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The Effect of Fineness Modulus of Fine Aggregate on Concrete Compressive Strength

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Abstract

Concrete is the major material used for most civil engineering constructions like buildings, bridges, culvert, rigid road pavement, dam spillway and so on. Concrete is made from a mixture of cement, fine aggregate (sand), coarse aggregate (granite or gravel), and water. The fineness modulus is one of the physical properties of fine aggregates (sand). The Fineness Modulus (FM) of fine aggregates (sand) is obtained from the grading size distribution test as summation of percentage cumulative retained by series of sieves and divided the sum by 100. The fineness modulus of sand differs for each sand quarry. The purpose of this research is to analyze the effect of fineness modulus of fine aggregate (sand) from three different sand quarries on concrete compressive strength. The sand for the study were taken from three quarries (Ayegun, Akufo and Awotan) in Ibadan, Oyo state, Nigeria. The specimens of concrete used in the form of the cube measuring 150x150x150 mm amounted to 36 specimens. The compressive strength of concrete (f_c') targeted is 21 N/mm^2 with W/C ratio 0.5. Concrete mix ratio of 1:2:4 was batched by weight. The results showed that the fineness modulus of sand strongly influence the compressive strength of concrete. The classification of sand type is differentiated based on the results of fineness modulus test on each sand sample. Sand fineness modulus (FM) of Ayegun quarry is 2.64 called medium sand (zone 2). Sand fineness modulus of Akufo quarry is 2.35 called mild sand (zone 3), and, sand fineness modulus of Awotan quarry is 1.57 called fine sand (zone 4). Concrete compressive strength values of Ayegun, Akufo and Awotan quarries sand were 21.3 N/mm^2, 22.4 N/mm^2, and 20.5 N/mm^2, respectively. The value of sand fineness modulus does not affect the increase in the concrete compressive strength. The best classification of fine aggregate to increase concrete compressive strength is mild sand (Akufo quarry) and all the sand samples meet the planned concrete compressive strength of 21 N/mm^2.

Keywords: *Aggregate sources, Concrete, Compressive strength, Fine aggregate, Fineness modulus*,.

Introduction

Concrete is a composite material which is composed of aggregates, cement and water. Concrete is used more than any other manmade material in the world (Meilandy *et al.*, 2017). Concrete is an artificial material similar in appearance and properties to some natural lime stone rock. It is a manmade composite material, the major constituent being natural aggregate such as gravel, or crushed rock, sand and fine particles of cement power all mixed with water. The concrete as time goes on through a process of hydration of the cement paste, producing a required strength to withstand load. Concrete is one of the most commonly used material in construction industry and is the second most consumed substance in the world after water (Meilandy *et al.*, 2017).

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Sand is one component of concrete mixing and usually sourced from river beds or sand dunes originally formed by the action of winds. It is a naturally occurring granular material composed of finely divided rock and mineral particles. The usual particle size of sand grains is between 0.075 mm to 4.75 mm with further subdivision of coarse sand in range of 2 mm to 4.75mm, medium sand in range of 0.42 mm to 2 mm and fine sand in between 0.075 mm to 0.42 mm (Gauhar et *al.,* 2016). In the usage of concrete, the designer should be knowledgeable of the strength and weaknesses of concrete. Aggregate is the granular material, such as sand, gravel, crushed stone, crushed blast-furnace slag, or construction and demolition waste that is used with a cementing medium to produce either concrete or mortar. In the production of good concrete, fine and coarse aggregate combined in a correct ratio or proportion are bonded together by a cementitious material (usually Portland cement) to form a harden matrix concrete (Zongjin *et al.*, 2011).

