INTERNATIONAL JOUNAL OF: ENGINEERING RESEARCH AND TECHNOLOGY

TIMBOU-AFRICA ACADEMIC PUBLICATIONS
INTERNATIONAL JOURNAL, AUGUST, 2022 EDITIONS
VOL. 10 NO. 5 ISSN: 2707-5654

EFFECT OF VIBRATION ON CONCRETE STRENGTH USING NIGERIAN PORTLAND LIMESTONE CEMENT GRADES 32.5 AND 42.5.

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ABSTRACT

This paper investigated the effect of vibration on the properties of concrete produced with different Nigerian Portland-Limestone cement grades (32.5R and 42.5N). Various tests were carried out on the constituent materials; Dangote Portland cement of two grades (32.5R and 42.5N{3x}), river sand and crushed granite stones. Concrete

Introduction

Most buildings in Nigeria are owned by common individuals who cannot afford to engage the qualified professionals for the construction of their buildings, hereby engaging craftsmen particularly common bricklayers. Craftsmen construct building without proper design and methods; even load-bearing structures (Adewole & Ajagbe, 2015). The incessant collapse of building is a common occurrence in Nigeria. A survey conducted revealed that building experts have identified the use of low quality building materials, the use of incompetent artisans/craftsmen, lack of supervision of building construction works by

were prepared to 1:2:4 and 1:1.5:3 ratios for both vibrated and non-vibrated concrete. 60 concrete cubes of 150 x150 x 150 mm^3 were moulded and cured for 7,14, 28 and 35 days .Workability and compressive strength tests were carried out on the wet and dry concrete respectively . The results reveal that the consistency, initial and final setting time for 32.5 grade of cement varies from that of 42.5N grade. The compressive strength of concrete increases as the age increases for both grades at 1:2:4 and 1:1.5:3 mix ratios. Also concrete produced with cement grade of 32.5R have a lower compressive strength compared with the 42.5N grade of both vibrated and non-vibrated concrete for both grades 1::2:4 and 1:1.5:3 mix ratios. Vibrated concrete produced a denser and a higher compressive strength concrete compared to non-vibrated concrete due to the considerable reduction of voids and the lower rate of water absorption. It is recommended that the users of cement be mindful of the grade of cement in-use so as to achieve a targeted strength. More so structures like water retaining structures, bridges, slabs, beams columns e.t.c which require high compressive strength should be made with 42.5N grade and be properly vibrated.

Keywords: *Cement, Vibrated Concrete, Aggregate, Curing, Compressive strength.*

qualified professionals, use of improper concreting methods such as; self-compaction or vibration has the main reasons for the incessant collapse of building in Nigeria (Oloyede, 2010)

Concrete, one of the most consumers' materials that is widely used in the construction industries in the world (Naik, 2008). Generally, concrete consist of cement, fine aggregate and coarse aggregate where their proportion is based on the grade of concrete and strength. Its versatility and relative economy in filling wild range of needs has made it a competitive building material. (Enchanta, 2008). Concrete moves from fresh to hardened state and it is expected to fulfill certain requirements in term of strength, durability and other properties depending on the purpose it is expected to serve. Therefore the behaviour of concrete should be controlled right from the fresh state to hardened state (Grupta et al, 2020) .

Buildings should be constructed by the professionals who will ensure trial mixes, appropriate methods and grades to obtain the right mix ratios to achieve the required concrete grade, concrete quality and assured tests are conducted. The craftsmen generally use the common convectional 1:2:4 cement-fine aggregate-coarse aggregate mix ratio irrespective of the strength grade of the cement as they are unaware of the presence of different cement grades in the Nigerian open market and their effects on concrete strength. Nigerians generally are only aware of the different cement brand names and they buy and use cement based on brand names rather than cement grades. In the Nigerian open market, the two cement grades classes that are available and which are used for building construction are cement grade 32.5 and cement grade 42.5. Apart from the lack of awareness of the different cement grades in Nigeria, most Nigerian craftsmen and professional, engineers as well as academics and researchers is novice of the fact that the bagged Portland-limestone cement (the only cement type in the Nigerian open market) is not the same Ordinary Portland Cement (OPC) they used in the past. They are not aware that the OPC, which was the only cement type allowed to be produced in Nigeria by the old Nigerian industrial standards for cement: NIS 11: 1974 and NIS 439:2000 no longer exist in the bagged form in Nigeria. In Nigeria presently, OPC is only produced in bulk on request by the big construction companies handling big government projects. Cement manufacturers in Nigeria started producing Portland-limestone cement (PLC) following the adoption and implementation of the current Nigerian Industrial Standards for cement, NIS 444-1:2003. From 2003 till date, Portland-limestone cement is the only bagged cement in the Nigerian open market (Adewole & Ajagbe, 2015)

