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EXPERIMENTAL AND MODELLING OF FLEXURAL STRENGTH PRODUCED FROM GRANITE-GRAVEL COMBINATION IN SELF-COMPACTING CONCRETE

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ABSTRACT

The roles of coarse aggregate in concrete production cannot be over emphasized because of the volume coarse aggregate occupied in total concrete volume. The availability of locally sourced gravel aggregate (both washed and unwashed) but not put to optimal use called for this current study. The granite-gravel aggregates were varied in percentage proportions of 100/0, 90/10, 80/20, 70/30, 60/40, 50/50. A total number of 108 beams of 100×100×500 mm size were produced and cured for 28, 56 and 91 days, crushing of beams were done in line with the standard to determine the flexural strength. The MINITAB software was used to model the concrete produced. The test results indicate that 100% granite and granite-washed gravel combination up to 30% behaves satisfactorily in the reinforced concrete structure using self-compacting concrete while 40 and 50% for washed gravel showed a bit of satisfactions. Similar trend was observed for unwashed gravel of which flexural strength of the beam is still reliable at 40% unwashed gravel.

Keywords: Flexural Strength, Self-Compacting Concrete, Gravel, Cement, Granite.

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1. INTRODUCTION

Concrete is a building material that can be molded virtually into any form and shape and can be delivered in a plastic state to the job site [1]. Concrete is an heterogeneous material that composed of crushed stone (coarse aggregates), sand (fine aggregates), water and hydrated cement [2]. Concrete can be used to construct varieties of structures because it provides wide latitude in colors and surface textures. These include highways and streets bridges, culverts, dams, large buildings, airport runways, irrigation structure, breakwaters, soils and farm building, homes, sewage-treatment works, railways sleepers, cooling towers, shell structures, columns, beam and slabs, chimneys and even barge and ships [3]. Self-compacting concrete (SCC) is one of the most recent innovations in the building industry [4].

Zhang et al. [5] defines self-compacting concrete as a concrete that can flow under its own weight through congested reinforcement, and fill void without internal or external vibration. Favorable workability is essential for fresh SCC to ensure that densely reinforced structural element can be encapsulated and fill a form [6]. Bamigboye et al. [7] studied the properties related to workability of SCC and concluded that consistency of the mix, segregation, mobility of concrete, pumpability, bleeding and finishability of concrete are some of the properties affecting self-compacting concrete. Some of the factor affecting the rheology of concrete are aggregates properties, time, cement characteristics, temperature, type of admixtures and mixing condition [8]. Interparticle forces of aggregates such as friction and interlocking of solid particles affect the flowability of fresh concrete mixtures [9].

Granite and gravel are coarse aggregates used in concrete production. This study is meant to explore natural gravel which is in abundance without the attendant air and noise pollution that accompany the blasting and crushing of granite for SCC. Gravel is readily available and is obtained at cheaper price than granite in most parts of Nigeria. In an attempt to reduce granite without compromising standard, the flexural strength of concrete using washed and unwashed gravel aggregate as partial replacement for granite aggregates were investigated in this study. Gravel aggregates have not been adequately utilized as they should, partly because of the fear that gravel cannot withstand as much pressure as granite.

Aggregates, generally, occupy about 60-70% of the total volume of concrete and can therefore be expected to have an important influence on its properties [10]. Su et al. [11] and Topcu and Uygunoglu [12] reported that aggregate exerts a major influence on the characteristic proportions of SCC and can be likely to have an significant effect on other properties as well due to large volume fractions it occupies in SCC. Zakariyya and Adedeji [13] studied the influence of aggregate properties on strength of concrete and reported that the flakiness of coarse aggregates adversely affected the workability and mobility of concrete as well as the strength, which decreased with the increasing flakiness.

