EFFECTS OF SEPARATION OF GRAIN SIZES OF FINE AGGREGATE ON PROPERTIES OF CONCRETE CONTAINING GRANITE FINES

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ABSTRACT

In this study, seven grain size ranges of granite fines were used: 4.75 – 3.35mm, 3.35 – 2.36mm, 2.36 – 1.70mm, 1.70 – 1.18mm, 1.18 – 0.30mm, 0.30 – 0.063mm and 4.75 – 0.063mm (those containing all grain sizes). The properties considered for the investigation are compressive and flexural strengths, density and workability. Four mix proportions of cement, fine and coarse aggregates 1:1½: 3, 1:2:4, 1:3:6 and 1:0:3 (no fines) by weight were used in the tests. 100mm cubes and 100 x 100 x 500mm beams were cast and cured in water at 21 ± 1°C. The specimens were tested at 7, 14, 21 and 28 days. The results showed that the compressive and flexural strengths and density increased with decreasing grain sizes, while the workability decreased with decrease in grain sizes.

Keywords: *Grain size, granite fines, compressive strength, flexural strengths, workability, density.*

INTRODUCTION

The use of abundantly available materials to replace normal aggregates in concrete for structural purposes would prove to be economical provided reliable design data are available. In Nigeria, granite fines are available in large quantity. They are used as a base course in road construction, for making well and culvert rings, electric poles and in the manufacture of hollow-block wholly or partially when blended with other soils. The proportioning of the soils is based on trial and error. The advantages of granite fines over conventional fine aggregate (sand) are that they do not the require additional washing before they are used and procurement process is less tedious. Also it has been reported [1] that the strength of concrete containing 100% granite fines is higher than that of 100% sand. This led to the conclusion that granite fines could be used wholly in concrete to replace sand. In Nigeria and other countries, other local raw materials, (laterite [2] and scoria [3]) have been investigated and found suitable as substitute for sand. The replacement of coarse aggregate with palm kernel shell [4] resulted in reduced strength of the concrete produced.

The search for alternative materials to cement has led to the investigation of sawdust ash [5] Mauritian bagasse ash [6], pulverised fuel ash [7] and bauxite pozzolana [8] as its possible complement in concrete but the reports indicated that these materials are not suitable substitute for cement. Traditionally, concrete has been accepted to be a durable material but this view is no longer strongly held. Inadequate design, care and supervision during construction and wrong choice of construction materials are among the reasons for concrete incapability to satisfy this requirement. The present investigation provides information on some structural properties of concrete such as compressive and flexural strength, workability and density and the effect of grain size fractions of granite fines on them.

MATERIALS AND EXPERIMENTAL PROCEDURE

The cement used for this investigation is ordinary Portland cement whose properties conform to BS 12 [9]. The particle sizes of the coarse aggregate used are those passing sieve with aperture 19mm but retained on 10mm aperture. Sieves with apertures 4.75mm, 3.35mm, 2.36mm, 1.70mm, 1.18mm, 0.30mm and 0.063mm were used for the grains separation. The particle ranges are 4.75 – 3.35mm (those passing 4.75mm but retained on 3.35mm), 3.35 – 2.36mm, 2.36 – 1.70mm, 1.70mm – 1.18mm, 1.18 – 0.30mm, 0.30 – 0.063 and 4.75 – 0.063 (those containing all grain sizes).

Each particle size range was collected separately in a sack. Four mix proportions of cement, fine and coarse aggregates were used namely 1:1½: 3, 1:2:4, 1:3:6 and 1:0:3 (no fines) with

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corresponding water/cement ratios of 0.60, 0.70, 0.90 and 0.50.

100mm cubes and 100 x 100 x 500mm beams were used. Three cubes were cast for each mix and age, batching was by weight. Mixing was done mechanically in a mobile rotating drum type mixer. The specimens were made in accordance with BS 1881 [10]. The concrete components were thoroughly mixed in the mixer, while mixing continued, the required quantity of water was added. Slump test was carried out on each freshly prepared concrete batch to measure the variation of workability with grain size ranges. After the specimens had been cast, they were left in the moulds for 24 ± ½ hours to set under ambient temperature. They were subsequently demoulded and transferred into a curing tank containing clean water. The curing temperature was 21 ± 1°C.

