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Effect of Cement Grades on some Strength Properties of Concrete

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Abstract

The purpose of this study is to investigate the effects of cement grades on some strength properties of concrete in Nigeria. Thirty samples of 100mmx100mm concrete cubes were cast with grade 32.5 and 42.5 cement (elephant brand) and cured for 3, 7, 14, 21, and 28days with a design mix of grade 20 (C20). Also twenty four samples of 100mmx100mmx600mm concrete beams were cast and cured for 7, 14, 21, and 28days with a design mix of grade 25 (C25) respectively. The compressive strength test results obtained for the grade 32.5 cement at 3, 7, 14, 21, and 28 days curing period were 7.17N/mm^2, 14.33N/mm^2, 18.0N/mm^2, 20.33N/mm^2 and 21.0 N/mm^2 respectively. Similarly, the compressive strength results for grade 42.5 cement results at 3, 7, 14, 21, and 28 days curing period were 7.33N/mm^2, 14.33N/mm^2, 19.33N/mm^2, 22.83N/mm^2 and 23.0N/mm^2 respectively. Both cement grades meet grade 20(C20) concrete requirements design mix. Furthermore, the flexural strength test results of concrete beams made with 42.5 cement grade includes 0.10N/mm^2, 0.11N/mm^2, and 0.14N/mm^2, 0.19N/mm^2 respectively at 7, 14, 21 and 28days respectively. While the flexural strength test results of concrete beams made with grade 32.5 cement includes 0.07N/mm^2, 0.08N/mm^2, 0.09N/mm^2 and 0.10N/mm^2 at 7, 14, 21, and 28 days. The difference between the flexural strength of 32.5 and 42.5 cement grades were not enormous. This study has revealed that cement grades does not translate to concrete strength.

1.0 Introduction

Concrete is the most commonly used material for all types of construction, and cement is a primary component. The cement content of a mixture is commonly perceived to control concrete strength. Based on this perception, minimum cement content is often specified in order not to exceed the amount needed to achieve the desired strength and durability. Asuzu [1] reported in his work that concrete performance is directly dependant on the water/cement ratios and aggregate/ cement ratios which determines the strength of the concrete and not necessarily on the cement grades.

Nwankwo [2] revealed that the cement grade is the strength of a certain mortar size made from cement. This translate to the actual strength that will be achieved at 28 days by a prism of specific dimensions made from that particular cement, sand and water (the cement/sand ratio being 1:3), and tested in a prescribed manner.

Taylor[3] worked on Optimizing Cementitious Content in Concrete Mixtures for Required Performance. He discovered that increasing cement content improves workability, but reduces setting time and increases chloride and air permeability of the concrete mixtures.

Yurdaku[4] also said in his work that to meet thedesired workability, strength and durability requirements; the paste volume should be withinthe range of 160% to 170% of the volume of voids. Exceeding this range will adverselyaffect the concrete performance by decreasing strength, and increasing chloride penetrationand air permeability.

Strength is considered to be a function of water/cement ratiosand independent of cement content for agiven water/cement ratio, therefore increasing cement content does not affect strength [5-7].

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2.0 Types of Portland Cement

ASTM [8]has designated five types of Portland cement, designated Types I-V. Physically and chemically, these cement types differ primarily in their content of Calcium Aluminate Minerals (C_3A), Calcium Silicate Minerals (C_3S) and in their fineness. In terms of performance, they differ primarily in the rate of early hydration and in their ability to resist sulfate attack. The general characteristics of these types are listed in Table 1.

Table 1: General Features of the Main Types of Portland cement

	Classification	**Characteristics**	**Applications**
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

(Source: [8])

The differences between these cement types are rather subtle. All five types contain about 75% Calcium Silicate Minerals, and the properties of mature concretes made with all five are quite similar. Thus these five types are often described by the term "Ordinary Portland Cement", or OPC.