The pavements design can be achieved by using modulus of rupture or flexural strength of concrete and other slabs on ground compressive strength, which is easier to measure than flexural strength [14-15]. ACI Committee [16] reported that high-strength concrete is becoming more popular than normal strength concrete, because, it is generally hard but liable to brake easily than normal-strength concrete. Kankam and Odum-Ewuakye [17] discovered that a high-strength reinforced concrete beam must be properly design if not it could fail in a brittle manner. To prevent such occurrence the study recommended proper attention when designing high strength concrete beam to ascertain that a required level of ductility is provided. Jagadeesh and Ramesh [18] studied the maximum polypropylene fibers percentage proportion that can be added to self-compacting concrete to achieve maximum flexural and compressive strength and found that there is an increase in flexural and compressive strength with the addition of 0.1% polypropylene fibers.

Adams et al. [19] studied the flexural behaviour of self-compacting steel fibre concrete and found that comparing SCC with steel fiber to conventionally-played concrete with steel fiber, it was observed that there is an increase in flexural and compressive strengths of SCC with steel fiber. However, glass fiber incorporation in concrete increased both the flexural and compressive strengths of concrete at 28 days [20]. Klug and Holschemacher [21] studied the split tensile and flexural strength of both self-compacting concrete and normal concrete and concluded that SCC typically produced improved concrete compared to normal concrete due to the improved interfacial transition zone, the improved microstructure of the paste and the denser bulk paste.

The experimental and modelling of flexural strength produced from varying percentage proportion of granite-gravel combination in SCC is missing in the literature and thus was investigated in this study.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials, Mix design and Experimental procedure

The concrete beams were produced from ordinary Portland cement, fine aggregate from natural river sand and granite-gravel combination as coarse aggregate of maximum size of 12.5 mm. Table 1 provides details of samples used for this study while Table 2 shows the mix proportion of self-compacting concrete samples. The beams of $100 \times 100 \times 500\, mm$ size with the moulds first cleaned and greased were filed with concrete without any agitation (tamping); all the specimens were cured for required period of time. After 28, 56 and 90 specified curing days, crushing followed in line with [22]. The Minitab 17 software was used to model the beam results produced. The beam lies on a support span while the load was applied at the center by the loading nose which produces a deformation at a specified rate as shown in the Plate 1.0. The maximum capacity of the machine is 1000 kN with three dial gauges arranged to measure the central deflection of the beams. Line loads were applied equally at the middle of the span. The load from a hydraulic jack itself was supported on the slab at the third points. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and the test stops when the specimen breaks. The test programme comprised of 108 beams, of which 54 beams made of SCC with varying granite-washed gravel combination and the remaining 54 beams made of SCC with varying proportions of granite-unwashed gravel, with 12 mm reinforcement. The beam test specimen's dimensions were 100 x 100 x 500 mm. The beam test specimens were kept in curing tank for 28, 56 and 90 days.

Table 1 Details of samples used

Sample	Main Composition
A1	100% granite
A2	90 % granite / 10 % gravel
A3	80 % granite / 20 % gravel
A4	70 % granite / 30 % gravel
A5	60 % granite / 40 % gravel
A6	50 % granite / 50 % gravel

Table 2 Mix proportions of self-compacting concrete samples

S/N	Mix Samples	Mix Proportion (%)	Cement (g)	Fine Aggregate (g)	Coarse Aggregate (g)		Water (g)	Super-Plasticizer (%)
					Granite	Gravel		
1	SCC1	100	561	977	620	-	168.8	1.14
2	SCC2	90/10	561	977	558	62	168.8	1.14
3	SCC3	80/20	561	977	496	124	168.8	1.14
4	SCC4	70/30	561	977	434	186	168.8	1.14
5	SCC5	60/40	561	977	372	248	168.8	1.14
6	SCC6	50/50	561	977	310	310	168.8	1.14

Bamigboye et al. [7]

