COMPARATIVE ANALYSIS OF CONCRETE CYLINDER AND CUBE SPECIMENS IN COMPRESSION TESTING

BY

OKOLIE, CHUKWUEMEKA OMENA

ENG1704125

DEPARTMENT OF STRUCTURAL ENGINEERING,

FACULTY OF ENGINEERING.

UNIVERSITY OF BENIN,

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A PROJECT SUBMITTED TO THE DEPARTMENT OF STRUCTURAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR'S DEGREE IN STRUCTURAL ENGINEERING (B.ENG)

SEPTEMBER, 2023.

CERTIFICATION

This is to certify that this work was carried out by OKOLIE CHUKWUEMEKA OMENA with Matriculation Number, ENG1704125 of the Department of Structural Engineering, Faculty of Engineering, University of Benin and has been read and approved as meeting the requirements of the Department of Civil Engineering, University of Benin for the award of Bachelor of Engineering (B.Eng.) degree in Civil Engineering.

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ENGR. EHI ORIA-USIFO　　　　**DATE**

PROJECT SUPERVISOR

………………………………………　　　　**………………………………………**

ENGR. EHI ORIA-USIFO　　　　**DATE**

PROJECT CO-ORDINATOR

………………………………………　　　　**………………………………………**

ENGR. DR. MRS NGOZI IHIMIKPEN　　　　**DATE**

HEAD OF DEPARTMENT

DEDICATION

This project is dedicated to Almighty God, the source of my inspiration, who has given nme the grace and opportunity to alive in the land of the living today. His name be praised and glorified forever.

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I give my profound gratitude to God almighty for providing me with strength and wisdom and support for me throughout this work. I wish to give special thanks to my supervisor Engr. Ehi Oria Usifo for his valuable guidance and supervision during this project. I am indebted to him for sparing his valuable time in giving me concrete suggestions and enhancing my knowledge through fruitful discussions

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A warm and hearty thanks to my Parents Mr. and Mrs Okolie for their love, prayers, and financial and moral support during this project and schooling years. To my aunties (Mrs Ghalo, Mrs Erovwo, Mrs Ewoma, Mrs Oreva) Uncles (Mr Majiri, Mr Okezi, Mr Eghale, Mr Nifo) and grandma Mrs Dorcas Ovie thank you so much for the care, love and support. Also, to the ballers in my class and all my classmates, friends, the Students Union Uniben, and colleagues are too numerous to mention who have one way or another other contributed to my success. May God bless you all.

ABSTRACT

The assessment of concrete's compressive strength is a pivotal component in ensuring the safety and durability of structural elements in the construction industry. Two commonly employed methods for this assessment involve the use of concrete cylinder and cube specimens. This research endeavor undertakes a thorough investigation to compare the effectiveness and reliability of these two specimen types in gauging concrete's compressive strength. A battery of compression tests is conducted on these specimens, encompassing a wide range of concrete grades and curing durations. The results are meticulously analyzed to evaluate the accuracy, repeatability, and practicality of each testing method.

Preliminary findings indicate variations in the compressive strength values obtained from the two specimen types. Factors such as specimen geometry, surface characteristics, and stress distribution are scrutinized to elucidate the observed differences. Furthermore, the study delves into the economic and logistical aspects of specimen preparation, testing, and storage. The insights derived from this study have the potential to impact testing standards, quality control procedures, and structural design protocols. Engineers, researchers, and stakeholders in the construction industry will benefit from a nuanced comprehension of the advantages and limitations of each specimen type. From the analysis carried out, the average compressive strength of concrete cubes after a total curing period of 28 days was obtained to be 19.784KN/m^2 while that of the cylinders is 19.641KN/m^2, the difference was obtained as 0.143KN/m^2. This showed a very infinitesimal difference of less than 1% of the designed strength (20 KN/m^2).

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ACRONYMS

PVC	Polyvinyl Chloride
W/C	Water Cement Ratio
S/N	Serial Number
FIG	Figure
LTR	Liter
MAX	Maximum
IBS/FT	Pounds per Foot
PSI	Pounds per Square Inch per Foot
KG/M	Kilogram per Meter
KN	Kilo - Newton
M/S	Meter per Seconds
M	Meters
MM	Millimeters
N/MM	Newton per Millimeter
%	Percentage

CHAPTER ONE

INTRODUCTION

1.1. Background of Study

Concrete is simply a mixture of cement, fine aggregate, coarse aggregate and water or any other solution that maybe used as a solvent. The water is often admitted as a part of the concrete in order to enable the cement to hydrate so as to form a gel like paste around and between the aggregates. This therefore makes the cement to act as a binder (Park, 2014). Concrete is one of the most commonly used building materials in the world today because of its high durability (Musa, 2019) and its ability to flow which enables it to be made into different shapes and sizes when wet (Chung, 2011).

Generally, in the laboratory analysis of concrete specimens for compressive strength, it is a common practice to cast the fresh concrete samples into cubic or cylindrical cavities. The fresh concrete subsequently takes the geometry of the cavities upon setting. However, it has been reported that the geometry of the concrete specimen often influences the compressive strength of the concrete (Siva, 2010). As the compressive strength of the concrete is being influenced by its geometry due to the position of its neutral axis, it therefore implies that its durability can easily be altered resulting into underperformance when subjected to compressive or axial loads.

The compressive strength of concrete element is an essential factor which must be duely paid attention to in order to determine its suitability for application purpose. The negligence of the structural and mechanical behaviour of structures expected to perform under compression has resulted into some structural disasters such as differential settlements and even structural collapses in some instances. These disasters often result into great loss of life and property and even the integrity of the structural or design engineers. To avoid this therefore, proper design must therefore be carried out so as to determine the actual or proper load which a structural element can resist and maintain good suitability and its structural integrity through its design lifespan (Hojual, 2010).

In an attempt to determine this suitable load or external actions, the geometry of the structural element must never be neglected, especially its cross-sectional geometry as this often poses great influence on the stability of the structural element. This occurs as long as the structure is erected on the earth's surface, which is under the influence of gravity (Ben, 2016). In considering the characteristics strength of concrete element, the geometry of the specimen has been observed to be of utmost importance due to the influence of the gravitational force or effect of gravity on it.

In (Bruno, 2017) research, he prioritized the effect of polarizing concrete specimen on the overall design and characteristic strength of the concrete element. He employed strength tests such as compression test, flexural test, split tensile test, pull out test and tensile test. In all, he summarily reported that the geometry of a concrete specimen used for particular purpose is very essential since it determines the overall effect of gravity on it which subsequently determines the stability of the composite structure which is made up of the concrete specimen under considerations. As a conclusion to his research, he suggested that the purpose and the particular structural element for which the concrete is to be used for are essential factors which must equally be considered in order to ensure that the expected load on the structural element is not jeopardized.

The stability of a concrete work is a function of its shape in addition to some other determining factors such as the material composition, response to environmental factors and chemical attacks. This is because the influence of these factors combined to determine the overall performance of the concrete structure. This was as reported by Laporte in research on the behavior of homogeneous concrete material cast into various shape cavities in 2011. Though according to him, the difference in strength was not too noticeable, especially for similar shapes but however, he was of the view that the larger the center of gravity of the specimen, the more stable it tends to be.

It must be noted that the suitability of a structural element for a particular purpose is a factor several determinants including but not limited to the geometrical arrangement of the particles which altogether form the rigid elements which are geometrically arranged to obtain the required structure. These nano elements and their binding energies are vital in determining the structural rigidity of the structure in its entirety. This was as reported by Mario, et al in their study on the significance of binding energy nano materials on the structural stability of high-rise structures in tropic regions. In their study, in addition to the behavior of these particular elements between themselves, they equally considered some of such factors which can commonly influence rigidity of the elemental materials and they concluded that the rigidity of the materials is significantly determined by the kind or type of binder used in binding the materials together so as to obtain the required strength.