In Nigeria, we have various brands of Ordinary Portland Cement which includes Dangote Cement, Elephant Cement, Ashaka Cement, Ibeto Cement, Sokoto Cement e.t.c. These fall into Type I class of cement [8]. The various brands have been used for many decades in the construction industry without knowing their various grades and the purposes for each. Not until recently governmental bodies, cooperate bodies and non-governmental organizations raised the concern for the grading of cement in Nigeria.

One of these organizations is Standard Organization of Nigeria (SON). In [9] SON approved 32.5Mpa, 42.5Mpa and 52.5Mpa grades of cement in Nigeria and directed all cement companies to comply. They further said that grade 32.5Mpa cement should be used for plastering only; grade 42.5Mpa cement should be used for cast of beams, slabs and block moulding while grade 52.5Mpa cement was meant for construction of bridges and specialized applications.

In a swift reaction, Council for the Regulation of Engineering in Nigeria (COREN) stated categorically in a stakeholder's meeting held in Sheraton Hotel and Towers, Lagos on 14th March, 2014 that cement grades do not translate to concrete strength. It rather depends on the concrete mix design. The building collapse experience in the country is as a result of 'poor concrete' not poor cement grade and encourage members of the public to consult qualified professionals in carrying out their construction needs. However, more researches needed to be carried out on the various brands of cement in the country to ascertain their quality. By definition, the strength that will be achieved at 28 days by a prism of specific dimensions made from particular cement, sand and water (with cement/sand ratio of 1:3) gives the cement grade of 32.5, 42.5 and 52.5 Mpa . It also implies that the cement grade is the strength of a certain mortar size made from the cement. It means invariably, that grades 42.5 Mpa and 52.5 Mpa will yield higher strength than grade 32.5 Mpa [2].

At this juncture, there was a need to carry out experimental work on the compressive strength of concrete of various cement grades in the country together with their setting time test in order to actually draw conclusions between the relationships of cement grades and compressive strengths of concrete.

3.0 Materials

The cement used for this work was Ordinary Portland cement (Elephant brand) of grade 42.5 and 32.5 meeting the requirement of type 1 cement [8]. The fine aggregate and coarse aggregate used to produce concrete were all obtained from Benin City, Edo state, Nigeria. Sieve analysis was carried out for the fine aggregate while consistency test was carried out on the cement paste for both grade of cement. Water/cement ratio of0.45 was used to produce a total of 30 samples of 100mm x 100mm concrete cubes for grade 20(C20) concrete design mix and also a water/cement ratio of 0.58 was used to produce 24nos of beam of 100mmx100mmx600mm size for the flexural concrete test for grade 25 (C25) concrete . The work studied the compressive strength and flexural strength test of concrete for ages 3, 7, 14, 21 and 28 days respectively. Design mixes were carried out for grade 20(C20) concrete at 0.45 water/cementratios for the compressive strength test and for grade 25(C25) concrete at 0.58 water/cement ratios for the flexural test respectively.

3.1 Compressive Strength Test

With the addition of water into the mix, the whole mix was then mixed thoroughly into a fine paste. Meanwhile, the concrete moulds were oiled (lubricated) to prevent the concrete from sticking to them and for easy de-moulding. The concrete was then poured into the concrete mould and placed on the compacting machine, which when switched on vibrated the concrete moulds, making the concrete to lose the trapped air in the mix. This was allowed for 2 minutes before the switching off. The excess concrete was cleared from the surface with the aid of the trowel and the concrete moulds were marked for easy identification to prevent mix-up.

After the cast of the samples, they were allowed to set and harden for 24 hours before de-moulding.

After de-moulding the samples were placed in a curing tank for specified numbers of days (i.e., 3, 7, 14, 21, 28 days respectively). At each specified period of days, the samples were crushed to determine the compressive strength of the concretes.

