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Analysis of the significance of Properties of Different Brands of Cement on the Compressive Strength of Optimized Concrete Mix

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Abstract

The influence of the constituent materials of concrete on its overall properties and performance cannot be over emphasised. This study analysed effect of using different brands of cement on optimized aggregate gradation for different sizes of coarse aggregate using ANOVA. The calculated F values for 12.5mm single size and 12.5mm combined aggregates are 9.35 and 143.3 for the different aggregate forms and the different brands/grades of cement respectively. Similarly, that of 19mm single size and 19mm combined aggregates are 40.36 and 603.36 while that of 25mm single size and 25mm combined aggregates are 27.11 and 301.72 respectively. These results imply that there are significant differences in the sample means for both the different aggregate sizes from the various cement brands/grades.

Keywords: Properties, Brands of Cement, Compressive Strength, Optimized, Concrete, Mix

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1. Introduction

According to (Hanson 1995), concrete is rated as the second most highly consumed product after water. It consists of aggregate (fine and coarse), cement and water. Cement is the binding/bonding material having cohesive and adhesive properties which makes it capable to unite the different construction materials and form the compacted assembly. Bhatt, (2014) defines the role of cement in concrete as the material that binds the fine aggregate (usually sand) and coarse (gravel, crushed granites etc) together to form a rigid/solid mass that is capable of sustaining loads thus giving strength to the concrete. In their opinion, the compressive strength of concrete is to a great extent determined by both the quality and quantity of cement. They further averred that the code BS EN 197-1:2011 stipulated five groups of cement which consist of different proportions of clinker and another major constituent.

The five groups are CEM I Portland cement: comprising mainly grounded clinker and up to 5% of minor additional constituents, CEM II Portland composite cement: This comprises of seven types which contain clinker and up to 35% of another single constituent, CEM III blast furnace cement (CEM III/A, CEM III/B, CEM III/C): This comprises clinker and a higher percentage (36-95%) of blast furnace slag than that in CEM II/A-S and CEM II/B-S, CEM IV pozzolanic cement (CEM IV/A, CEM IV/B): This comprises of clinker and a mixture of silica fume, pozzolanas and fly ash, CEM V composite cement (CEM V/A, CEM V/B): This comprises clinker and a higher percentage of blast furnace slag and pozzolana or fly ash.

However, Adewole Olutoge and Hamzat (2016) stated that the old Nigerian Industrial Standards (NIS) for cement NIS 11: 1974, approved only Ordinary Portland Cement (OPC) for production and it was the only cement available in the Nigerian market and known to Nigerians before the implementation of the present Nigerian Industrial Standards for cement NIS 444-1:2003. According to them, NIS 439:2000 specified that OPC is made of clinker and gypsum both of which constitute 95% to 100% of the cement and addition of 0%-5% minor additional constituent of calcareous material (e.g. limestone). While NIS 444-1:2003 makes provisions for different grades and different types of cement. that none of the cement in bagged form, which is the form that is used by majority of Nigerians for building and other concrete structures construction, is Ordinary Portland Cement as they are all Portland-limestone cement designated as CEM II in NIS 444-1:2003.

In their averment, COREN 2013 stated that three types of cement grades – grade 32.5, grade 42.5 and grade 52.5 are produced globally, but there are focus and dominance of a particular grade in some countries. It was further stated that grade 33, grade 43, and grade 53 represent cement with a minimum of 32.5MPa, 42.5MPa and 52.5MPa compressive strengths respectively. They further claimed that in terms of the quality assurance of cement, any cement with compressive strength of 32.5MPa would be adjudged as meeting the strength requirement of cement grade 32.5.

Shetty (2010) categorizes tests of cement into two, field testing and laboratory testing and proceeded to list the laboratory tests as Fineness test, Setting time test, Strength test, Soundness and Heat of hydration test. However, the following tests were carried out on the various brands and grades of cement in the course of this research: Specific gravity, consistency, setting time and soundness test.