1.2. Statement of the Problem

In construction and material testing, we often use two shapes, concrete cylinders and cubes, for compression testing. However, there is inadequate comparison of these shapes in terms of accuracy, reliability, and practical use. The problems often faced are Limited in Research (where there's not enough research comparing how well cylinders and cubes work in compression tests), Confusing Standards (where different testing standards recommend different shapes, leading to confusion in the industry), Choosing between cylinders and cubes which affects not only lab tests but also real construction projects. It impacts how much material you need, how you transport it, and how you interpret results on the job, Informed Choices (without enough data comparing these shapes, it's hard to make smart choices for compression testing)

1.3. Aim and Objectives

This research aims to compare concrete cylinder and cube specimens for compression testing to provide practical guidance for specimen selection, leading to more accurate concrete quality assessments and improved construction practices.

The specific objectives are:

1. To obtain and determine the ideal optimal diameter for cylindrical specimens while maintaining an equivalent height to cubic specimens used.
2. To conduct and examine a thorough particle distribution analysis of the concrete materials employed.
3. To perform compression testing on both cubic and cylindrical specimens to assess and compare their compressive strength, stress-strain behavior, and failure modes.
4. To compare and analyze the results gotten from the compressive tests.
5. To assess and evaluate the cost requirements associated with the production of both cubic and cylindrical specimens.

1.4. Scope of the Study

The scope of this study shall entail majorly laboratory assessment and compares of cubic and cylindrical concrete specimens using suitable laboratory tests. This test includes

i. Particle Size Distribution test (Sieve Analysis) of the concrete materials.

ii. Workability test on the fresh concrete before casting it into cubic and cylindrical concrete cavities (moulds).

iii. Compression test on the concrete specimens.

iv. Recommendations wherever necessary on the applicability of the two concrete geometries.

1.5. Justification

Both cube and cylinder are essential geometries in concrete making. This is because of the uniqueness in the positioning of their neutral axis which results into appreciable stability and hence balancing under the influence of the gravity. This feature has made the both shapes to be commonly used in the making of concrete specimens both for laboratory and field studies. For instance, it has been reported that over 85% of concrete specimens commonly found in concrete laboratories come in cubic or resembling shapes (Sarr, 2011). However, of these two shapes, their characteristic features often vary basically of the variation in their parameters of analytical studies. Hence, the need for comparative study of these geometries so as to ascertain their discrepancies among one another in terms of structural strength and stability and also to determine the most suitable applicability for each and under which conditions can each perform optimally without undue failure or shears.

CHAPTER TWO

LITERATURE REVIEW

2.1. Concrete

Concrete is one of the commonest building materials used globally. Some researchers have reported it as the second most consumed building material in the globally after water. The current consumption rate of concrete has been estimated to be about 25 billion tonne per annum in developing countries such as Nigeria and many other Africans and Asians countries while over 30 billion tonne are being consumed in developed countries such as the United Kingdom, China, the United States of America and many other American and European countries. (Kesh, 2015). Concrete is a composite material which is made by combining few materials (cement, aggregate and water) in a given proportion to give the required strength for a particular structural or mechanical purpose. The cement or any other binding agent is usually used to bind the other ingredients together, water affords the concrete viscosity and initiates the hydration reaction when mixed with other ingredients, the aggregates which makes up between 60-75% of the total volume of the concrete adds bulk to the concrete, though does not take part in the chemical reaction which occur during the curing or setting of the concrete (Daves, 2011).

With the current global economic realities being experienced in developing economies of the world, it has become very pertinent that different geometries of the concrete be considered and compared so as to investigate the possibility of achieving a required strength of concrete specimen with less quantities of the material serving the same required structural purpose (Chung,2016).

Concrete has been observed to be one of the most durable building materials in the world today. This is owed to some of its distinguishing properties such as: high fire resistance, rusting, corrosion and resistance to both chemical and termite attacks when compared to wood as a construction (Kosmatka,1988). It also gains strength and builds it up over long period of time, even when it is under use. This makes it more viable and suitable for construction purposes when compared to other construction materials such as glass and plastic elements. These special properties of the concrete equally makes it a very vital material in the oil and other petrochemical industries where a little rust of a material can result into some disastrous effects.

Concrete is today the largest consumable material in the world that utilizes the natural resources such as sand, crushed stone and water. Due to the depletion of these natural resources for concreting, research is being carried out nowadays to reduce the consumption of these resources. Rapid development of construction in India has resulted in shortage of conventional construction material. In developed country like India use of concrete is higher quantity and availability of raw material is very less. The ceramic industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes, in the ceramic industry about 15% - 30% productions goes as waste (Muzammil Ahmed et al.2018).

It is possible to inspect, test, and evaluate concrete that has been in use for a considerable amount of time, analyze the results, and come to the conclusion that the concrete has been "durable" or not. The term "durable" refers to a specific concrete subject to a specific service environment rather than being an attribute of concrete in general, or of a given class or level of a set of properties. A concrete is considered "durable" if it has provided the desired service life in its environment without incurring excessive maintenance and repair costs as a result of degradation or deterioration. Concrete doesn't have the quality of being durable. If concrete is going to be used in an environment where it will never freeze in a critically water-saturated condition, it is no more "quality" than concrete that cannot withstand freezing and thawing.

The oldest concrete discovered dates from around 7000 BC. It was found in 1985 when a concrete floor was uncovered during the construction of a road at Yiftah El in Galilee, Israel. It consisted of a lime concrete, made from burning limestone to produce quicklime, which when mixed with water and stone, hardened to form concrete (Brown 1996 and Auburn 2000).

The development of portland cement was the result of persistent investigation by science and industry to produce a superior quality natural cement. Much of it still stands today (Courtesy of J. Catella). portland cement is generally credited to Joseph Aspdin, an English mason. In 1824, he obtained a patent for a product which he named portland cement. When set, Aspdin's product resembled the color of the natural limestone quarried on the Isle of Portland in the English Channel (Aspdin 1824). The name has endured and is now used throughout the world, with many manufacturers adding their own trade or brand names.

The foundation of much of civilization's physical development and infrastructure is concrete. Concrete is used in construction twice as much as all other building materials combined. It is a foundational structure material for offices, homes, office buildings, and transportation infrastructure. Although concrete has properties that make it a very low-impact construction material from an environmental and sustainability standpoint, manufacturing is resource- and energy-intensive perspective.

The sequence of charging ingredients into a concrete mixer can play a significant role in uniformity of the finished product, but the sequence can be varied and still produce high-quality concrete. Different sequences require adjustments in the time of water addition, the total number of revolutions of the mixer drum, and the speed of revolution. Other crucial factors to consider include the amount of water to be added, the total number of revolutions, and the speed of revolution.

Noncombustible concrete buildings offer effective fire protection. As a separation wall, concrete helps to prevent a fire from spreading within a structure. As an exterior wall or roof, concrete helps to prevent a fire from involving other buildings. The fire endurance of concrete can be determined by its thickness and type of aggregate used by applying ACI Committee 216 procedures (ACI 216 2007).

2.2. Concrete Compositions

Concrete is a heterogeneous (contains different materials) mixture of:

i. Cement.

ii. Aggregates (fine and coarse).

iii. Water

iv. Admixtures (optional)

v. Air.

