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The Effect of the Dimensions of Concrete Samples on the Physio- Mechanical Properties of Normal Concrete Blocks

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ABSTRACT

170 samples of various shapes and sizes of M30 grade of concrete samples was produced which included 100 mm , 150 mm and 200 mm cubes, 100 mm and 150 mm diameter cylinders and 100 mm, 150 mm based prisms. The compressive test for various shapes produced were tested to evaluate the shapes and dimensions that gave the highest compressive strength. The cubes of 100 mm and 150 mm with a slenderness ratio of one(1) (height/ [diameter]width) gave the highest compressive strength. The compressive strength for the 100 mm based cube at 28days cure was 41.52 Mpa, and the compressive strength for the 150 mm cube at 28days cure was 39.00 MPa. The compressive strength of the cylinders and prisms reduced as the slendernes ratio increased due to the reduced compressive force as a result of the reduced shear force at the platen concrete interface as a constant load was applied by the compression testing machine.

Keywords: concrete blocks, compressive strength, dimensions, slenderness ratio

I. INTRODUCTION

The author(s) were interested in the introduction of waste plastics as filler in concrete in order to solve the problems of pollution caused by waste plastics to the environment. However, challenges were encountered along the way as to which concrete shape to be utilized as a standard for testing compression and split tensile test of the concrete blocks. The work of M.V. Krishna Roa *etal,* 2011, showed that there is higher compressive strength in concrete cubes with glass fiber addition for the 100 mm cube compared to that of the 150 mm cubes; similarly the 100 mm diameter cylinder had higher compressive strength than the 150 mm cylinder. There is an increase in the splitting strength and modulus of rupture as the dimensions and size of mortar reduced using either the cubical or cylindrical shapes respectively (Sura. A. Majeed, 2011). The investigation of (J.K. kim, 2001), showed that the effect of specimen size on the Flexural Compressive Strength of Concrete, and found out that for all types of loading conditions, the trend showed that the compressive strength of the sample concrete decreased as the length and depth increased. The primodal compressive strength of concrete blocks decrease with an increase in the height(h) to width(d) ratio and approaches a value (Ꞷ),(where Ꞷ =h/d=4), beyond the point where Ꞷ ≥4, the compressive strength remains relatively constant and will equal 0.7 times the strength of the cube which has h/d=1(Neville, 1997).

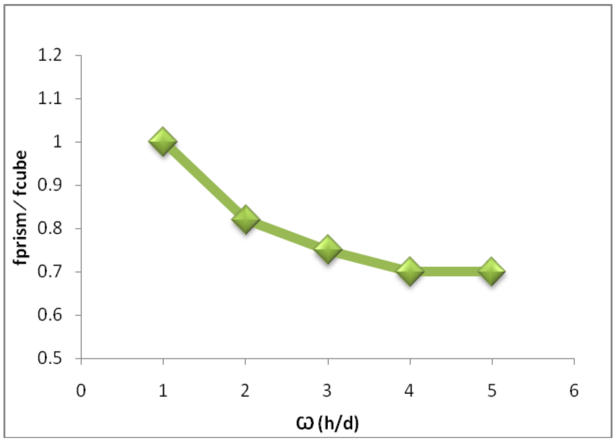

Figure 1: Variation of Primodal Strength with h/d Ratio

Various samples of cubes, cylinders and prism were prepared and their compressive strength was compared to see how the values varied with the sizes and dimensions of the samples. The samples that gave the best compressive strength and met targeted mean compressive strength (TMCS) were then utilized for the investigation the author(s) were interested in.

II. MATERIALS AND METHODS

Materials

Cement: - Ordinary Portland Lime Stone Cement Grade 42.5, Type – 1, was used in the mix proportion for this study. The chemical and physical properties are shown in Tables 1 and 2 below.

