

Modification Analysis of Two Different Cement Grades and Their Impact on Vibrated Concrete Qualities

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Abstract This project investigated the effect of changing the cement grade on the properties of vibrated concrete. Various tests were conducted on the constituent materials: Dangote Portland cement of two grades (32.5N and 42.5R), rivers and crushed granite stones. Concrete was prepared to 1:2:4 non-vibrated concrete and 1:11/2:3 ratios for both vibrated and 60 concrete cubes of 150x150x150 mm³ were moulded and cured for 7, 14, 28, 35 and 56 days. Workability and compressive strength tests were conducted on wet and dry concrete. The results reveal that the consistency, initial and final setting time for 32.5 cement grade varies from that of 42.5N. The compressive strength of concrete increases as the age increases for both grades at 1:2:4 and 1:11/2:3 mix ratios. Also, concrete produced with a cement grade of 32.5N has a lower compressive strength than the 42.5 grade of vibrated and non-vibrated concrete for both grades 1:2:4 and 1:1/2:3 mix ratios. Vibrated concrete produced a denser and higher compressive strength than non-vibrated concrete due to the considerable reduction of voids and the water absorption rate. It is recommended that cement users be mindful of the grade of cement they use to achieve a targeted strength. Structures like water retaining structures, bridges, slabs, beams, columns, etc., which require high compressive strength, should be adequately vibrated.

Keywords: Cement; Concrete; Compressive Strength; Vibration; Grade; Workability.

INTRODUCTION

Concrete, like other materials, plays a crucial role in construction development. Concrete is a composite construction material composed of cement (commonly Portland cement) and other cementation materials such as slag cement, aggregate, i.e., coarse aggregate, and chemical admixtures [1]. Concrete is the most extensively used material in civil engineering construction because of its quality, allowing veracity. Concrete is high in compression and low in tension [1].

There are some distinguished types of concrete which are non-cementitious. This type can be seen in asphalt concrete, in which bitumen is used as the binder and is frequently used for road surfaces and polymer concrete, which uses polymers as the binder. Concrete is used in structures (substructure and superstructure works). Concrete must be readily available for every meaningful construction in a construction firm. However, the design engineer defines this concrete's properties, performance, and efficiency. Famous concrete structures include the Hoover, Panama Canal, and the Roman Pantheon [2].

Cement is a binder or substance used during construction and can set, harden, and adhere to other materials to bind them together. Conventionally, cement is the primary substance used as a binder in concrete. There are diverse types of cement: Ordinary Portland cement, Heat Cement, Pozzolana cement, Rapid Hardening Portland cement, Extra Rapid Hardening Portland cement, Hydraulic cement, etc. [2]. Cement varies functionally due to the diversities and the differences in the proportion of these constituents. Varied factors are considered to determine the best cement suitable for specific work.

The cement grade refers to the cement's compressive strength, i.e., how much strength cement can yield or bear. These cement grades are classified according to the compressive strength of the cement, evaluated after 56 days. Cement is the vital ingredient of concrete, and its strength is directly proportional to its strength. As the cement grade increases, its strength increases.

Vibrated structural concrete has been vibrated internally or externally after being placed in the cast-in-situ (formwork) to produce a denser mass. Vibrating concrete is critical because it helps remove air pockets and pack the aggregate

particles together; it increases the density and strength of the concrete. Tightly packed particles will produce a more robust and durable concrete structure. Concrete that has not been vibrated is full of air pockets (honeycomb), resulting in poor finishing and weak structure that might lead to collapse.

Concrete mix design is finding the right proportions of cement, fine aggregate, and coarse aggregate for concrete to achieve targeted strength in structure. Concrete mix design can be stated as cement: fine aggregates: coarse aggregates. The concrete mix design involves various steps, calculations and laboratory testing to find the right mix proportions. This process is usually adopted for structures requiring higher grades of concrete, such as M25 and above, and large construction projects with enormous quantities of concrete. The benefit of concrete mix is that it provides the right proportions of materials, thus making concrete construction economical and achieving the required strength of structural members. As the quantity of concrete required for large constructions is enormous, the economy of materials such as cement makes the project construction economical and suitable for specific work.

The mix ratio (in concrete) can be referred to as the proportion of the constituents present in the concrete. Mix ratio is measured using varied materials, i.e., head pan, wheelbarrow, etc. Varieties of factors are considered when selecting the mix ratio in concrete production. Commonly used mix ratios are 1:2:4 and 1:3:6, where 1:2:4 means one portion of cement, two portions of fine aggregate, and four portions of coarse aggregate. The amount of cement required determines the water required for the mix ratio. This is called the water/cement ratio.

Concrete is an elastic-plastic material composed of fine and coarse aggregate, binding agent (cement) and water. No reaction will occur until sufficient water is added to the concrete materials admixture and allowed to set over time. There are two types of concrete: dense concrete and lightweight concrete. Lightweight concrete is those that weigh less than 1920 kg/m^3 . Examples of lightweight concrete include aerated concrete, lightweight aggregate concrete, etc. Dense concrete is the most generic concrete form for reinforced concrete work; the average density is 2400 kg/m^3 . Reinforced concrete contains

reinforcing steel embedded into the concrete as rods, bars, and mesh [3].

Numerous structures have collapsed or undergone defects because of a faulty mix ratio (non-standard mix ratio). Using cement for concrete without determining the best suitable for a particular construction has contributed to the settlement or displacement of some part of the structure or the entire structure. Segregation, bleeding, cracks, etc., are all perceived in some structures due to adopting inappropriate (non-standard) mix proportions.

This project *aims* to investigate the effect of changing cement grade on the properties of vibrated structural concrete.

The Objectives are as follows:

1. To survey and take inventory of various cement grades available in the marketplace.
2. To conduct various tests on the constituent materials.
3. To determine the workability of vibrated and non-vibrated concrete produced from 42.5 and 32.5 grades of cement.
4. To determine the effect of variation in the compressive strength of vibrated and non-vibrated concrete using 1:2:4 and 1:1.5:3 mix ratios.
5. The effect of vibration on the compressive strength of concrete.

Cement is a durable and versatile construction material. It is not only robust but also economical and aesthetically satisfying. However, experience has shown that concrete is vulnerable to deterioration unless preventive measures are taken during the design and production of the concrete. For this, we need to understand the influence of cement grade on concrete behaviour and produce a concrete mix within tightly controlled tolerance.

The effect of changing cement grade on the properties of vibrated structural concrete. The grades of cement used are 32.5N and 42.5N.

