Effect of silt/clay Contamination in Sedimentary Rock Aggregate on Concrete Strength

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Abstract -Sedimentary rock aggregates are often ladened with clay and silt contamination which reduces drastically the strength of concrete produced with them below an expected level. This type of aggregate is, however, one of the commonest aggregate used in Nigeria for concrete production, especially in the regions where outcrops of sedimentary rock are predominant. These aggregates are used indiscriminately without cleaning off the 'contamination', taking for granted that the expected design strength will not be affected. This exposes users of this aggregate to serious structural failure and sometimes catastrophic ones. This work studied the detrimental effect of clay and silt contamination in sedimentary rock aggregates in order to advice stakeholders appropriately on the safe use of this aggregate. In so doing three samples of 12-mm maximum size coarse aggregate were collected, respectively, from three separate quarry sites of the aggregate in South-Eastern Nigeria, namely Oji-River, Neyi-Aguleri and Umunya quarries. The aggregates were subjected, individually, to sieve analysis test and concrete strength test of concrete made with them, using predetermined mix proportions. It was observed that the aggregates contained contaminations as follow: Neyi-Aguleri sample; 17.1%, Oji-River sample; 18.5% and Umunya sample; 35.3%. The following maximum compressive strength results were also obtained for the concretes made with the sample of aggregates: Neyi-Aguleri sample; 11.78N/mm2, Oji-River sample; 11.63N/mm2 and Umunya sample; 6.96N/mm2. It was observed that none of the samples attained the expected strength of 20N/mm2 for structural design of most buildings, and that the strength of concrete produced from them decreased rapidly with increase in contamination in the aggregate. It was also deduced that the strength of the resulting concrete would rise to a satisfactory level if contaminations could be reduce below 8% for all the sample. Sieving the aggregate with sieve size of about 4.75mm or washing the aggregate with water before use was recommended.

Keywords: Aggregates, Concrete, Contaminations, Strength

I. INTRODUCTION

Two types of rock aggregates commonly used in Nigeria for cement concretes are sedimentary rock aggregates and granite rock aggregates. The outcrops of these rocks occur so wide apart that they can hardly be used as alternatives without paying high price. In the South-Eastern block of Nigeria, one of the few places where granite rocks outcrop is in Abakaliki. Transportation cost of the aggregates from Abakaliki to any other place of use in that region is very high. For this reason the most frequently used type of aggregate in that region is sedimentary rock. Similar experiences are also found in areas where mainly granite rocks occur.

In terms of construction purpose, granite rock aggregates are of higher quality than the sedimentary rock aggregates. The granite rocks have greater mechanical strength and more uniform in both mechanical and chemical properties [1]. The sedimentary rocks are softer, lighter, more porous, sometimes highly contaminated with silt and clay and very erratic with respect to these mechanical properties as one moves from one quarry site to the other [2]. These aggregate properties influence concrete strength in different ways. In normal concretes, for instance, the strength of aggregate is of little significance, because most aggregates are stronger than the cement mortar at that level. In high strength concrete, however, the mortar strength is often greater than the strength of most aggregates and aggregates of very high strength and inter-locking property are normally sought [3]. The porosity of aggregate describes the tendency of the aggregate to absorb the mixing water that is meant for hydration of the cement to form strong mortar. The influence of porosity of the aggregate is controlled by ensuring that the aggregates are used at saturated-surface-dry condition. For clay and silt contamination the story is different: the aggregate must be further processed by sieving or washing. The presence of contamination in aggregates (that is particles passing sieve size 0.075mm) weakens the mortar phase generally and reduces the bond between aggregates and mortar.

The magnitude of strength reduction caused by contamination in aggregates depends on the magnitude of the contamination level [4]. This is the problem with sedimentary rock aggregate whereby aggregates from different quarry sites give different concrete strengths for the same mix proportion, because the aggregates undergo different levels of cleaning during production.

Another bad consequence of contamination in sedimentary rock aggregate is that it is not always easy to apply normal mix-design procedure to such concretes as the aggregate differs in property from granite rocks for which the charts and tables of the design process are built. These aggregate are consequently used, taking for granted that the expected strength will surely be met, and formal tests are omitted. This conjures the feeling that most of the building failures in the region where sedimentary rocks are abound are caused by this negligence [5].

