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Effect of various types and sizes of aggregate on self-compacting concrete

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Abstract. Aggregates play important role in concrete; it serves as Structural fillers which are used in concrete production. Aggregate sizes, types and gradation are the most important factor when selecting aggregate. This study examines incorporating different sizes and types of coarse aggregate. Testing rheology and strength of self-compacting concrete mixes at varying sizes and different types of coarse aggregate. The various aggregate sizes used in the Various mixes are 10, 12.5 and 20mm, the types of aggregate used are granite, gravel and ceramic tiles and superplasticizer used is Conplast SP 430 with water cement ratio of 0.45. slump flow test, T50, L-box and V-funnel test were carried out on the various mix to determine the fresh properties of the concrete mix. The mechanical properties (compressive, flexural and split tensile strength test) were conducted on the mixes at different curing age (7, 21 and 28 days). The aggregate size 10mm and granite types had the highest slump flow for the fresh test. It was observed from the mechanical test 10mm and 12.5mm granite size had a higher strength than gravel and ceramic tiles.

1. Introduction

Self-compacting concrete (SCC) is a highly workable concrete which was introduced by a Japan researcher in the late 1980's. This concrete can flow freely without restriction and compact under its own weight without restriction without bleeding and segregation taking place. SCC ensures structural performance and long-term durability in structures not only that but also maintains homogeneity in placement and transportation of the fresh mix. Self-compacting concrete was brought about by reduction in quality construction work and skilled workers the concrete was proposed by Okamura [1] at Tokyo University In 1988. When self-compacting concrete is poured into the formwork, it fills the formwork uniformly at every corner while maintaining homogeneity and stability all through the form work [1]. A good balance must be ensured by controlling the total volume used, aggregate particle size and type and superplasticizer with water cement ratio to obtain good workability. To produce a good mix, mix proportion and selection of aggregate with specific characteristic are very important. [2] achieved self-compacting ability by adjusting the water/powder ratio and superplasticizer dosage but made the coarse and fine aggregate fixed. [2] also presented anchorage performance at highly congested regions of reinforcement mostly beam to column joint area by investigating the effect of aggregate size on self-compacting concrete and normal concrete tested by axial tensile loading. He reported that the beam column joint can be prepared using 20 mm and 16 mm of coarse aggregate sizes and 10 mm and 8 mm size can be used in self-compacting concrete. [3] carried out an experiment on the properties of SCC with different types of aggregates (dolomite, gravel, basalt) at different percentages of water and cement were designed; result showed that slump flow concrete produced with dolomite is greater than other concrete mix. The test (compressive, split tensile and flexural) on the hardened concrete produced with dolomite gave better result. For compressive strength at 28 days gave 397,466 and 462 kg/cm^2, split tensile gave 36.2, 37.3 and 48.2 kg/cm^2 and for flexural strength gave 59.1, 72.3 and 89.2 kg/cm^2 at different water cement ratio. [4] investigated on the consequence of dissimilar coarse aggregates sizes on the properties of normal compacting concrete and SCC using different aggregate sizes (20, 16, 12.5, 10 mm) and he stated that the fresh properties reduced with increase in size of CA and the hardened properties of NCC and SCC of 20 mm size of aggregate used produced better compressive strength in the concrete. [5] assessed the strength properties of cassava peel ash concrete. Cassava peel ash was used to partially replace cement at varying percentages and curing days. It was seen that the concrete can be used for light construction works where high strength is not a major requirement. [6] used statistical analysis to determine the dataset on predictive compressive strength models of SCC. They concluded that water cement ratio, aggregate combination, superplasticizer and binder combination are variables that affect compressive strength for 7, 28 and 90 days. [7] concrete durability of palm oil fuel ash at 14, 28 and 90 days of water absorption on the cube specimen of where also tested for acid and sulphate resistance, from the result it is observed mixes with ash had low resistance to the acid and sulphate test compared to SCC with palm oil fuel ash which had high values. Nine mixes and one NCC (control) were made by [8] to evaluate the performance of SCC with high volume of fly ash at 40, 50 and 60%. In this study the water cement ratio varied from 0.35-0.45. 26-48 MPa strength was achieved by the SCC mix at 28 days and economical SCC mixes was successfully developed by high use of class F fly ash. This present study will determined the effect of various type and size of aggregate on SCC.