RESULTS AND DISCUSSION

The methods that will be used to achieve the aim and objectives of this project work are as follows:

1. Procurement of materials.
2. Laboratory tests on constituent materials.

3. Production of vibrated and non-vibrated concrete with mix ratios 1:2:4 and 1:1.5:3.

4. Curing of concrete.

Concrete. Whether good or bad, concrete is made from the same ingredients: cement, aggregate, and water. Only the know-how backed up by understanding is responsible for the difference. Bad concrete is a substance with unsuitable consistency, hardening into a honeycomb and non-homogenous mass, while satisfactory compressive strength and adequate durability characterise good concrete. For instance, structural members in a building are often made in situ, and their quality is exclusively dependent on the concrete placed and mixed. Concrete is used in pavement construction, manufacturing of pipes, architectural structures, foundations, roads, bridges, parking structures, block walls, and footing for gates, fences, poles, etc.

Concrete is a mixture of cementitious materials, aggregates, and water. Aggregate is commonly considered as inter filler, which amounts to 60-80 % of the volume and 70-85 % of the weight of concrete. However, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified as two diverse types (coarse and fine). Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve). The compressive aggregate strength is a crucial factor in the selection of aggregate. When determining the strength of standard concrete, most concrete aggregates are several times stronger than other concrete components.

Types of concrete. The selection of the diverse types of concrete is frequently governed by the strength required, which depends on the intensity of loading, form, and size of the structural member. For example, in the lower column of a multi-storey building, a higher-strength concrete may be chosen in preference to increasing the size of the column selection with a resultant loss in clear floor space [4].

The concrete strength is assessed by measuring the crushing strength of cubes or cylinders made from the mix. These are usually cured and evaluated after twenty-eight days according to standard procedures. Concrete of a given strength is identified by its grade; grade 20 concrete has a characteristic cube-crushing strength of 20 N/mm [4]. Concrete can also be classified in

terms of the constituent materials, i.e., cement and aggregate types, as well as the result of exposure and durability. For example, a structure subjected to corrosive conditions in a chemical plant would require a dense and higher grade of cement than the interior of school or office blocks. Although ordinary Portland cement could be used in most structures, other cement types can also be advantageous. A blast furnace or sulphate-resistant cement may resist chemical attacks; heat cement may reduce heat radiation and rapid hardening cement when early cement is required [4].

The several types of concrete include regular concrete, high-performance concrete, self-consolidating concrete, pervious concrete, vacuum concrete, stamped concrete, polymer concrete, refractory concrete, concrete cloth, innovative mixture, and gypsum concrete. The main types of concrete are: 1) Mass concrete; 2) Reinforced concrete; 3) Prestressed concrete.

Composition of concrete. Concrete is extensively used in modern buildings and most structural engineering works. Concrete is heterogeneous and consists of numerous materials, influencing its fresh, hardened, and finished properties. The proportion of concrete ingredients given in terms of mix design is responsible for the numerous types of concrete available. Mix design can also be affected by the type of structure being built, i.e., the purpose of serving.

The constituents of concrete include cement, water, fine and coarse aggregate. Admixtures are added when behavioural efficiency is desired from the concrete; such admixtures are plasticisers, pozzolana and air-entraining agents.

Properties of fresh concrete. Concrete is made of constituents with different properties. Therefore, variation of the constituents of a given mix will alter the strength/properties of the concrete. This can be done by introducing special cement, particular aggregate, admixtures, water, and unique curing methods.

Workability. Concrete that can be readily compacted is said to be workable. Workability determines the ease of placement and the resistance to segregation of the concrete, but the description is an understatement. The desired workability in any case will depend on the means of compaction, and the result may vary with the type of concrete used, i.e., the circumstances of a particular construction [4].

The ACI (American Concrete Institute) definition of workability is given in ACI 116R-90 as that property of freshly mixed concrete or mortar, which determines the ease or homogeneity with which it can be mixed, placed, consolidated, and finished. Concrete workability is vital in fresh and hardened concrete as it affects its strength. In other words, sufficient compaction in wet concrete reduces its void to the barest minimum, which translates to the concrete's strength in its finished (hardened) state. Factors affecting workability are water content, size of aggregate particles, coarse and fine aggregate ratio, relative quantity of paste and aggregate, particle interference, particle interlock, grading of aggregate and use of admixtures [4].

Slump Test. The slump test is extensively used all over the world. Although it does not measure the actual workability of concrete, it is used for finding the variation in the uniformity of mix of a given nominal proportion and a specific procedure for determining the consistency of concrete where the nominal maximum size of the aggregate does not exceed 38.0 mm.

The decrease in the height of the centre of the slumped concrete is called slump and is measured to the nearest 5 mm. Thus, slump is the difference between the original height of the concrete in the mould and the highest part of the concrete in the subsided position. The experiment should be conducted in a place free from vibration or shock and for 2 minutes after taking a sample from the mix. Slumping in true slump occurs evenly all around, but in the case of shear slump, one-half of the cone slides down in an inclined plane. When shear slump persists in the case of harsh mix, it indicates the non-cohesive mix. Mixes of stuff consistency have zero slumps, and in the dry range of mix, no variation will be detected between mixes of different workability. Thus, this is not an accurate guide to workability but a measure of consistency or wetness of the mix. This test is suitable for concrete with a 12.5-25 mm slump, which is medium to high workability.

Mixes that are harsh and evaluated to have the same slump may not have the same workability with one another, with varied proportions of sand (significant sand content). The slump value is the difference between the mould height and the average subsidence value for the shear slump. It also shows that the concrete is non-cohesive and indicates segregation characteristics. If the concrete spreads, then it is called collapse. An

increase (change) in a slump for mixes is assumed to be the same, which implies either an unexpected change in aggregate moisture content or grading of aggregate as changed (deficiency in sand).

Segregation. A cohesive concrete should not easily segregate and is expected to be workable. However, the absence of a tendency to segregate is not included in the definition of a workable mix. Segregation can be defined as the segregation of consistency of a heterogeneous mix so that the distribution is no longer uniform. Concrete, which tends to show a separation of one ingredient (say coarse aggregate) from the other, is said to have undergone segregation. This is caused by differences in the size of aggregate articles and the specific gravity of the mix constituents. However, its extent can be controlled by the choice of suitable grading and by care in handling. It is worth noting that concrete mixed with fresh cement paste of high viscosity militates against the downward movement of the heavier aggregate particles. Consequently, mixes with a low water-cement ratio are less prone to segregation.