The term coarse aggregate refers to the aggregate particles larger than 4.75 mm (No. 4 sieve), and the term fine aggregate refers to the aggregate particles smaller than 4.75 mm but larger than 75 μm (N0. 200 sieve). Gravel is the coarse aggregate resulting from natural disintegration by weathering of rock. The term sand is commonly used for fine aggregate resulting from either natural weathering or crushing of stone. Crushed stone is the product resulting from industrial crushing of rocks, boulders, or large cobblestones. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The usual particle size of sand grains is between 0.075 to 4.75 mm with further subdivision of coarse sand in range of 2 to 4.75mm, medium sand in range of 0.42 to 2 mm and fine sand in between 0.075 to 0.42 mm (Gauhar *et al.*, 2016). Sand is one component of concrete mixing and usually sourced from river beds or sand dunes originally formed by the action of wind. Donza *et al.* (2002), conducted research on high strength concrete with different fine aggregates and found that concrete with crushed stone sand results in higher strength than the corresponding natural sand concrete at all test ages. They also concluded that the shape and texture of crushed sand particles have an important effect on the interlocking of paste and aggregate particles, leading to an improvement of strength of concrete (Donza *et al.*, 2002).

Haritha and Srujana (2015) evaluated the use of crushed rock as fine aggregate in high strength concrete in comparison to the natural fine aggregate and concluded that the crushed rock as fine aggregate gives improved compressive strength of concrete. The split tensile strength of concrete also increases when fine aggregate is completely replaced with crushed rock (Haritha and Srujana 2015). According to Meilandy *et al.*,(2017), studied the effect of fineness modulus of sand on the concrete compressive strength. The study showed that the higher the value of the fineness modulus of sand does not affect the value of the compressive strength. In this study the effect of fineness modulus of fine aggregate (sand) on concrete compressive strength was investigated.

Materials and Methods

Materials

Ordinary Portland cement of grade 42.5 in accordance with (BS 12: 1996) was used. Crushed granite stone from Wetip quarry in Ibadan was used as coarse aggregate with maximum size of 19mm. The sand from the three different quarries location (Ayegun, Akufo and Awotan) were obtained and used as the fine aggregate.

Specimen Preparation

Concrete batching was done by weight using mix ratio 1:2:4.for all the classes of fine aggregates used and the planned concrete strength of 21 kN/m^2 and density of $2400kg/m^3$ with w/c factor of 0.5. Preparation of the planned test object is the cube with the size of 150 mm x 150 mm x 150 mm as much as 36 pieces of concrete cube with four stages of testing, namely the concrete age 7, 14, 21, and 28 days. Total specimens of cubes can be seen in Table 1. Concrete mix design by weight of each material can be seen in Table 2.

Table 1: The specimens 150x150x150 mm cubes used for the compression test.

No	Quarry	Cube concrete crushed (days)				Total
		7	14	21	28	
1.	Ayegun	3	3	3	3	12
2.	Akufo	3	3	3	3	12
3.	Awotan	3	3	3	3	12

Table 2: Concrete Material used for mixing by weight

Quarry Sand	Water (litre)	Cement (kg)	Sand (kg)	Granite (kg)
Ayegun	7	13.89	27.77	55.54
Akufo	7	13.89	27.77	55.54
Awotan	7	13.89	27.77	55.54

Sand Classification

The samples of sand taken from the three quarry locations were classified in accordance with SNI-T-15-1990-03, shown in Table 3. It classified the sand into four classes from Coarse to Fine sand using the sieve analysis test results. The sieve analysis test was conducted on all the sand samples by taking a measured amount (500g) of dry well pulverized soil and passing through a stack of progressively finer sieve sizes, with pan at the bottom. The amount of soil retained on each sieve is measured and the cumulative percentage of soil retained or passing through each sieve is determined to get the soil fineness modulus and classification in Table 3, the result of sieve analysis for each sample is shown in Tables 4-6.