Cement is a binder, a substance used for construction that have the ability to sets, harden and adheres to other materials to bind together. Conventionally, cement is the major substance use as binder in concrete. There are different types of cement such as: Ordinary Portland cement, Low heat cement, Pozzolana cement, Rapid hardening Portland cement,

TIJERAT
ISSN: 2707-5654

extra rapid hardening portland cement, hydraulic cement etc (Neville & Brook, 2010).

The regularly utilized cement in the construction industry is PLC and OPC. They are primarily classified into three: 33 grade cement, 43 grade cement and 53 grade cement. It is the minimum 28^{th} day compressive strength of cement also known as cement strength classes of 32.5MPa, 42.5MPa AND 55.5MPa respectively and it is also used to define cement grades. The cement grade refers to the cement compressive strength that means how much strength cement can yield or bear. The grade of cement is a numerical value to measure its compressive strength (Fapohunda et al., 2020). The suffix" N" denotes cement with normal early strength whereas ''R"denotes cement with significant early strength. (Adewole et al., 2014) , higher concrete grades/strength classes such as concrete grades/strength classes: C25/30, C30/37, C35/45 are recommended to be used for reinforced concrete foundations and other reinforced concrete structural members (Fapohunda et al., 2020).

(Okonkwo & Omaliko, 2022) who studied the effect of Nigerian Portland-limestone cement grades on strength of concrete investigated the 3 grades of cement: 32.5R, 42.5R and 42.5N with mix design 1:2:4 and varying water cement ratio of 0.4, 0.5 and 0.6. He concluded that 42.5 N grade has the optimum compressive strength on 28^{th} day of curing and concrete with 32.5R will produce a more workable and weaker concrete than 42,5R irrespective of their water cement ratio.

Vibrated structural concrete are concrete that has been vibrated either internally or externally after it has been placed in order to produce a denser mass. Vibrating concrete is critical because by removing air pockets and packing the aggregate particles together, it increases the density and strength of the concrete. Tightly packed particles will result in a stronger and more durable concrete structure. Concrete which has not been vibrated is full of air pockets (honeycomb) which results in a poor finish and weak structure that leads to collapse. Walk. M (2008, Li,et al (2004)

METHODOLOGY

The procedure to be employed in carrying out this research work is divided into the following stages;

- The procurement of the needed materials such as Dangote cement of: 32.5R and 42.5N{3x} , fine aggregate (sharp sand), coarse aggregate (granite), poker (vibrating machine) and the 150x150x150 mm^3 mould etc

- Laboratory tests on the constituent materials.
- The mixing and casting of vibrated and non-vibrated of concrete in mix ratios 1:2:4 &1:1.5:3
- The curing process for 7 days, 14 days , 28 days and 35 days.
- Laboratory Tests on Compressive Strength of the Produced Concrete Cubes.

Material Procurement

Nigerian Portland-limestone Cement; Dangote brand of 32.5R and 42.5N conforming to NIS 444-1:2003 was procured in the market and used for the concrete production. The fine aggregate that was used is free of dirt and impurities. The fine aggregate was sand passing through 2.43mm sieves while coarse aggregate is defined as any material greater than 4.75mm, its make up to 60-80% of the volume of concrete. It also imports for strength, thermal and elastic properties of concrete. 19mm graded size of the granite was used. The water been used was gotten from one of the school tap.