The two forms of segregation are [4]:

- 1) A coarse particle tends to separate because it travels further along the settlement slope than the fine particle. It occurs in a lean mix (of specific grading) with excessive dryness but can be improved upon by the addition of water to increase its cohesion can be improved upon by the increase of water.
- 2) Segregation of grout (cement + water) from mix usually occurs in the wet mix. Concrete segregation will produce weak concrete with undesirable properties in its hardened form.

Segregation is caused by:

- 1) Excessive vibration is used to spread concrete (especially for spreading heaped concrete over a large area).
- 2) Dropping of concrete from a height of more than one meter.
- 3) Badly proportion mix, where sufficient parts do not bind the aggregate.
- 4) Conveyor belts, wheelbarrows, long-distance hauls by dumper, and long lifts by skip and hoist concrete conveyance.
- 5) Concrete with poor mixing and excess water (insufficiently mixed concrete with more water).

6) Concrete discharge from a poorly designed mix or a worn-out blade mixer.

Segregation can be avoided through proper mixing, compacting, and finishing, correct proportioning of the mix, and proper transportation handling and placing.

Bleeding. This is referred to as water gain, a form of segregation.

Some freshly placed concrete has the lowest specific gravity of all concrete ingredients. The phenomenon of bleeding is caused due to the inability of the solid material to hold the mixing water when it settles down [5].

Bleeding is observed under the following conditions: 1) It's a badly proportioned mix; 2) Insufficiently mixed concrete; 3) In thin members like roof slabs, road slabs, etc.; 4) When concrete is placed in sunny weather.

The amount of bleeding in concrete depends on the properties of the cement. It can be reduced by taking the following measures: addition of calcium chloride to the cement, increasing the fineness of the cement, and addition of high content of C3A in the cement, etc.

Water-cement ratio. The primary factor controlling strength, everything else equal, is the amount of water used per bag of cement [6]. Maximum strength is obtained by using just the amount of water, and no more, required for the complete hydration of the cement. However, a mix of this type may be too dry to be workable. The concrete mix always contains more water than required to attain maximum strength. The point for you to remember is that the strength of concrete decreases as the amount of extra water increases. The specific water-cement ratio is the happy medium between the maximum possible strength of the concrete and the necessary maximum workability requirement. The strength of the building concrete is expressed in terms of the compressive strength in the Newton per square meter reached after 56 days for a fully compacted proportional to the water-cement ratio.

Batching and mixing of concrete. This is the correct measurement of various materials used in the concrete mix. It has been observed that batching error is responsible for more variation in the quality of concrete than any other factor. Still, reasonable control can reduce this part variation to an insignificant amount. Batching can be

adequately controlled over other factors responsible for the variation in the quality of concrete. The available type of batching is volume batching by weight.

The objective of mixing concrete is to coat the surface.

Aggregate particles with the cement paste and blend all concrete ingredients into a uniform mass. Mixing of concrete can be done either by hand or by machine. Mixing concrete by hand is less efficient than mixing by machine, but in small or unimportant works, hand mixing can still be practised [5]. Concrete mixing by hand should never be done on the ground, such as earth and dirty, dry grasses, leaves, etc.

Curing. This is the name given to the procedure used for promoting cement hydration. It controls the temperature of concrete and moisture movement from and into the concrete. The object of curing is to keep the concrete saturated or as saturated as possible till the originally water-filled space in the fresh cement paste has been filled to the desired extent by the cement hydration product [7]. In the case of site concrete, it has been observed that active curing stops long before the maximum possible hydration can take place. Curing is necessary since cement hydration can occur only in water-filled capillaries [5]. That is why the loss of water by evaporation from capillaries should be prevented.

Water absorption in concrete. The pre-structure of concrete is known to be of high importance for the durability of the material. The water absorption by immersion gives an estimation of the total pore volume of the concrete. Still, it does not indicate the concrete permeability, which is more critical about durability.

Cement. Cement is a general word used to describe a material with adhesive and cohesive properties, making it capable of bonding mineral fragments into a compact whole. For construction purposes, the mineral properties are stones, sand, bricks, building blocks, etc.

These types of cement are compounds of lime that have its principal constituent. The cement used in making concrete has properties of setting and hardening under water by a chemical reaction and is, therefore, called hydraulics cement [4]. The most widely used hydraulic cement is Portland cement, which is also used in civil engineering construction. It is produced by heating limestone (a source of calcium) with clay to form clinkers,

which are also ground with gypsum (a source of sulphate) [5].

In any concrete of a given mix, cement constitutes 7% to 15% of the volume of the mix). It is the active portion of the binding medium and, therefore, the most essential ingredient of the concrete [8].

Properties of cement. The properties of cement are:

- 1) Hydration is the chemical reaction between cement and water (cement paste).
- 2) Fineness is a physical property of cement that affects the cement hydration and strength rate, i.e., the finer the material, the larger the surface area, and the higher the reaction rate.
- 3) Setting and Hardening: Setting is the transformation of cement paste. It moves from the initial set to the final set. Hardening is the ability of solidity obtained from a set cement paste to gain its strength.
- 4) Soundness: This is the ability of cement paste to retain its original volume after setting. The amount of free lime in each cement sample usually influences it.
- 5) Consistency of Standard Paste: This is the water content when a standard 10 mm diameter rod penetrates a consistent paste cement to 5 mm.

Water. Water is the most abundant molecule on the earth's surface, consisting of about 70% of the planet's surface. Naturally, water exists in liquid, solid and gaseous form; hydration of cement to form cement paste occurs when water in its liquid reacts with cement (cementitious material). The cement pastes the aggregate together, fills the void, and allows it to flow more freely. The strength and durability of concrete (cement paste) are a function of the quantity and quality of water in it and other factors. Less water will give a free-flowing concrete with a higher slump. The quality of water, which is defined in terms of its physical and chemical properties, also affects the durability and strength of concrete.

Therefore, pure/drinkable water is highly recommended for concrete.

Works such as using impure water for concrete can lead to problems when setting or cause premature structure failure. The water sources are surface water (lakes, rivers, and streams), underground water and rainwater.

1) Surface Water. Lakes, rivers, and streams. They are naturally occurring on the earth's surface. They tend to be affected by human activities.

2) Underground Water. Underground water is saturated in aquifers. It is not easily affected by human activities. Rainwater: This is the natural precipitation from the cloud to the surface.

Properties of water. At room temperature, water is said to be colourless with a hint of blue, tasteless, and odourless liquid. Many substances dissolve in water, commonly referred to as a universal solvent. Because of this, it is rarely pure in nature and use, and some of its properties may vary slightly from those of the pure substance. Other properties are defined in terms of density (1000 kg/m), melting point (0°C), boiling point (100°C), and pH 0.7 and so on.

