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A Study of the Effect of Aggregate Proportioning On Concrete Properties

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ABSTRACT: *This paper investigated the effect of aggregate proportion on concrete properties both at the fresh state and in the hardened state. Aggregate proportion as used in this research refers to the ratio of fine aggregate to coarse aggregate in a concrete mix. Five concrete mixtures with different aggregate proportion ranging from 0.3-0.5 were batched to check the effect of aggregate proportioning on concrete properties. In other to reduce the effect of other experimental variables on the concrete, the water cement ratio was kept constant at 0.6 for the concrete mix. The result indicates a reduction in the workability of concrete when the aggregate proportion was varied slightly above and below (0.4 and 0.6 aggregate proportion) the standard aggregate proportion of 0.5. However the compressive strength result shows that for aggregate proportion of 0.4 and 0.6, the compressive strength of the concrete improved by 5% and 3% respectively over the control aggregate proportion of 0.5. Then when the aggregate proportion was varied beyond 0.4 and 0.6 there was a reduction in the strength of the concrete. The flexural strength test result showed a progressive decrease in the flexural strength as the concrete aggregate proportion was varied slightly above and below the control aggregate proportion. All the concrete cubes and beams were cured at room temperature by complete immersion in water and they were tested at the age of 7days, 14days, 21days, and 28days.*

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I. INTRODUCTION

Concrete is a mixture of water, cement or binder and aggregates and is a commonly used material for construction. (Barritt, 1984). The strength of concrete depends on aggregate type, size and source(Abdullahi, 2012; Hassan, 2014: Aginam et al 2013; Jimoh and Awe 2007;Okonkwo and Arinze 2015;Topcu and Sengel 2004). Aggregate occupies 70% to 75% of the volume of conventional normal strength Portland cement concrete and therefore the properties of aggregates have a dominant effect on the overall performance of concrete in its fresh and hardened state (Parasad, et al., 2013). These aggregates include fine aggregate and coarse aggregate and the proportion of this aggregate (aggregate proportion) is likely to have a significant effect on the overall performance of concrete in its fresh and hardened state. Aggregate proportion as used in this study is the ratio of fine aggregate to coarse aggregate in a concrete mix. The aggregate proportion determines whether a concrete mix will be sandy that is containing more of sand or stony. Traditionally, nominal mix which is now known as standardized prescribed concrete is batched in ratios (e.g. 1:1:2, 1:1½:3, 1:2:4 etc.) using head-pan or wheelbarrow measures. When batching by volume is used, possible sources of error could lead to variation in the amount of aggregate in a specific volume. These errors often lead to variations in the fresh and hardened properties of concrete as against specified characteristics properties (Kolapo, et al., 2012). This research examined some concrete properties such as workability, compressive strength and flexural strength to determine the effect of aggregate proportioning on these properties.

A range of factors affect the ultimate strength of concrete, including the water: cement ratio, compaction, the aggregates used and workmanship. General purpose cement concrete usually has an average compressive strength of about 25 MPa, while that of lime concrete could range from about 5 to 10 MPa (Mitchell, 1909).

Consistency is defined as “the relative mobility or ability of freshly mixed concrete of mortar to flow; the usual measurements are slump for concrete, flow for mortar or grouts, and penetration resistance for neat cement paste.” Associated with the concept of workability is the problem of classifying fresh concrete. Qualitative descriptions are commonly used. A mixture may be "sticky" or "wet" while another may be "too lean" while yet another has "good flow." All of these classifications may be accurate to the mixture in question and perhaps they more aptly describe the mix than another more "quantifiable" method might. For more specific and quantifiable descriptions, there are numerous testing methods and apparatus for both field and laboratory applications (Koehler, 2003).