Production of Concrete

Mix Design

Batching by weight was adopted. The mass of each constituent was determined relatively to the mass of cement required in the mix using absolute equation. And a mix ratio of 1:1.5:3 and 1:2:4 with water cement ratio of 0.5 was employed. The material were batched by weight using absolute weight equation 1.0

$$\frac{w}{100c} + \frac{W_C}{S.G_{C\,X\,10^3}} + \frac{W_1}{S.G_{1\,X\,10^3}} + \frac{W_2}{S.G_{2\,X\,10^3}} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn } 1.0$$

Where W_w = weight of water, W_c = weight of cement, W_1=weight of sand, W_2=weight of gravel, $S.G_c$=specific gravity of cement, $S.G_1$ = Specific gravity of sand

$S.G_2$ = specific gravity of coarse aggregate, Density of water = 1000kg/m^3

For nominal concrete mix proportion with maximum aggregates size of 19mm the volume of concrete required for three moulds each of size 150x150x150 (mm^3)
3 moulds = (0.150^3x3)m= 0.010125m^3=0.01013m^3
Add 15% waste = 0.0015195= 0.01013+0.0015195
Volume of concrete for three moulds=0.012m^3

Material Content

For nominal mix proportion for 1:2:4 with water cement ratio of 0.5
concrete for water cement ratio of 0.5

Cement = $\frac{0.5c}{1000}+\frac{1c}{3150}+\frac{2c}{2500}+\frac{4c}{2600}=1$ Eqn 2

0.0005c+0.00032c+0.00077+0.0015c =0.012
C=0.0031=0.012
C=0.012/0.0031 =3.9kg
Fine aggregate 2c =3x3.9=7.8
Coarse aggregate 6c=6 x3.9=15.6
Water = 0.5x3.9=1.95kg=1.95liters, *Ditto For* 1:1.5:3

Mixing of Concrete

The aggregate was spread in a uniform layer on hard, clear and non-porous face. Cement was then uniformly spread over the aggregate and the dry materials were mixed manually by turning over from one end to the other and cutting with a shovel until the mix appears uniform. Water is then gradually added so that neither water nor water with cement can escape. The mix was then mixed again until it appears uniform in color and consistency as shown in plate 1.0-2.0

Preparation of the Concrete Cubes.

This study utilized the mix ratio of 1:1.5:3 and 1:2:4 with water cement ratio of 0.5 and vibrated and non-vibrated was produced using Poker (concrete vibrator) see plate 3.0. Concrete was poured and transferred from the point to mixing to its compacted state with the mould. The mix concrete was placed into the metal formwork cubes of 150mm x 150mm x 150mm. (plate 4.0). Formwork was removed from the concrete after 24 hours. This was done gently so that the cubes will not experience buckling or cracks because of the low strength attained at that time. The hardened concrete cubes are immediately fully immersed in the container filled with water, for the period of 7, 14 , 28 and 35 days for curing.

Plate 1 : Mixing of concrete

Plate 2 : Vibrating and Placing of concrete in the concrete moulds

Plate 4 : Concrete Vibrating Machine

Plate 3 : Concrete cubes produced

Compressive Strength Test on the Concrete Cubes.

The cubes were weighted after their curing days. Compressive strength was performed in the laboratory at the Department of Civil Engineering, Kwara State Polytechnic Ilorin. The cubes were placed on the lower steel flatten plates of the testing machine with both smooth surface facing the top and bottom flatten plates. After which the load was applied and the load failure for each cubes was recorded by taking the reading on the load meter on the machine. By ascertaining the failure load and surface area of the cube, the cube concrete compressive strength was calculated using Equation 1.0

The loading pattern adopted for the test was Centre point loading method, the loads applied at the center point were gradually increased and the maximum load that breaks the cubes were observed and recorded in accordance with BS 1881.