Aggregates. This is a general term applied to inert material when bonded. Cement paste forms about 70–75% of the concrete volume. In addition to being inert, its thermos physical properties influence the performance of concrete. Aggregates possess properties which affect the strength and durability of concrete. Aggregates are classified into two sizes, the dividing line being the 4.75 mm LS sieve. Material retained on a 4.75 mm 1.S sieve is "coarse aggregate", whereas material passing this sieve size is classified as "fine aggregate" by ASTM, 1946-69.

Classification of aggregate. Aggregate can be classified as:

1) According to the Size of Aggregate Particles, aggregate is subdivided into fine and coarse aggregate. Fine aggregate is those passing a 4.75 mm IS sieve, while coarse aggregate is those retained on a 4.75 mm IS sieve.

2) According to Mode of Preparation. This distinguishes between aggregates of their present size by natural agents and crushed aggregates obtained by deliberate rock fragmentation.

3) According to Sources. This classification groups aggregate into natural gravel sand) and artificial (burnt clay aggregate).

4) According to Mineralogical Composition. This classification regards aggregate as siliceous or calcareous. They can all be obtained from igneous, sedimentary, and metamorphic rocks.

Properties of aggregate. Apart from the cement ratio, which has a high influence on the properties of concrete, aggregate contributes to concrete's

strength, stability and durability through the following properties [1].

1) Shape and Texture of Particles. The shape depends upon the source of the aggregate. The aggregate shape affects the workability of concrete, hence its strength and durability [5]. Shape affects compressive strength by 28% and flexure strength by 30%.

2) Surface Texture. This is based on the degree to which the surface of the aggregate is polished or dull, smooth or rough, etc. It depends on grain size and the pore characteristics of the parent rock. Surface texture can be granular, smooth, rough, crystal, glassy, honey, etc., which affects compressive strength more than flexure strength.

3) Hardness. This is measured as the resistance of aggregate to wear by abrasion, and the aggregate abrasion value is defined as the percentage of weight loss by abrasion.

4) Porosity of Water in Aggregates All aggregate is said to have pores within its body, and it influences the properties of concrete. The porosity, permeability, and absorption of aggregate influence the resistance of concrete to freezing and cement paste, as well as the resistance to concrete abrasion.

5) Quantity of impurities (Deleterious Material). These can be classified into three categories: organic impurities, coating on aggregate, and sound aggregate particles.

6) Specific Gravity. This is the ratio of the weight of a unit volume to the unit volume of water at the stated temperature. Specific gravity can be further grouped into apparent specific gravity, bulk gravity, and absolute specific gravity.

7) Toughness. This is defined as the resistance of aggregate to failure by impact. The impact value of bulk aggregate can be determined as per IS 23869 [9].

Sieve analysis. This refers to the simple operation of dividing a sample of aggregate into a fraction of particles of the same size. Practically, each fraction contains particles within specific limits, these being the opening of a standard test sieve. Test sieves used for concrete aggregate have a square opening, and their properties are prescribed by BS 410: 1986 and ASTM 11-87. In the later standard, the sieve can be described by the opening size (in inches) for larger sizes and several openings per lineal inch for sieves smaller than 0.25 inches. The standard approach is to

designate the sieve size by nominal aperture in millimetres or micrometres. Sieve for material smaller than 4mm (0.16 in) are typically made of mire cloth, while sieve for coarse aggregate is made of brass or mild steel.

The screening area, i.e., the opening area as a percentage of the gross area of the sieve, varies between 28% and 56%, being more significant for opening. Coarse test sieves with 4 mm (0.16 inch) and larger are made of a perforated plate with a 44% to 65% screening area. Sieves are arranged in order of decreasing sizes, with the largest and the smallest (pan) bases. For grading purposes, the sieve, which is the same as BS812 part - 1, is as follows: 13.2mm, 2.36mm, 2.00mm, 0.85mm, 710 μ m, 600 μ m, 500 μ m, 425 μ m, 350 μ m, 200 μ m, 150 μ m, 75 μ m.

Grading curve. This refers to the graphical representation of the results of sieve analysis. The use of grading curves helps to see quickly or briefly how the grading of a given sample conforms to the specific grading. It will show whether it is too coarse, too delicate, or decent more than a particular size. In the grading curves, the ordinate represents cumulative percentage passing, and the abscissa represents the sieve opening plotted to a logarithmic scale. A logarithm plot shows these openings at a constant spacing, as the opening of a sieve in a constant sieve is in the ratio of 1:2 [1].

The grading of aggregate for a given mix is such that the following lower fraction fills the voids of the large particle, and the voids of fine aggregate are filled by cement. The strength of a fully compacted concrete with a given water-cement ratio is independent of the grading of the aggregate. Grading affects only the workability of the mix, and the development of the strength corresponding to a given water-cement ratio requires full compaction; it can be achieved only with a sufficiently workable mix. In actual practice, there is no ideal curve. Still, a compromise is aimed at factors affecting the grading of aggregate, including the surface area of the aggregate, the relative volume occupied by the aggregate, the mix's workability, and the mix's segregation.

A mix ratio of 1:2:4 and 1:1.5:3 and a water/cement ratio of 0.5 were used for concrete production to estimate the proportion of concrete mix material. To ensure the concrete standard produced, adequate mixing of concrete material and particle distribution of fine and coarse

aggregate are given proper attention. The various tests conducted during this project's work are as follows.

- 1) Consistency test. It determines the maximum amount of water required to start a chemical reaction between cement and water.
- 2) Initial setting time. It is the process by which cement starts to lose its plasticity (semi-liquid state) after mixing with water.
- 3) Final setting time. It is the process by which cement completely loses its plasticity and becomes hardened.
- 4) Specific gravity of fine aggregate. Used in determining the specific gravity of fine aggregate.
- 5) Sieve Analysis. This determines the aggregate size expected for various samples (Fine and Coarse Aggregate).
- 6) Aggregate Impact Value Test. This gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to slowly applied compressive loads.
- 7) Slump Test. Used to determine the degree of consistency and nature of workability of the concrete.
- 8) Compression Test. Used in determining the compressive test of the concrete.

The materials used for this project include sand as a fine aggregate, washed gravel as a coarse aggregate, cement as a binder, and borehole water.