2. Materials and Methods

Various sizes of coarse aggregate that conform to the requirements of BS EN 933-1:1997 and BS 882:1992 and different grades of cement conforming to the requirement of BS 12 (1996) and different sizes of aggregates were used to cast concrete cubes which were cured for 7, 14, 21 and 28 days. While the fine aggregates used for all specimens are of the same gradation, the sizes of the coarse aggregates were varied. The various sizes of coarse aggregates used were 9.5mm, 12.5mm, 19mm, and 25mm. Three brands (Dangote, Pure Chem, and Lafarge) and two grades (32.5 and 42.5) of cement were used. The water used was drinkable tap water. The mix ratio was 1:2:4, while the water/cement ratio used was 0.5. The size of the cube mould was 150x150x150mm.

3. Results and Discussions

Table 1: Values of Properties of all Brands/Grades of Cement

Cement Brand/ Grade	Specific Gravity	Normal Consistency (%)	Initial Setting Time (Minutes)	Final Setting Time Hours
Dangote (42.5)	3.02	26%	75	4.5
Lafarge (32.5)	2.92	25%	90	5.25
Purechem (32.5)	3.01	25%	135	6.75

The specific gravity of Cement: The values of the Specific gravity for all the cement samples used for the study are shown in Table 1, Dangote cement has the highest value with 3.02 closely followed by Lafarge cement with a value of 3.01 while Purechem cement has the least value of 2.92. According to Burtler (2015), the result of Specific gravity tests conducted on thirty different types of cement ranges within 3.026 and 3.138. The results obtained for both Dangote and Lafarge are very close to the values obtained by Butler but that of Purechem cement is a little bit at variance.

Soundness of Cement: All the three cement samples tested positive for the soundness test as none of them exhibits any significant expansion after boiling the moulded samples for about 3½ hours. However, it was observed that Elephant cement has a visual appearance of greater expansion than the two other brands of Dangote and Purechem cement.

Normal consistency of Cement: The normal consistency of Dangote is the highest with water content of 26% while the normal consistency of Lafarge and Purechem cements are 25%.

Initial and Final Setting Time of Cement: As shown in Table 1 the initial setting time for Dangote cement was 74minutes which is greater than the required time of 60minutes for grade 42.5 cement, while the final setting time was 4hours 30minutes lesser than the specified 10hours as specified in. The initial setting times for Lafarge cement (grade 32.5) was 90minutes and for Purechem cement (grade 32.5) was 135minutes. All these values are greater than the 75 minutes specified for grade 32.5 cements. Also, the final setting times of 5hours 15 minutes and 6hours 45minutes for Lafarge and Purechem cements respectively are lesser than the specified 10hours. It can also be observed that Dangote cement has the earliest initial and final setting time while Purechem cement has the least initial and final setting time. Additionally, both the initial and final setting time of grade Dangote cement of grade 42.5 are lesser than that of Lafarge and Purechem of grade 32.5. This is an indication that concrete made with Dangote cement will set earlier than that of Lafarge and Purechem. Also, concrete made with Lafarge cement will set before those made with Purechem even though they are of the same grade since both the initial and final setting time of Lafarge cement is lower than for Purechem cement.

Compressive Strength Test on Concrete Cubes

Table 2: Values of the 28Days Compressive Strength of Concrete for all Brands/Grades of Cement

Cement Brand and Grade/ Aggregate Size	Dangote (42.5) N/mm^2	Lafarge (32.5) N/mm^2	Purechem (32.5) N/mm^2
12.5mm Single	29.37	21.71	20.08
12.5mm Combined	31.26	23.48	20.97
19.5mm Single	34.37	26.11	23.89
19.5mm Combined	36.64	27.60	25.29
25mm Single	31.99	24.02	22.93
25mm Combined	34.36	25.88	24.10

From table 2, it shows that the compressive strength of Dangote Cement of grade 42.5 is consistently higher than that of Lafarge and Purechem (both of which are of grade 32.5). The results also reveal that the strength of concrete made with Lafarge cement is consistently higher than that of Purechem cement although they are of the same grade. Comparatively it can be noticed that for all the brands/grades of cement, there is a relationship between the initial and final setting time of cement and the compressive strength of concrete made with them. The results also indicate that there is an improvement in the strength of concrete when single sized aggregates are combined with smaller sizes. However, the combination of 19.5mm coarse aggregate with lower sizes of 12.5mm and 9.5mm produced the optimal strength of $36.64N/mm^2$.