The compressive strength formula as follows:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{failure load } (kN)}{\text{Cross sectional area } (mm^2)} \quad \text{Eqn 1.0}$$

RESULTS AND DISCUSSSION

The results of the various tests on the cement ; Initial and final setting time tests, Consistency Test for Cement Grade 32.5R and 42.5N. specific gravity and grain size distributions of sand and granite, workability and compressive strength tests on fresh and hardened concrete are presented on Tables 1.0- 9.0

Table 1.0: Consistency Test Results for Cement Grade 42.5N

Trial No	Weight of Cement (g)	% of water (%)	Amount of Water (g)	Penetration (mm)	Gauge time (minutes)
1	400	27%	108	40	4
2	400	29%	116	32	4
3	400	31%	124	11	4
4	400	32%	128	5	4

Table 2.0: Initial Setting Time for cement of Grade 42.5 (Interval time = 30 minute)

Time (minutes)	Amount of water (g)	Penetration (mm)
12:59pm	128	0
1:29pm	128	0

1:59pm	128	0
2:30pm	128	6

Table 3.0: Final Setting Time for cement of Grade 42.5N (Interval time = 1 hour)

Time (minutes)	Amount of water (g)	Penetration (mm)
12:59pm	128	0
1:59pm	128	6
2:59pm	128	10
3:59pm	128	16
5:00pm	128	20
6:14pm	128	Surface

Table 4.0: Consistency Test Result for Cement Test for Grade 32.5R

Trial No	Weight of Cement (g)	% of water (%)	Amount of Water (g)	Penetration (mm)	Gauge time (minutes)
1	400	27%	108	35	4
2	400	29%	116	26	4
3	400	31%	124	13	4

Table 5.0: Initial Setting Time for cement of Grade 32.5R (Interval time = 1 hour)

Time (minutes)	Amount of water (g)	Penetration (mm)
12:58pm	132	0
1:28pm	132	0
1:58pm	132	0
2:28pm	132	0
2:58pm	132	0
3:28pm	132	7

Table 6.0: Final Setting Time for cement of Grade 32.5R (Interval time = 1 hour)

Time (minutes)	Amount of water (g)	Penetration (mm)
3:28pm	132	0
4:28pm	132	0
5:28pm	132	7
6:28pm	132	10

7:28pm	132	18
8:28pm	132	30
9.28pm	132	Surface

Table 7.0: Specific Gravity for Fine Aggregate

	W1(g)	W2(g)	W3(g)	W4(g)	Specific Gravity (S.G)
Sample 1	**479**	**923**	**1783**	**1506**	**2.66**
Sample 2	**488**	**944**	**1870**	**1591**	**2.58**
Sample 3	**482**	**929**	**1781**	**1498**	**2.73**
Average S.G			**2.65**		

Table 8.0: Specific Gravity for Coarse Aggregate

	W1(g)	W2(g)	W3(g)	W4(g)	Specific Gravity (S.G)	Bulk Density.(B.D)
Sample 1	**1083**	**485**	**969**	**990**	**2.53**	**2.67**
Sample 2	**1086**	**484**	**964**	**1001**	**2.51**	**2.77**
Sample 3	**1084**	**483**	**966**	**994**	**2.53**	**2.72**
Average S.G			**2.52**			
Average B.D			**2.72**			

Table 9.0: Aggregate Impact Test Result for Coarse Aggregate

Samples	A(g)	B(g)	Av(%)
Sample 1	**692**	**135**	**19.51**
Sample 2	**739**	**143**	**19.35**
Sample 3	**709**	**139**	**19.61**
Average		**19.49%**	

Table 10.0: Slump Test result of the fresh concrete

SLUMP TEST VALUE				
CEMENT GRADE	Grade 32.5R		Grade 42.5N	
Water/ Cement ratios	0.5		0.5	
	1:2:4	1:1.5:3	1:2:4	1:1.5:3
	35mm	40mm	45mm	55mm