1.1 *Properties of SCC*

As previously stated in introduction, concrete can be referred to as Self Compacting if it meets the basic requirements of segregation resistance and passing and filling ability. Below is a table showing a typical acceptable criterion for SCC, with respect to the equipment used to test SCC in this project research.

Table 1. Acceptance Criteria for SCC [9][10]

S/N	Methods	Properties	Units	Minimum range	Maximum range
1	slump flow	filling ability	Mm	650	800
2	T50cm	filling ability	Sec	2	5
3	V – funnel	filling ability	Sec	6	12
4	L – box	passing ability	h2/h1	0.8	1.0

2. Experimental Study and Methods

2.1. Materials

Cement serves as a binder; the cement used in all the mixtures for each of the coarse aggregate for this research work was ordinary Portland cement (OPC) of grade 53, manufactured by Dangote cement Plc. Three size of coarse aggregates were used 10, 12.5, 20 mm and three type of coarse aggregates were used gravel, granite and ceramic tiles as seen in Figure 1. The fine aggregate is sharp sand without any organic impurities from local source in Abeokuta Ogun state, Nigeria. The water used for the study was obtained from a borehole laboratory at Covenant University. The water was clean and free from any visible impurities. The superplasticizer used is conplast SP430 and it gotten from a pure-chem shop in Ota.

Figure 1. Different coarse aggregate type used

2.2. Mix Proportion

Table 2. Mix Proportion of Self Compacting Concrete

Mix NO	Water	cement	Sand	Coarse aggregate	Superplasticizer	Types and Sizes of Coarse Aggregate
Mix1	171	510	780.26	735.44	2%	10mm
Mix2	171	510	780.26	772.53	2%	12.5mm
Mix3	171	510	780.26	780.55	2%	20mm
Mix4	171	780.26	780.26	720.59	2%	Granite
Mix5	171	780.55	780.26	720.65	2%	Gravel
Mix 6	171	772.53	780.26	720	2%	Ceramic Tiles

2.3. Test Procedure

A total number of nine number of mixes were cast for each but their workability properties where first tested and recorded for different sizes and types of coarse aggregate. The following fresh concrete test where carried out; slump flow which test the Self-compacting concrete in the absence of obstruction to assess the horizontal free flow as seen in Figure 2, T50 cm slump diameter is used to indicate deformation rate of the mix while the time taken from when the cone is lifted to the concrete reaching the 50 cm diameter is known, Figure 3 shows the V-funnel test which is the time taken for the concrete to flow through the v-funnel apparatus and Figure 4 shows the L-box test which is the extent to which the concrete flow is subjected to blocking by reinforcement to test each mix for flow ability, passing ability and filling ability. Compressive, Flexural and Split tensile test were carried out on the mixes to test their hardened properties at 7, 21, and 28 days of curing.

Figure 2. Slump flow test

Figure 3. V-funnel test

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Figure 4. showing the L-box test

3. Result and Discussion

3.1. Fresh Test

The difference between the workability mixes of the same water cement ratio and superplasticizer percentage is reported in the table 3 below.

Table 3. Fresh properties of aggregate size and types of self-compacting concrete:

S/N	Aggregate	Slump flow	T50cm	V-funnel	L-box
1	*10mm*	750	3.3	9.5	0.95
2	*12.5mm*	720	3.8	10.5	0.90
3	*20mm*	680	4.6	11.08	0.85
4	*granite*	750	3.3	9.5	0.95
5	*gravel*	700	3.5	11	0.84
6	*ceramic tile*	650	4.3	11.5	0.82