Table 1: Chemical Properties of Cement Utilized in the study

Constituents	% Weight
lime	60.20
Silica	20.4
Iron Oxide	3.48
Sulfite	2.32
Magnesium Oxide	1.48
Loss On Ignition	0.76
Lime Saturation Factor	0.92
Insoluble Residue	0.36
Compunds on Gelation of Cement Using Bogue Equation	
Tricalcium silicate	50.10
Dicalcium Silicate	21.55
Tri calcium aluminate	9.23
Tetra calcium aluminoferrite	10.89

Table 2: Physical Properties of OPC Utilized in the Study

Properties	OPC
Specific gravity	3.15
Bulk Density	1452Kg/m^3
Initial Setting Time	36mins
Final Setting Time	301mins
Soundness (%)	0.18
Fineness	224m^3/Kg
3 days Compressive Strength (MPa)	25.00
7 days Compressive Strength (Mpa)	33.00
14days Compressive Strength (MPa)	38.80
21 days Compressive Strength(MPa)	42.00
28Days Compressive Strength((MPa)	45.00

Fine Aggregate(FA): - The FA was natural river sand obtained from Ahmadu Bello University (ABU) Dam, in Zaria, Kaduna State in Nigeria. Samples of the FA were collected and sieved with 5mm sieve size to remove deleterious materials in accordance with ASTM C 33, which limits the permissible amounts of deleterious substances found in the FA. The FA was kept at ambient temperature in the laboratory and was utilized under surface saturated dry (SSD) conditions. Samples were kept and collected in accordance with ASTM D 75-03. The maximum size, nominal maximum size and fineness modulus was 5mm, 4.75mm and 3.14 respectively. The specific gravity of the fine aggregate was 2.64, with a loose bulk density of 1630kg/m^3 and a compacted bulk density 1750kg/m^3 with a compaction factor of 0.93. It had water absorption of 1.0 percent, the fineness modulus was 3.14, and no free surface moisture was present. Particle size analysis of the FA is shown in Table 3.

Coarse Aggregate (CA): - The CA were obtained from a quarry site opposite Nigerian College of Aviation Technology (NCAT) along Sokoto Road Zaria in Kaduna State. Nigeria. Samples of the CA were collected and were sieved through the 20mm sieve size and retained on the 5mm sieve to remove deleterious materials according to ASTM C 33. The CA was then kept at ambient temperature in the laboratory to attain surface dry conditions. Samples were kept and collected according to ASTM D 75-03. The maximum size, nominal maximum size and fineness modulus was 20mm, 19.5mm and 6.95 respectively. The loose bulk density was 1542kg/m^3 and the compacted bulk density was 1647Kg/m^3, with a compaction factor of 0.94. The water absorption was 0.50 percent and the surface moisture was zero (utilized in SSD condition). The fineness modulus was 6.95. The particle size analysis of the CA is shown in Table 4.

Table 3: Particle Size Analysis of Fine Aggregate

Mass FA=2Kg Sieve size (mm)	Mass Retained	% Mass Retained	% Mass Passed	Cumulative % Retained
10.00	0	0	100	0
5.00	0	0	100	0
4.75	80	4	96	4
2.35	278	14	82	18
1.18	537	27	55	45
600	438	22	33	67
300	318	16	17	83
150	259	13	4	96
Pan	79	4	-	-
Total	1989	**100**		**314** Fineness Modulus =314/100=3.14

Table 4: Particle Size Analysis of Coarse Aggregate

Mass CA= 4Kg Sieve size (mm)	Mass Retained(g)	% Mass Retained	%Mass Passed	Cumulative % Mass Retained
25.00	0	0	100	0
19.00	0	0	100	0
12.5	2875	72	28	72
9.5	917	23	5	95
4.75	198	5	0	100
2.36	0	0	0	100
1.18	0	0	0	100
0.60	0	0	0	100
0.30	0	0	0	100
0.15	0	0	0	100
Pan	0	0	0	100
Total	3390	100		∑695 Fineness Modulus=695/100=6.95

Casting and Curing Water: - Portable tap water was utilized for casting and curing of the concrete utilized in the study with specific gravity of 1g/cm^3.