- 1) Coarse Aggregate. Three distinct categories of coarse aggregate used during this project are as follows: a) Those that pass through 9.5 mm but retain 4.75 mm BS are known as Sample A; b) Those that pass through 13.2 mm but are retained on 9.5 mm BS sieve are known as sample B; c) Those that pass through 19.0 mm but are retained on a 13.2 mm BS sieve are known as sample C.
- 2) Fine Aggregate. The fine aggregate used is known as sharp sand and was sourced from the riverbed.
- 3) Cement. Ordinary Portland cement produced by the Dangote group of companies was used as a binder (Grade 32.5N and 42.5R).
- 4) Water. Treated water supplied by the polytechnic was used to prepare and cure concrete plate cubes.

Laboratory tests for various properties of materials

Consistency of cement. Consistency test. It is used to determine the maximum water required to start a chemical. Reaction between cement and water. The experiments aim to determine the physical properties of the cement consistency of standard paste.

Apparatus: 1) The apparatus is complete with mould, plunger, and initial and final set needles; 2) Weighing Balance; 3) Hand trowel; 4) Cement paste; 5) Stop-watch.

The precautions taken are: 1) We ensured that the apparatus was free from vibration during penetration; 2) The test was conducted at room temperature 20–25 °C.

Procedure. 400 g of cement was weighed and prepared to cement paste with 27% volume of water to the weight of cement. The gauge time is kept between 3 to 5 minutes, and the stop-watch is started at the instant when the water is added to the cement paste, and the time is recorded as (T1). The vicar mould was filled, resting on a glass plate, with the cement paste gauged as above. The mould was filled, and the surface was smooth off the paste, making it level with the top of the mould. The cement block thus prepared is called a test block. The needle was lowered gently until it met the surface of the test block and quickly released, allowing it to penetrate the test block.

The specific gravity of fine aggregate. The specific gravity of any material is defined as the ratio of the weight of that material to an equal volume of distilled water. The specific gravity G is the ratio of the weight of an equal volume of distilled water at that temperature to both weights taken in air. In determining the unit, the weight of the concrete constituent's specific gravity of such material is expected to be known. ASTM standards conducted the specific gravity test for each constituent material in concrete production. The specific gravities of gravel, sand, cement, and water were determined during this project.

Apparatus: 1) Weighing balance; 2) The material needed is sharp sand; 3) Pycnometer bottle (used to determine specific gravity for fine aggregate).

The procedure is as follows:

a) The dried measuring pycnometer bottle weighed W1(g).

b) The measuring cylinder was filled to 1/3rd of its volume with a saturated surface dried sample to be evaluated for and weighed W2(g).

c) The cylinder was half-filled with distilled water.

d) The solution was stirred correctly for about 3-4 minutes to remove entrapped air and the pycnometer bottle with distilled water.

e) The outside of the cylinder was wiped with a hand towel, dried, and weighed with its content as W3 (g).

f) The content of the cylinder was then poured away, rinsed with water and dried.

g) The cylinder was filled with distilled water and weighed W4 (g).

h) The whole procedure was repeated twice for a fresh sample.

$$\text{Specific Gravity} = (W_2 - W_1) / (W_2 - W_1) - (W_3 - W_4)$$

where W_1 – the weight of the empty pycnometer; W_2 – the weight of the measuring cylinder and sample of filled to 1/3rd of the cylinder; W_3 – the weight of the measuring cylinder, sample, and distilled water; W_4 – the weight of the measuring cylinder and distilled water.

The mean specific gravity of the aggregate obtained by finding the average was used as aggregate specific gravity.

Aggregate Impact Test. The aggregate impact is defined as a relative measure of the resistance of an aggregate to sudden shock or impact. In some aggregate, it differs from the resistance to a slowly applied compressive load. The setup procedure for conducting the impact test is as follows:

Apparatus: 1) An aggregate impact test machine and a metal stamping rod are needed; 2) A weighing balance; 3) BS test sieve of aperture size 13.2 mm, 9.5 mm, and 4.75 mm; 4) Material: Coarse aggregate (granite).

The sample granite was allowed to pass through a 13.2 mm sieve and retained on a 9.5 mm sieve, after which the fraction was retained on a 4.75 mm sieve.

Procedure:

1) The measured cylinder cup in the impact test machine was filled in three equal layers, and each layer was tamped with 15 blows of tamping rod.

It was falling freely from about 50 mm above the surface of the aggregate. It was then weighed to determine the net weight of the aggregate and the cylinder cup, which was tagged A.

2) The steel cup and the aggregate sample were rigidly fixed on the machine's base.

3) The aggregate was subjected to 15 blows, ensuring that each was delivered at an interval of not less than one second and 25 blows for the three layers.

4) The crushed aggregate was removed and passed through a sieve of size 4.75 mm, after which both fractions that passed through and retained on the 4.75mm were weighed.

5) The whole procedure was repeated twice for a fresh sample.

$$\% \text{ fine} = B/A \times 100,$$

where A – Mass of fraction that passes through sieve no 4.75mm (g); B – Mass of coarse aggregate (g); % fine = aggregate impact value was obtained from the mean value of the three results.

Sieve analysis for fine and coarse aggregate. Sieve analysis is aimed at showing the size distribution of the sample. Such analysis is usually conducted in the laboratory using the ASTM C136 standard. A dried sample, allowed to pass through a set of sieves, is commonly used. Weight retained on each sieve and their percentages are also calculated. The sizes of particles of an aggregate have a considerable influence on the workability of fresh concrete. In the design of concrete mixes, the grading of aggregate is to classify the particle size distribution of aggregates.

Apparatus: 1) Sample (sharp sand and granite); 2) Weighing balance; 3) Sieve; 4) Sieve shaker; 5) Hand trowel

The setup for conducting sieve analysis is as follows:

1) Materials needed are air dry, sharp sand and granite.

2) Apparatus are weighing balance, hand trowel, sieve shaker, sieve brushes, one set of sieve sizes 13.2, 2.36, 2.00, 0.85, 0.71, 0.60, 0.50, 0.425, 0.35, 0.20, 0.15, 0.075 mm and pan for fine aggregate (sharp sand).

3) The apparatus is weighing balance, hand trowel, sieve shaker, sieve brushes, and one set of

sieve sizes 37.5, 22.4, 19.0, 13.2, 9.5, 4.75, 0.707 mm and pan for coarse aggregate (granite).

The procedure for sieve analysis of fine and coarse aggregate is as follows: 1) 1000 g of air-dry sample was weighed using a weighing balance; 2) The set of the sieve was cleaned with sieve brushes, weighed and arranged in descending order of 37.5, 22.4, 19.0, 13.2, 9.5, 4.75, 0.707 mm and pan for coarse aggregate (granite) and 13.2, 2.36, 2.00, 0.85, 0.71, 0.60, 0.50, 0.425, 0.35, 0.20, 0.15, 0.075 mm and pan for fine aggregate (sharp sand).