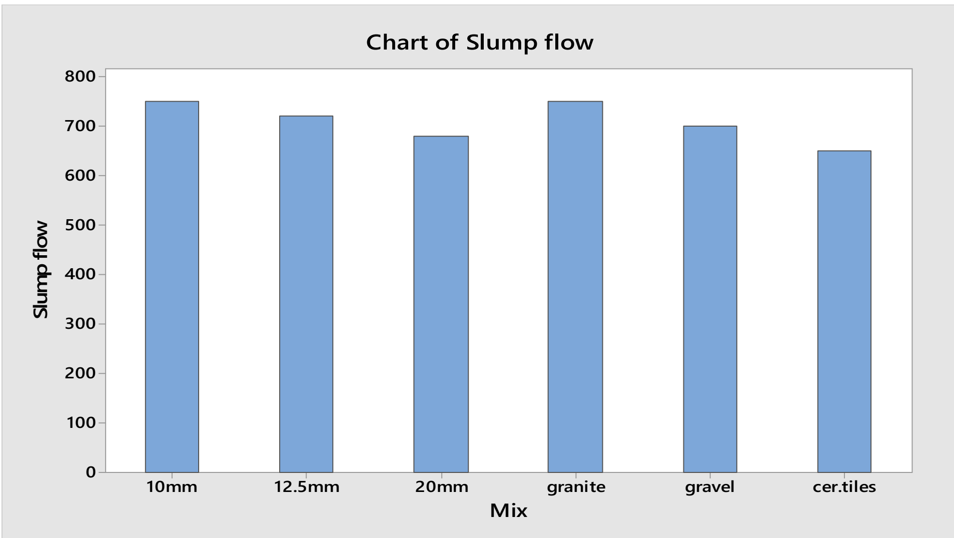

Figure 5. showing the slump flow of various aggregate size mix

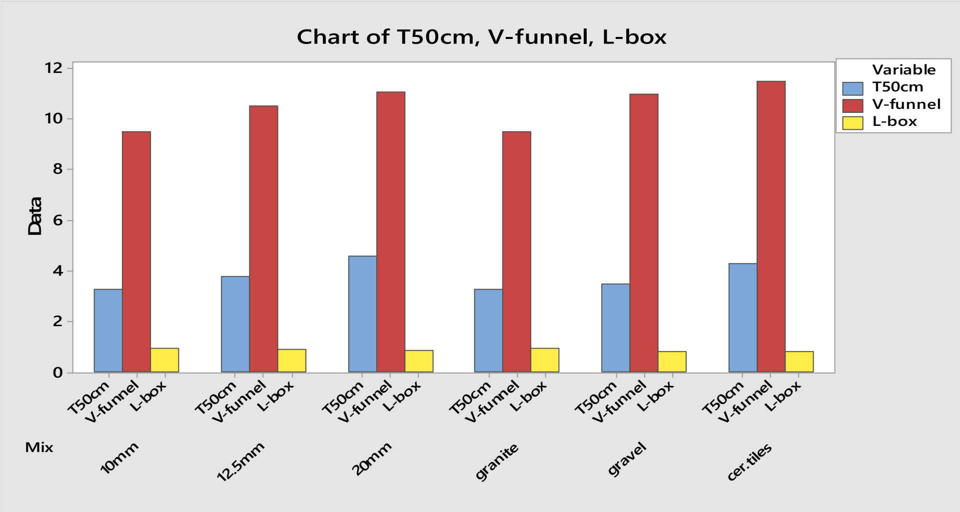

Figure 6. Showing the T50 slump, v-funnel and L-box test of the aggregate size

From the Figure 5 and 6, it is noted that the granite mix had the highest passing ability for the test on various aggregate type while for the test on aggregate sizes the 10mm size provided a higher workability in terms of slump flow which gave a slump of 750 mm which according to [10] standard gave a good slump for SCC. Also, it was observed through the workability test for both 10m size and granite types of aggregate gave good filling, passing and flowing ability. For the different aggregate size workability test it was observed that the higher the aggregate size the lesser the values obtained.

3.2. Mechanical Test

Table 4. Showing the hardened properties of the various aggregate sizes and types

Size of CA	compressive strength (N/mm^2)			Flexural strength (N/mm^2)			Split Tensile strength (N/mm^2)		
	7day	21days	28days	7days	21days	28days	7days	21days	28days
10mm	27.23	28.20	35.40	5.78	6.80	7.50	2.50	3.48	4.01
12.5mm	25.50	26.60	30.1	5.50	6.20	6.85	2.31	3.12	3.60
20mm	23.91	25.50	29.05	5.08	5.80	6.03	2.10	3.04	3.23
Granite	26.83	30.5	35.5	5.39	6.33	6.50	2.30	4.2	4.37
Gravel	24.27	28.07	33.7	5.18	6.23	6.38	2.25	4.06	4.26
Ceram.Tiles	23.05	26.9	31.5	5.06	5.64	5.97	2.14	3.84	4.02