II. MATERIALS AND METHODS

The coarse aggregate used in this test were crushed granite stones with a maximum size of 19mm. The fine aggregate used was river sand with a maximum size of 2mm, free from all organic substances. Ordinary Portland cement was used (Dangote 3x cement brand of 42.5 cement grade). The concrete used in this experiment was batched by volume and the concrete mix ratio of 1:2:4 was employed. This means that for every one volume of cement, two volumes of fine aggregates was measured, while four volumes of coarse aggregate was added. This was the control mix with aggregate proportion of 0.5 as shown below:

$$\text{Aggregate Proportion} = \frac{Fine\ Aggregate}{Coarse\ \ Aggregate} = \frac{2}{4} = 0.5$$

In other to achieve the aim of this research as stated above this aggregate proportion was varied slightly above and below this standard proportion. Five concrete mixes with different aggregate proportion was made as shown in the Table 1 below:

Table 1: Proportion of fine aggregate to coarse aggregate

	Ratio
Aggregate proportion = $\frac{Fine\ Aggregate}{Coarse\ Agregate}$	Mix 1 = 0.3, x : 3 :10
	Mix 2 = 0.4, x : 2 : 5
	Mix 3 = 0.5, 1 : 2 : 4
	Mix 4 = 0.6, x : 3 : 5
	Mix 5 = 0.7, x : 7 : 10

The quantity of cement was to be kept constant for all the concrete mix, hence in other to determine the quantity of cement for each of the mix two containers of constant volume was employed. From the control mix (1:2:4) six volumes of aggregate requires one volume of cement. The six volumes of aggregates were properly mixed and were placed in the container and then with a sharp object the level of the aggregate was carefully mark out. Having this in mind for every of the mix when the fine and coarse aggregates are measured out, they are thoroughly mixed together and then placed in the second container (the bucket) to the already marked level. For every measurement of this bucket a fixed volume of cement was added, this process will continue until the required quantity of materials for the cubes and beams are obtained. A water cement ratio of 0.6 was maintained throughout the experiment. The concrete used in this experiment were all mixed manually with the aid of a hand trowel and a shovel on a concrete floor in other to prevent lost of moisture

III. RESULTS AND DISCUSSION

3.1.1. Sieve Analysis

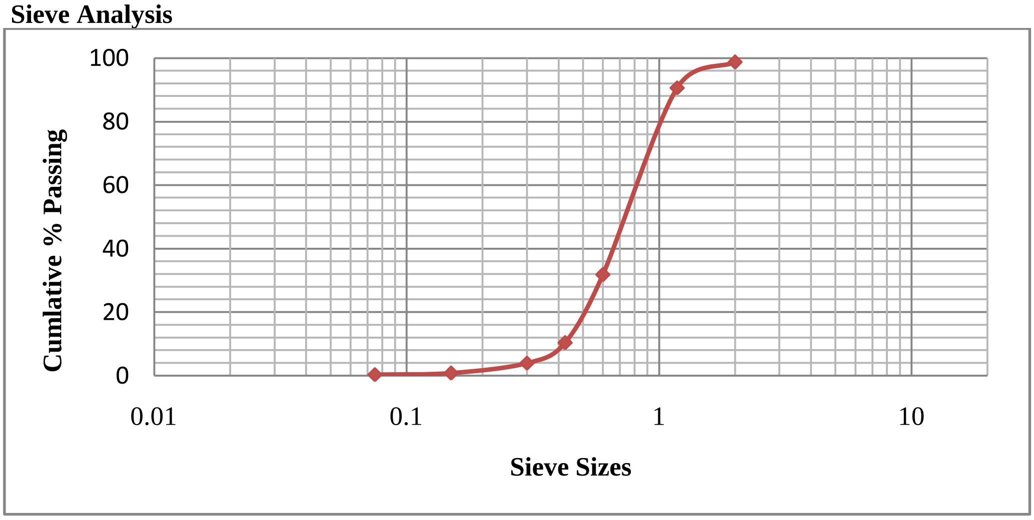

Figure 1: Fine Aggregate gradation curve

From the figure 1;
D10 = 0.42mm

D60 = 0.82mm
D30 = 0.58mm
Uniformity Coefficient (U) = $\frac{D60}{D10} = \frac{0.82}{0.41} = 2$
Coefficient of Curvature (Cz) = $\frac{D30^2}{(D60 \times D10)} = \frac{0.58^2}{0.82 \times 0.41} = 1$
From the above values using Unified soil classification system as shown in the Table 2 below, we have