Table 3: Classification of Fine Aggregate based on SNI-T-15-1990-03

sieve size (mm)	**% passing for**			
	Grading Zone 1	**Grading Zone 2**	**Grading Zone 3**	**Grading Zone 4**
9.52	100	100	100	100
4.75	90-100	90-100	90-100	90-100
2.4	60-95	75-100	85-100	95-100
1.1	30-70	55-90	75-100	90-100
0.6	15-34	35-59	60-79	80-100
0.3	5-20	8-30	12-40	15-50
0.15	0-10	0-10	0-10	0-15
Pan	0	0	0	0
Classified	**Coarse sand**	**Medium sand**	**Mild sand**	**Fine sand**

Table 4: Sieve Analysis of Ayegun Quarry

Sieve Size (mm)	Weight Ret.	% Ret.	% Cumulative Ret.	% passing	limit of Zone 2
9.52	0	0	0	100	100
4.75	3.1	0.62	0.62	99.38	90-100
2.36	30	6	6.62	93.38	75-100
1.18	64	12.8	19.62	80.38	55-90
0.6	175.95	35.19	54.61	45.39	35 -59
0.3	149.75	29.95	84.56	15.44	8-30
0.075	67	13.4	97.96	2.04	0-10
Pan	10.2	2.04	-	-	-
Total	**500**		**263.99**		

Table 5: Sieve Analysis of Akufo Quarry

Sieve Size (mm)	Weight Ret.	% Ret.	% Cumulative Ret.	% passing	limit of Zone 3
9.52	0	0	0	100	100
4.75	2.54	0.508	0.508	99.49	90-100
2.36	31.5	6.3	6.808	93.19	85-100
1.18	42.7	8.54	15.348	84.6	75-100
0.6	100	2 0	35.348	64.65	60-79
0.3	230	46	81.348	18.65	12-40
0.075	73.26	14.65	95.998	4	0-10
Pan	20	4	-	-	-
Total	**500**		**235.34**		

Table 6: Sieve Analysis of Awotan Quarry

Sieve Size (mm)	Weight Ret.	% Ret.	% Cumulative Ret.	% passing	limit of Zone 4
9.52	0	0	0	100	100
4.75	1.38	0.28	0.28	99.72	95-100
2.36	6.6	1.32	1.6	98.4	95-100
1.18	8.65	1.72	3.32	96.68	90-100
0.6	35	7	10.32	89.68	80 -100
0.3	210	42	52.32	47.68	15-50
0.075	182.55	36.51	88.83	11.17	0-15
Pan	55.84	11.17	-	-	-
Total	**500**		**156.67**		

Results and Discussion

Fineness modulus and sand classification

The value of the fineness modulus of the three quarries sand (Ayegun, Akufo and Awotan) are 2.64, 2.35 and 1.57 respectively. This show that Ayegun quarry sand has the highest value of fineness modulus as shown in Figure 1. The sand from the three quarries were also classified according to SNI-T-15-1990-03 as medium sand (zone 2), mild sand (zone 3) and fine sand (zone 4) respectively as shown in Figure 2-4. The result categorized the sand from medium to fine sand generally and this is also in conformity with Meilandy *et al.*, (2017) work that categorized the sand from Johar, Tanjung Karang and Alur Bamban quarry in Aceh Tamiang District as medium, mild and fine sand respectively.