Plate 1 Flexural machine and flexural beam under load

3. RESULTS AND DISCUSSIONS

3.1. Experimental Results

A material is considered to have completely failed once it reaches the ultimate stress. It is therefore important to assess the resistance of a beam to flexural load. The tested beams specimens were of dimension 100×100×500 mm. The tested specimens were kept under a mild exposure condition for 28, 56 and 90 days before flexural assessment. The mix proportion yielded a characteristic 28th day compressive of 10.93 N/mm^2. The behavior of beam under load as shown in Figures 1 and 2 for washed and unwashed gravel, indicates different failure modes. The control mix failed suddenly in flexure and impact, while the remaining specimens with varying granite/gravel combination failed in a ductile manner. Which is a proof that granite-gravel combination in SCC reduce sudden failure in flexure and impact. Tension failure occurs when the reinforcement yields before the concrete fails, while compression failure occurs when the tension reinforcement remains unyielded even when the concrete has failed completely. Balance failure occurs when the tension reinforcement just yield when the concrete fails, whereas shear failure occurs when the concrete fails laterally, as if there is no shear reinforcement within the concrete. From the result in Figures 1 and 2, it was shown that 100% granite and granite/gravel combination up to 30% behaves satisfactorily in the reinforced concrete structure. Forty percent (40%) and 50% on the other hand behave satisfactorily, but do not seem as strong as 100% granite and granite/gravel combination up to 30% but also reliable. For beams with 40 and 50 percentage of granite-gravel combination after the first noticeable cracks were perceived, the cracking turn out to be wide and crack thicknesses increased steadily. Subsequently, large flexural cracks opened during the test and final collapse occurred by concrete crushing within the compression zone.

The final loads documented were 10.93 N/mm^2 at 28 days, 12.05 N/mm^2 at 56 days and 15 N/mm^2 at 90 days for 100% granite while at 10% washed gravel 10.51 N/mm^2 load were recorded at 28 days, 11.62 N/mm^2 for 56 days and 13.90 N/mm^2 for 90 days, also for 20% washed gravel the following loads were recorded 10.01 N/mm^2 at 28 days, 11.03 N/mm^2 at 56 days and 11.5 N/mm^2 at 90 days. At 30%, the following results were arrived at: 9.82 N/mm^2 at 28 days, 9.99 N/mm^2 at 56 days and 10.99 N/mm^2 at 90 days respectively. The flexural strength results decreases with increases in the percentage of gravel. The flexural results obtained from this study produced better results when compared with standard. Similar trend was observed for unwashed gravel of which flexural strength of the beam is still reliable at 40% unwashed gravel. Which is an indication that percentage variation of granite/gravel improve the flexural strength of SCC.