TIJERAT
ISSN: 2707-5654

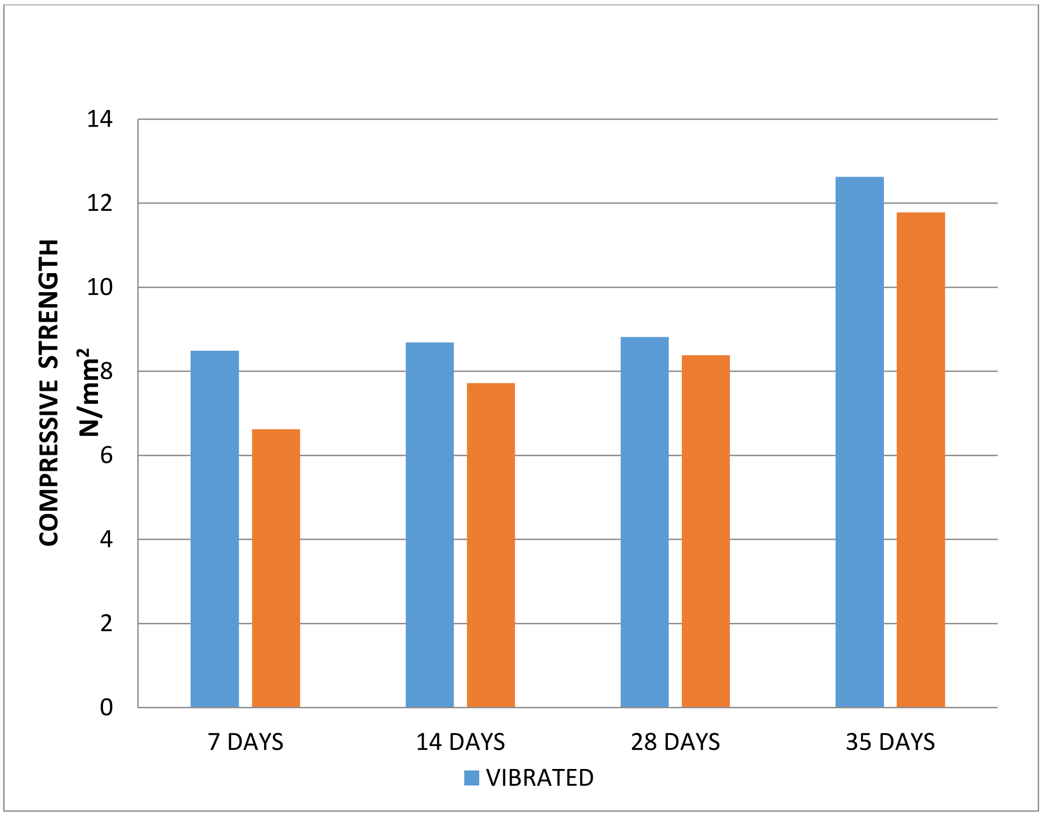

Figure 1.0: Compressive Strength of Vibrated and Non-Vibrated Concrete in 1:2:4 Mix Ratio with 32.5R Cement Grade.