METHODS

Mix Design Parameters: - M30 grade of concrete was produced using the ACI 211-91 mix design method for the proportioning of the fresh concrete mixture. The properties of the cement, fine and coarse aggregate enumerated above were used for the proportioning of the concrete block. The concrete produced was for mild exposure and the Targeted Mean Compressive Strength (TMCS) was 38.50 MPa, 35 percent air content and slump was between 25-75mm. The aggregates were utilized in their SSD condition.

Table 5: Details of Materials Tested

S/N	Specimen Type	Specimen Size (mm)	Designation	14days Cure, No. of specimen Tested	21days Cure, No. of Specimen Tested
1	Cube	100 BD X 100 WDX 100 HT	$CU_1$1	5	5
		150 BD X 150 WDX 150 HT	$CU_1$2	5	5
		200 BD X 200 WD X 200 HT	$CU_1$3	5	5
2	Cylinder	100 D X100 HT	$CY_1$1	5	5
		150 D X 150 HT	$CY_1$2	5	5
3	Cylinder	100 D X 200 HT	$CY_2$3	5	5
		150 D X 300 HT	$CY_2$4	5	5
4	Cylinder	100 D X 300 HT	$CY_3$5	5	5
		150 D X 450 HT	$CY_3$6	5	5
5	Cylinder	100 D X 400 HT	$CY_4$7	5	5
		150 D X 600 HT	$CY_4$8	5	5
6	Prism	100 BD X 100 WD X 200 HT	$PR_2$1	5	5
		150 BD X 150 WD X 300 HT	$PR_2$2	5	5
7	Prism	100 BD X 100 WD X 300 HT	$PR_3$3	5	5
		150 BD X 150 WD X 450 HT	$PR_3$4	5	5
8	Prism	100 BD X 100 WD X 400 HT	$PR_4$5	5	5
		150 BD X 150 WD X 600 HT	$PR_4$6	5	5
9	Prism	100 BD X 100 WD X 500 HT	$PR_5$7	5	5
			Total	85	85
				170 samples	

Note: The cube and prism don't have a diameter; the slenderness ratio will be Height (HT)/Width (WD)

Table 6: Mix Design Proportion for the Concrete Produced for the Study

S/N	Method	Grade Of Concrete	TMCS (MPa) at 28 Days cure	W/C	Cement (CMT) Content (kg/m^3)	Water Content (Kg/m^3)	FA Content (Kg/m^3)	CA Content (Kg/m^3)	TAC (Kg/m^3)	TAC/CMT
1	ACI Method	M30	38.50	0.40	420.00	168.00	615.62	1087.02	1702.64	4.05

Key: Total Aggregate Content (TAC), TMCS= Targeted Mean Compressive Strength

Casting and Curing: - Casting and curing of test specimen were done according to ASTM C192/C192M- 16a. Tests were carried out after 14 and 28days cure in water.

Tests carried out on Specimens: - The compressive test was carried out on the cylindrical samples according to ASTM C39/ C39M-16b and the compressive strength was carried out on the cubical samples according to ASTM C 109 -99.The test results were compared with their counterparts in order to observe the trend as the dimensions of the samples of the concretes were adjusted in relation to their compressive strength. The results were discussed and, informed conclusions were made.

III. RESULTS AND DISCUSSIONS

Table 7: Compressive Test Results of Different Dimensions of Concrete Specimens

S/N	Specimen Type	Specimen Size (mm)	Slenderness Ratio (HT/D)	Designation	14days compressive Strength (MPa)	28days compressive Strength (MPa)
1.	Cube	100 BD X 100 WD X 100 HT	1	$CU_1$1	36.31	41.52
		150 BD X 150 WD X 150 HT	1	$CU_1$2	35.00	39.00
		200 BD X 200 WD X 200 HT	1	$CU_1$3	34.00	38.55
2.	Cylinder	100 D X 100 HT	1	$CY_1$1	34.75	38.83
		150 D X 150 HT	1	$CY_1$2	33.80	37.67
3.	Cylinder	100 D X 200 HT	2	$CY_2$3	28.53	33.10
		150 D X 300 HT	2	$CY_2$4	24.12	30.46
4.	Cylinder	100 D X 300 HT	3	$CY_3$5	25.18	31.85
		150 D X 450 HT	3	$CY_3$6	23.23	28.52
5.	Cylinder	100 D X 400 HT	4	$CY_4$7	23.08	29.15
		150 D X 600 HT	4	$CY_4$8	18.21	24.67
6.	Prism	100 BD X 100 WD X 200 HT	2	$PR_2$1	32.15	36.32
		150 BD X 150 WD X 300 HT	2	$PR_2$2	33.02	38.02
7.	Prism	100 BD X 100 WD X 300 HT	3	$PR_3$3	29.93	34.90
		150 BD X 150 WD X 450 HT	3	$PR_3$4	30.99	36.39
8.	Prism	100 BD X100 WD X 400 HT	4	$PR_4$5	28.33	33.23
		150 BD X 1500 WD X 600 HT	4	$PR_4$6	28.52	32.07
9.	Prism	100 BD X 100 WD X 500 HT	5	$PR_5$7	23.37	29.50