Table 2: Extract from the Unified soil classification system for fine aggregate

Symbol	Percent Fines (Passing 0.075mm sieve size)	Grading	Plasticity	Remarks
SP	0.5 (which is within 0-5)	U = 2 Does not satisfy (U > 4 and 1< Cz < 3)	Does not apply	Therefore the group symbol will be SP
SP means Poorly graded sands, gravelly sands, with little or no fines.				

Therefore the fine aggregate used in this experiment can be described as poorly graded sands, gravelly sands, with little or no fines, which is appropriate for concrete work. Also from the uniformity coefficient of 2 the soil is said to be uniformly graded.
For the Coarse Aggregate

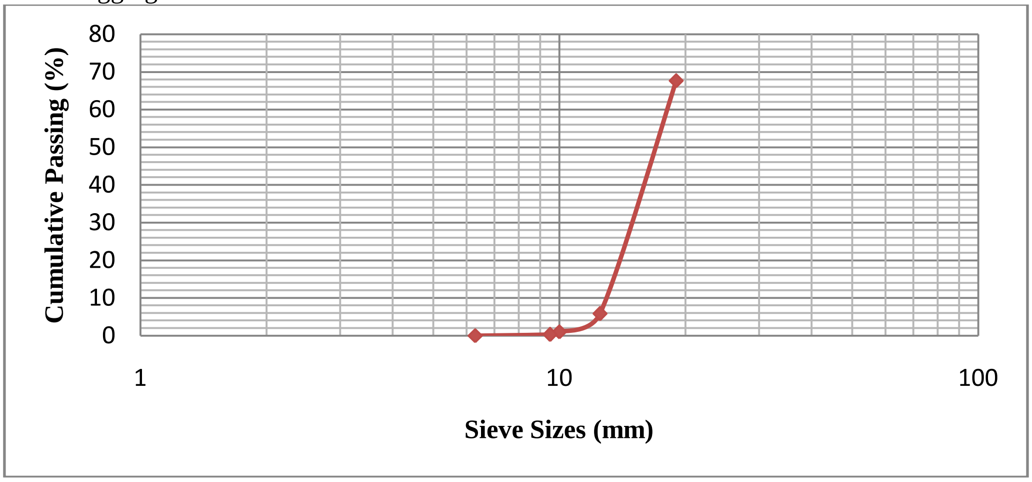

Figure 2: Coarse Aggregate gradation curve

From the figure 2;
D10 = 12
D30 = 15
D60 = 17
Uniformity Coefficient (U) = $\frac{D60}{D10} = \frac{17}{12} = 1.42$
Coefficient of Curvature (Cz) = $\frac{D30^2}{(D60 \times D10)} = \frac{15^2}{17 \times 12} = 1.1$
From the above values using Unified soil classification system for classifying gravels

Table 3: Extract from the Unified soil classification System for Coarse aggregate

Symbol	Percent Fines (Passing 0.075mm sieve size)	Grading	Plasticity	Remarks
GP	0 (which is within 0-5)	U = 1.1 Does not satisfy (U > 4 and 1< Cz < 3)	Does not apply	Therefore the group symbol will be GP
GP means Poorly graded gravels, with little or no fines.				