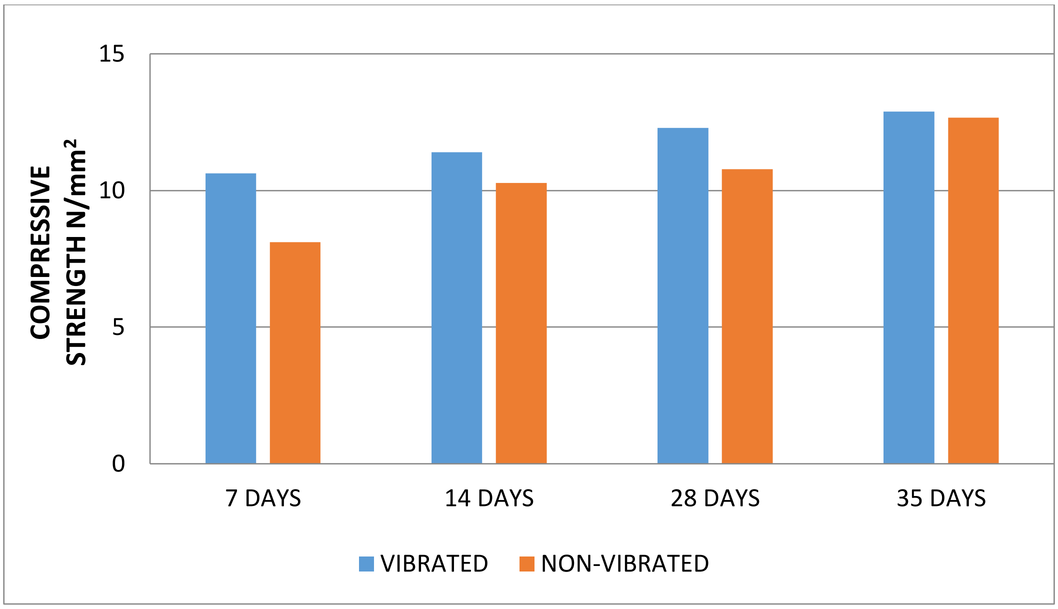

Figure 2.0: Compressive Strength of Vibrated and Non-Vibrated Concrete in 1:1.5:3 Mix Ratio with 32.5R Cement Grade.

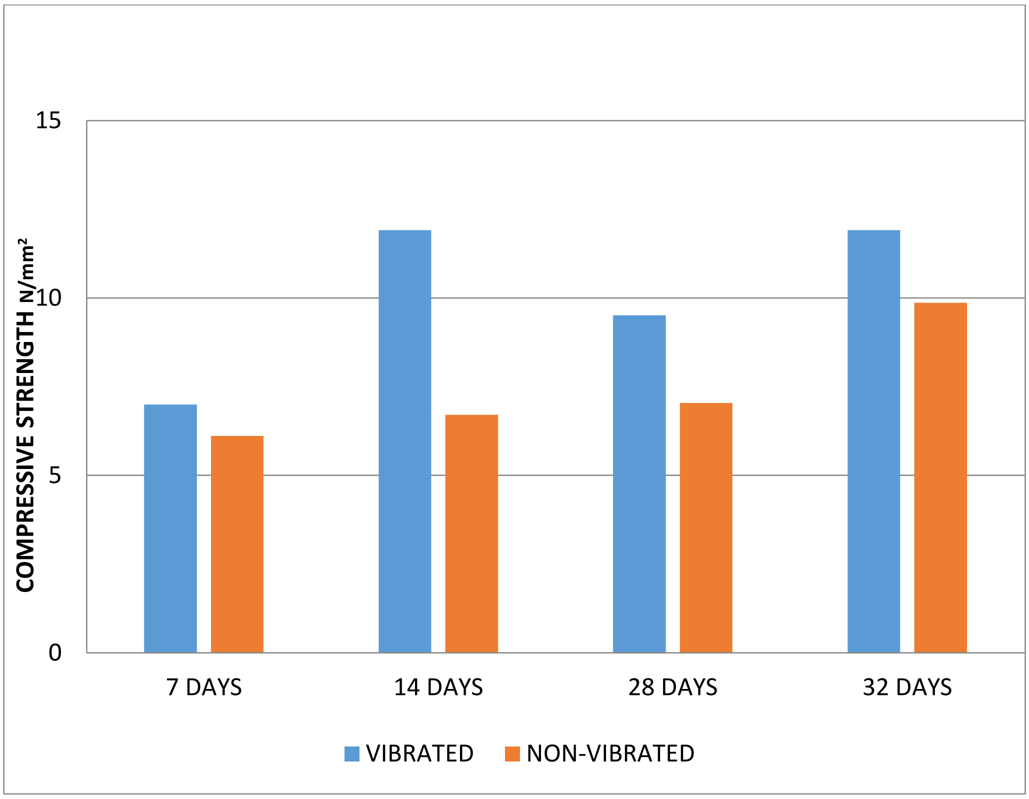

Figure 3.0: Compressive Strength of Vibrated and Non-Vibrated Concrete in 1:2:4 Mix Ratio with 42.5N Cement Grade.