Comparatively, the value of 28 days compressive strength of concrete cubes produced with Purechem cement with a mix ratio of 1:2:4 in the research carried out by Okigbo (2013) is 19.11N/mm^2. The compressive strength of concrete cubes for the different sizes of aggregates produced with Purechem cement are of higher value than the result obtained by Okigbo (2013). In the same vein, the value of 28 days compressive strength of concrete cubes produced with Dangote cement with a mix ratio of 1:2:4 in the research carried out by Okigbo (2013) 36.52N/mm^2. The compressive strength of concrete cubes for of aggregates produced with Dangote cement in this research is 36.64N/mm^2 which is of higher value than the result obtained by Okigbo (2013).

4. Analysis of Relationship

Table 3 Analysis of variance for the 28 days' compressive strength for 12.5mm single size and 12.5mm combined aggregates for the various brands/grades of cement.

Source of variation	SS	df	MS	F-	5% F-Limit
Between different aggregate forms	3.46	(2-1) = 1	$\frac{3.46}{1}$ =3.46	$\frac{3.46}{0.37}$= 9.35	F (1,2) =19
Between varieties of cements	106.04	(3-1) = 1	$\frac{106.04}{2}$= 53.02	$\frac{53.02}{0.37}$ = 143.3	F (2,2) =199.5
Residual factor/ Error	0.74	2	$\frac{0.74}{2}$= 0.37		

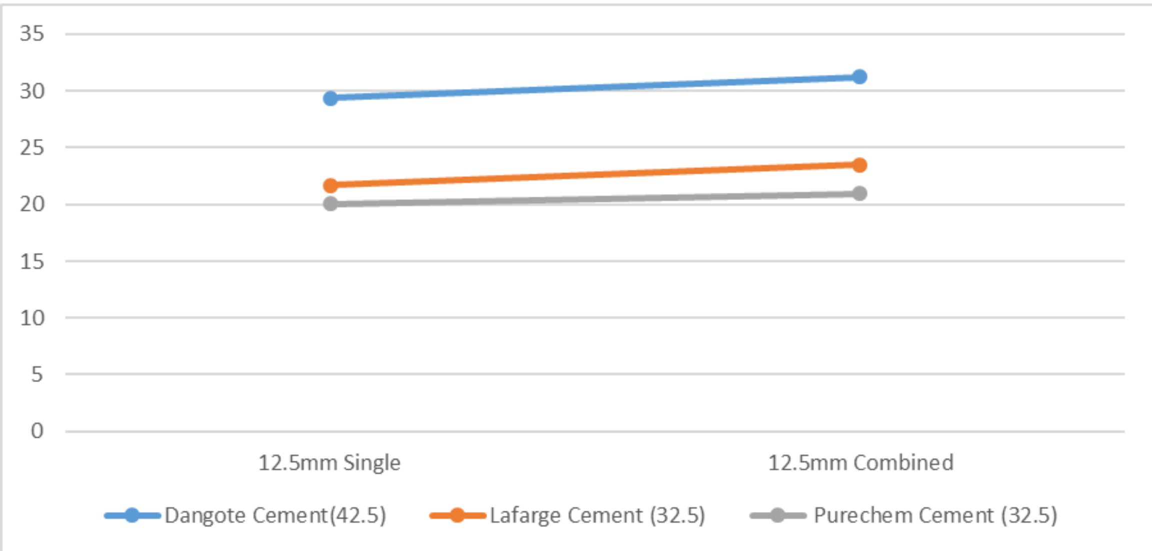

Figure 1 Analysis of variance for the 28 days' compressive strength for 12.5mm single size and 12.5mm combined aggregates for the various brands/grades of cement.