3.2 Flexural Strength Test

The beams were subjected to flexural testing with point loading at the mid span. With the aid of dial gauge attached to set up, deflection was measured due to the load applied to the beams by universal testing machine. The applied load was gradually increased until the ultimate failure load was reached. Readings were made at intervals of 1KN. The beams were simply supported by roller, point over a span of 400mm. Deflections were measured directly under the beam at the point of application of load.

Table 2: Sieve Analysis for Fine Aggregate

Sieve Sizes (mm)	Weight Retained (g)	Weight Passing (g)	Percentage Passing (%)
2.36	0.37	99.63	99.63
2.00	0.67	98.96	98.96
1.18	3.85	95.11	95.11
600µm	10.32	84.79	84.79
425	11.44	74.35	74.35
300	24.81	98.54	98.54
212	21.69	26.85	26.85
150	14.45	12.4	12.4
75	5.40	7	7

Table 3: Consistency Test of Grade 32.5 and Grade 42.5 Cement Mortar

	Grade 32.5	Grade42.5
Quantity of Cement	400g	400g
Consistency	128ml	140ml
Penetration	5.5mm	7mm
Initial Setting Time	2hrs 10mins	2hrs 18mins
Final Setting Time	3hrs 40mins	3hrs 32mins

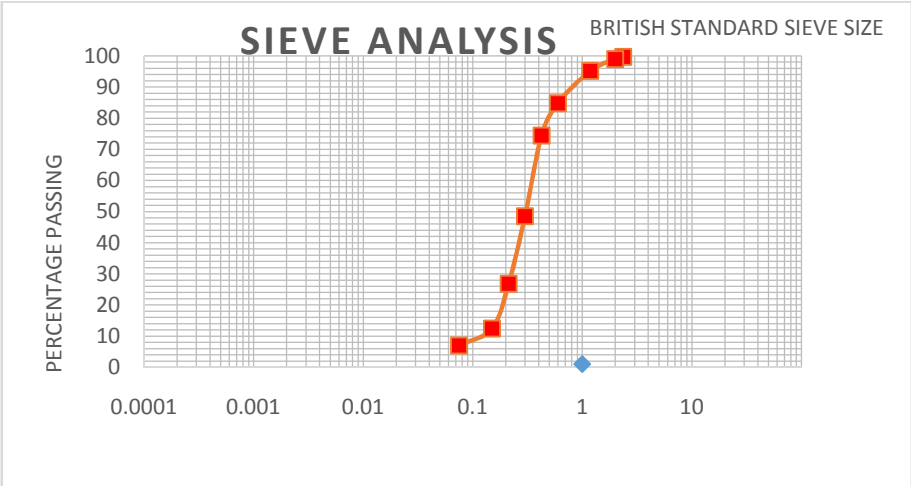

Fig 1: Sieve Analysis Graph

4.0 Results and Discussions

Table 2 reveals the results for the sieve analysis of the fine aggregate which falls into zone 3 according to [10] making it fit for concrete use. Table 3 shows the results for the consistency test for both grade 32.5 and 42.5 cement paste mortar. The initial and final setting time for grade32.5 cement paste were 2hrs 10mins and 3hrs 40mins while that of 42.5 grade cement paste are 2hrs 18mins and 3hrs 32mins respectively. Both satisfy the requirements of minimum initial setting time of 45mins and 10hours for final setting time [11]. Table 4 shows the compressive strength test results for 3, 7, 14, 21, and 28 days curing period which were 7.17N/mm^2, 14.33N/mm^2, 18.0N/mm^2, 20.33N/mm^2 and 21.0 N/mm^2 respectively. These met the characteristic strength of grade C20 concrete requirements because at 28days period of curing, the compressive strength of grade 32.5 cement was 21N/mm^2. Similarly, Table 5shows the compressive strength results for grade 42.5 cement. Compressive strength test results for 3, 7, 14, 21, and 28 days curing period were 7.33N/mm^2, 14.33N/mm^2, 19.33N/mm^2, 22.83N/mm^2 and 23.0N/mm^2 respectively. These also met the characteristic strength of grade C20 concrete requirements because at 28days period of curing, the compressive strength of grade 42.5 cement was 23.0 N/mm^2.