The 1000 g of air-dry sample was placed at the top of the sieve and covered with a lid.

The net of the sieve was placed on the sieve shaker, clamped securely, and shaken for five minutes.

Then, each sieve was weighed with the residue and the percentage passing for each sieve was determined in a tabular form.

Then, the grading curve was plotted on the logarithm graph with the sieve sizes on the abscissa and the percentage passing the ordinate.

Production of vibrated and non-vibrated concrete

Preparation of mould. A set of moulds 150×150×150 mm were used for casting concrete cubes. The cube was clipped together with bolt and nut firmly on metal plates, serving as a base plate for the moulds. The inside of the mould was smeared with oil in preparation for casting concrete cubes. However, to produce concrete cubes, a standard steel mould of 150×150×150 mm size was used in preparation for casting concrete cubes.

Batching and mixing of concrete. The weight was applied when mixing the concrete ingredients, such as cement, aggregate, and water. This method is called batching by weight, which requires adequate quality control. Mixing nominal mix ratios 1:2:4 and 1:1:5:3 was manually conducted on a flat, non-absorbent surface. Cement and fine aggregate were first properly mixed before spreading the coarse aggregate; after this, water was added in bits to prevent bleeding from the mixing water and cement paste, which were mixed correctly.

Slump test for fresh concrete. A concrete slump test measures the consistency of a concrete batch to see how easily the concrete will flow. It is performed to check the workability of freshly made concrete.

Apparatus: 1) Slump cone; 2) Slump cone base; 3) Tamping rod, AST, specification (16 mm diameter and 60 mm long); 4) Concrete; 5) Measuring tape; 6) Hand trowel; 7) Ruler.

Procedure:

1) The slump cone was moist with oil, and the base of the cone was then placed on the base plate. The cone was filled, and the surface was levelled. The cone was lifted gently vertically, and the slump failure was measured.

2) A slump cone with an internal diameter of eight inches (203.2 mm) at the bottom, four inches (101.6 mm) at the top, and a height of 12 inches was used to conduct the test.

3) With its inside damped, the slump cone was placed on a smooth, flat, non-absorbent surface and held firmly in place by standing on the flat piece.

4) It was then filled with fresh concrete in three layers. Each layer was tamped throughout its depth 25 times with a 16mm diameter and 610 mm long tamping rod, having one of its ends rounded to a hemispherical tip. The process was repeated two times, compacting each layer with a stroke that generated the underlying layer, after which the excess protruding beyond the top of the cone was struck off with a rolling and spreading motion of the tapping rod, placed horizontally, filling the cone exactly. Then, the slump cone was immediately removed, raising it vertically with a steady upward lift. Then, it was placed upside down adjacent to the concrete slump. The vertical difference between the top of the mould and the displaced original centre of the top surface of the specimen was measured. The drop in height is known as the slump test value of the fresh concrete.

Casting of cube samples. The mixed concrete was placed in the mould smeared with engine oil for easy removal. After this proper concrete compaction, the upper surface was levelled with a hand trowel and marked for identification. The mould for casting concrete cubes was filled and compacted in three layers after the mould's inner surface had been smeared with engine oil. Then, the upper surface was levelled with a hand trowel and marked with the identification number and date. The concrete cubes were allowed to be set for 24 hours, removed from the mould, and cured by the BS 1881- part 3 requirement.

Curing of concrete cubes. As discussed earlier, curing is the process of keeping concrete in a moist condition for some days to facilitate the

hydration of cement paste for concrete to gain strength. The rate and degree of hydration of cement paste and strength are positively affected by proper curing, thereby contributing to the gradual development of strength in concrete structure. The concrete tank model and cubes were underwater in a curing tank for 35 days.

Compressive strength of hardened concrete. Compressive strength was performed in the Department of Civil Engineering Laboratory, Kwara State Polytechnic Ilorin. The cubes were placed on the lower steel flattened plates of the testing machine, with both smooth surfaces facing the top and bottom flattened plates. After this, the load was applied, and the load failure for each cube was recorded by reading the machine's load meter. The cube concrete compressive strength was calculated by ascertaining the cube's failure load and surface area. The specimens were cast in 150 mm cubes of metal moulds by BS 1881-3:1970 specifications. The mould was oiled on their inside surfaces to prevent the development of bonds between the moulds and the concrete. The moulds were assembled, and bolts and nuts were tightened to prevent leakage of cement paste.

Concrete was mixed at 1:2:4 and 1:1.5:3 proportions. The moulds were filled with concrete in three layers, each layer being compacted using a vibrator and a tamping rod to remove as much entrapped air as possible and to produce full compaction of concrete without segregation. The moulds were filled to overflow, and the sawing action of the steel rule removed excess concrete. Surface finishing was then done using a trowel. The test specimens were undisturbed in the moulds for 24 hours and protected against shock, vibration, and dehydration. The concrete was cured at the laboratory for 7, 14, 28 and 35 days.

Before placing the cubes into a curing tank, they were marked with a proof marker. Details to be marked on the cubes are the type of mix, date of casting, and the duration of curing and crushing day. Afterwards, the concrete was cast into 150×150 mm cube mould by BS 8110 part 3 (1892) provisions and covered with a sack in the laboratory for 24 hours to prevent flash set by sunlight. After 24 hours, the cubes were demoulded and immersed in a curing tank until 7, 14, 28 and 35 days cubes were removed for hours before crushing it. After curing the cubes for the specified period, they were removed and wiped to remove the surface moisture in readiness for a compressive test. The cubes were then placed

with the cast faces in contact with the plates of the testing machine, that is, the position of the cube when the test should be at right angles to that as cast. The readings on the dial gauge were then recorded for each cube. Several factors, including the water/cement ratio, degree of compaction, type of cement, and quality, influence the crushing strength type and surface of the aggregate, curing efficiency, temperature, age, and moisture condition.

Apparatus: 1) Compressive strength testing machine; 2) Weighing balance; 3) Cubes size (150×150 mm).

Procedure:

- 1) After the specified curing time, the specimen was removed from the water, and excess water was wiped from the surface.
- 2) The dimension of the specimens was taken, and the bearing surface of the testing machine was cleaned.
- 3) Then, the specimen was placed in the automated machine to apply the load to the opposite sides of the cube cast, which was aligned centrally on the base plate.
- 4) The machine was switched on until the specimen failed, the maximum load was recorded, and any usual feature in the type of failure was noted.

$$F_{ck} = P/A \text{ (N/mm}^2\text{)},$$

were P – Expected maximum load; A – Area of the specimen.