In Table 3, it can be observed that the calculated F – ratio for the 28 days' compressive strength for 12.5mm single size and 12.5mm combined aggregates and for the various brands/grades of cement the calculated values of 9.35 and 143.3 are lesser than the table value of 19 and 199.5 obtained from the F – distribution table. This is an indication that there are no significant differences in the sample means for both the different aggregate sizes from the various cement brands/grades. Figure 1 also reveals that the lines of the graphs in does not cross one another, thus it can be concluded that there is no definite interaction or inter-relationship between the two factors that is different sizes of aggregates and various brands/grades of cement.

Table 4 Analysis of variance for the 28 days' compressive strength for 19.5mm single size and 19.5mm combined aggregates for the various brands/grades of cement.

Source of variation	SS	df	MS	F-	5% F-Limit
Between different aggregate forms	4.44	(2-1) = 1	$\frac{4.44}{1} = 4.44$	$\frac{4.44}{0.11} = 40.36$	F (1,2) =19
Between varieties of cements	132.73	(3-1) = 1	$\frac{132.73}{2} = 66.37$	$\frac{66.37}{0.11} = 603.37$	F (2,2) =199.5
Residual factor/ Error	0.22	2	$\frac{0.22}{2} = 0.11$		

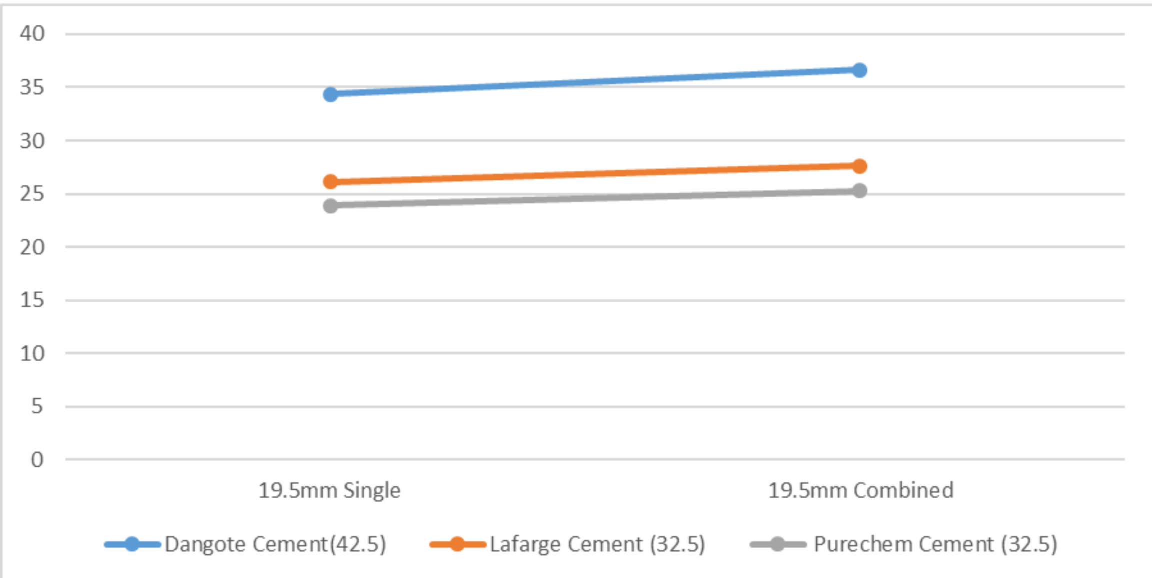

Figure 2 Analysis of variance for the 28 days' compressive strength for 19.5mm single size and 19.5mm combined aggregates for the various brands/grades of cement.

In table 4, the calculated value of F ratio for 19mm single size and 19mm combined aggregates are 40.36 and 603.36. Both values are higher than the values of 19 and 199.5 obtained from the F – distribution table. This implies that there are significant differences in the sample means for both the different aggregate sizes from the various cement brands/grades. Additionally, the lines of the graphs in figure 2 does not cross one another, thus it can be concluded that there is no definite interaction or inter-relationship between the two factors that is different sizes of aggregates and the various cement brands/grades.

Table 5: Analysis of variance for the 28 days' compressive strength for 25mm single size and 25mm combined aggregates for the various brands/grades of cement.