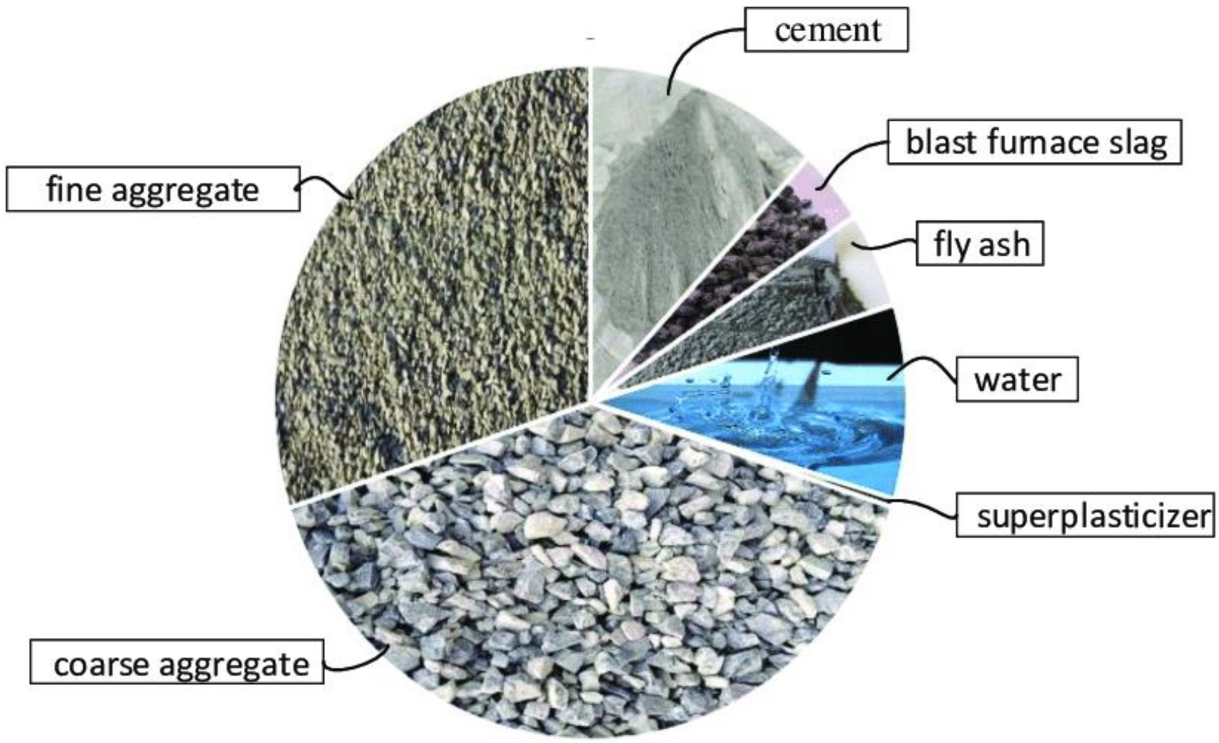

Figure 2.1: The composition of concrete by volume (Chen et al., 2022).

2.2.1. Cement

Cement in its general term, can be described as a material with adhesive and cohesive properties which make it capable of binding the material fragments into the compact whole. Basically, the raw materials used in the manufacture of Portland cement consist mainly of lime, silica, alumina and iron oxide. These compounds interact with one another in the kiln to form a series of more complex products and apart from a small residue of uncombined lime which has not had sufficient time to react, a state of chemical equilibrium is reached.

Neville (1997) described cement as a material with adhesive and cohesive properties that make it capable of bonding mineral fragments (stones, sand, bricks, building block) into a compact whole. The cement referred here is the hydraulic cement having the property of setting and hardening under water by virtue of a chemical reaction with it. The principal constituents of this cement are mainly of silicates and aluminates of lime. This hydraulic cement which is commonly known as 'Portland' cement is due to its resemblance of the colour and quality of the hardened cement to Portland stone, limestone quarried in Dorset, United Kingdom. The various types and classifications of Portland cement and its properties are stipulated in accordance with ASTM C 150-2005 and BS EN 197-1:2000. Many types of cements have been developed to ensure good durability of concrete under a variety of conditions. Table-2.1 shows a list of different types of Portland cement in the British classification together with the American classification (Neville, 1997).

Figure 2.2: Bulk cement (Diaferio et al., 2022)

Cement comes in various forms and types. However, the commonest of them all is the Portland cement. The Portland cement was discovered by a British masonry worker, Joseph Aspdin as far back as in the year 1824. The name portland was given to the cement because its color had great resemblance to that of Portland limestone which was quarried from the English Isle of Portland used in the London Architecture (Anon, 2011). Before the discovery of portland cement, large quantities of natural cement were used, which were produced by burning a naturally occurring mixture of lime and clay (Anon, 2011). However, the discovery of the portland cement was a major breakthrough as a good replacement of the natural cement which was mixed in nature and hence possessed varied properties and hence, made it very difficult for a uniform application, especially under uncertain environmental and other atmospheric conditions.

In the new era of concrete industry, Ordinary Portland Cement (OPC) was still remains as a major binder in hydration process to produce High Performance Concrete. It has been used as total binder in concrete mixes or as binder proportions in blended cements. The main compounds of OPC named as tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A) and tetracalcium aluminoferrite (C4AF) (Handoo, Mahajan Kaila 2003). C3S comprises angular crystal content about 52% of OPC volume. It is responsible on initial setting and rapid strength gain especially to give an early strength (for example, 7 days). C2S is more rounded crystal content about 19% of OPC volume and it is responsible for long term strength. It will harden slowly, but contributes notably to strengthen at ages over a month (Ajiwe et al, 2000).

While C3A may be in rectangular or amorphous crystal forms, it is responsible for rapid setting and C4AF, a non-crystalline composition, is responsible for grey colour with little contribution to setting or strength as placed surrounding the cement matrix content about 10% and 8% of OPC volume respectively (Taylor, 2002).

The reaction of C3A with water is very violent and leads to immediate stiffening of the paste, known as flash set. To prevent the flash setting phenomenon, gypsum will normally be added to cement clinker. The presence of C3A with its rapid setting, high heat emission and sulphate susceptibility, is undesirable in concrete. The actual proportions of the various compounds vary considerably from cement to cement, and indeed different types of cement are obtained by suitable proportioning of the raw materials. The major composition of OPC is lime, silica, alumina and iron oxide. With the presence of water these compounds interact with one another to produce hydrated product which is Calcium Silicate Hydrate (C-S-H) and Calcium Hydroxide (Ca[OH2]). The C-S-H takes the form of extremely small interlocking crystals which grow out slowly from cement grains to occupy previously water-filled spaces. The microcrystalline material is responsible for strength in the harden concrete (Regourd, 1992).

Ca(OH)2 forms in a much larger crystal that acts as fillers in the hardened concrete but do not interlock to form strength. In the presence of moisture in the concrete matrix, Ca(OH)2 will partly dissolve to form an alkaline solution that is useful to protect reinforcement in the reinforced concrete structure (Regourd,M.M 1992). The ratio of C-S-H to Ca(OH)2 is approximately 7:2 by mass of concrete (Neville, 1997). At any stage of hydration, the hardened paste consists of very poorly crystallized hydrates of the various compounds. It is referred to, collectively, as gel, crystals of Ca(OH)2, with some minor components, unhydrated cement and the residue of water-filled spaces in the fresh paste (Neville, 1997).

As $Ca(OH)_2$ is crystallised in massive superimposed hexagonal plates, it has created a capillary pore in the cement paste matrix. The capillary pore has been generated either by $Ca(OH)_2$, air bubbles or micro crack that has become a factor, attributed to low engineering properties and performance of concrete (Regourd, 1992). 16 The capillary pores represent a part of the gross volume which has not been filled by the products of hydration. Commonly, the hydration product of OPC occupy twice the volume of the original solid phase, therefore, the volume of capillary system is reduced with the progress of hydration (Neville, 1997).

The hydration progress depends on water/cement ratio and on the degree of hydration. Water/cement ratios lower than 0.23 would have self-desiccation problems and a water/cement ratio higher than 0.36 used the capillary pores will occur since the volume of the gel is not sufficient to fill all the space available (Taylor. 2002).

An improvement has been obtained by several processes which reduce the porosity and the water/cement ratio. One of the process as introduced is blending OPC with pozzolanics materials named as pozzolanic cements or pozzolanic blended cement. The small particles of pozzolans will generate a large surface area for the precipitation of the hydration product, and make the cement paste become more homogeneous and dense as for the distribution of the finer pores. This is due to the pozzolanic reactions between the amorphous silica of the mineral addition and $Ca(OH)_2$ produced by cement hydration reactions.

Ordinary Portland Cement (Type I) is admirably suitable for use in general concrete construction when there is no exposure to sulphates in the soil or in ground water. The specification for this cement is given in BS 12:1978 (British Classification). In addition to the main compounds mentioned above, there exist minor compounds like manganese oxide, magnesium oxide, sodium oxide and potassium oxide. They usually amount to less than a few percent of the weight of cement.

