ASSESSING THE EFFECT OF BAMBOO AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE ON CONCRETE WORKABILITY

BY

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SUBMITTED TO

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CERTIFICATION

This is to certify that this research study was conducted by **SAMUEL ,Ayomide Komolafe (ND/23/CEC/PT/0225)** and has been read and approved as meeting the requirement for the award of National Diploma (ND) in Civil Engineering of the Department of Civil Engineering, Institute of Technology, Kwara State Polytechnic Ilorin..

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DEDICATION

This work is dedicated to Almighty God for his unmerited grace and steady fast love given to me throughout my Academic pursuit of National Diploma (ND) in Kwara State Polytechnic, Ilorin.

It is also dedicated to my beloved family **Mr. & Mrs. Komolafe.**

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My Appreciation goes to Almighty Allah for his guidance and protection over my life up till this moment and the mercy he has granted me in the course of my pursuit of this National Diploma (ND) may his name be highly glorified.

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ABSTRACT

This study investigates the effect of using bamboo as a partial replacement for coarse aggregate on the workability of concrete. The growing environmental concerns and increasing cost of traditional aggregates necessitate the exploration of alternative, sustainable materials. Crushed bamboo, an agricultural waste product, was examined for its suitability as a coarse aggregate in concrete mixtures. The study was guided by three main objectives: to determine the physical properties of bamboo, to evaluate its potential as a coarse aggregate, and to assess its impact on concrete workability. Laboratory tests were conducted to assess the physical and mechanical properties of bamboo aggregates, including specific gravity, bulk density, water absorption, impact value, and abrasion value. The results showed that bamboo has a specific gravity of 1.25 and bulk density of 636.44 kg/m³, indicating its lightweight nature. It also demonstrated low impact (5.02%) and abrasion values (5.32%), making it suitable for non-structural applications. Workability was measured using a slump test for concrete mixes containing 0%, 10%, 20%, and 30% bamboo replacements. The results indicated that slump values increased with higher bamboo content, reaching up to 13 cm at 30% replacement, thus confirming improved workability. The study concludes that bamboo can be used as a partial replacement for coarse aggregate, especially at 10–20% replacement levels, to enhance workability without significantly compromising cohesion. This research supports the adoption of bamboo as a cost-effective and eco-friendly alternative in concrete production, particularly for lightweight or non-load-bearing construction. Further studies are recommended to evaluate the long-term performance and durability of bamboo-based concrete.

Keywords: Crushed bamboo, Concrete workability, Coarse aggregate, Slump test, Lightweight concrete, Sustainable construction

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Concrete is one of the most globally utilized man-made materials for building construction (Danraka, 2015). Its great resourcefulness and relative low cost in meeting wide range of demands has made it a keen building material (Sashidar and Rao, 2014). Concrete is the premier civil engineering construction material (Mukhtyar and Kumar, 2018). Concrete manufacturing involves consumption of ingredients like cement, aggregates (coarse and fine), water and admixtures (Mukhtyar and Kumar, 2018). Concrete stands as the cornerstone of modern construction, underpinning the edifice of urban development and infrastructure worldwide. Renowned for its versatility, durability, and cost-effectiveness, concrete is the foundational material that architects and engineers rely on to realize structures of varied scales and complexities. Its widespread application spans from towering skyscrapers to intricate bridge structures, from residential dwellings to critical transportation networks etc. Concrete plays an instrumental role in providing structural stability, ensuring longevity, and withstanding the diverse environmental challenges posed by the rigors of construction. However, a study by Mehta and Monteiro (2006) estimated that modern-day production of concrete consumes a huge amount of nonrenewable natural resources, resulting in depletion of natural resources, environmental degradation, greenhouse gases emission and intensive energy consumption. In the contemporary era marked by a growing emphasis on sustainability, concrete finds itself at the nexus of innovation. Therefore, with the increasing concern about the deteriorating environment, depletion of natural resources, pollution and the need to embrace sustainability, researchers and practitioners alike are fervently exploring alternative formulations, additives, and manufacturing techniques to reduce the environmental footprint of concrete production and enhance its eco- friendly profile. This has necessitated the needs for alternative materials for substituting some of the traditional constituent materials of concrete (Ede, Olofinnade, Ugwu, & Salau, 2018; Olofinnade, Ndambuki, Ede, & Booth, 2017; Olofinnade, Ndambuki, Ede, & Olukanni, 2016; Singh, Mithulraj, & Arya, 2019).