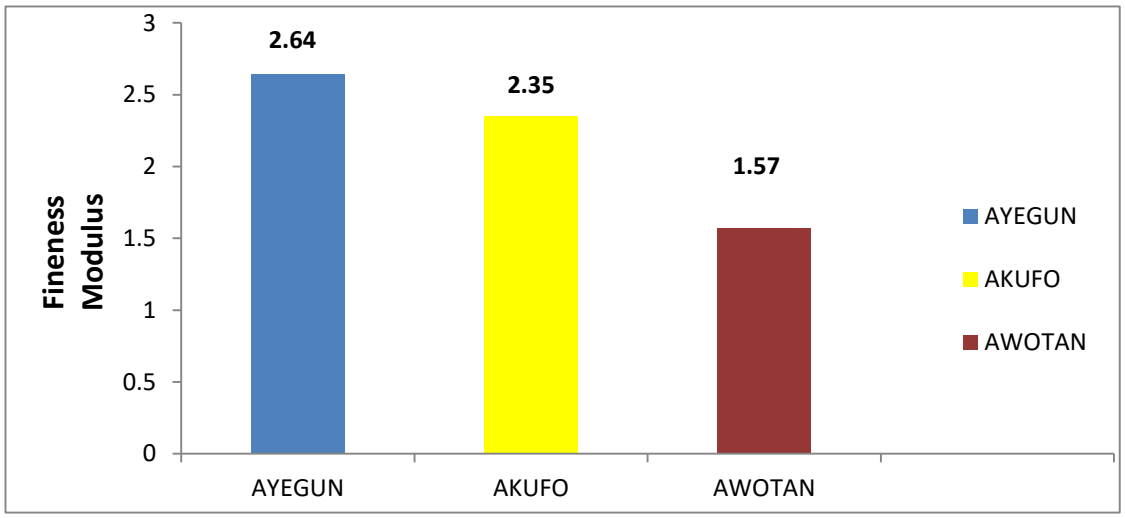

Figure 1: Graph Fineness Modulus of Fine Aggregate

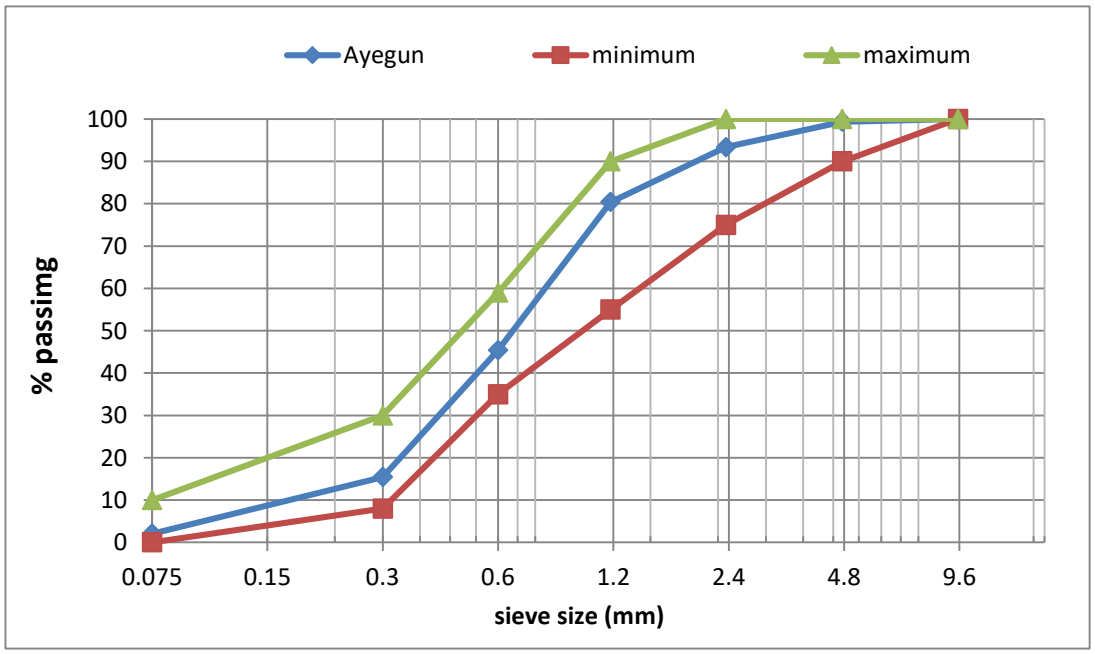

Figure 2: Graph Sieve Analysis of Ayegun Quarry