RESULTS AND DISCUSSION

Based on the experimental procedure adopted in this project, the results of various tests on the constituents' materials, including the aggregate impact test on coarse aggregate, specific gravity for fine aggregate, sieve analysis, consistency test, slump test, and compressive strength test, are presented in Tables 1 to 12.

Aggregate impact test on coarse aggregate:

$$\% \text{ fine} = B/A \times 100,$$

where A – Mass of fraction that pass-through sieve no 4.75mm (g); B – Mass of coarse aggregate (g); % fine = aggregate impact value was obtained from the mean value of the three results.

Table 1 – Result for aggregate impact test on coarse aggregate

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

Sample 1:

Mass of empty cylinder = 2830 g

Mass of empty cylinder + coarse aggregate = 2965 g

B = (Mass of empty cylinder + coarse aggregate) - Mass of empty cylinder

B = Mass of coarse aggregate in cylinder = 3569 - 2830 = 135 g

Mass of empty cylinder = 2830 g

Mass of Coarse aggregate that passes sieve no 4.75 mm = 3522 g

A = (Mass of Coarse aggregate that pass-through sieve no 4.75 mm) - Mass of empty cylinder

A = Mass of coarse aggregate after passing through sieve no 4.75 mm 3569-2830=692

Sample 2

Mass of empty cylinder = 2830 g

Mass of empty cylinder + coarse aggregate = 2973 g

B = (Mass of empty cylinder + coarse aggregate) - Mass of empty cylinder

B=Mass of coarse aggregate in cylinder = 143 g

Mass of empty cylinder = 2830 g

Mass of Coarse aggregate that passes sieve no 4.75 mm = 3569 g

A = (Mass of Coarse aggregate that pass-through sieve no 4.75 mm) - Mass of empty cylinder.

A = Mass of coarse aggregate after passing through sieve no 4.75 mm = 3569-2830 = 739 g

Sample 3:

Mass of empty cylinder = 2830g

Mass of empty cylinder+ coarse aggregate = 2969 g

B = (Mass of empty cylinder + coarse aggregate) - Mass of empty cylinder

B = Mass of coarse aggregate in cylinder = 139 g

Mass of empty cylinder = 2830 g

Mass of Coarse aggregate that passes sieve no 4.75 mm = 3539 g

A = (Mass of Coarse aggregate that pass-through sieve no 4.75 mm) - Mass of empty cylinder

A = Mass of coarse aggregate after passing through sieve no 4.75 mm = 3569-2830=709 g.

A = 709 g, B = 139 g, % of fine = B/A × 100; % of fine = 139/709 × 100 = 19.61%.

The coarse aggregate is vital for concrete production and surfacing since the Aggregate impact value falls within 10–20%.

Specific gravity G. S = $(W - W_1) / (W_4 - W_1) - (W_3 - W_2)$

where W₁ – weight of empty pycnometer bottle; W₂ – weight of pycnometer and aggregate; W₃ – weight of pycnometer, aggregate and distilled water; W₄ – weight of pycnometer and distilled water.

The experiment is conducted as per the instructions below. The specific gravity of fine aggregate is obtained in Table 2. The value falls in the range of 2.5 to 2.8. Hence, the type of fine aggregate (sharp sand) is natural aggregate.

Apparent Specific GRAVITY = $W_4 / [W_4 - (W_1 - W_2)]$

Bulk Density = $W_4 / [W_3 - (W_1 - W_2)]$

where W₁ – the weight of saturated aggregate and basket in water; W₂ – the weight of basket in water; W₃ – weight of saturated aggregate; W₄ – weight of oven dry aggregate.

Table 2 – Results of specific gravity for fine aggregate

Samples	W1 (g)	W2 (g)	W3 (g)	W4 (g)	G. S
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 G. S					2.65

The experiment is conducted as per the instructions below. The specific gravity of coarse aggregate is obtained, as stated in Table 3. The value falls in the range of 2.5 to 3.0. Hence, the coarse aggregate (granite) is natural aggregate.

Table 3 – Results of apparent specific gravity for coarse aggregate

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

The value of the uniformity coefficient is less than or equal to 4 is recorded for the shared sand, suggesting that it is uniformly graded. The value of the coefficient of curvature is between 1-3. Therefore, the sharp sand is well-graded.

Table 4 – Particle size distribution for fine aggregate (sharp sand)

Sieve size (mm)	Weight of empty sieve (g)	Weight of sieve + Retained soil (g)	Weight of soil retained (g)	Cumulative weight of retained soil (g)	Percentage cumulative weight of retained soil (%)	Percentage passing through soil retained (g)
13.2	520	520	0	0	0	100
2.36	265	280	15	15	3.75	96.25
2.00	327	318	9	24	6	94
0.85	272	314	42	66	16.5	83.5
0.71	444	579	129	195	48.75	51.25
0.60	371	441	70	265	66.25	33.75
0.50	422	450	28	293	73.25	26.75
0.425	303	327	24	317	79.25	20.75
0.35	380	418	38	355	88.75	11.25
0.20	296	318	22	377	94.25	5.75
0.15	357	374	17	394	98.5	1.5
0.075	309	312	3	397	99.25	0.75
Pan	286	289	3	400	100	0

Table 5 – Results of consistency test for grade 42.5R

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 6 – Initial setting time measurement (15 mins) for grade 42.5R

Time (minutes)	Amount of water (g)	Penetration (mm)
12:59 pm	128	0
1:16 pm	128	0
1:31 pm	128	0
1:46 pm	128	0
2:01 pm	128	0
2:16 pm	128	6

Notes: Starting time for consistency test – 1:16 pm - 12:59 pm = 33min; Initial setting time – 2:16 pm; Initial setting time penetration – 1 hr 06 min; Initial setting time penetration value – 6 mm.

Table 7 – Final setting time measurement (1 hr) for grade 42.5R

Time (minutes)	Amount of water (g)	Penetration
12:59 pm	128	0
1:59 pm	128	6
2:59 pm	128	10
3:59 pm	128	16
4:59 pm	128	20
5:59 pm	128	Surface

Notes: Final setting time – 5:59 pm; Final setting time penetration – 3 hrs 58 mins; Final setting time penetration value – surface.

Table 8 – Results of consistency test for grade 32.5N

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
4	400	33	132	6	4

Table 9 – Initial setting time measurement (30 mins) for grade 32.5N

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

Notes: Starting time for consistency test – 12:17– 12:58 pm = 41min; Initial setting time – 3:28 pm; Initial setting time penetration – 2 hr 30 min; Initial setting time penetration value – 7 mm.