Therefore the coarse aggregate used in this experiment can be described as poorly graded gravels, with little or no fines, which is appropriate for concrete work. Also from the uniformity coefficient of 1.1 the gravel is said to be uniformly graded.
At 0.3 Aggregate Proportion
The concrete mix at 0.3 aggregate proportion was more of the coarse aggregate, cement paste was small and the mix was also very wet. The walls of the concrete cubes were not smooth (honey comb).
At 0.4 Aggregate Proportion

The concrete mix was more of coarse aggregates, cement paste was more than 0.3 mix. The walls of the concrete cubes were not as smooth, but it was better than the 0.3 aggregate proportions.

At 0.5 Aggregate Proportion

The quantity of cement paste and the coarse aggregate in this mix were almost at equilibrium and the compaction was effective. The walls of the concrete cubes and beams were very smooth.

At 0.6 Aggregate Proportion

The fresh concrete mix was becoming stiff and dried. The compaction became more effective. The walls of the concrete cubes were rough. The concrete also seem to be porous (tiny openings).

At 0.7 Aggregate Proportion

This mix was very sandy and the compaction was very effective in this mix compared with all other mix. The walls of these concrete cubes and beams were very rough and honey combs were also in the wall of the harden concrete.

The effect of concrete aggregate proportioning on workability as observed in the experiment is shown in the figure 6 and 7 below:

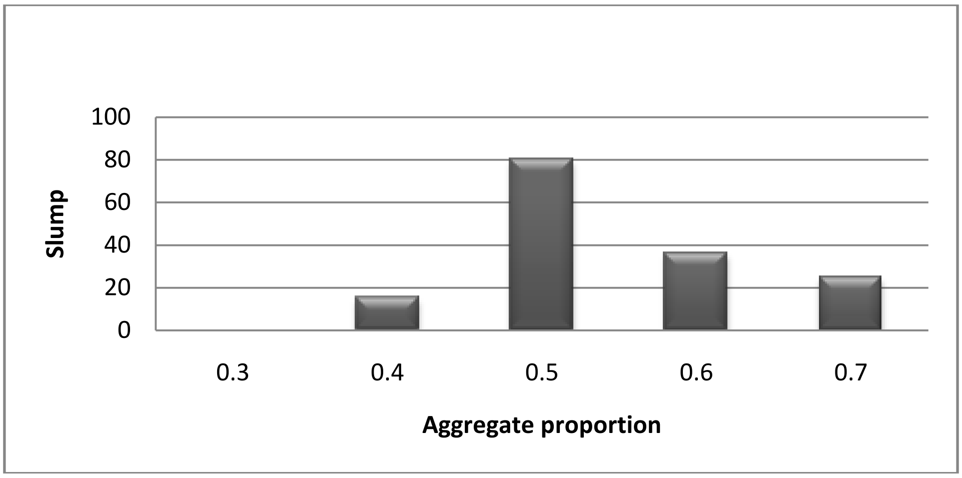

Figure 3: The effect of aggregate proportion on workability

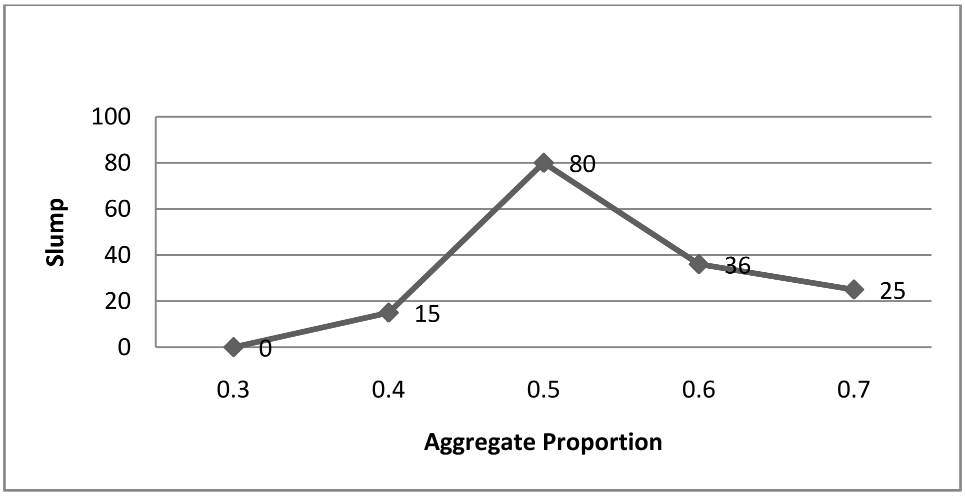

Figure 4: The effect of aggregate proportion on workability

Figure 3 and 4 above shows that, for a given water cement ratio, workability decreases as the coarse aggregate proportion increases in a concrete mix, this is probably because there is insufficient paste to lubricate the aggregates. It is also observed that the workability is decreases as the quantity of fine aggregate is increased and this is likely due to the increase in the surface area of the aggregate proportion and the dryness of the concrete mix.

This result indicates that adequate paste content and aggregate surface area is required to achieve a certain degree of workability.

Figures 5 and 6 shows the result of the compressive strength test as obtained from crushing the concrete cubes made with different aggregate proportion. The cubes were cured for the age of 7days, 14days, 21days and 28days as shown in the table below;

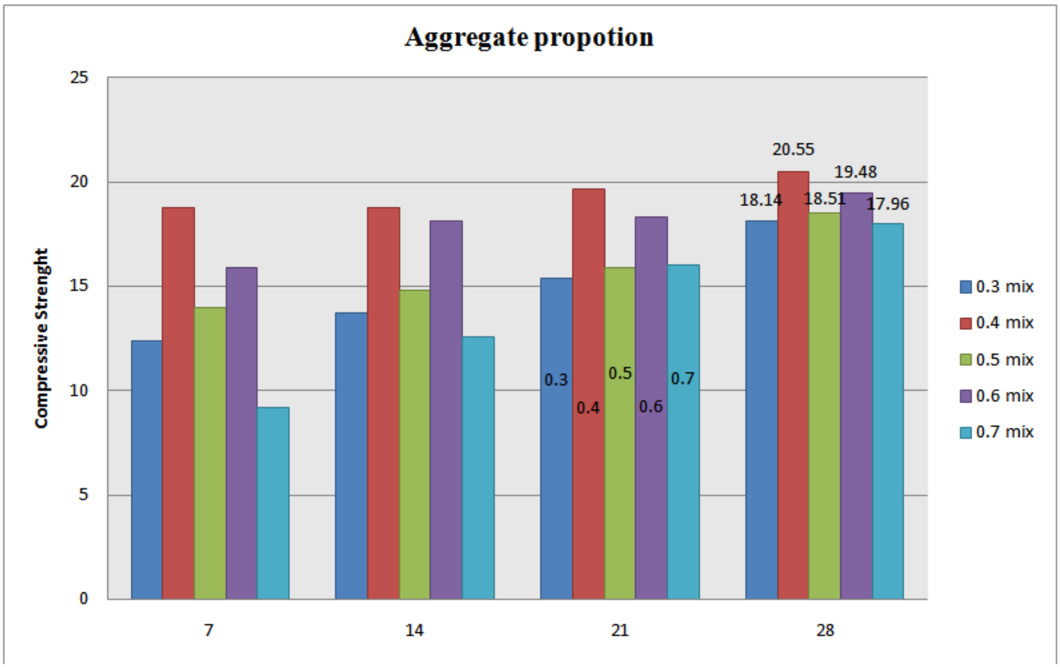

Figure 5: Variation of compressive strength with curing age at different Aggregate proportion