This work, therefore intends to demonstrate the detrimental effect of clay and silt contamination on concrete strength through laboratory experiment, in order to emphasis the need to process sedimentary rock aggregate thoroughly to remove contaminations entirely before use in concrete production.

In order to achieve this, 12-mm (maximum size) coarse aggregate samples were collected from three different quarry sites, used in South-Eastern Nigeria, namely: Oji-River, Neyi-Aguleri and Umunya quarries. Sieve analysis and concrete cube crushing strength experiments were conducted on each of the samples in order to study the general trend of the concrete strengths with changes in levels of contamination in the aggregates, and to make recommendations accordingly to stakeholder for better concrete production with sedimentary rock aggregates.

II. METHODOLOGY

2.1 Materials and Equipment

The materials used for the experiments were coarse aggregates of 12-mm maximum size, fine aggregate, Portland cement and water. Three samples of coarse aggregates were obtained from three different sedimentary rock aggregate quarrys located at Oji-River, Neyi-Aguleri and Umunya, respectively; all in South-Eastern Nigeria. The fine aggregate was a clean river sand from the bed of the Niger River at Onitsha, Anambra State Nigeria. The cement used was a Portland cement, of strength designation of 42.5 N/mm2, a rapid hardening type, bought from cement dealers. Equipment used were a universal cube crushing machine, concrete moulds, B.S sieves, sieve shaker and weighing balance.

2.2 Experiments

The experiments conducted were sieve analysis and concrete cube crushing test. Each of the tests was conducted independently on the various aggregate samples using the following procedures.

i. Sieve Analysis

The sieves were selected in accordance with B.S 812 requirements, and arranged in descending order of sizes with the tray at the bottom. 1000 grams of air-dried aggregate sample was measured with a balance and introduced at the top of the stalk, which was vibrated with a sieve shaker, until passage of aggregates stopped. Aggregates retained in each sieve was weighed and tabulated accordingly. The grading curves of the aggregates were plotted on semi-log graphs.

ii. Concrete strength test

For ten pre-selected mix proportions (randomly chosen) two concrete cubes were prepared for each mix proportion, following the B.S standard procedures, for each aggregate sample. The cubes were cured for 28 days in water, then crushed in the universal crushing machine. The average crushing strengths for each mix-proportion and for each aggregate sample were tabulated.

III. RESULTS AND DISCUSSION

3.1 Sieve Analysis Results

The results of sieve analysis for the various samples are presented in Figs 1 to 3

Table 1: Sieve analysis table for Oji-River sample

B.S Sieve (mm or µ)	**Weight aggregate retained (g)**	**Cumulative weight passing (g)**	**Cumulative weight passing (%)**
26.5mm	78	922	92.2
19.0mm	11.5	910.5	91.1
13.2mm	72	838.5	83.9
6.3mm	375	463.5	46.4
5.6mm	36	427.5	42.8
4.75mm	41	386.5	38.7
2.4mm	91	295.5	29.6
1.2mm	19	276.5	27.7
600µ	13	263.5	26.4
420µ	27	263.5	23.7
300µ	3	233.5	23.4
210µ	19.5	214	21.4
150µ	23	191	19.1
75µ	6	185	18.5