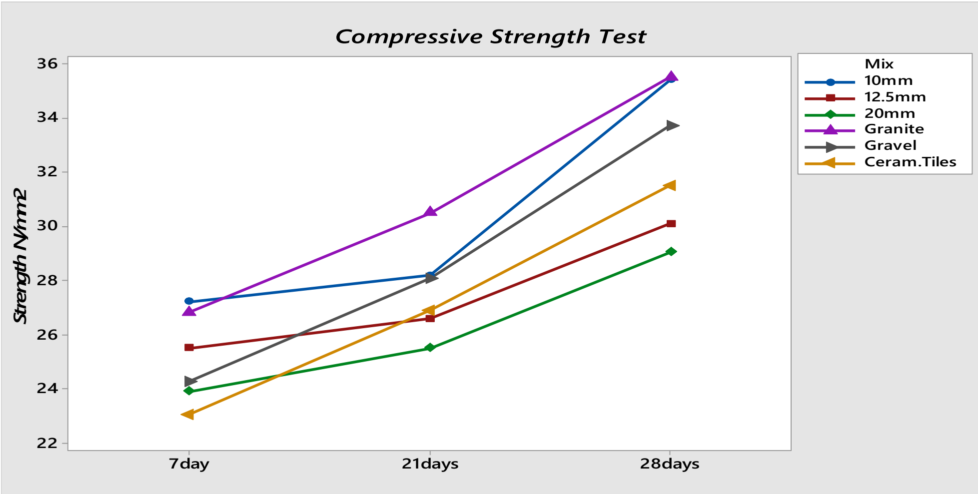

Figure 7. Chart showing compressive strength of various aggregate type and size

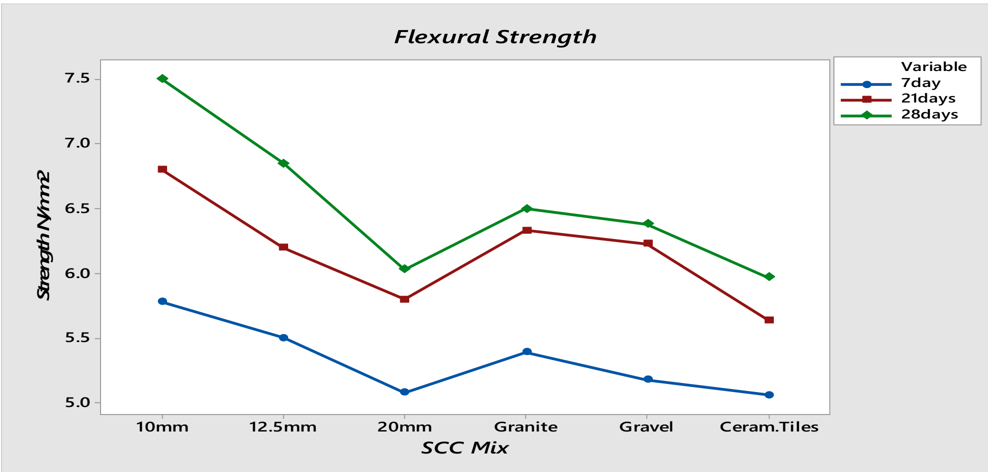

Figure 8. Chart showing flexural strength of aggregate at varying curing days

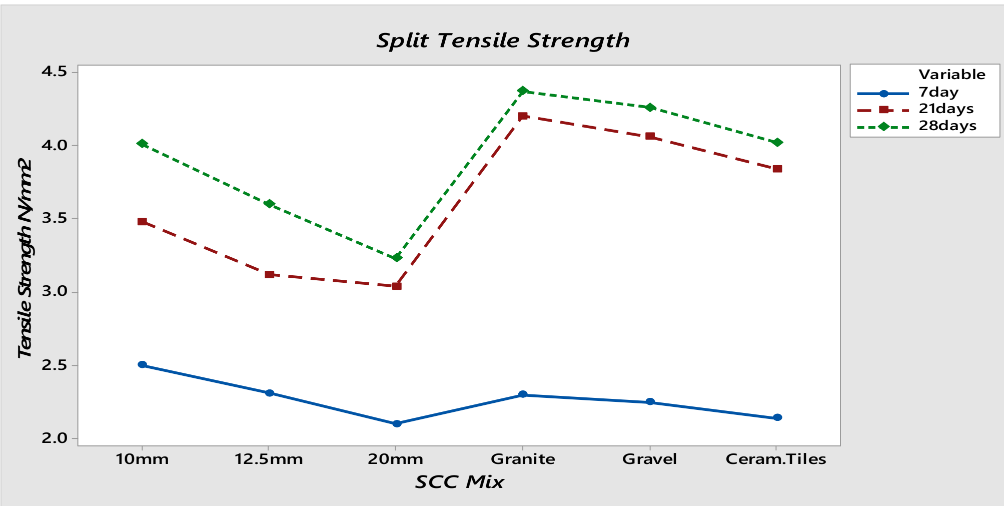

Figure 9. Showing split tensile strength of aggregate mixes at varying curing days

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From the result above in Figure 7 at 7, 21 and 28 days of compressive strength (IS) of same water ratio and superplasticizer dosage shows that 10 mm aggregate size had the highest resistance to load applied and value 35.40 N/mm^2 with a strength increase of 30% at 28 days while for the test on different aggregate types, granite mix had a compressive strength of 35.5 N/mm^2 with strength increase of 32%, gravel 38.8% and ceramic tile 36.7% at 28 days. The result of the specimen under split tensile strength test, specimen undergoes tensile strength to be estimated [13], which granite gave the highest resistance and 10 mm aggregate size gave a better strength of 4.01 N/mm^2 and increased in strength by 15.2% at 28 days. From the result reported it was noted that 10 mm achieved a flexural strength of 5.78 N/mm^2 at 7 days and 7.50 N/mm^2 at 28 days. Flexural strength of aggregate type mix varied between 5.06 and 5.39 N/mm^2 at 7 days and between 5.97 and 6.50 N/mm^2 at 28 days the concrete mix with granite had the best strength development behaviour. The 10 mm mix had the highest strength increase of 60.4% from 7 to 28 days.

4. Conclusion

From the detailed experiment conducted on the aggregates types and sizes to compare which aggregate size produce the best workability and suitable for SCC mix, which aggregate type produced the best self-compacting mix and the best hardened properties. It was generally observed in all mix that addition of superplasticizer enhanced the workability. Aggregate and superplasticizer have important