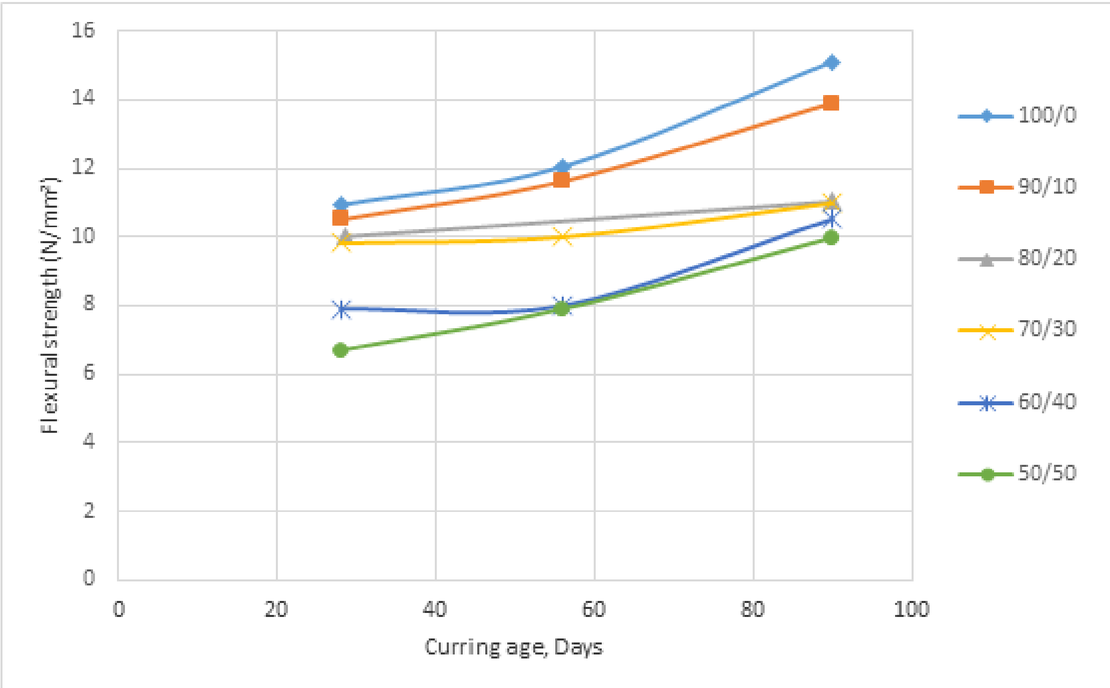

Figure 1 The relationship between Flexural strength of SCC of varying granite- washed gravel combination as coarse aggregate and curing days.

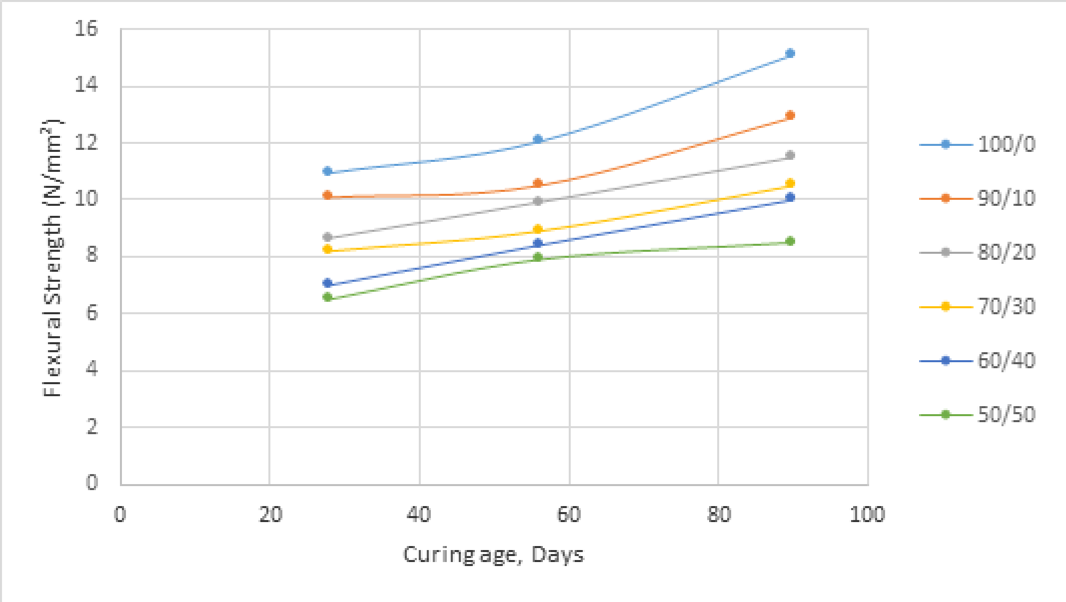

Figure 2 The relationship between Flexural strength of SCC of varying granite-unwashed gravel combination as coarse aggregate and curing days

3.2. Surface Plots of SCC granite-washed gravel combination for flexural strength using Minitab

3.2.1. Surface plot of Flexural strength versus percentage proportion of granite, percentage proportion of washed gravel

From Figure 3, increase in flexural strength of beam produced from granite-washed gravel combination as coarse aggregate in self-compacting concrete was observed with increase in percentage proportion of granite content and decrease in percentage proportion of washed gravel content

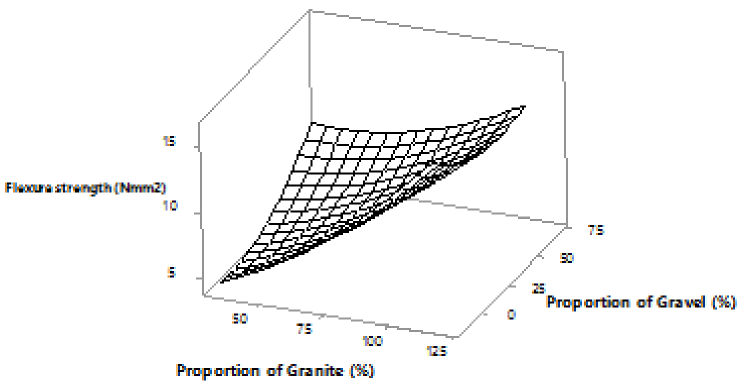

Figure 3 Response surface plot of proportions of granite and washed gravel against flexural strength