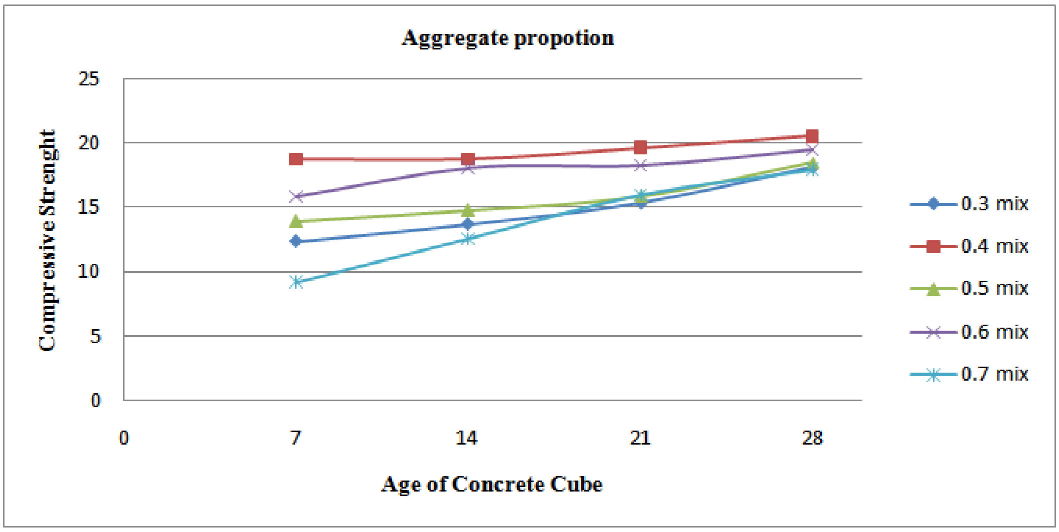

Figure 6: Variation of compressive strength with curing age at different Aggregate proportion

The result of the compressive strengths of concrete specimens batched at different aggregate proportion using a constant water-cement ratios are presented in the Figure 5 and 6.

They show that the compressive strengths increased progressively with increase in curing age for the different aggregate proportion in the concrete. They also show that the compressive strength of the concrete improved when the concrete aggregated proportion was varied slightly from the control mixture that is when the concrete was slightly sandy (0.6 aggregate proportion) and stony (0.4 aggregate proportion) the compressive strength improved.

It can also be noticed from the figures above that an early strength was obtained when the concrete mix had an aggregate proportion of 0.4 and there was no much difference in the strength gain between 7days and 28days while the mix ratio of 0.7 aggregate proportion gave the direct opposite of this result.

From the figure 5 and 6 the aggregate proportion of 0.4 gave the highest compressive strength followed by the 0.6 aggregate proportions before the control aggregate proportion of 0.5 while the aggregate proportion of 0.7 gave the least strength.

From the figure 8 and 9 it can also be said that there are some slight difference between the compressive strength of concrete when the aggregate proportion is varied slightly from the control mix.

The effect of aggregate proportioning on the flexural strength of concrete is shown in the figure 7. The water cement ratio was kept constant at 0.6 and the beams were cured for 28days only.