SPECIMEN TESTING FOR STRENGTH

Three cubes for each mix proportion were tested at 7, 14, 21 and 28 days on 600kN Avery Denison machine using a loading rate of 120kN per minute. The average load at which a group of three cubes failed was used to determine the compressive strength. The beam specimens were tested at 28th day on ELE Universal beam testing machine using a loading rate of 120kN per minute. A third point loading on simply supported beams with effective span of 400mm was used. The mean value of the load at which a group of three beams failed was used to calculate the flexural strength.

RESULTS AND DISCUSSION

The results of the tests are presented in Tables 1 and 2.

Compressive and flexural strengths

The strength values increased with decrease in grain sizes. This trend was observed within the grain size ranges of 4.75 and 0.30mm. From 0.30 to 0.063mm particles, the strength values decreased. In Table 1 for 1:1½: 3 mix, the compressive strength of concrete made with 4.75 – 3.35mm particle size is 18.7N/mm² at 28-day. For the same curing age and mix the values are 20.8Nmm², 23.6N/mm², 28.2N/mm², 31.3N/mm² and 23.1N/mm² for 3.35 – 2.36mm, 2.36 – 1.70mm, 1.70 – 1.18mm, 1.18 – 0.30mm and 0.30-0.063mm respectively. The corresponding flexural strength values are 3.3N/mm², 3.6N/mm², 4.0N/mm², 4.3N/mm², 4.4N/mm² and 3.6N/mm² for the same mix, age and particle size ranges. The highest strength values (compressive and flexural) were obtained for particle size range 1.18 – 0.30mm. Other ages and mix proportions followed the same trend. The initial increase in strength values from 4.75mm particle size to 0.30mm size may be attributed to the fact that the smaller the particles, the more they can be closely packed to fill the voids within the coarse aggregate fractions. The greater the amount of solid particles that can be packed into a given volume of concrete the higher its strength.

The reduction in strength from 0.30mm – 0.063mm particles size may be due to presence of high proportion of dust particles which may act as coating on the coarse aggregate. The dust coating hinders the bond between the concrete matrix resulting in poor strength. The 28-day compressive and flexural strength values of the concrete that contained all the grain sizes are 27.1N/mm² and 3.8N/mm². This is 14% less than the maximum compressive and 15% of the flexural strength values obtained for 1.18 – 0.30mm particle size range that gave the highest values. The lower strength recorded by concrete that contained all the particle sizes can be attributed to the presence of different particle size ranges with varying strength values. The compressive strength at 28-day for no fine concrete is 17.9N/mm² (Table 1). Lack of fine aggregate reduced the volume of cement paste available to hold the coarse aggregate in suspension. The fine aggregate is to fill the interstices between the coarse aggregate grains and therefore the absence of fine aggregate suggests the presence of high void ratio in concrete matrix in which free water could be entrapped. This resulted in lower strength because of concentrations of stresses around the voids. In a compressed test specimens, compressive and tensile stresses concentrate at the voids in the concrete matrix, the tensile stresses act on plane parallel to the compressive force.

Table 1: Variation of compressive and flexural strengths with different grain size ranges

