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Determination of Tolerance Limit of Silt and Clay Impurities in the Strength of Concrete made with Abuja Sand

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Abstract: *This research work is aimed at establishing the percentage at which silt and clay content in river bed fine sands sourced in Abuja and environ are not suitable for concrete work. Fine aggregate samples were collected from five major locations within Abuja and environ namely: Bwari, Mararaba, Kuje, Jere and Gwagwalada. The percentage silt and clay content present in each sample was examined to be 9.76%, 9.68%, 5.7%, 2.99% and 15.38%, and named as samples 1, 2, 3, 4 and 5. Afterwards, sixty (60) concrete cube samples of 150 x 150 x 150 mm dimension were cast using a 1: 2: 4 mix ratio and water - cement ratio of 0.5 and cured for 7, 14, 21 and 28 days prior to crushing. In addition, the average compressive strength results of the samples were established. Thereafter, to determine the percentage of silt and clay content not fit for concrete works, sample five (5) was thoroughly washed and dried to zero moisture content and thereafter, eighty-four (84) standard concrete cubes of 150 x 150 x 150 mm dimension were cast using a 1: 2: 4 mix ratio and water - cement ratio of 0.5. The washed sand was partially replaced with processed silt and clay at 0%, 2%, 4%, 6%, 8%, 10% and 12% and crushed at 7, 14, 21 and 28 days. From the study, the percentage at which silt and clay content in river bed fine sands is not fit for engineering uses particularly concrete was established to be 7%.*
Keywords *- Tolerance limit, silt and clay, fine aggregate, concrete strength, compressive strength.*

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I. INTRODUCTION

Concrete is a major component of most of our infrastructural facilities today in the 21st century because of its versatility in use. Concrete is used more than any other man-made material in the world. As of 2006, about 7.5 cubic kilometers of concrete were made each year—more than one cubic meter for every person on Earth [1]. Invariably, the importance of concrete in modern society cannot be underestimated [2]. Concrete is used in making pavements, small bungalows, high-rise buildings, classroom blocks, office buildings, dams, bridges, warehouses, and motorways/roads, bridges, parking structures, fences and poles. In nutshell, concrete is applied in parts of foundations to buildings and used to make floor slabs, columns, beams, lintels, roof, staircases, walls, arches, etc. Concrete is an artificial stone-like material used for various constructional purposes and manufactured by mixing cement and various aggregates, such as sand, pebbles, gravel, stone, shale, etc with water and sometimes admixture and allowing the mixture to harden by hydration. Better still, concrete could be a composite material, which is made up of filler and a binder [2 - 11]. Concrete being a major construction material commonly and regularly used in virtually any type of construction work constitute at least about 40% of the total works, [12]. Therefore, its importance and a proper study of its regular production and utilization cannot be overemphasized, especially now that its utilization in construction activity is increasingly rising. This is why [13], opined that, merely choosing the appropriate constituent materials for a particular concrete is a necessary but not a sufficient condition for the production of high-quality concrete. Remarking that, the materials must be proportioned correctly, and the concrete must then be mixed, placed, and cured properly, and also there must be careful quality control of every part of the concrete-making process which requires the full cooperation among the materials supplier, the builder and the engineer. Concrete fails when it can no longer provide the required strength to support its designed load. The failure of concrete can sometimes be mild with visible cracks and deflections or severe, leading to partial or total collapse of the structure either during the construction or post-construction stage. Incidences of failures of structures linked to bad concrete practice are abounding in Nigeria particularly in our major cities such as Lagos, Port-Harcourt, and Abuja, among others. Generally, the sand available in the river bed is very coarse and contains very high percentage of silt and clay. The silt and clay present in the sand reduce the strength of the concrete and holds dampness, [14]. In recent time, assessment of the influences of silt and clay impurities present in fine aggregates on the concrete strength was carried out within Ado-Ekiti, Ekiti State, Nigeria. It was discovered that the fine aggregates samples from the five locations did not have the same percentage of silt and clay content, as the silt and clay content increases, the compressive strength of concrete decreases. The concrete produced from these fine aggregate samples do not have the same slump, the slump decreases as the percentage of silt and clay content increases. From the analysis carried out on results of tests performed, it was observed that the percentage of silt and clay from various locations varies from 0 % - 9.6 % respectively. From the computed results obtained from the study, it is obvious that the compressive strength of concrete decreases with increase in silt and clay content and increases with curing days [3] [4]. This reduction in compressive strength is as a result of improper bonding of silt and clay materials. The sieve analysis results from the fine aggregates samples from various locations (apart from stone dust from quarry) contained silt and clay content which technically affects the concrete strength. Silt is generally considered to be materials between 0.06 mm and 0.002 mm while Clay are materials less than 0.002 mm particle size (BS 882,1992). In analysing the influence(s) of silt/clay on the concrete strength; if the silt/clay content is found to increase the concrete strength, it means silt/clay can partially replace fine aggregates. This will reduce the cost of concrete production but if otherwise, it will be a pivotal information to all concrete designers and users to ensure that fine aggregates are free from silt/clay impurities. Silt/ clay is not as strong as typical fine aggregates. They can absorb water and their properties can change. In fresh concrete, silt/clay will interfere with the bonding of aggregates to cement. In hardened concrete, if the silt/clay come in contact with water in air voids, it can shrink or swell, either building internal pressure (swelling) or leaving larger voids and weakening the concrete (shrinking). Silt/clay is much finer than fine aggregates and having non-cohesive property due to which it does not react with cement, fine aggregates and with water it starts reacting like shrinking and swelling but still exists in concrete which cause unwanted hairline or sometimes major cracks in the concrete depending on percentage of silt/clay which should not be more than 4%. Failure of concrete structures leading to collapse of building has initiated various researches on the quality of construction materials. This failure has resulted into injuries, loss of lives and investments has been largely attributed to use of poor-quality concrete ingredients. The fine aggregates of high quality have high positive effect on the quality of compressive strength of concrete and the presence of silt/clay above certain percentage in fine aggregates requires more cement to coat other ingredients of concrete [4, 10-16].