At the early stage of this discovery, the portland cement equally faced certain set-backs in terms of application and certainty of its chemical compositions, however, modern Portland cement is manufactured to detailed standards of compositing elements and their respective percentage compositions. The chemical elements present in the cement are essential for the hydration process which enhances the binding process of the cement paste to other ingredients which make up the concrete as a composite material (Biden, 2010). Portland cement is a mixture of calcium silicates (alite, belite), aluminates and ferrites compounds which consist calcium, silicon, aluminium and iron in forms which will react with water. The main oxide compositions of the cement include typically: Lime (CaO 60-65%), Silica ($Si0_2$ 18-25%), alumina (Al_20_3 3-8%), iron oxide (Fe_20_3 0.5-5%) (Siva, 2015).

The properties of the cement are presented on table 2.1 and 2.2

Table 2.1: Physical Properties of Cement (Source: dangotecement)

S/N	PROPERTY	VALUES
1	Fineness of cement (%)	7
2	Normal consistency (mm)	33
3	Setting time	
	Initial (minutes)	85
	Final (minutes)	24

Table 2.2: Chemical Properties of Cement (Source: dangotecement)

S/N	PROPERTY	VALUES
1	Lime	60.87
2	Alumina	5.36
3	Soluble silica	20.55
4	Iron oxide	4.00
5	Chloride	0.0173
6	Magnesia	0.74
7	Sulfuric Anhydride	1.83
8	Insoluble residue	2.93
9	Al_2O_3/Fe_2O_3	1.34

When cement is mixed with water, the various compounds present begin to react chemically with the water. For a short time, this cement water paste remains plastic such that it is possible for it to be disturbed and remix without any harmful effects. However, as the chemical reaction continues, the paste begins to stiffen (harden) or set. The arbitrary beginning and the ending of the period of setting of the concrete paste is usually referred to as the initial and the final setting of the cement respectively. A typical volume of concrete contains about 7-14 % of cement, though, this may vary depending on the mix ratio adopted in mixing the concrete depending on the characteristic strength of the concrete that is being prepared. In Nigeria, the most common cement type is the Portland limestone cement (Zarina, et al., 2016).

According to the American Society for Testing and Materials (ASTM), Portland cement can be classified into five basic types. They include:

<u>Type I cement</u>: this is the standard or the general purpose portland cement. It is the most common type of cement and it is used when sulphate exposure is expected to be minimal.

<u>Type II cement</u>: this is used for making concrete which is expected to be exposed to a low sulphate content such as soils that contain a low concentration of sulphate.

<u>Type III cement</u>: this is used when early strength is required.

<u>Type IV cement</u>: this is used when early setting time is required, such as in dams and places that require large amounts of concrete.

<u>Type V cement</u>: this is the high sulphate- resistant Portland cements, there are used in applications where concrete is exposed to a high concentration of sulphate, such as sewer water (Craig, 2007).

2.2.2 Aggregates

Aggregates used in concrete making come in two forms. They include the fine and coarse aggregates. The fine aggregate often come basically as natural sand or crushed stone sand or even crushed gravel sand and usually consist of particles mainly passing a 5 mm sieve.

The properties of the fine aggregate used for the research work are given in table 3.2.

Table 2.3. The Properties of the Fine Aggregate (Source: directscience)

S/N	PROPERTY	VALUE
1	Specific gravity	2.66
2	zone	II
3	Percentage passing by weight	80-100%
4	Bulk density	1.52

The nominal size distribution of the aggregate determines how much binder is required. For instance, aggregates with a very even size distribution has the biggest gaps whereas adding aggregate with a smaller size tends to fill this gap. It is an essential requirement that the aggregate should be durable and chemically inert under the conditions to which it will be exposed in order to achieve the required structural strength.

Figure 2.3 Bulk Aggregate

Some other essential characteristic requirements of this form of aggregate may include the size, geometry, surface texture and also the gradation. The second form of aggregate, the coarse aggregate which come as the crushed stone, crushed gravel or uncrushed gravel and usually, it consists of particles which can be retained on a 5 mm sieve or on other sieves of higher nominal size depending on the gradation of the aggregates.

The properties of the coarse aggregate used for this research are presented on table 3.3

Table 2.4: The Properties of the Coarse Aggregate (Source: ASTM C33)

S/N	Property	Value
1	Specific gravity	2.65
2	Density	1.41
3	Crushed / uncrushed	Crushed
4	Maximum size of aggregate	20mm

Also, it worth's noting that the size of the coarse aggregate to be employed in a particular often depends on the application and the structural and mechanical requirements of the structure in terms of use and lifespan (Mehta, 1993).

2.2.3. Water

As a standard, the water used in concrete making is expected to be in its pure physical and chemical. It is expected to satisfy the requirements of Section 5.4 of IS: 456 – 2000 which provides that "water used for mixing and curing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances which may be detrimental to the strength of the concrete and steel". In other words, the water used in concrete making must be generally suitable for drinking, that is, it must be potable (Somayaji,2001).

Apart from the wetting and lubricating surface provided by the water, it is also considered an essential component when making concrete. This is because, the moisture that water provides also gives the concrete its strength during the curing process. Concrete sets as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.35 pounds (or 0.35 kg or corresponding unit) of water is needed to fully complete hydration reactions (Somayaji, 2001). However, inasmuch as water is an essential component of concrete, it must be noted that excess water in concrete results into reduction in its overall characteristic strength.

2.3. Classes of Concrete

Based on specific applications, concrete may be classified into various classes. Some of the common classes of concrete which are available in the Nigerian construction market today. The difference between them usually depends on the variations in the constituents of the concrete material and the quantity of the materials being used in order to achieve the required strength for a specific purpose (Hauser, 2005).

Some of these classes are:

2.3.1 Ordinary concrete: this essentially consists of cement, aggregates and a specific amount of water. It is used in pavement constructions where very high tensile strength is not required.

Figure 2.4: Bulk Ordinary concrete

2.3.2 Lightweight concrete: this refers to any type of concrete whose density is less than 1920kg/m^3 it is singled out for its very low thermal conductivity.

Figure 2.5 Bulk Light weight Concrete

2.3.3 High-density concrete: this is also known as heavy weight concrete. It possesses high density of about 3000-4000 kg/m^3. It is mostly used in atomic power plants and other similar structures due to its high radiation resistance.

Figure 2.6 Bulk High density Concrete

Other classes of concrete include the reinforced concrete, precast concrete and the prestressed concrete. Efforts are still on through researches and innovations to identify some other classes of concrete which are not yet popular in the construction industries today (Hauser, 2005).

2.4. Workability of Concrete

Simply put, workability refers to the characteristic of freshly mixed concrete or mortar with which it can easily be hauled, poured, compacted and finished with ease and homogeneity in order to prevent it from bleeding or segregation within the forming and curing processes.

Workability is also enhanced by the use of super plasticizers (ACI 238.1, 2008, Duggal, 2012). A well graded aggregate also helps in reducing voids making cement paste available for better lubrication (ACI 238.1, 2008). However, Kaplan, (2015) and Donzar et al, (2002) pointed out that angular and flaky aggregate reduces workability because they have greater surface area and more voids which reduces the available paste for lubrication. Pereira et al (2012) also showed that concrete with super plasticizers produced a superior workability to that without admixtures. Abdullah, (2001) writes that increased temperature increases the rate of hydration and evaporation with attendant loss of workability. This paper presents an experimental investigation into the effect of time delayed after concrete mixture of different constituent proportions under different management conditions.

The workability of concrete is usually inversely proportional to its strength under ambient temperature and pressure. The workability of concrete in the laboratory maybe determined using either the slump, compaction factor or the Vee-bee tests. In some cases, the consistometer may also be used to determine the workable characteristic of a fresh concrete. For fresh cement paste however, the consistency and setting time or any other suitable laboratory tests may be used to determine its workability (Cheng, 2016).

When used, concrete needs to be sufficiently workable. When the sections are thin and heavily reinforced, a higher workability is needed. The characteristics of the various concrete ingredients affect how workable concrete is. Typically, a higher water/cement ratio than that calculated is necessary to enable the concrete to be fully compacted with the given efforts. Theoretical analysis might be necessary. that is to say, water also has the purpose of lubricating the concrete so that with the right amount of effort, the concrete can be compacted during site work. the handling lubrication needed (Ijirset, 2018).

