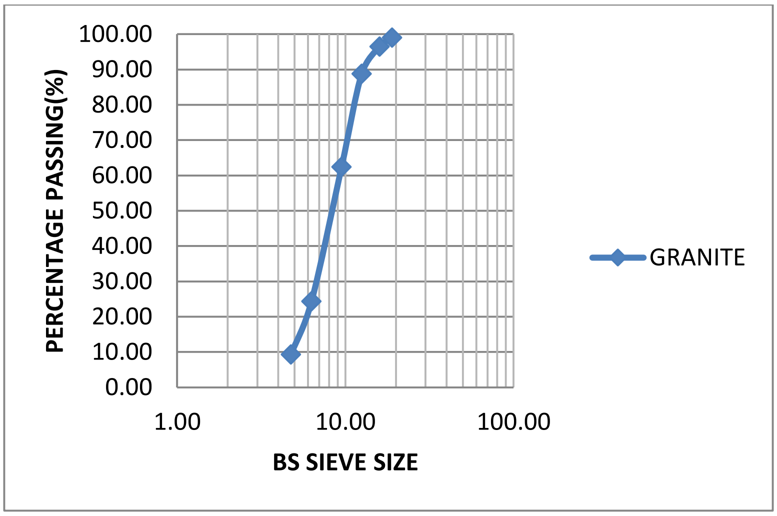

Figure 4.4 Graph of Coarse Aggregate.

4.3 Workability of the Concrete

The slump test and the compacting factor test were used to ascertain the workability of each of the mix.

4.3.1 Slump Test Results

The slump tests result are presented in Table 2 and Figure 4.5. The results showed that quarry dust concrete required a considerable higher amount of water as compared with the river sharp sand concrete. The mix containing quarry fines alone had a generally low workability as compared to the sample with sharp sand alone. The mix with 100% quarry dust had a zero slump compared to a slump of 48mm for the 100% sand mix. This can be seen from the graphs of variations of slump values. The slump values decrease with increase in the quarry dust content. This shows that the high proportion of fine particles in concrete made with quarry dust reduces the water effect; so much of the water is first used to wet the fine aggregates before bonding them together. This leaves the amount of water available for bonding inadequate to create a workable mix.

4.3.2 Compacting Factor Test Result

The compacting factor test results ranges from 0.78 - 0.95 which is close to the range of 0.7 – 0.95 specified in BS 1881; Part 103 of 1993. The results of compacting factor tests are presented in Table 4.2 and Figure 4.6. From the graph it is obvious that the compacting factor is high with increase in quarry dust replacement.

4.4 Properties of Hardened Concrete

4.4.1 Density

The density of the tested concrete is presented in Table 2. The 28th day density of the Quarry dust concrete ranged from 2296 to 2546 kg/m^3. This lies within the range of 2100 to 2300 kg/m^3 specified for normal weight concrete (Neville 2000). Quarry dust concrete could be confirmed to be normal weight concrete.

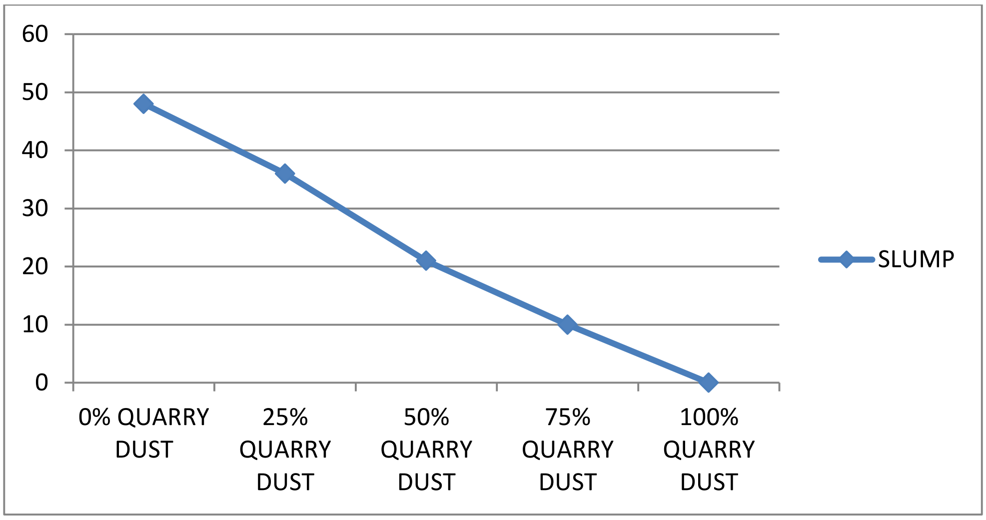

Figure 4.5 Graph of slump values against the percentage of quarry dust used (mm).