Furthermore, Table 6 shows the results the flexural strength test of concrete beams made with 42.5 cement grade. These include 0.10N/mm^2, 0.11N/mm^2, and 0.14N/mm^2, 0.19N/mm^2 respectively for 7, 14, 21 and 28days respectively. Table 7 provided the flexural strength test results of concrete beams made with 32.5 cement grades. These include 0.07N/mm^2, 0.08N/mm^2, 0.09N/mm^2 and 0.10N/mm^2 for 7, 14, 21, and 28 days. The difference between the flexural strength of 32.5 cement grade which was 0.10N/mm^2 and the flexural strength of 42.5 cement grade which was 0.19N/m^2 is not enormous.

Table 4: Compressive Strength for Concrete using Grade 32.5 Cement

Curing (Days)	Weight of samples (Kg)	Crushing Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm^2)
3	2.465	90	9.0	7.17
	2.565	60	6.0	
	2.495	65	6.5	
7	2.490	140	14.0	14.33
	2.570	110	11.0	
	2.550	180	18.0	
14	2.445	180	18.0	18.00
	2.450	210	21.0	
	2.460	150	15.0	
21	2.500	240	24.0	20.33
	2.640	220	22.0	
	2.625	150	15.0	
28	2.475	240	24.0	21.00
	2.450	210	21.0	
	2.520	180	18.0	

Table5 : Compressive Strength for Concrete using Grade 42.5 Cement

Curing (Days)	Weight of samples (Kg)	Crushing Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm^2)
3	2.445	80	8.0	7.33
	2.450	70	7.0	
	2.520	70	7.0	
7	2.520	150	15.0	14.33
	2.640	110	11.0	
	2.475	170	17.0	
14	2.490	200	20.0	19.33
	2.565	230	23.0	
	2.640	150	15.0	
21	2.445	240	24.0	22.83
	2.450	225	22.5	
	2.495	220	22.0	
28	2.455	245	24.5	23.00
	2.520	220	22.0	
	2.450	225	22.5	

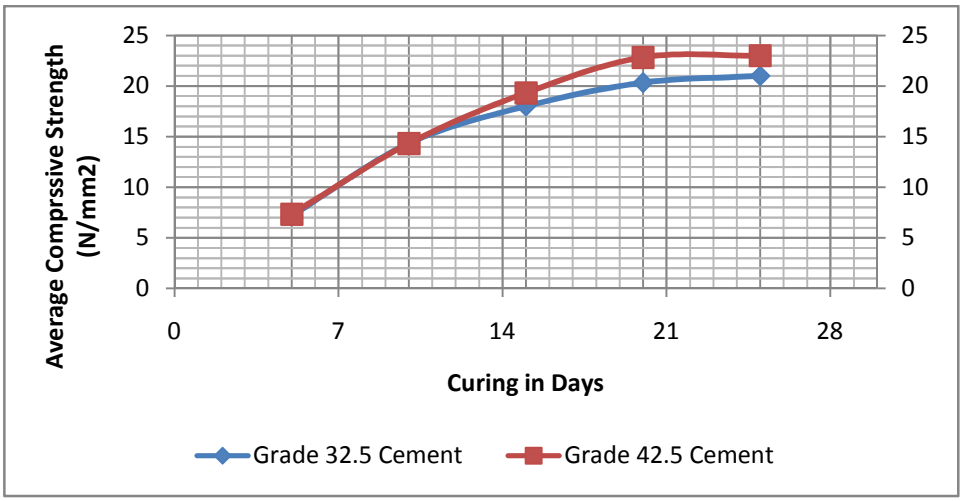

Fig 2: Relationship between the Compressive Strengths of Concrete made with Grade 42.5 and 32.5 Cement (Elephant brand)