Key: D= Diameter, HT= Height, WD= Width, BT= Breath, HT= Height. Note: The Cubes and Prism don't have a diameter the slenderness ratio will be Height (HT)/ Width (WD).

Effect of Dimensions of Samples on the Compressive Strength of the Concrete Cubes $CU_1$1, $CU_1$2 and $CU_1$3

The result(s) showed that there was slight increase in compressive strength as the cubic size increased for the $CU_1$1, $CU_1$2 and $CU_1$3 based cubes (Fig. 2). This is because there are always flaws such as micro cracks and voids in the concrete samples produced. The larger samples are statistically more likely to contain more of these flaws and will therefore have lower compressive strength on the application of load, than the smaller cubes. Another reason why smaller cubes have higher strength than the larger cubes is because smaller cubes have greater confinement than the larger cubes, confining pressure reduces the expansion and growth of micro cracks in the concrete and this resulted in higher compressive strength in the smaller cubes during application of load (Arghya Deb, 2017). In addition the larger cubes had higher stress concentration at the corners thus, this initiated earlier cracks making the compression test measured to be lower (Neville, 1997). The compressive strength of the $CU_1$1 based cube was higher than that of the

$CU_1$2, and $CU_1$3 for the 14days cure by 3.74 and 6.79 percent respectively. Similarly the compressive strength of the $CU_1$1 based cube was higher than that of the $CU_1$2, and $CU_1$3 for the 28days cure by 6.46 and 7.70 percent respectively. Not withstanding however, both the $CU_1$2 and $CU_1$3 based cubes met the targeted compressive strength (TMCS) of the concrete produced thus, both samples can be used for the study of compressive forces of concrete cubes, but $CU_1$1 can be recommended because it is easier to move around and it also saves cost.

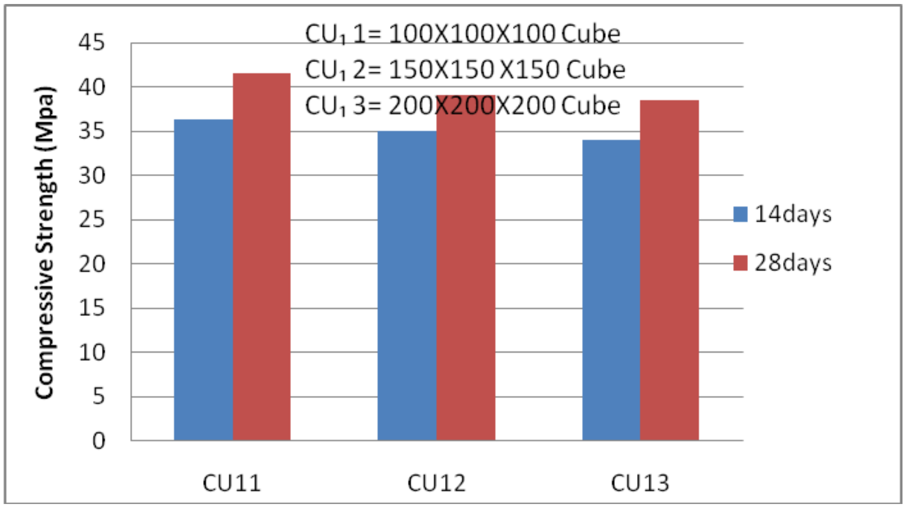

Figure 2: Compressive Strength for $CU_1$1, $CU_1$2, and $CU_1$3, Cubes for 14 and 28Days Cure