Table 10 – Final setting time measurement (1 hour) for grade 32.5N

Time, minutes	Amount of water, g	Penetration, mm
3:28 pm	132	0
4:28 pm	132	0
5:28 pm	132	7
6:28 pm	132	10
7:28 pm	132	25
8:28 pm	132	Surface

Notes: Final setting time – 8:28 pm; Final setting time penetration = 5 hrs; Final setting time penetration value.

The physical properties of the cement and mortar grades are presented in Tables 5 and 8. It is observed that grade 32.5N has a higher consistency. This means a higher amount of water is required by grade 32.5N to achieve a standard consistency. Also, initial setting times of 66 and 85 minutes for 32.5N and 42.5R, respectively, are higher than the 60 minutes stipulated by BS EN 197-2000. BS 12(196) and EN 197-2000 must be limited or recommended regarding the final setting time. It can thus be concluded that the final setting time was obtained for both 32.5N and 42.5R.

Workability is required for maximum compaction to develop compressive strength, and it is vital to achieve maximum density. The slump characteristics of concrete specimens with different grades of Portland limestone cement water/cement ratios are presented in Table 4.11.

Table 11 – Slump test

Cement grade	Water cement ratios	Slump test value		Slump test value	
		Grade 32.5N		Grade 42.5R	
32.5N	35 mm	1:2:4 1:1.5:3		1:2:4 1:1.5:3	
42.5R	50 mm	13 cm	14 cm	15 cm	15.5 cm

The slump increased with the water/cement ratio. Also, both grades of cement have different values in a slump and exhibit a shear slump. For slump values of between 20-50 mm for water/cement ratios, the workability of both cement grades is as medium.

CONCLUSIONS

Vibrated concrete was produced with both grades 32.5N and 42.5R; the two grades gave the highest

compressive strength with a mix ratio of 1:1.5:3 and ratio of 1:2:4 compared to non-vibrated concrete, which means that there is a considerable reduction in the percentage of voids in the concrete when appropriately vibrated concrete are produced than concrete produced with non- vibrated concrete. In other words, the grade 42.5N produced more compressive strength than 32.5R, and the more concrete vibrated, the more the reduction in the volume of voids was and the higher the compressive strength of concrete was. Vibrated concrete contained the lowest void volume and absorbed the most minor water.

The vibrated structural concrete gives more strength than non-vibrated because it tends to remove voids. The vibrated concrete has a higher density than non-vibrated concrete because the reduction in the void will increase the density (Table 12).

Table 12 – Compressive strength of vibrated and non-vibrated concrete using 42.5R cement grade of 1:2:4 and 1:1.5

Age of crushing, Days	Type Vibrated	Mix ratio, 1:2:4	Concrete samples	Dry weight, kg	Size of cubes, mm ³	Dry density, kg/m ³	Failure load, KN	Compressive strength, N/mm ²	Average strength, N/mm ²	
7 days	Vibrated	1:2:4	Sample 1	8.109	150	2403	105	4.67	7.00	
			Sample 2	8.334		2469	210	9.33		
14 days			Sample 1	8.232	150	2439	200	8.89	11.91	
			Sample 2	8.045		2384	125	5.57		
28 days	Sample 1		7.739	150	2293	180	8.00	9.51		
	Sample 2		8.392		2487	248	11.02			
35 days	Sample 1		8.380	150	2483	304	13.51	11.91		
	Sample 2		8.333		2469	232	10.31			
7 days	Non-Vibrated		1:2:4	Sample 1	8.342	150	2472	165	7.33	6.11
				Sample 2	8.034		2380	110	4.89	
14 days				Sample 1	8.090	150	2397	142	6.31	6.71
				Sample 2	8.202		2430	160	7.11	
28 days	Sample 1			7.991	150	2368	154	6.84	7.04	
	Sample 2			8.154		2416	163	7.24		
35 days	Sample 1	8.078		150	2393	215	9.56	9.87		
	Sample 2	8.322			2466	229	10.18			
7 days	Vibrated	1:1.5:3		Sample 1	8.527	150	2527	269	13.33	11.91
				Sample 2	8.285		2455	236	10.49	
14 days				Sample 1	8.373	150	2481	265	11.78	12.00
				Sample 2	8.214		2434	275	12.22	
28 days	Sample 1			8.225	150	2437	292	12.98	14.49	
	Sample 2			8.453		2505	360	16.00		
35 days	Sample 1		8.171	150	2421	360	16.00	14.98		

Age of crushing, Days	Type Vibrated	Mix ratio, 1:2:4	Concrete samples	Dry weight, kg	Size of cubes, mm ³	Dry density, kg/m ³	Failure load, KN	Compressive strength, N/mm ²	Average strength, N/mm ²
			Sample 2	8.258		2447	314	13.96	
7 days	Non-Vibrated		Sample 1	8.234	150	2440	182	8.09	8.00
			Sample 2	8.113		2404	178	7.91	
14 days			Sample 1	8.315	150	2464	237	10.53	9.51
			Sample 2	8.216		2434	200	8.89	
28 days			Sample 1	7.845	150	2324	260	11.60	12.14
			Sample 2	8.432		2498	286	12.71	
35 days		Sample 1	8.341	150	2471	240	10.67	12.32	
		Sample 2	8.187		2426	314	13.96		

Concrete tends to increase strength with curing. The more concrete is curing, the more the increment in strength of specific concrete.

The cement grade 42.5N consistency developed higher densities at the water/cement ratio. This may be equivalent to an additional unforeseen dead load at the design stage, which now amounts to an underestimation of the dead load and, thus, the design load (Table 5).

The concrete specimens produced with cement grades of 32.5N and 42.5R have different strength development patterns. The concrete specimens with cement grades 32.5N and 42.5R developed different 35 days compressive strength. Changing the cement grades during concreting for the same structural member is not supported by the national code and will not result in a safe and durable concrete structure.

Among many parameters and circumstances of usage, this paper presented some relevant

structural implications of changing cement grades during concreting. This aims to present empirical data that will aid the structural decision-making process of the technical team or personnel involved in building concrete structures. Other parameters concerning the available cement grades have yet to be investigated in Nigeria. They include strength relations, equations for Strength prediction, durability studies of concrete made with 32.5N and 42.5R, and many others. They are thus recommended for future works.

Appropriate vibrated concrete should be used to construct structures requiring high compressive strength. An increment in the mix ratio enhances strength, and it is recommended if there is a need to change the cement grade. Every construction company should make sure there is a vibrating machine at every site where concrete work is needed. Curing duration should be extended in cases where higher strength is needed to be achieved.

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