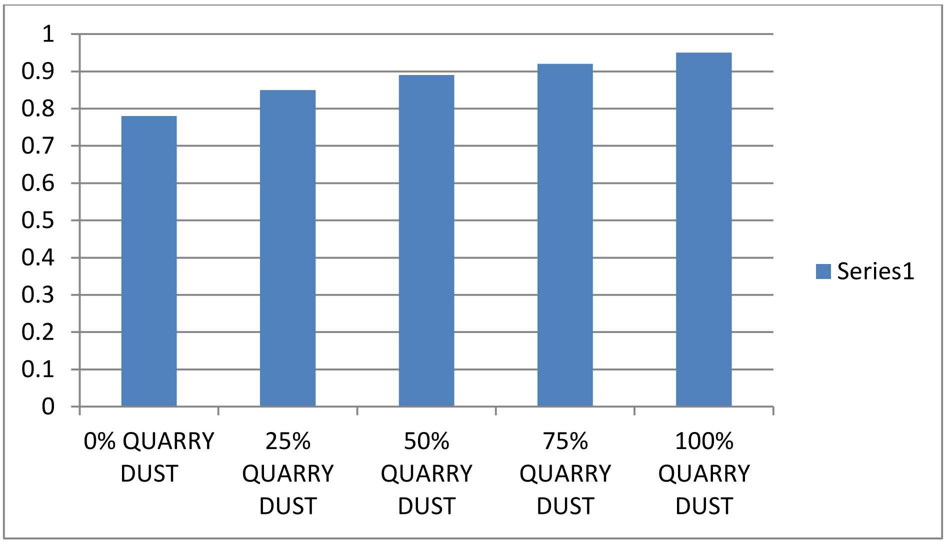

Figure 4.6 Graph Of Compacting Factor Values For Different Mix.

4.4.2 Water Absorption Test Result: The results of the water absorption test are presented in Table 2 and Figure 8. The graph shows a unique and clear understanding that as the percentage replacement of quarry dust increased, more water is absorbed (at 100% quarry dust, percentage of water absorbed is 3.75) than in concrete made with only river sharp sand as the only fine aggregate(100% sharp sand, percentage of water absorbed is 1.88).

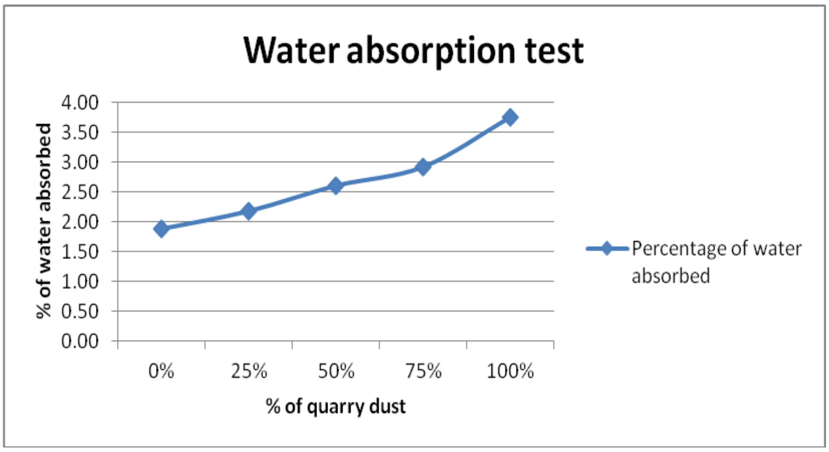

Figure 4.8: Water absorption capacity of the concrete

The Effect of Replacement of River Sharp Sand with Quarry Fines on the Split Tensile Strength of Concrete

4.5.3 Split Tensile Strength

Table 4.3 and Figure 4.7 shows the split tensile strengths of concrete for the different curing ages.

Table 4.3: Split Tensile Strengths of Quarry dust Concrete

% replacement		Tensile strength				
Sharp Sand	Quarry Dust	3 days	7 days	14 days	21 days	28 days
100%	0%	1.19±0.11	1.20±0.05	1.42±0.02	1.45±0.03	1.53±0.04
75%	25%	1.32±0.05	1.52±0.08	1.53±0.05	1.71±0.05	1.81±0.05
50%	50%	1.79±0.21	1.83±0.02	2.04±0.07	2.11±0.02	2.19±0.11
25%	75%	1.86±0.17	2.22±0.27	2.43±0.08	2.54±0.36	2.66±0.12
0%	100%	1.55±0.12	1.67±0.04	1.74±0.03	1.87±0.59	1.97±0.10