Compressive Strength Against Slenderness Ratio for 100mm & 150mm Cylinder Based Concrete Samples

Fig. 3; showed the compressive strength against slenderness ratio of the concrete samples for the 100mm based cylinder designated as $CY_1$1, $CY_2$3, $CY_3$5, and $CY_4$7 (Tables 5 & 7). Fig. 4; showed the compressive strength for the 150mm based cylinder designated as $CY_1$2, $CY_2$4, $CY_3$6, and $CY_4$8 (Tables 5 &7). The result(s) showed that there was gradual decrease in compressive strength of the specimens as slenderness ratio increased. This is because as the height to width of the cylinders increased, the resultant effect of shear on compressive strength becomes smaller thereby exhibiting lower compressive strength. The compressive strength of $CY_1$1 was higher in compressive strength compared to the $CY_2$3, $CY_3$5, $CY_4$7 by 33%, 51% and 64% respectively for the 14 days cure and 33%, 38% and 51% respectively for the 28days cure respectively. Similarly the compressive strength of the $CY_1$2, was higher in compressive strength compared to the $CY_2$4, $CY_3$6, $CY_4$8 by 44.28%, 49.81% and 91.21% for 14days cure and 31.32%, 40.25% and 62.14% respectively for 28days cure. The use of samples with a slenderness ration of one (1) gave the best results. Thus, $CY_1$1 is recommended for 100mm based cylinders and $CY_1$2 is recommended for the 150mm cylinders. Choice can be made based on availability of materials, laboratory facilities available and cost.

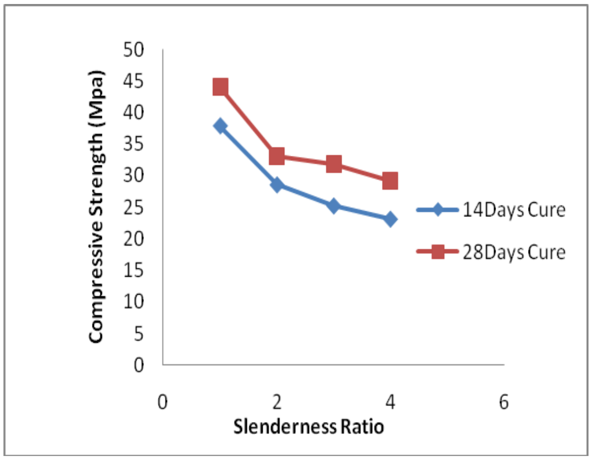

Figure 3: 100mm Cylinder Based Samples

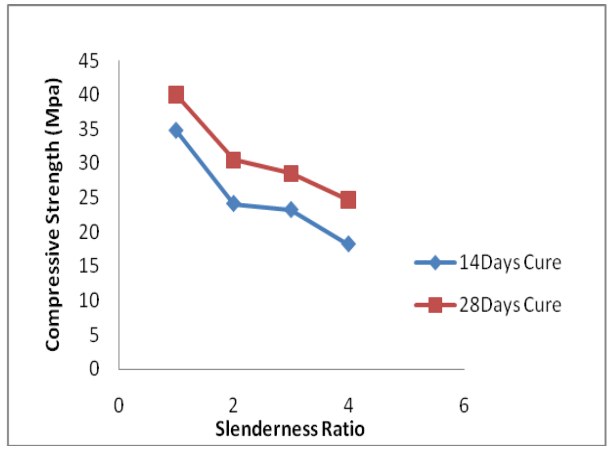

Figure 4: 150mm Cylinder Based Samples

Compressive Strength Against Slenderness Ratio for 100mm and 150mm Prism Based Concrete Samples.