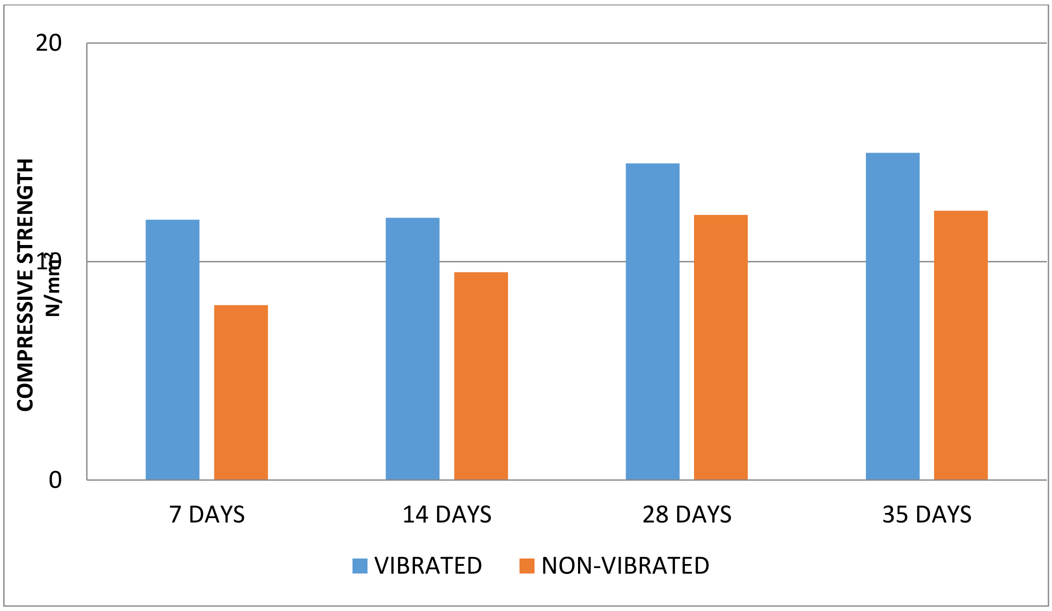

Figure 4.0: Compressive Strength of Vibrated and Non-Vibrated Concrete in 1:1.5:3 Mix Ratio with 42.5N Cement Grade.

Discussion

The physical properties of the cement grades 32.5R and 42.5N and their mortars are presented in Table 1.0-9.0. It was observed that the initial and final setting time of grade 42.5N (1hour 30miuntes and 4hours 14 minutes) is earlier than that of 32.5R (2hour 30miuntes and 6hours 00minutes) respectively. Cement grade 42.5N has a higher consistency; this means higher amount of water is required by grade 42.5N to achieve a standard consistency. Also, initial setting time of above 100 minutes for both 32.5R and 42.5 N are higher than 60 minutes stipulated by BS EN 197- (2000). The final setting time, met both the BS 12 (196) and EN 197-1 (2000) limit . It can thus be concluded that the final settling time obtained for both 32.5R and 42.5N are acceptable. The Coefficient of Uniformity is of less than 4 and the value of Coefficient of Curvature is between 1-3; therefore the sharp sand is uniformly and well graded respectively. Specific gravity for fine and coarse aggregate falls in the range 2.5 to 2.8. Hence the type of fine aggregate and coarse aggregate are considered to be natural aggregate. Also, since the Aggregate impact value falls within 10 - 20%, the coarse aggregate is strong for the concrete production and surfacing. For slump values of between 20-50mm for water/cement ratios, the workability of both cement grades is considered as medium. Vibrated concrete produced with both grade 32.5R and 42.5N gave the highest compressive strength with mix ratio 1:1.5:3 and ratio 1:2:4 compared to non-vibrated concrete, which means that there is considerable reduction in percentage of voids in the concrete when properly vibrated concrete are produced than concrete produced with non- vibrated concrete.

CONCLUSION

Based on this research work, the following conclusions are hereby made;

- **The strength of concrete increases with age (Figures 1.0-4.0)**
- **The concrete specimen produced with cement grades of 32.5R and 42.5N have different strength development pattern.**
- **42.5N cement grades produced higher strength grade than 32.5R cement grades**
- Vibration enhances higher compressive strengths in both concrete made with **cement grades of 32.5R and 42.5N .**

RECOMMENDATIONS

- For the construction of concrete structure that requires high compressive strength, cement grade 42.5N and properly vibrated concrete should be used.
- Increment in mix ratio enhances strength, an increase in mix ratio is recommended if there is a need to change cement grade.
- **Addition of admixtures to enhance strength properties, durability studies of concrete made with 32.5R and 42.5N is also recommended for future works.**

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