role in concrete mix, From the test conducted and result observed the following conclusion where drawn from the workability test and result obtained it was concluded that aggregate size and type mix all gave good workability result with slump flow range of 650-750 mm which 10mm size and granite type gave the highest slump. The slump value increased with the reduction of aggregate size and reduced with the aggregate type used in the concrete mix with ceramic tile yielding less slump. Also, for the passing and filling ability test both the 10mm and granite mix gave good result.

Form the mechanical test carried out, the compressive strength of granite cube was higher compared to gravel and ceramic tiles which had a decrease resistance to the compressive load applied. The decrease in compressive strength of ceramic tile resulted in weaker bonds developed between the cement and aggregate used or the angular nature of the broken tiles. The compressive value of the cube size of 10mm was higher compared to 12.5 and 20 mm size of aggregate. The lesser aggregate size (10 mm) resulted in an increase surface area of the binding material which caused an increase in the strength.

The split tensile strength of concrete mix at 7 to 28 days of the aggregates mix of both size and types was observed to increase. For aggregate size mix it was observed that the marginal difference in the varying sizes at 28 days were more significant. The 10 mm mix had the highest strength increase from 60.4% at 7 to 28 days. Granite type mix had the highest resistance to lateral expansion of 4.37 N/mm^2. The flexural result reported 10mm achieved a flexural strength of 5.78 N/mm^2 at 7 days and 7.50 N/mm^2 at 28 days. Flexural strength of aggregate type mix varied between 5.06 and 5.39 N/mm^2 at 7 days and between 5.97 and 6.50 N/mm^2 at 28 days the concrete mix with granite had the best strength development behaviour.

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