3.2.2. Surface plot of flexural strength versus curing days, percentage proportion of granite

Increase in both percentage proportion of granite and curing days increases the flexural strength of the beam as shown in Figure 4. The flexural strength was dependent on percentage proportion of granite and curing days

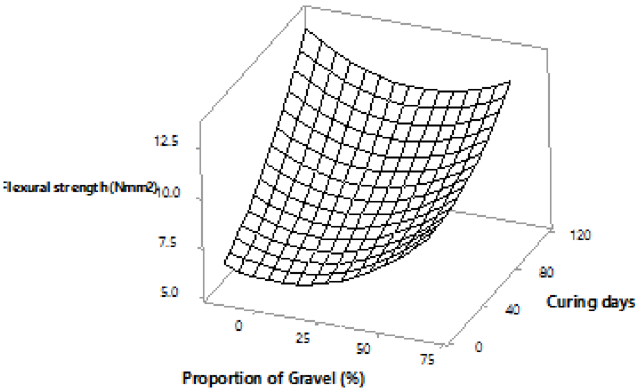

Figure 4 Response surface plot of proportions of granite and curing days against flexural strength

3.2.3. Surface plot of Flexural strength versus curing days, proportion of washed gravel

Figure 5, indicates that variation of percentage proportion of washed gravel and curing days affects the flexural strength of the beam. Effect of both percentage proportion of washed gravel and curing days on flexural strength was significant. Increase in percentage proportion of washed gravel and curing day's decreases the flexural strength with value less than 15 Nmm^2 obtained for percentage proportion of washed

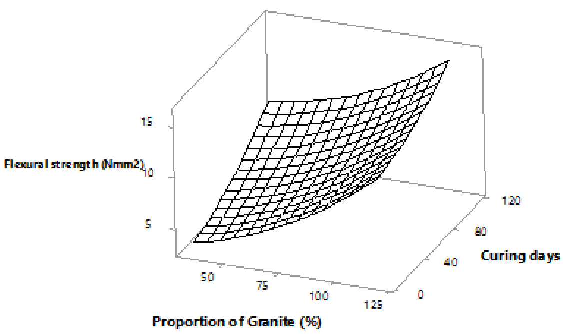

Figure 5 Response surface plot of proportions of washed gravel and curing days against flexural strength

3.3. Surface Plots of SCC granite-gravel (unwashed) combination for flexural strength

3.3.1. Surface plot of Flexural strength versus percentage proportion of granite, percentage proportion of unwashed gravel.

Figure 6, shows the effect of percentage proportion of granite and percentage proportion of unwashed gravel on the flexural strength of the beam keeping other factors constant. The lowest flexural strength was obtained around 50% of granite and unwashed gravel, irrespective of the strength of granite. Highest flexural strength was obtained at 100% proportion of granite and 0% percentage proportion of unwashed gravel. At 50% proportion of granite the flexural strength decreases with increase in percentage proportion of gravel.

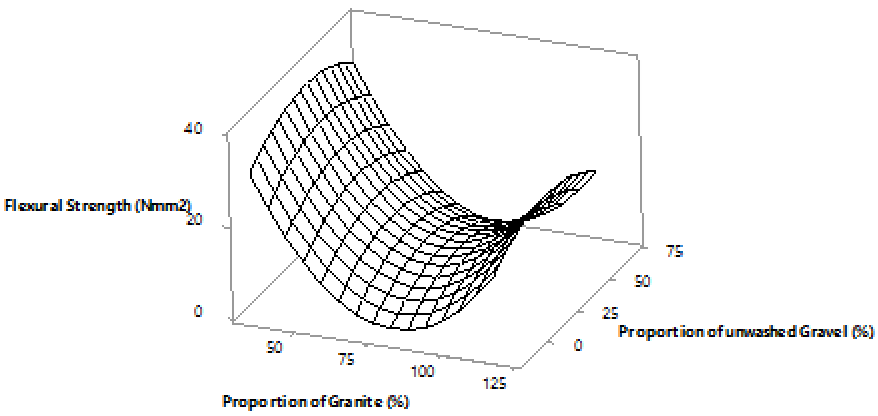

Figure 6 Response surface plot of proportions of granite and unwashed gravel against flexural strength