The 28th day split tensile strength of quarry dust concrete ranged from 1.53 N/mm^2 to 2.66 N/mm^2 at 25% sharp sand to 75% quarry dust mix. The strength however reduced to 1.97N/mm^2 at 100% sand concrete mix. This shows that the incorporation of quarry dust into the mix increases the split tensile strength of the concrete. The same trend is also observed at other curing ages. There was also a gradual increase of split tensile strengths from the 3rd day of curing till the 28th day. The 28th day split tensile strength increased within the range of 22.3% to 43.0% above the 3rd day strength. At 75% replacement of sand with quarry dust, the strength was found to be 1.86, 2.22, 2.43, 2.54 and 2.66 respectively for 3, 7, 14, 21 and 28th day's curing. However, the 28th day strength reduced to 1.97N/mm^2 at 100% replacement of sand with quarry dust but is still higher than the strength gotten from 100% sharp sand which stood at 1.53. The maximum split tensile strength recorded was 2.66N/mm2 at 25% sand and 75% quarry dust mix, while the minimum strength recorded was 1.53N/mm2 at 100% sharp sand, 0% quarry dust mix.

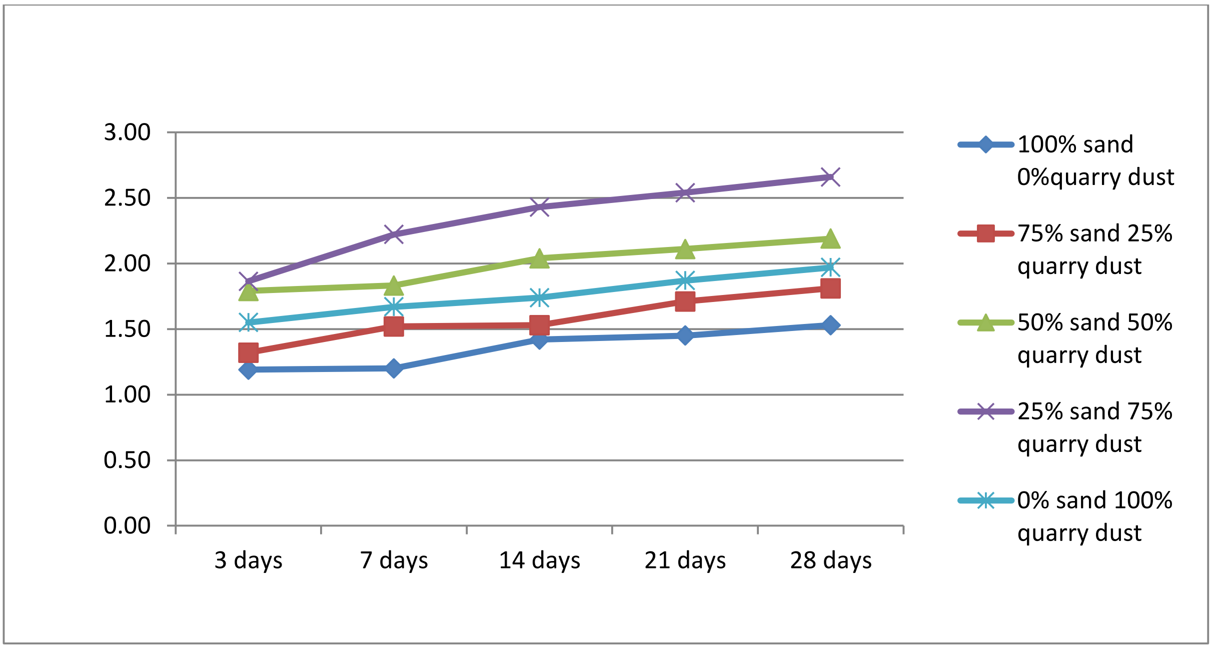

Figure 4.7 Graph of Split Tensile Strength.

5. CONCLUSION

Based on the results obtained from the experiment conducted, it can be concluded that the workability decreases while percentage of water absorption increases with increase in replacement level of sand with quarry dust. The strength of the concrete increased with age of curing. It also increased with increase in the replacement of sand with quarry dust.

This experimental data shows that the addition of quarry dust improved the concrete properties**.** Since its properties are as good as those of sand, the quarry dust can be used as fine aggregate to replace sand in the concrete**.**

Usage of quarry dust in concrete reduces the workability of concrete hence a greater amount of water is needed in quarry dust concrete to make it more workable.

There is increment in strength of the concrete when quarry dust replaces sand up to 75%.

Utilization of quarry fines in concrete will reduce overdependence on natural sources of aggregates i.e. river sand and also promote environmental sustainability.

Quarry dust concrete can be classified as normal weight concrete because of its high density.

6. RECOMMENDATIONS

Quarry dust is recommended as a suitable replacement for sand in concrete especially at a replacement level of 50% and 75%.

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