For placement without losing homogeneity, compacting with the necessary effort, and concrete without segregation forthcoming and to complete it with enough ease, the presence of a specific amount of water is important. Many researchers have attempted to define workability. Workability is defined as the property of concrete that determines the amount of useful internal work required to produce full compaction, according to extensive studies in the fields of compaction and workability (Ijirset, 2018).

2.5. Concrete Grading

The grade of a concrete refers to its strength or class. It illustrates the compressive strength of concrete which is taken on the 28th after casting. The concrete cube or beam is usually crush under compressive pressure to determine this strength and the behaviours of the concrete material when subjected to constant loading (Emiero, 2017). The grade of a concrete is denoted by the prefix M to the desired strength in MPa.

For instance, grade 20 concrete may just be denoted as 30MPa strength or M20.The capital letter 'M' represents the mix of mix ratio used in forming the concrete. The grade of concrete element to be used in construction is usually selected based on structural design requirements and application purposes (Anon., 2011).

In the construction world, two types of concrete mixes exist. They include the nominal mix and design mix. The Nominal mix concrete refers to those which are generally used for small scale construction and small residential buildings where concrete consumption is in little quantity. Nominal mix takes care of factor of safety against various quality control problems generally occurring during concrete construction. Nominal mixes for grades of concrete such as M15, M20 and M25 are generally used for small scale construction (Joel, 2013). Design mix concretes refer to those whose mix proportions are obtained from various laboratory tests. The use of design mix concrete requires good quality control during material selection, mixing, transportation and the actual placement of the concrete element.

Large structures have high strength requirements because of the large amount of the load expected to be imposed on them, thus, hence, while designing for such structures, it is wise to go for higher grades of concrete such as M30 or higher grades depending on some factors such as the placement method, the intended use of the structures and its design lifespan. The mix proportions of these concretes are usually based on mix design. Some of the commonly available concrete grades include the M15, M20, M25 and M30. For plain cement concrete works, a low strength concrete such as M15 can be applied. For reinforced concrete (R.C) work however, a minimum of grade 20 concrete is expected to be used (Shaw, 2010).Some of the common concrete grades and their mix proportions are shown on table 2.1

Table 2.5: The different grades of concrete, mix ratio and their compressive strength (Source: wecivilengineers@worldpress.com)

Classification of Grades of Concrete			
Designation	Mix Proportion (Cement: Sand: Coarse aggregate)	Characteristic Compressive strength in N/mm²	Group
M5	1 ; 5 ; 10	5	Lean concrete
M7.5	1 ; 4 ; 8	7.5	
M10	1 ; 3 ; 6	10	Ordinary concrete
M15	1; 2 ; 4	15	
M20	1; 1.5 ; 3	20	
M25	1; 1 ; 2	25	Standard concret
M30	Design mix	30	
M40		40	
M50		50	
M55		55	
M60		60	High strength concrete
M80		80	

The value and importance of concrete continues to increase because most of its applications have not been suitably substituted by some other commonly available materials such as plastic, rubber or wood (Tiwari, 2013). For this reason, several researches have been made in attempts to get a cheaper form of concrete especially the use of waste products as an attempt to reduce the heavy dependency on any or all of the concrete materials (cement, fine aggregates and coarse aggregates) (Bruno, 2011).

Around the world, concrete mix design is a well-known practice. The majority of nations have standardized their approaches to concrete mix design. Concrete has developed remarkably quickly in recent years. There is ongoing research on mix design practices standardized by various nations, the effect of ingredient variability on the properties of fresh and hardened concrete, and the use of various supplementary and recycled materials. The empirical relationships, charts, graphs, and tables used in the IS and ACI methods of concrete mix design were developed through extensive experiments and investigations using their own locally accessible materials. Although the selection of mix design parameters is generally the same for all of these methods, there are some procedural differences between them.

For instance, in the year 2010, Ikponmwosa reported that concrete is compose of about 75% of coarse aggregate on average, which makes it an indispensable part of the concrete. He however suggested that the use of industrial and agricultural byproducts as an alternative to thus material can reduce both the cost of construction and the self-weight of the concrete element or structure. He equally opted that the strength and surface texture of any material to be used as a substitute of any of the concrete material are essential and must be considered since the overall strength of the concrete depends on these and some other properties of the constituents.

2.6. Common Properties of Concrete

Concrete possesses some unique vital properties which define its performance as a building material. It has been reported that most of these properties increase as the age of the concrete increases provided that the curing method and conditions adopted are favourable and suitable to the purpose for which the concrete has been designed. The three most important properties of concrete include its durability, porosity and density.

2.6.1. Durability

Concrete has been observed to possess great resistance to physiochemical attack from its environment as a result of frost, atmospheric pollution, rain and other hazardous environmental factors (Bade, 2013). The service life and durability of concrete structures need to receive more attention due to the increased importance placed on life cycle cost analysis for construction projects. Although compressive strength and slump are typically used to specify concrete, it is well known that the concrete's transport properties, such as diffusivity, permeability, and sorptivity, have a greater impact on durability. This quality often makes it very suitable for structures situated in almost every environment even when exposed to some physical hazardous environmental conditions or attacks since it can resist them with very little or no defect (Dele, 2016).

2.6.2. Porosity and Density

These properties are usually responsible and to an extent determine the strength and durability of concrete. The less porous a concrete is, the better performance it yields and the greater its durability and vice versa (Usman, 2012).

The density of concrete is greatly affected by the water content of the concrete element. It has been reported that high volume of water in concrete reduces its density and vice versa. Hence, to obtain high density for a concrete specimen, the dimensions and gradation of the aggregates must be optimized while the water content is being reduced to a suitable volume (Siva, 2017).

2.7. Concrete Geometry (shape)

The stability of concrete specimen is greatly determined by its stability under gravity. The stability of the concrete maybe considered as the roughness or smoothness of the exposed surfaces of the specimen. The stability equally affects some of the structural and mechanical properties such as the compression, flexural and tensile strengths of the concrete element. In summary, it has been observed and reported that geometries with large centre of gravity such as cubes, cuboids and the like shapes often possess higher stability compare to pyramidic shapes such as the cylinders, cones and the likes. These shapes are possibly obtained with concrete material since it can be molded into various shapes as long as it remains wet or fresh. In this study, the effect of some of these shapes may be considered and proper recommendations offered (Egar, 2010).

2.8. Review of Previous Researches on the topic (start)

Ismaila, in 2009 studied the effect of geometric shape of concrete specimen on its mechanical properties. He employed laboratory approach carrying out the compression and split tensile tests on the both specimens. His result showed that the compression strength of the concrete cube is slightly higher than those of the cylindrical specimens. He used 150mm by 150mm cube with the same equal volume of concrete being cast into the counterpart cylinders.

In 2017, Pele,E.R. studied the difference in the characteristic strength of equal volume concrete specimens cast into various shapes. He cured the specimen under ambient temperature for a period of twenty-one (21) days. He conducted compression test on the specimens and discovered that those shapes with more stable surfaces such as the cubes and the cuboids provided better compression strength than those with low centre of gravity such as the cones and pyramids. However, he observed and conclude that the difference in the strength was not too significant but decreases as the surface of stability decreases.

Tande, et al in 2019 conducted tensile test on the concrete cylinders and cubes of equal volume of concrete. However, he had two sets of cylinders, one set with equal diameter as the equal side of the cube while the second set had a height that was equal to the equal side of the cube. His aim was to investigate whether the strength of the concrete specimen depends on the parameters of the cylinders that is, the diameter and the perpendicular height. He discovered that no significant difference was measured at the end of the curing period. He therefore concluded that since all the six sides of the cube are equal, it therefore means that as long as equal volume of concrete is cast into a cylinder of either height or diameter to that of the cube, no significant variation can be recorded provide that they were mixed, cast and cured under the same conditions of temperature and pressure.