II. MATERIAL AND METHODS

3.1 Materials:

The cement used in this study is the Dangote brand of Ordinary Portland Cement**.** It was sourced in Abuja, and it conforms with BS EN 197 – (2000). The Fine aggregate employed was from river bed sourced within Abuja and the coarse aggregate used consists of granite obtained from a quarry in Abuja. It was clean and free of dust.

3.2 Processed Silt and Clay

The processed silt and clay used as partial replacement for the washed sand was thoroughly dried to attain zero percent moisture content. Thereafter, the material was pounded in a mortar and sieved in 150um to 75um sieve sets so as to be sure that the processed silt and clay deployed is 100% silt and clay in accordance to BS 882, 1992. Recall that silt is generally considered to be material between 0. 06mm and 0.002mm while clay are materials less than 0.002mm particle size. [5] [24].

3.3 Slump test

Slump test is the most common method used for measuring the workability of a fresh concrete mixed concrete. To be more specific, the test measured the consistency of the concrete mix in a specified batch. The consistency of concrete refers to the ease at which it can flow, hence the test is used to determine the degree of wetness. Practically, the mixes which are wet are more workable than those which are dry. The apparatus used consists of a metal mould, frustum of a cone with both ends open and provided with two handles with dimensions of about 305 mm high, 203 mm internal at the bottom and 102 mm diameter at the top [19].

3.4 Sieve Analysis

The process of dividing a sample of aggregate into fractions of same particle size is known as sieve analysis. The purpose is to determine the grading of size distribution of the aggregate. In practice each fraction contains particles between the openings of the standard test sieves. The grading of aggregates is expressed in terms of percentages by weight retained on a series of sieves. Test sieves used for concrete aggregates have square openings and described by the size of the opening [13] [14] [22] [25].

3.5 Compressive Strength Test

The compressive strength of concrete is one of the most important and useful properties of concrete. The primary purpose for design concrete is to resist compressive strength in structural members. Hence it is the role of a concrete designer to specify the expected characteristics strength of concrete/mix proportion to enable it resist external force. Concrete cubes produced from unwashed and washed fine aggregates samples with the same coarse aggregates, cement and water ratio were subjected to this test to determine variation in strength as regards the different percentage of silt and clay present in unwashed samples fine aggregates and partial replacement of washed fine aggregate with processed silt and clay, to determine silt and clay tolerance limit in concrete. The concrete cubes were cured by immersion in water. The concrete cubes were crushed using Universal testing machine [10] [11] [12] [17] [24].