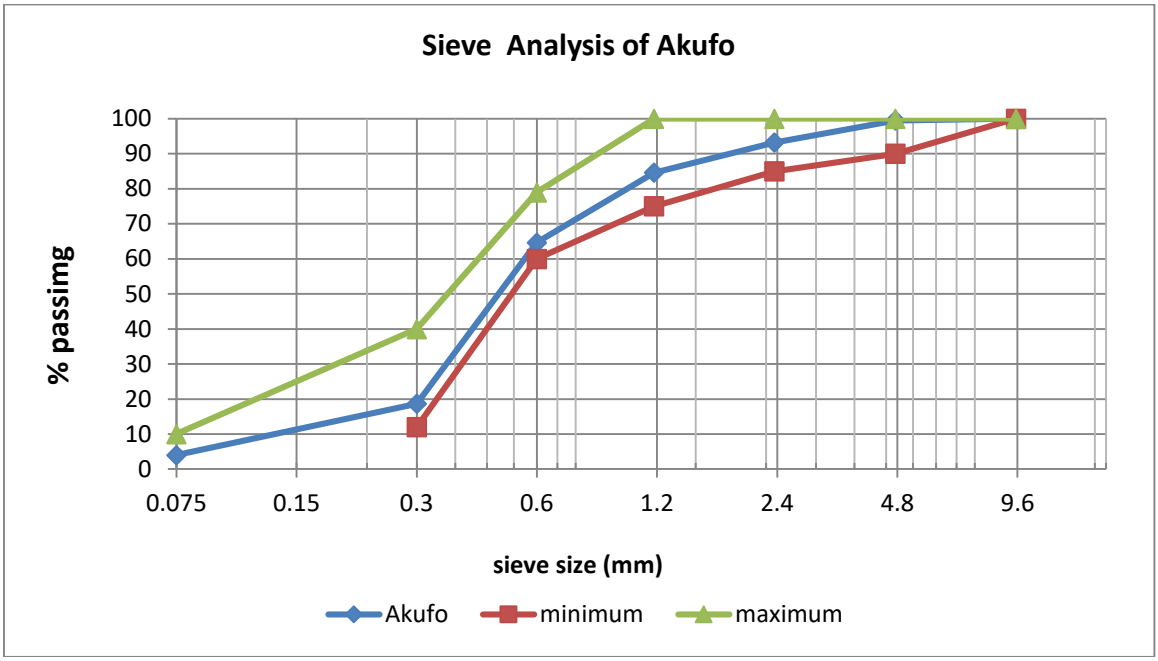

Figure 3: Graph Sieve Analysis of Akufo Quarry

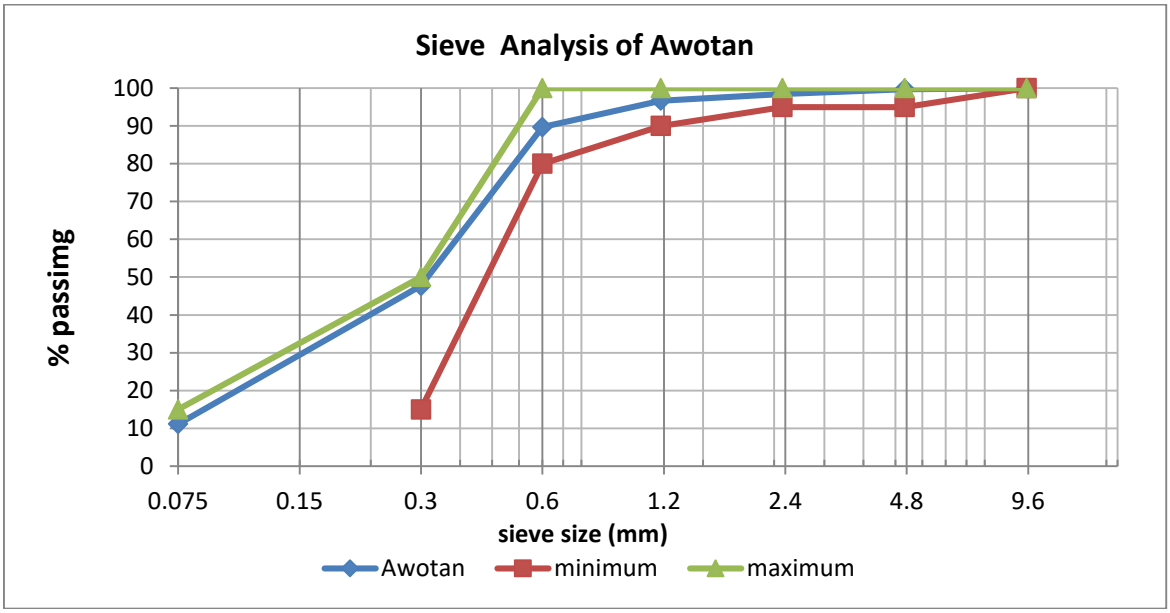

Figure 4: Graph Sieve Analysis of Awotan Quarry.