Mural, S.D. in 2011 reported that for little volume of concrete, the geometry of the specimen is insignificant but for very large volume of concrete, the geometry may be of great interest, especially where strength is of optimum interest. Naik et al., in 2015 equally studied the suitability of cylindrical concrete geometry for high rise building construction. He concluded that for temperate areas, the geometry may be suitable but must be properly bound with suitable paste. In 2017, Chung also considered the aesthetics and strength implications of different concrete geometries on structures. He concluded that since the aesthetics of s structure does not guarantee its strength, therefore, attention must be focused more on the durability of the concrete which determines its strength. He further reviewed that variation in the geometry of light concrete construction or specimen does not have a drastic or dangerous effect on its overall characteristic strength but for heavy construction or specimen, the best geometry must be chosen considering some factors ranging from the environmental and soil factors of the immediate environment of the structures.

Dr. Krishna Reddy (2013) Efficient uninterrupted curing is the key to quality concrete. Proper curing of concrete is crucial to obtain design strength and maximum durability. The curing period depends on the required properties of concrete, the purpose for which it is to be used, and the surrounding atmosphere namely temperature and relative humidity. Curing is designed primarily to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method. The present paper is directed to evaluate effectiveness of different curing methods and study the influence of climate on the strength properties of concrete.

Gnana Venkatesh. (2014) This experimental work was carried out to investigate the effect of concrete strength in terms of compressive and split tensile strength of normal strength M20and medium strength M40 grade concrete by adopting Immersion curing, Wet gunny bags curing and accelerated warm water curing as per 10262:1999, IS 9031:1978. Traditionally, quality of concrete in construction works is calculated in terms of its 28 days compressive strength. If after 28 days, the quality of concrete is found to be dubious, it would have considerably hardened by that time and also might have been buried by subsequent construction. What is essentially needed for assessing quality of controlled concrete is an acceptance test which can supply results, within about 24 hours after casting. With the assistance of reliable test methods employing accelerated curing techniques, it is now possible to test the compressive strength of concrete within a short period and thereby the test results of compressive strength and split tensile strength having good agreement with the specified strength at 28 days.

Dr. Pamnani Nanak (2015) Self-Compacting Concrete (SCC) is highly workable concrete with high strength and high performance that can flow under its own weight through restricted sections without segregation and bleeding. SCC is achieved by reducing the volume ratio of aggregate to cementitious materials, increasing the paste volume and using various viscosity enhancing admixtures and superplasticizers. It is observed that the behaviour of the design concrete mix is significantly affected by variation in humidity and temperature both in fresh and hardened state. In this paper effect of few water-based curing techniques on shear strength of M30 grade self-compacting concrete (M30SCC) is discussed and compared with shear strength of normal vibrated concrete of same grade (M30NVC).

CHAPTER THREE

METHODOLOGY

3.1 Mix Design

The mix design for the concrete made with granite including the tests carried out and the procedures involved in carrying out the test are all included in this chapter. The concrete cube and cylinder samples were produced in accordance with BS1881. The experiment was performed in the Structural Laboratory of the Civil Engineering Department of the University of Benin, Benin City. The tests carried out in this research project include:

(i) Sieve Analysis Test
(ii) Slump Test
(iii) Compressive Test

For all the tests, no replacement was made for any of the concrete constituents (cement, fine and coarse aggregates).

3.2 Materials used

The following materials were used in producing the concrete cubes and cylinders in the laboratory.

i) Coarse Aggregate
ii) Fine Aggregate
iii) Cement
iv) Water
v) Oil
vi) Concrete cubes and cylinder cavities

3.2.1 Cement

The cement type used in this research was the Portland Limestone Cement of 42.5 grade (Dangote brand). It was gotten from a cement depot located by the Agen Junction, Oluku Ovia North-East L.G.A of Edo State. The cement was carefully handled and stored by keeping it air-tight and was only opened when a sample of it was needed.

3.2.2 Fine Aggregate

This was gotten along the Ugbowo-Lagos road Edo state. Sieve analysis was conducted on the fine aggregate and the aggregate passed through sieve 4.75mm and was retained on 600µm sieve showing that it belongs to zone II. The fine aggregate was made free from all impurities by handpicking and proper sieving. The fine aggregate was air dried for 72 hours before casting was done to ensure that its inherent moisture is reduced to a level that it could not alter the results of the test.

3.2.3 Coarse Aggregate

The coarse aggregate used in this study was uncrushed granite gotten along the Ugbowo-Lagos Expressway by the Agen Aluminium, Benin City. The coarse aggregate was with an average nominal diameter of 20mm. Th e grading was in accordance with ASTM C33.

3.2.4 Water

Water suitable for drinking was used throughout this study. This was gotten from the borehole water system in the civil engineering laboratory, University of Benin, Benin city. The water was free from all forms of impurities and organic matter. A specific volume of water was added to the concrete for mixing according to the mix design while the same potable water of reasonable volume was used for curing it after it had been demoulded from the concrete cavities (cubes and cylinders).

3.2.5 Oil/Grease

Grease was used in lubricating the concrete moulds (concrete cube cavities) in order for the concrete specimens to be easily separated (demoulded) from it after it had solidified. It was also used in lubricating the slump cone during slump test for easy removal to prevent any damage or crump to the fresh concrete specimen.

3.3 Machines and Equipment used during the tests

The tools, equipment and machines used during this study include:

i) Concrete mixer
ii) Compression testing machine
iii) Vibrating table
iv) Weighing machine
v) Shovel
vi) A set of sieves
vii) Head pans
viii) Buckets
ix) Tamping rod
x) Measuring tape
xi) Cone and its accessories
xii) Measuring cylinder
xiii) Hand trowel.

3.4 Experimental Procedures

The following experimental procedure and tests were carried out chronologically

i) Sampling of aggregates.
ii) Sieve Analysis test on the prospective concrete materials.
iii) Preparing the concrete Mix Design.
iv) Preparing of the fresh concrete.
v) Slump test.
vi) Casting of concrete cubes.
vii) Demoulding of the concrete specimens from their cavities.
viii) Curing in water.
ix) Compression test on the concrete cubes and cylinders.

3.5 Laboratory Tests on the concrete Specimens

3.5.1 Sieve Analysis

Sieve Analysis is a practice used to assess the particle size distribution of a granular material by allowing the material to pass through a series of sieve sizes arranged in a particular order of nominal diameter. A typical sieve analysis involves a nested column of sieves of different sizes with wire mesh arranged accordingly on a solid base.

The sieve analysis for this study was conducted in accordance with ASTM C136.

Procedure

i. A representative weighed sample (100g for fine aggregate and 2000g for coarse aggregate) is poured onto the top sieve which has the highest screen opening. (the lower sieve has smaller openings than the ones above).

ii. The receiver was located at the base.
iii. The column of the sieve was then shaken for about 5 minutes.
iv. The amount of material retained on each sieve was weighed.
v. The mass was then divided by the total mass to determine the percentage retained on each sieve.

3.5.2 Slump Test

After the concrete materials had been assembled and their representatives obtained, the materials were batched by mass. After thorough mixing in the concrete mixer, slump test was carried out to ascertain the workability (flowability) of the concrete specimen.

Procedure

i. The internal surface of the apparatus (cone) was cleaned and oiled.
ii. The cone was placed on a smooth horizontal non-porous base plate.
iii. The mould was filled with the prepared concrete in three (3) approximately equal layers.
iv. Each layer was tamped with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould with each tamping penetrating the underlying layer.
v. The excess concrete was removed and the surface levelled with a trowel.
vi. The mortar and the leaked water around the mould were cleaned off.
vii. The mould was raised from the concrete immediately and carefully in a vertical direction.
viii. The difference between the height of the mould and that of the height of the specimen was measured and recorded (in millimetre) as the slump.

Precautions

i. Safety googles were worn during this experiment to prevent concrete from coming in contact with the eyes.
ii. The apparatus was cleaned and oiled properly before the experiment was conducted.

3.5.3 Casting of Concrete Cubes

The fresh concrete used for the slump test was remixed in the mixer and then cast into the concrete cube and cylinder cavities.