3.6 Method of Data Analysis

The study is mainly experimental work. The results obtained from various experiments served as data for the study. The analysis of data in most cases was done by graphical illustrations. However, other forms of statistical analysis were employed, to determine the level of significance, using statistical analysis [25].

3.7 Statistical Analysis of Results

An independent sample t-test was conducted on washed sample which was partially replaced with processed silt and clay content at 2% increase in each mix batch to determine if there is no significant difference, that is $p > 0.05$ between the mean compressive strength of the concrete results with control compressive strength value in accordance to BS 1881.

III. RESULT

3.1 Summary of Sand Bottle Test for Fine Aggregate Samples 1 - 5

Table 1: Shows the percentage Silt and Clay content of fine aggregate samples sourced from five major locations in Abuja and environ. The contents were calculated as; Sample 1 (Bwari) - 9.76%, Sample 2 (Mararaba) - 9.68%, Sample 3 (Kuje) - 5.7%, Sample 4 (Jere) - 2.99% and Sample 5 (Gwagwalada/Kwali) - 15.38%.

Table 1: Summary of Sand Bottle Test for Fine Aggregate Samples 1 - 5

Sample	Location	% Silt and Clay
1	Bwari	9.76%
2	Mararaba	9.68%
3	Kuje	5.70%
4	Jere	2.99%
5	Gwagwalada	15.38%

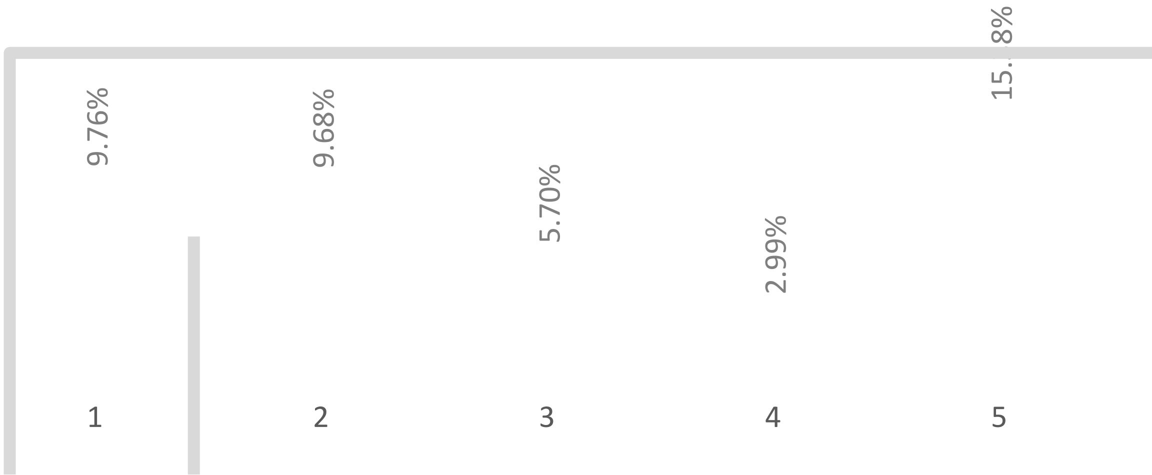

Figure 1: Silt/Clay content in each Fine Aggregate Sample 1 - 5

3.2 Slump Test

Table 2: Shows the summary of slump test of washed fine aggregate sample partially replaced with processed silt and clay at 2% interval. The washed sand was partially replaced with processed silt and clay at 0%, 2%, 4%, 6%, 8%, 10% and 12%.