Source of variation	SS	df	MS	F-	5% F-Limit
Between different aggregate forms	4.88	(2-1) = 1	$\frac{4.88}{1} = 4.88$	$\frac{4.88}{0.18} = 27.11$	F (1,2) =19
Between varieties of cements	108.61	(3-1) = 1	$\frac{108.61}{2} = 54.31$	$\frac{54.31}{0.18} = 301.72$	F (2,2) =199.5
Residual factor/ Error	0.35	2	$\frac{0.35}{2} = 0.18$		

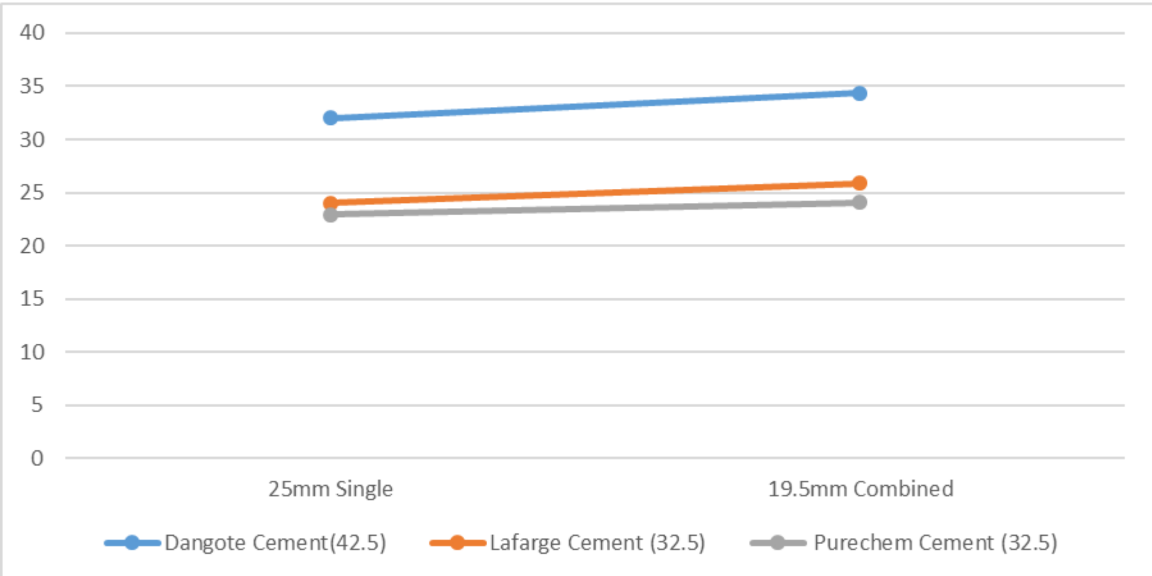

Figure 2 Analysis of variance for the 28 days' compressive strength for 25mm single size and 25mm combined aggregates for the various brands/grades of cement.

Similarly, the calculated value of F ratio for 25mm single size and 25mm combined aggregates as presented in Table 5 are 40.36 and 603.36 which are higher than the values of 19 and 199.5 obtained from the F – distribution table. This an indication that there are significant differences in the sample means for both the different aggregate sizes from the various cement brands/grades. Also, in figure 3 the lines of the graphs do not cross one another, leading to the conclusion that there is no definite interaction or inter-relationship between the two factors that is different sizes of aggregates and the various cement brands/grades.

5. Conclusion

From the results obtained in this study, it can be concluded that all the brands of cement used in the study are in line with the relevant standards. However, both the initial and final setting time of grade Dangote cement of grade 42.5 are lesser than that of Lafarge and Purechem of grade 32.5. It was also discovered that there is improvement in the strengths of concrete when single sized aggregates were combined with smaller sizes. However, the combination of 19.5mm coarse aggregate with lower sizes of 12.5mm and 9.5mm produced the optimal strength. The analysis of the results using ANOVA indicates that there are no significant differences in the sample means for 12.5mm single size and 12.5mm combined aggregate but there were significant differences in the sample means of both 19.5mm and 25mm single and combined aggregates for the various cement brands/grades. Notwithstanding, there are no definite interaction or inter-relationship between the two factors that is different sizes of aggregates and the various cement brands/grades.

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