A total of twelve (12) concrete cubes were cast and twelve (12) concrete cylinders of equal volume to the cubes were cast. The break down is shown in table 3.6.

Table 3.1. Breakdown of concrete cubes and cylinders cast

Crushing Day	No of Cubes	No of Cylinders
7	3	3
14	3	3
21	3	3
28	3	3
Total	**12**	**12**

3.5.4 Curing of Concrete

Immediately the cubes and the cylinder specimens were remoulded, they were immediately taken into the curing tank in the curing room for curing at the ambient (room) temperature until the crushing day for each sample.

3.5.5 Compression test on concrete cubes

The test on concrete for strength (compression test) was carried out on each cubes and cylinders cast (they were tested at days 7, 14, 21 and 28). On each of the crushing or testing days, each of the samples to be tested was weighed using the weighing balance (machine). Their weights under gravity were recorded accordingly. Three (3) cubes and three (3) cylinders were tested on each of the crushing days. Their failure load as obtained on the screen of the digital compression machine was recorded against their respective weights while their average was obtained for the purpose of the analysis of the result in the next chapter. The test was conducted in accordance with the provision of BS 1881-116

Procedure

i. In testing for the compressive strength of the concrete samples, the compression machine was turned on and the gauges were set to zero.

ii. Thereafter, the samples were taken one at a time and was set at the loading point of the machine, the top screw was lowered to hold the cubes in place, (the hydraulic lever was turned until it locked the sample firmly).

iii. After this had been done, the compression machine started exerting compressive force on the sample, such that the sample is crushed at a particular maximum force, the dial gauge gave the maximum force reading. The test results are shown in the next chapter.

iv. A total of three cubes and three cylinders were tested on 7, 14, 21 and 28 days respectively.

v. Steps 1-4 were conducted and the average taken as the final answer.

3.6. Calculation for Density

$$\textbf{Density} = \frac{Average\ mass\ of\ concrete\ cubes}{Volume\ of\ concrete\ cubes} \qquad \textbf{(3.1)}$$

3.7. Calculation for compressive strength

$$\textbf{Compressive strength} = \frac{Compressive\ Force}{Area\ of\ cubes} \qquad \textbf{(3.2)}$$

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results from Slump Test

The results obtained from the slump test carried out on the fresh concrete are shown on table 4.1

Table 4.1: Results of the slump test on the fresh concrete

Samples	**Slump 1 (mm)**	**Slump 2 (mm)**	**Slump 3 (mm)**	**Slump Average (mm)**
Cubes	37.00	32.00	35.00	34.66
Cylinders	34.00	39.00	32.00	35.00

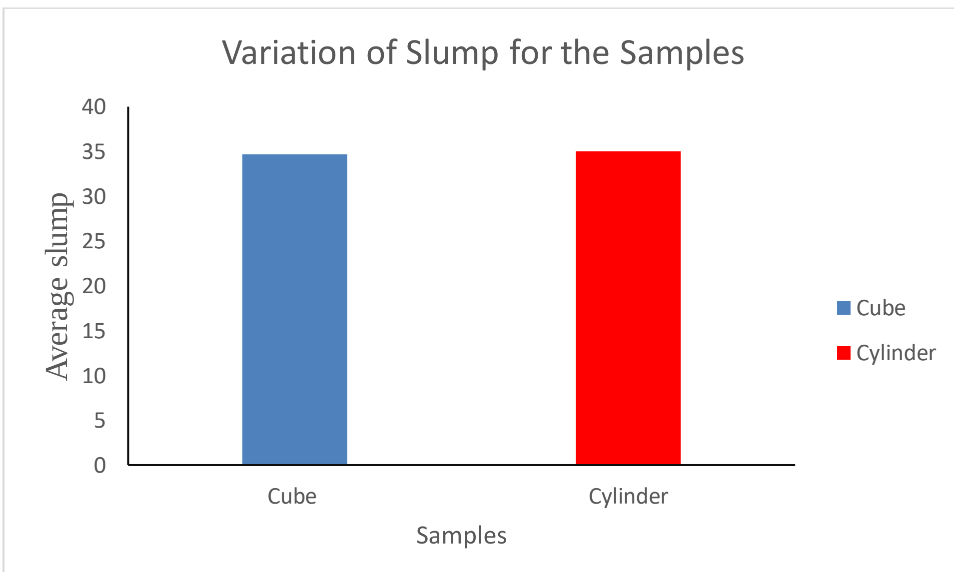

Fig 4.1.1 Variation of Slump for the two Specimen

4.1.1 Discussion of result from slump test

From the result shown in table 4.1, it can be seen that the slump for the two specimen samples fall within the standard value for the designed concrete characteristic strength (20MPa). A close look at the slumps for the two samples (cubes and cylinders) shows no significant difference in their, hence, it is clear that no significant error was encountered during the mixing of the concrete materials for casting of the concrete cubes and cylinders for compression test.

Table 4.2: Result from Sieve Analysis for fine aggregate

Total Mass of sand tested = 100g

Sieve Size (mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative percentage Retained (%)	Percentage Passing (%)
2.36	1.74	1.74	1.74	98.26
200	0.89	0.89	2.63	97.37
1.18	7.57	7.57	10.20	89.80
600	33.25	33.25	43.45	56.55
425	16.66	16.66	60.11	39.89
300	23.54	23.54	83.65	16.35
212	11.43	11.43	95.08	4.92
150	0.77	0.77	95.85	4.15
75	1.55	1.55	97.40	2.60
Pan	1.25	1.25	98.65	1.35

$$\% \text{ Retained} = \frac{Mass\ retained}{Total\ mass\ tested} \times 100 \qquad (4.1)$$

Cumulative % Retained = % retained + the succeeding % retained

% passing = 100 − Cummulative % Retained

Loss = weight used for test – Cumulative % on the pan

Loss = 100 – 98.65 = 1.35

% loss = 1.35/100 * 100 = 1.35 < 3% (result acceptable)

4.1.2 Discussion of the Results obtained from the Sieve Analysis

From the results obtained from the sieve analysis for the fine aggregate, the aggregate used is a naturally crushed sand (river sand). The loss incurred is very insignificant compared to the amount of sample tested, hence, necessary precautions were taken to ensure efficiency of the results.Table 4.3a Result from Compression Test

The tables below show the results from the compression tests for the various samples

Table 4.3 Result for Compression Test for the concrete cubes (mix ratio 1:2:4)

Days	Sample	Weight (kg)	Density of sample cubes (kg/m^3)	Failure load (KN)	Compressive strength (N/mm^2)	Average density (kg/m^3)	Average compressive strength (N/mm^2)
7	W_1	2.541	2541	183.070	18.307	2540	18.528
	W_2	2.562	2562	193.216	19.322		
	W_3	2.517	2517	179.540	17.954		
14	W_1	2.553	2553	194.451	19.445	2543	19.241
	W_2	2.548	2548	189.792	18.979		
	W_3	2.529	2529	192.987	19.299		
21	W_1	2.545	2545	204.361	20.436	2550	20.205
	W_2	2.562	2562	199.372	19.937		
	W_3	2.543	2543	202.415	20.242		
28	W_1	2.564	2564	200.916	20.092	2565	21.161
	W_2	2.573	2573	224.121	22.412		
	W_3	2.557	2557	209.783	20.978		

Average Compressive Strength after 28 days for cube specimens

= (18.528+19.241+20.205+21.161)/4

=79.135/4 = 19.784 KN/m^2

Table 4.3 Result for Compression Test for the concrete cylinders (mix ratio 1:2:4)

Days	**Sample**	**Weight (kg)**	**Density of sample cubes (kg/m^3)**	**Failure load (KN)**	**Compressive strength (N/mm^2)**	**Average density (kg/m^3)**	**Average compressive strength (N/mm^2)**
7	W_1	2.491	2491	179.910	17.991	2508	18.925
	W_2	2.521	2521	188.706	18.871		
	W_3	2.512	2512	199.125	19.913		
14	W_1	2.540	2540	191.051	19.105	2527	19.293
	W_2	2.591	2591	189.927	18.993		
	W_3	2.449	2449	197.803	19.780		
21	W_1	2.550	2550	197.452	19.745	2541	19.490
	W_2	2.512	2512	199.916	19.992		
	W_3	2.562	2562	187.323	18.732		
28	W_1	2.549	2549	221.726	22.173	2554	20.856
	W_2	2.532	2532	201.181	20.118		
	W_3	2.581	2581	202.765	20.277		