Table 2: Slump Test of Washed Fine Aggregate Sample

Samples	**Average Slump (mm)**
0%	65
2%	65
4%	62
6%	60
8%	57
10%	52
12%	48

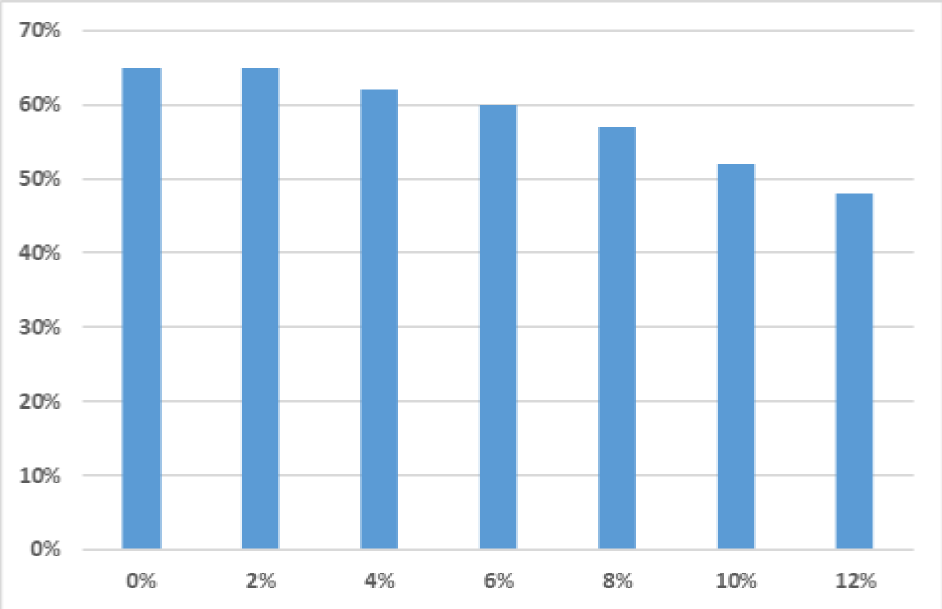

Figure 2: Slump Test of Washed Fine Aggregate Sample

3.3 Compressive Strength of Washed Sand

Table 3: Shows the average compressive strength of the washed fine aggregate sample. The Gwagwalada sample was thoroughly washed and partially replaced with processed silt/clay in the order of 2%, 4%, 6%, 8%, 10% and 12%. In accordance with standard requirements, the compressive strength results are greater than 13.5N/mm^2 from 0% to 8% at 7 days and greater than or equal to 20 N/mm^2 at 28 day (though 28 days average compressive strength result of 8% was less with small margin); indicating that a maximum of 7% silt/clay content in fine aggregates is useable in concrete works.

Table 3: Average Compressive Strength of Washed Fine Aggregate Sample

AGE (days)	**0%** (N/mm^2)	**2%** (N/mm^2)	**4%** (N/mm^2)	**6%** (N/mm^2)	**8%** (N/mm^2)	**10%** (N/mm^2)	**12%** (N/mm^2)
7	18.50	17.87	16.17	15.70	13.96	12.34	12.48
14	20.60	19.90	18.91	18.50	15.80	15.21	15.10
21	24.40	23.80	21.72	19.60	18.39	17.57	16.10
28	25.72	24.42	23.54	23.36	19.86	18.16	17.80