Table 6: Flexural Strength Test of 42.5 Cement Grade

Age(Days)	Specimen	Weight of Beams Samples	Load (KN)	Average Load (KN)	Average Flexural Strength (N/mm^2)
7	A	14.5	4	3.16	0.10
	B	13.5	3		
	C	15.0	2.5		
14	A	14.7	4	3.3	0.11
	B	15.2	4		
	C	15.5	3		
21	A	15.9	5	4.33	0.14
	B	16.4	4		
	C	13.6	4		
28	A	15.6	6	5.97	0.19
	B	16.1	5.82		
	C	15.1	6.1		

Table 7: Flexural Strength Test of 32.5 Cement Grade

Age(Days)	Specimen	Weight of Beams Samples	Flexural Strength (KN)	Average Load(KN)	Average Flexural Strength (N/mm^2)
7	A	14.0	2	2.16	0.072
	B	15.0	2		
	C	15.3	2.5		
14	A	16.0	1.7	2.4	0.08
	B	15.0	3		
	C	15.0	2.5		
21	A	14.0	4	2.66	0.088
	B	16.2	2		
	C	15.1	2		
28	A	15.5	4	3.26	0.10
	B	15.5	3.2		
	C	15.5	2.6		

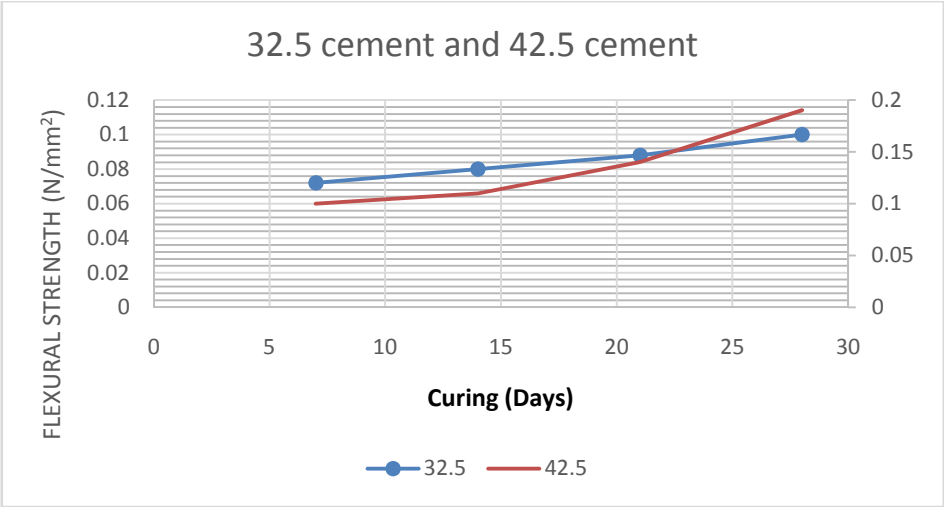

Fig. 3: Relationship between the Flexural Strength of Concrete made with Grade 42.5 and Grade 32.5 (Elephant Brand)

5.0 Conclusion

Due to the compressive strength results and the flexural strength test results obtained from Fig 2 and Fig 3 with grade 32.5 and 42.5 cement (elephant brand) at 28 days period of curing. The following can be inferred :

i. The grade of cement does not affect the compressive strength and flexural strength of concrete very adversely.
ii. Grade 32.5 elephant cement can be used for grade 20(C20) and grade 25 (C25) concrete as well as grade 42.5 elephant cement which means both can be used for concrete work.
iii. This study supports the statements of Council for the Regulation of Engineering in Nigeria (COREN) that the grade of cement does not translate to the compressive strength of concrete.
iv. Strength of concrete largely depends on water cement ratios, aggregate/cement ratios and minimally on cement grade.

6.1 References

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