3.3.2. Surface plot of Flexural strength versus curing days, percentage proportion of granite

Figure 7, shows the effect of percentage proportion of granite and curing days on the flexural strength of the beam keeping other factors constant. The lowest flexural strength was obtained around 50% of granite at 28 days, irrespective of the strength of granite. Highest flexural strength were obtained at 100% proportion of granite and 90 curing days. At 50 percentage proportion of granite the flexural strength increases with increase in curing days.

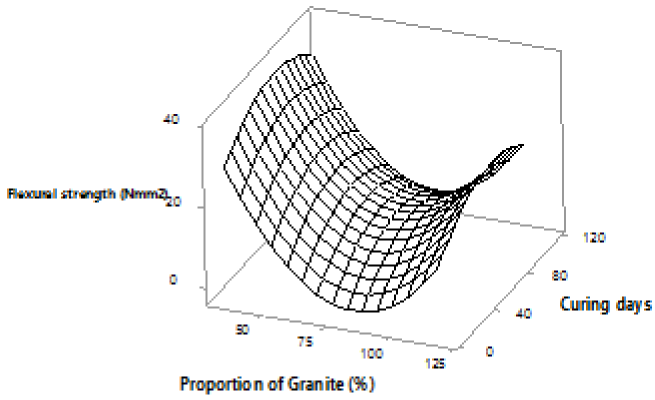

Figure 7 Response surface plot of proportions of granite and curing days against flexural strength

3.3.3. Surface plot of Flexural strength versus curing days, proportion of unwashed gravel

Figure 8, describes the response surface profile proportion of unwashed gravel and curing days against flexural strength. The curvature nature of three dimensional surfaces in Figure 8 indicates mutual interaction of percentage proportion of unwashed gravel and curing days. The dramatic upward curve shows a clear case of synergism between the curing and percentage proportion of unwashed gravel. The optimal value of 10 Nmm^2 was selected from the graph with 40 % unwashed gravel at 90 curing day.

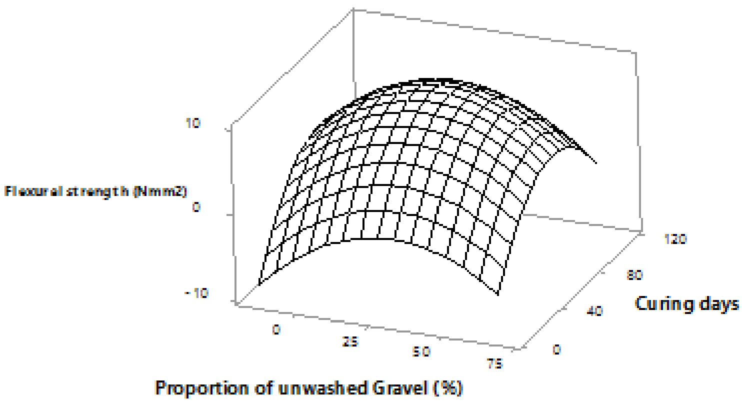

Figure 8 Response surface plot of proportions of unwashed gravel and curing days against flexural strength

4. CONCLUSIONS

From the Flexural result obtained from this study, it was shown that 100% granite and granite/gravel combination up to 30% behaves satisfactorily in the reinforced concrete structure while 40 and 50% on the other hand showed a bit of satisfactions but it was not as strong as 100% granite and granite-gravel combination up to 30% but also reliable. Forty percent (40%) unwashed gravel provides reliable threshold for flexural concrete. From the surface plot of flexural beam produced from washed gravel the flexural strength increase with increase in percentage proportion of granite content and decrease in percentage proportion of washed gravel content.

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