Fig. 5; Showed the compressive strength against slenderness ratio of the concrete samples for the 100mm based Prism designated as $PR_2$1, $PR_3$3, $PR_4$5 and $PR_4$5 (Tables 5 & 7) and Fig. 6; Showed the compressive strength for the 150mm based Prism designated as $PR_2$2, $PR_3$4, $PR_4$6(Tables 5 & 7). The $CU_1$1, and $CU_1$2 are also prisms with slenderness ratio of one (1) each for the 100 mm, and 150 mm based Prisms respectively. The result(s) showed that there was gradual decrease in compressive strength of the specimens as slenderness ratio increased for the 14days and 28days cure respectively. This is because the prisms with higher height to width ratio had lower platen restraint as frictional forces were developed on the concrete platen interface thus, the influence of shearing becomes less so that the sample readily fails at the centre, leading to lower compressive strength due to lower bearing load capacity (Neville, 1997).The compressive strength of $CU_1$1 was higher in compressive strength compared to the $PR_2$1, $PR_3$3, $PR_4$5 and $PR_5$7 by 12.9, 21.32, 28.17 and 55.37 percent respectively for 14 days cure and 14.31, 18, 24.95 and 40.75 percent respectively for the 28days cure for the 100 mm based prisms. Similarly the compressive strength of the $CU_1$2, was higher in compressive strength compared to the $PR_2$2, $PR_3$4, and $PR_4$6 by 6, 12.94 and 22.72 percent respectively for 14days cure and 2.58, 7.71, and 21.61 percent respectively for 28days cure. The $CU_1$1 & $CU_1$2, with a slenderness ration of one (1) gave the highest compressive strength.

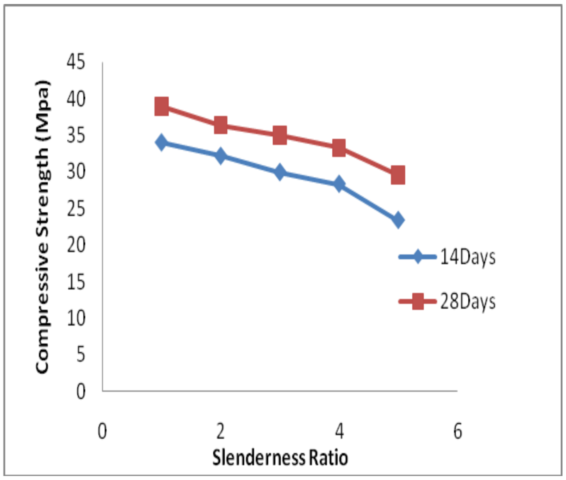

Figure 5: 100mm Prism Based Sample

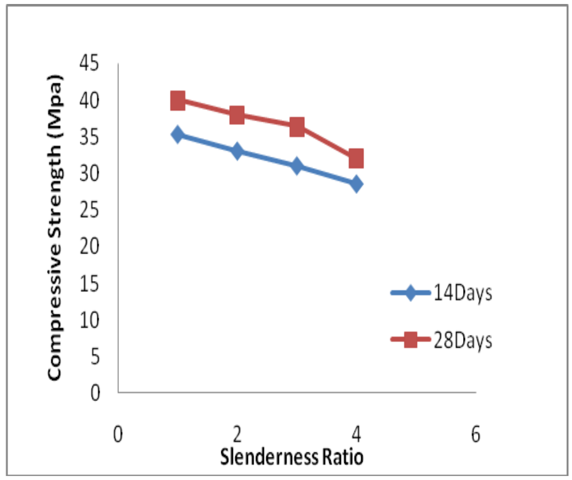

Figure 6: 200mm Prism Based Sample

IV. CONCLUSION

The effects of the dimensions of the concrete specimen on the compressive strength of the concrete have been successfully carried out. The cubes are the best samples to be utilized for testing the compressive strength of concrete because they met the TMCS. The cube of 100X100X100 mm gave the higher compressive strength than the 150X150X150 mm cube. The former can also be utilized when cost is to be minimized. Similarly the samples with the lowest slenderness ratio of one (1) gave the best compressive strength for both the cylinders and the prisms and therefore these samples are recommended for carrying out the testing of compressive strength for concrete.

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