Average Compressive Strength after 28 days for cube specimens

= (18.925+19.293+19.490+20.856)/4

=78.564/4 = 19.641 KN/m^{2ss}

Difference between the average strength of the two sets of samples after a curing period of 28 days = 19.784 - 19.641 = 0.143KN/m^2

% difference = difference/design strength * 100

0.143/20 * 100 = 0.715% < 1%

4.3b Discussion of the Compression Result

From the results obtained and analyzed, it was observed that under compressive load or stress, concrete cubes and cylinders of the same design and characteristic strength made of the same concrete materials give approximately equal strength with the difference being less than 1% of the designed strength. This simply suggests that for relatively light structure where the expected load is not extreme, the two concrete geometries may be used interchangeably. However, the method of placement and the binder are other factors to be considered which are outside the scope of this study. From the analysis carried out, the average compressive strength of concrete cubes after a total curing period of 28 days was obtained to be 19.784KN/m^2 while that of the cylinders is 19.641KN/m^2, the difference was obtained as 0.143KN/m^2. This showed a very infinitesimal difference of less than 1% of the designed strength (20 KN/m^2).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In conclusion, considering the compressive strength, concrete specimens made into cubic and cylindrical shapes have relatively equal strength. The geometry of a concrete specimen may not be ultimate factor to determine its strength as long as its stability is assured. Also, the texture of a concrete mould is essential in the casting of concrete specimen for laboratory test since it directly determines the stability of the concrete element. The overall compressive strength of a concrete element can greatly be influenced by its stability.

5.2 RECOMMENDATIONS

The following recommendations can be considered based on the conclusion made above. This includes that the geometry of a concrete specimen may not be a strong factor influencing its performance on a structural element, but more attention should be on its method of placement. A suitable curing method must be seen as an essential factor if a concrete specimen is to meet its design purpose.

Also, the stability of a concrete specimen must be ensured during casting if its designed strength is to be attained within the expected period under normal conditions. Comparing the performance of different concrete geometries, the particle distribution of the concrete materials being used must be ensured in order to obtain a truly comparable data under same conditions.

REFERENCES

ACI Committee 211. (2002). ACI : 211.1-91, (reapproved 2002) - Standard Practice for selecting proportions for normal, heavyweight, and mass concrete : American Concrete Institute . Anon, et al (2011) “Experimental study of concrete behavior” - Google Search. Retrieved January 25, 2024, from https://www.google.com/search?q=ACI+%3A+211.1-91%2C+(reapproved+2002)++Standard+Practice+for+selecting+proportions+for+normal%2C+heavyweight%2C+and+mass+concrete+%3A+American+Concrete+Institute+.+Anon%2C+et+al+(2011)+“Experimental+study+of+concrete+behav

Chen, Y., Wu, J., Zhang, Y., Fu, L., Luo, Y., Liu, Y., & Li, L. (2022). Research on Hyperparameter Optimization of Concrete Slump Prediction Model Based on Response Surface Method. Materials, 15(13). https://doi.org/10.3390/MA15134721

Diaferio, M., Varona Moya, F. B., Lavagna, L., & Nisticò, R. (2022). An Insight into the Chemistry of Cement—A Review. Applied Sciences 2023, Vol. 13, Page 203, 13(1), 203. https://doi.org/10.3390/APP13010203

Druta, C. (2003). CristianDruta, “Tensile strength and bonding characteristics of self-compacting concrete” B.S. (Mechanical Eng.), Polytechnic University of Bucharest, 1995 August 2003 - Google Search. Retrieved January 25, 2024, from https://www.google.com/search?q=CristianDruta%2C+“Tensile+strength+and+bonding+characteristics+of+self-compacting+concrete”+B.S.+(Mechanical+Eng.)%2C+Polytechnic+University+of+Bucharest%2C+1995+August+2003&rlz=1C1CHBD_enNG934NG935&oq=CristianDruta%2C+“Ten

E. Todorova1, G. Chernev1, P. M. (2013). Influence of metakaolinite and stone flour on the properties of selfcompacting concrete. Journal of Chemical Technology and Metallurgy, 48(2), 196–201. Retrieved from https://www.researchgate.net/profile/Elena-Todorova-6/publication/289226126_Influence_of_metakaolinite_and_stone_flour_on_the_properties_of_self-compacting_concrete/links/59b2d7d2aca2728472d51f57/Influence-of-metakaolinite-and-stone-flour-on-the-propertie

Girish, S., Ranganath, R. V., & Vengala, J. (2010). Influence of powder and paste on flow properties of SCC. Construction and Building Materials, 24(12), 2481–2488. https://doi.org/10.1016/j.conbuildmat.2010.06.008

Liu, S. H., & Wang, L. (2014). Influence of limestone powder on properties of self-compacting concrete. Retrieved January 26, 2024, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Surabhi.C.S%2C+Mini+Soman%2C+SyamPrakash.V%2C+“Influence+of+Limestone+Powder+on+Properties+of+Self-Compacting+Concrete”+10th+National+Conference+on+Technological+Trends+%28NCTT09%29+6-7+Nov+2009&btnG=

M Ahmed, A Anwar, S. A. (2018). Muzammil Ahmed et al. (2018) “A Literature Review on Study of Concrete Strength Using Partial Replacement of Cement With Rice Husk Ash And Fine Aggregate With Ceramic Powder” - Google Search. Retrieved January 25, 2024, from https://www.google.com/search?q=Muzammil+Ahmed+et+al.+(2018)+“A+Literature+Review+on+Study+of+Concrete+Strength+Using+Partial+Replacement+of+Cement+With+Rice+Husk+Ash+And+Fine+Aggregate+With+Ceramic+Powder”&rlz=1C1CHBD_enNG934NG935&oq=Muzammil+Ahmed+et+al

N Bouzoubaâ, M. L. (2001). Self-compacting concrete incorporating high volumes of class F fly ash: Preliminary results. Elsevier, 31(3), 413–420. Retrieved from https://www.sciencedirect.com/science/article/pii/S0008884600005044

P Aggarwal, R Siddique, Y Aggarwal, S. G. (2008). Self-compacting concrete-procedure for mix design. Leonardo Electronic Journal of Practices and Technologies, 7(12), 15–24. Retrieved from https://www.academia.edu/download/42118569/Self-Compacting_Concrete_-_Procedure_for20160204-6511-mcyrjy.pdf

Persson, B. (2001). A comparison between mechanical properties of self-compacting concrete and the corresponding properties of normal concrete. Elsevier, 31(2), 193–198. Retrieved from https://www.sciencedirect.com/science/article/pii/S000888460000497X

Rasiah, S., Ravindrarajah, R. S., Siladyi, D., & Adamopoulos, B. (2003). Development of high-strength self-compacting concrete with reduced segregation potential. Researchgate.NetRS, 1(1044pp), 17–20. Retrieved from https://www.researchgate.net/profile/Sriravindrarajah-Rasiah-2/publication/267799632_Development_of_high-strengh_self-compacting_concrete_with_reduced_segregation_potential/links/55d2c9a608ae0b8f3ef8e832/Development-of-high-strengh-self-compacting-concret

Roy, P. K. S., Mittal, A., & Bapat, S. G. (2004). Self-compacting concrete. Indian Concrete Journal, 78(10), 11–13. https://doi.org/10.3151/JACT.1.5

Su, N., Hsu, K. C., & Chai, H. W. (2001). A simple mix design method for self-compacting concrete. Elsevier, 31(12), 1799–1807. Retrieved from https://www.sciencedirect.com/science/article/pii/S000888460100566X

APPENDIX

Plate A1: Data computation for Compressive Test

Plate A2: Tightening of Compression Machine

Plate A3: Compression Test

Plate A4: Recording of Values

Plate A5: Project Student in Civil Laboratory