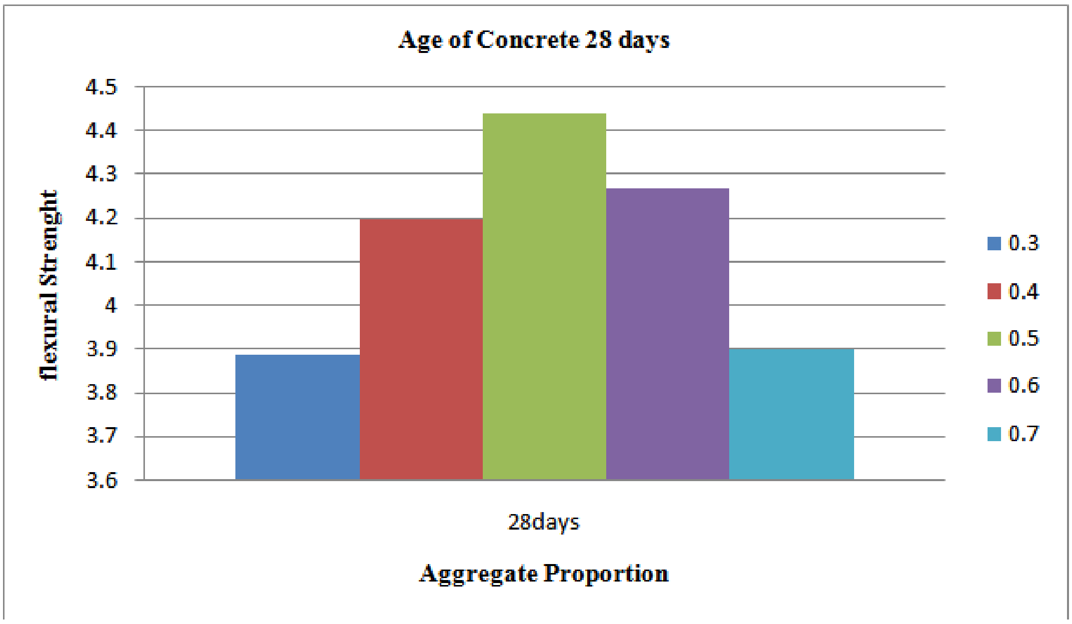

Figure 7: flexural strength with curing age of 28 at different Aggregate proportion

The Figure 7 above shows the flexural strength of concrete is affected significantly by variation in the aggregate proportion of the concrete. Also from the figure 7, the flexural strength of concrete was highest at the aggregate proportion of 0.5 which is the control aggregate proportion and this is likely because there was sufficient paste to completely fill all the voids in the concrete mix.

In addition we can further deduce from the graph that deviation from the control aggregate proportion will progressively reduce the flexural strength of the concrete by more than half of what it is supposed to be. This reduction in flexural strength is likely due the honey comb and the porous nature of the concrete when the aggregate proportion is stony or sandy.

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study investigated the effect of aggregate proportioning on concrete properties such as workability, compressive strength and flexural strength. The compressive strength result shows that for aggregate proportion of 0.4 and 0.6, the compressive strength of the concrete improved by 5% and 3% respectively over the control aggregate proportion of 0.5,which is in line with the discovery of Ekwulo and Eme (2017), but further variation beyond 0.4 and 0.6 aggregate proportion resulted in a loss of strength. The flexural strength result also showed that the aggregate proportion of 0.5 which is the control aggregate proportion gave the highest flexural strength and there was a progressive decrease in the flexural strength as the concrete aggregate proportion was varied slightly above and below the control aggregate proportion. The workability of the concrete reduced when the aggregate proportion was slightly sandy (from 0.5-0.6 aggregate) or stony (from 0.5-0.4 aggregate proportion) and the further the variation the lower the workability of the concrete. Based on the findings of this study, for the aggregate system used in this work, it is possible to vary the aggregate proportion of concrete slightly between 0.4 aggregate proportion and 0.6 aggregate proportion without sacrificing the compressive strength or the design strength of the concrete but the workability of the concrete and flexural strength of the concrete will decrease progressively.

4.2 Recommendation

Slight variation of the aggregate proportion is recommended if the concrete optimum compressive strength is required. This variation can be either above or below the standard proportion of 0.5 but must not be less than 0.4 or greater than 0.6 as this will not give the required gain in strength. In the variation of the aggregate proportion the aggregate that is readily available or cheaper should determine how the proportion is varied for economy. For reinforced concrete and concrete where flexural strength is required, using the standard aggregate proportion for concrete batching is recommended because variation of the aggregate proportion either above or below the standard proportion of 0.5 will result in a loss of flexural strength and this concretes are characterized with honeycombing which will not offer a good protection to the reinforcement members. Aggregate proportioning affects the properties of concrete and the intended quality of concrete hence it is recommended that close attention be paid to the measurement of aggregate whenever concrete is batching by volume.

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