Concrete compressive strength test

The graph of mean value of concrete compressive strength against curing age for three quarries sand sample is shown in the figure 5. It can be observed from the figure that the Akufo sand has the highest value of concrete compressive strength of 22.44 N/mm^2, follow by Ayegun with 21.33 N/mm^2 and that of the Awotan has lowest value of 21.1 N/mm^2 at 28 days. All the sand samples meet the planned concrete strength of 21 N/mm^2 and are all good as fine aggregate for the concrete.

The results of the compressive strength values also indicated that the fineness modulus of sand does not has influence on it. This is because the sand with the highest value of the fineness modulus (Ayegun) does not give the highest value of the concrete compressive strength. This finding can be attributed to the fact that other factors like cement content and water/cement ratio were same for all the samples and this also has great influence in the concrete compressive strength. The research finding is in accordance with the work of Meilandy et al (2017), which revealed also that the fineness modulus of sand does not affect the compressive strength of concrete.

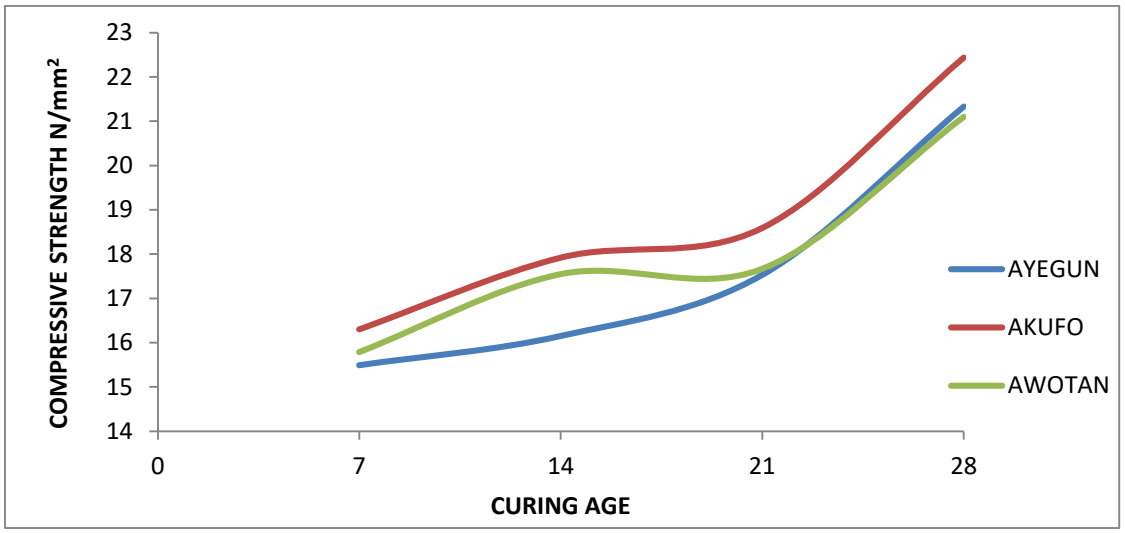

Figure 5: Compressive strength.

Conclusion

The following conclusions were drawn from the research work.

i. The fineness modulus of sand does not affect the concrete compressive strength as the mild sand of fineness modulus of 2.35 gives the best classification that have the highest concrete compressive strength according to this research finding.
ii. The sand with the highest fineness modulus of 2.64 (Ayegun) does not give the corresponding highest compressive strength.
iii. All the quarries sand samples (Ayegun, Akufo and Awotan) are good for fine aggregate in concrete as they all give the strength values that fall within the planned strength value of 21 N/mm^2.

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