Curing Age Days	Particle size range (mm)	1:1½:3		1:2:4		1:3:6		1:0:3
		Compre-ssive strength N/mm²	Flexural strength N/mm²	Compressive strength N/mm²	Flexural strength N/mm²	Compressive strength N/mm²	Flexural strength N/mm²	Compressive strength N/mm²
	0.063- 0.30	15.1		11.6		6.7		
	0.30 - 1.18	18.7		14.0		9.3		
	1.18 - 1.70	17.3		12.0		7.6		
7	1.70 - 2.36	13.8		10.7		6.4		
	2.36 - 3.35	12.0		8.9		4.9		
	3.35 - 4.75	10.9		8.0		4.2		
	0.063- 4.75	16.0		11.8		8.0		
	No-fines							10.4
	0.063- 0.30	20.0		15.5		10.2		
	0.30 - 1.18	25.2		19.1		12.4		
	1.18 - 1.70	22.2		16.0		10.4		
14	1.70 - 2.36	18.7		14.0		9.1		
	2.36 - 3.35	16.7		12.0		6.7		
	3.35 - 4.75	15.1		11.3		6.0		
	0.063- 4.75	21.7		16.0		11.0		
	No-fines							14.3
	0.063- 0.30	22.1		18.4		11.6		
	0.30 - 1.18	28.7		22.2		14.0		
	1.18 - 1.70	25.3		18.2		11.6		
21	1.70 - 2.36	22.4		16.2		10.0		
	2.36 - 3.35	19,3		14.0		8.0		
	3.35 - 4.75	17.2		12.9		6.7		
	0.063- 4.75	25.1		18.5		12.9		
	No-fines							16.7
	0.063- 0.30	23.1	3.6	19.0	3.1	13.3	2.6	
	0.30 - 1.18	31.3	4.4	23.6	3.8	15.7	2.7	
	1.18 - 1.70	28.2	4.3	20.0	3.7	13.3	1.8	
28	1.70 - 2.36	23.6	4.0	17.8	3.1	10.9	1.7	
	2.36 - 3.35	20.8	3.6	15.6	2.8	8.9	1.5	
	3.35 - 4.75	18.7	3.3	14.2	2.5	7.6	1.1	
	0.063- 4.75	27.1	3.8	20.0	3.2	13.8	2.3	
	No-fines							17.9

Table 2: Variation of workability and Initial Density with different grain size ranges

Particle size range mm	1:1½:3		1:2:41		1:3:6		1:0:3	
	Slump mm	28th Day density kg/m³	Slump mm	28th Day density kg/m³	Slump mm	28th Day density kg/m³	Slump mm	28th Day density kg/m³
0.063- 0.30	0	2340	0	2404	0	2265		
0.30 - 1.18	33	2427	33	2510	10	2436		
1.18 - 1.70	45	2404	45	2442	10	2351		
1.70 - 2.36	70	2348	70	2336	30	2291		
2.36 - 3.35	105	2300	105	2250	150	2175		
3.35 - 4.75	155	2235	155	2105	160	2110		
0.063- 4.75	30	2365	30	2400	30	23		
No-fines							Zero	2240

Tensile stresses at one hole overlap with those of adjacent hole. As a result, an axially compressed specimen is subjected to horizontal compressive and lateral tensile stresses. The net effect of the tensile stress is to reduce the load on each of the cube specimen. No-fines concrete could only be made with a mix concrete having aggregate/cement ratio not greater than 3. When the ratio exceeded 3, the cement paste and the coarse aggregate segregated.

Workability

The results of workability test are presented in Table 2. For 1:1½:3 mix, the workability increases with increase in particle size. This may be due to the fact that as particle size increases, the fineness of the aggregate decreases resulting in reduction of specific surface area to be wetted which requires lesser quantity of cement paste. Since the water/cement ratio is kept constant, excess water is available in the mix thus increasing workability. For 1:2:4 and 1:3:6 mix proportions, the results are erratic but still show that workability increases when maximum size of aggregate increases. No-fine concrete has zero slump.

Density

The density increased with decrease in particle size of the granite fine from 4.75mm to 0.30mm but from 0.30mm to 0.063mm the density decreased (Table 2). The initial increase may be attributed to the fact that the smaller the particles the more they can be closely packed in a given volume and the denser the specimen. Between 0.30mm and 0.063mm there is high proportion of dust which is less dense and hence reduced density. The density of concrete that contains all the particle sizes is 2340kg/m^3 and that of no-fine concrete is 2240kg/m^3.

CONCLUSION

The results of this study show that:

(i) The strength properties and density increase with decreasing grain sizes

(ii) The maximum compressive and flexural strengths of 31.3N/mm^2 and 4.4N/mm^2 were obtained for 1:1½:3 mix at 28-day for particle size range of 0.30 – 1.18mm. The compressive strength is 14% and the flexural strength is 15% greater than the strength values obtained for concrete containing all grain sizes for the same mix and age.

(iii) The workability decreases with decrease in grain sizes.

(iv) No-fine concrete can only be made when the aggregate/cement ratio is less than 3.

(v) The 28th day strength obtained for concrete containing all grain sizes is sufficient for normal concrete works.

It is recommended that granite fines be used for construction work without separating the grains which otherwise will increase the construction time without corresponding increase in strength values.

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