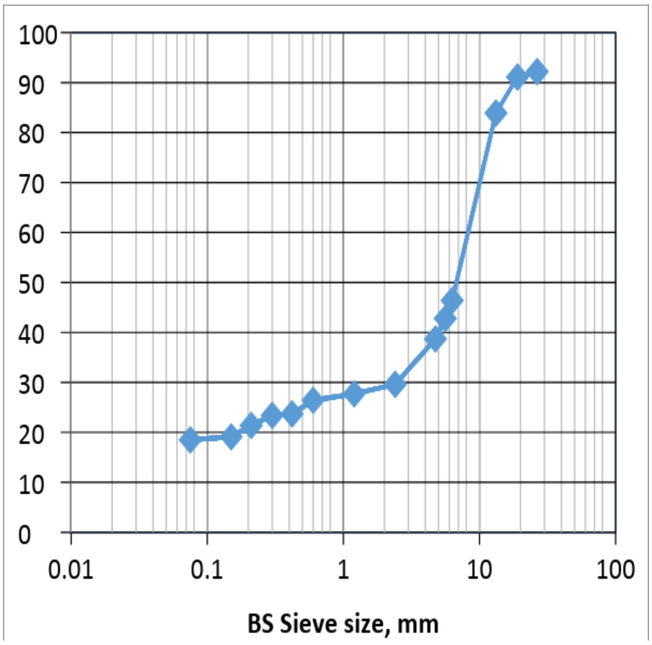

Fig 1. Grading curve for Oji-River sample

Table 2: Sieve analysis table for Neyi-Aguleri sample

B.S Sieve (mm or µ)	Weight aggregate retained (g)	Cumulative weight of aggregate passing (g)	Cumulative weight of aggregate passing (%)
26.5mm	-	1000	100
19.0mm	79	921	92.1
13.2mm	105	816	81.6
6.3mm	359	457	45.7
5.6mm	65	392	39.2
4.75mm	59	333	33.3
2.4 mm	80	253	25.3
1.2mm	10	243	24.3
600µ	11	232	23.2
420µ	18	214	21.4
300µ	11	203	20.3
210µ	11	192	19.2
150µ	12	180	18.0
75µ	9	171	17.1

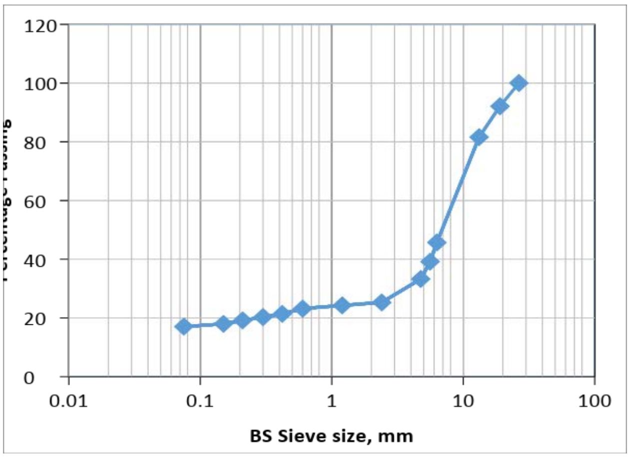

Fig 2. Grading curve for Neyi-Aguleri sample

Table 3: Sieve analysis table for Umunya sample

B.S Sieve (mm or µ)	Weight aggregate retained (g)	Cumulative weight of aggregate passing (g)	Cumulative weight of aggregate passing (%)
26.5mm	85	915	91.5
19.0mm	38	877	87.7
13.2mm	48	829	82.9
6.3mm	184.5	645	64.5
5.6mm	26	618.5	61.9
4.75mm	25	593.5	59.4
2.4 mm	56.5	537.0	53.7
1.2mm	36	501	50.1
600µ	33	468	46.8
420µ	57	411	41.1
300µ	3	408	40.8
210µ	14	394	39.4
150µ	21	373	37.3
75µ	20	3535	35.3

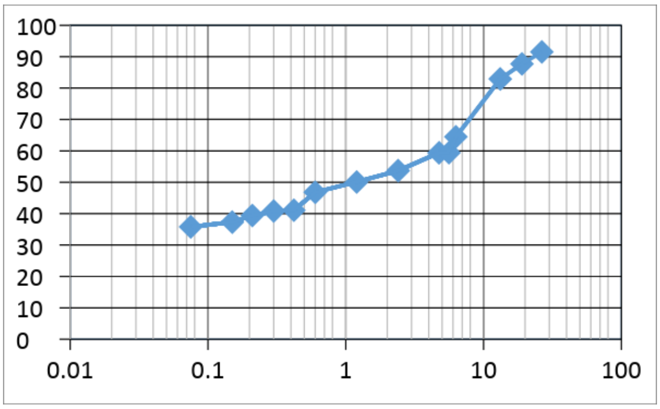

Fig 3. Grading curve for Umunya sample

From Table 1 and Fig.1, it can be seen that the quantity of silt and clay contamination is 18.5% for Oji-River sample. Values of 17.1% and 35.3% can be read for Neyi-Aguleri and Umunya samples, respectively. It can also be observed from the grading curve (Fig 3) that aggregate sizes less than 4.75mm (maximum sand size) are very few in Umunya sample because majority of them are silt and clay. The results for Oji-River and Neyi-Aguleri sample showcase a lot of aggregate particles of sand size with fewer quantity of contaminations. This means that Oji-River sample and Neyi-Aguleri samples are better concrete aggregates than Umunya sample.