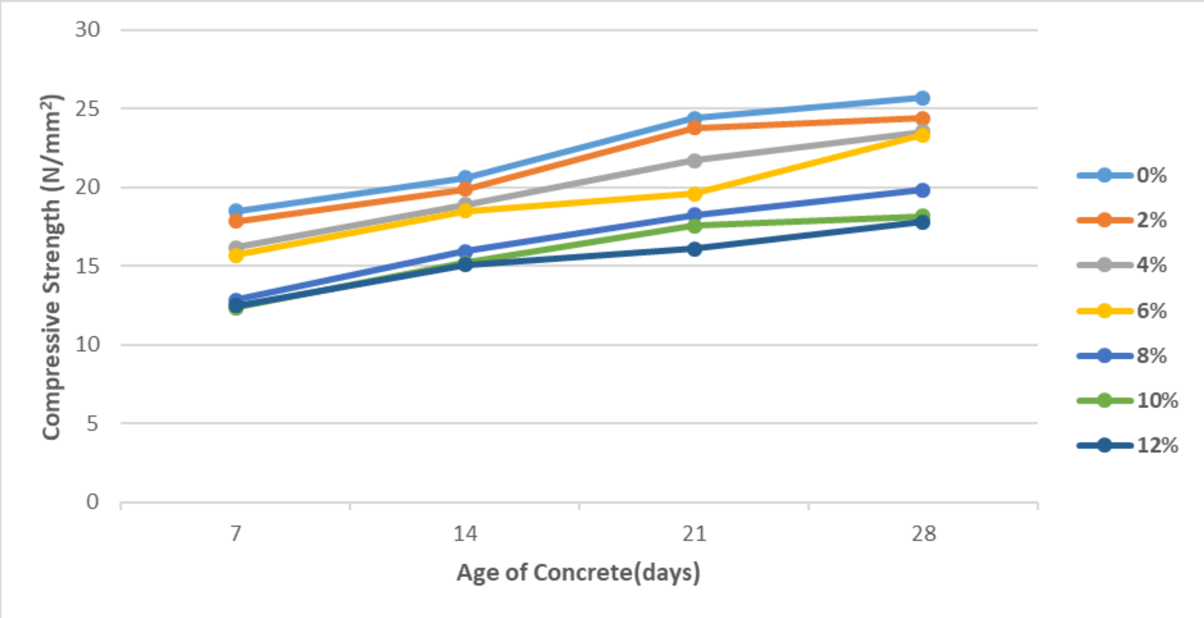

Figure 3: Average Compressive Strength of Washed Fine Aggregate Sample

3.4 Independent Sample t-test

Table 4: Shows an independent sample t-test conducted to determine the significant difference between the mean compressive strength of the concrete that contained 0% - 12% silt/clay as partial replacement and the mean compressive strength of the concrete as specified by BS 1881 at 7 and 28 days.

Table 4: Independent Sample t-test

Age	% Silt and Clay Content	p > 0.05	Sample
7 days (N/mm^2)	0%	0.004	0%
28 days (N/mm^2)	0%	0.003	0%
7 days (N/mm^2)	2%	0.001	2%
28 days (N/mm^2)	2%	0.003	2%
7 days (N/mm^2)	4%	0.003	4%
28 days (N/mm^2)	4%	0.003	4%
7 days (N/mm^2)	6%	0.005	6%
28 days (N/mm^2)	6%	0.009	6%
7 days (N/mm^2)	8%	0.057	8%
28 days (N/mm^2)	8%	0.054	8%
7 days (N/mm^2)	10%	0.060	10%
28 days (N/mm^2)	10%	0.061	10%
7 days (N/mm^2)	12%	0.061	12%
28 days (N/mm^2)	12%	0.060	12%

IV. CONCLUSION

[1] The compressive strength of concrete decreases with increases in silt/clay content. This reduction in compressive strength is as a result of improper bonding of silt and clay materials and rate of water absorption in concrete with higher silt and clay content.

[2] The workability average slump values obtained from the partial replacement of washed sample with processed silt and clay shows that as the silt and clay content are injected in to the washed sample at 2% interval, the values of slump are reducing from 65mm to 48mm.

[3] The compressive strength result of washed fine aggregate sample partially replaced with processed silt and clay at 2% interval met specified requirement from 0% to 6% silt/clay but gradually failed after 8% partial replacement with processed silt and clay.

[4] When the load is applied on the cubes the mode of failures shows that cubes with 10% and above processed silt and clay as partial replacement cracked completely

[5] The higher the silt and clay content value in a fine aggregate the more it requires higher water cement ratio to have adequate mix.

[6] Mixing result of concrete show that the constant water-cement ratio adopted for the entire 0% - 12% is not adequate to have homogenous mix particularly at 10% and above.

[7] From the independent sample t-test conducted, the significant difference is above p > 0.05 at 8% silt/ clay content.

Recommendation

It is recommended that all fine aggregates within Abuja and environ exceeding 7% silt and clay content are not advisable for concrete production. The 7% recommended is based on average compressive strength results obtained at 7 and 28 days of 6% and 8% partial replacement with processed silt and clay.

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