3.2 compressive strength results

In Table 4, the combined compressive strength results of Oji-River, Neyi-Aguleri, and Umunya samples are given for 10 different mix proportions. The combined bar-chart (Fig. 4) shows the variation of the concretes' strengths with mix proportions, for the three samples.

Table 4: Concrete strength for the three samples

S/N	Mix proportion	Strength of concrete for each sample in N /mm^2		
		Oji-River	Neyi-Aguleri	Umunya
1.	1:1: 4 W/c = 006	7.18	8.07	2.59
2.	1: 1½ :1 ½ , W/c = 0.5	7.26	10.22	6.96
3.	1: 1½ : 3, W/c = 0.55	8.59	11.78	5.41
4.	1: 2½ : 4, W/c 0.555	5.7	8.77	3.85
5.	1: 1 ¼: 2 2/4, W/c = 0.55	8.44	9.81	4.47
6.	1: 1 ½ 3 ½ , W/c = 0.575	8.81	6.74	4.07
7.	1:2:4, W/c = 0.578	9.33	8.25	3.26
8.	1:1¼: ¼, W/c = 0.525	11.63	10.47	4.74

9.	1: 1 3/4 : 2 ¾, W/c = 0.528	10.0	8.92	4.37
10.	1:2: 3 1/2 , W/c = 0.553	9.56	9.57	3.85

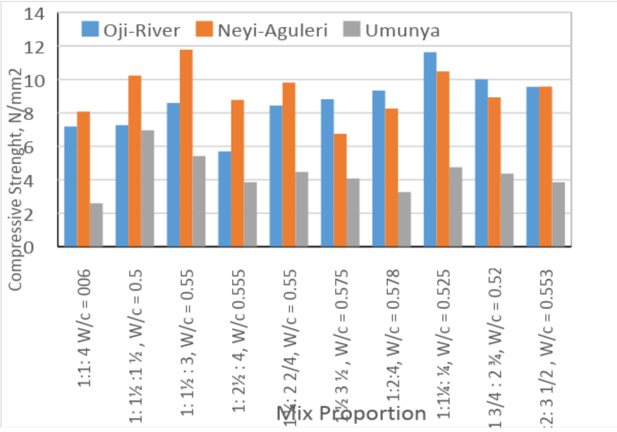

Fig 4: Combined bar chart of strength versus mix proportion for the three samples.

It can be seen from Table 4 that Neyi-Aguleri and Oji-River samples have much better strength of concrete than Umunya sample. It can be recalled by making reference to the foregoing that Neyi-Aguleri sample has 17.1% contamination, Oji-River; 18.5%, Umunya; 35.3%.

The general trend in the strength reduction is of inverse proportion to contamination level: Neyi-Aguleri sample has a maximum strength of 11.78N/mm2 and has the lowest contamination of 17.1%; Oji-River sample followed with a strength of 11.63N/mm2 and contamination of 18.5% (just 1.4% difference, but noticeable change in strength). Finally Umunya sample came with the least maximum strength of 6.96N/mm2. This also shows that 1.4% difference in contaminations produced a noticeable change between Neyi-Aguleri and Oji-River samples; and the strength reduced by half in Umunya sample when the contamination approximately doubled. One can then deduce from the trend that reducing the contamination to as low as 8% can bring the maximum compressive strength of the associated concrete to about 20N/mm2. These findings agree with the findings of published works on sieve analysis and strength tests of comparable concrete mixes [6,7]

Unfortunately, all these aggregates are used without cleaning them of contamination. It is generally assumed that a design strength of 20N/mm2 will always be attained – B.S 8110(1985) prescribes a mix proportion of 1.2:4 for a strength of 20N/mm2, commonly used for structural design [8]. This can cause very serious structural failures.

IV. CONCLUSION AND FUTURE SCOPE

From the foregoing discussions, change in compressive strength of concrete is very sensitive to contamination level. Contamination is a general characteristics of all sedimentary rock aggregate. It is therefore recommended that all sedimentary rock aggregate with noticeable contamination of silt and clay be sieved with sieve of aperture less than 4.75mm or washed with water to improve the strength of the resulting concrete and to eliminate catastrophic structural failures.

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