The ever increasing demand for low cost materials stimulated the interest towards production and utilization of using cow horn since they are affordable (Abdullah and Ahmad, 2013 ; Asuke and Aigbodion , 2016). The world has a surplus amount of cow horn, which has a great potential that can be used as composites material. Cow horn litter the entire environment which poses a significant disposal problem, and it continues to accumulate at a rising pace, causing natural issues if not adequately addressed. As a result, using cow horn as a sustainable material in concrete production would aid in the reservation of natural assets and maintain natural parity. However, the right know-how (technology) to convert these into engineering materials has remained a daunting challenge to materials engineers in the country. Several studies have been conducted to determine the mechanical properties of both fresh and hardened cement that have been partially replaced with cow bone ash. (Falade et al., 2012; Okoye and Odumosu., 2016 and Okeyinka et al., 2018) introduced the impact of bone ash for cement substitution as compelling. In any case, consideration was not given to the mineralogical constituents of the animal bone used to substitute the cement. Besides, exposing the horn to high temperatures results in a synthetic response that changes the cow horn's mineral components. Thus, there is a knowledge gap to examine both the cow horn's chemical composition and their proportion in powdered structure without subjecting it to high temperature relative to cement constituents.

Bamboo is known to exhibit pozzolanic properties, similar to other ash materials. Pozzolanic reactions involve the combination of ash with calcium hydroxide produced during the cement hydration process, forming additional cementitious compounds. This can contribute to increased strength and durability of the concrete. Bamboo leaf ash, on the other hand is obtained by the burning of bamboo leaf at a controlled temperature, has been found to possess high reactive silica, which makes it suitable for use as a supplementary cementitious material (Villar- Cociña, Santos, Savastano & Frías, 2011; Dwivedi, Singh, Das, & Singh, 2006; Arum, Ikumapayi & Aralepo, 2013). The use of bamboo leaf ash in concrete exposed to a sulfate environment has been reported (Ademola & Buari, 2012; Asha, Salman & Kumar, 2014) to enhance the resistance of concrete to sulfate attack. Adewuyi, Olusola and Oladokun (2013) reported its use as a supplementary cementitious material in the production of sandcrete blocks. The availability of bamboo leaf and the low technology required to process it into ash necessitates its usage as a material for the production of some building elements for affordable housing provision, especially in developing countries. Hence, the study seeks to investigate the effect of bamboo leaf ash blended with cement on the properties of lateritic bricks.

The high cost of cement, which is used as a binder in the production of concrete, combined with the need to create a greener environment, has prompted a search for alternatives, which has concentrated on partially replacing concrete with different materials, primarily agricultural and industrial by-products. The energy required to make cement is high and it emits carbon dioxide (CO2), which is hazardous to human health and depletes the ozone layer in the atmosphere. In this regard, the cost of obtaining cement for construction in our region is exceptionally high (Aderinola et al., 2018). Due to these effects, alternative cement materials have become increasingly common in recent decades. Numerous studies have been undertaken in this field to find materials that can wholly or partially substitute cement in the construction industry. Fly ash, coal-fired ash, rice husk ash, corncob ash, palm oil fuel ash, and other industrial and agro-based waste materials

(Aderinola et al., 2018; and Krammart and Tangtermsirikul., 2004) have been utilized. Krammart and Tangtermsirikul (2004) in their study used municipal solid waste incinerator bottom ash (MSWI) and calcium carbide waste (CCW) as a part of cement raw materials. Cement was replaced by 5% and 10% of MSWI and CCW in cement mortar, and the setting time of cement was drastically delayed due to high C2S and low C3S content in the samples compared with the control. Aderionla et al (2018) in a similar study used calcium carbide waste powder (CCWP) and bamboo leaf ash (BLA) to test the strength of cement based concrete. Their results showed that using a 10% substitute mixture of CCWP and BLA with 90% cement resulted in a 25% improvement in strength.

This research endeavors to contribute to this evolving landscape by scrutinizing the influence of unconventional additives, specifically cow horn and bamboo, on the mechanical properties of concrete. By digging into the nuanced interplay between traditional concrete elements and these natural additives, this study seeks to forge a path towards more sustainable and resilient construction practices. In doing so, it aspires to elevate the discourse on the importance of concrete in construction, offering insights that resonate with the imperatives of contemporary building practices and global sustainability goals.

1.2 Statement of the Problem

There is a growing need to ensure rational use of earth resource in the production of concrete. Concrete production incorporate the use of fine aggregate (sand), coarse aggregate (granite), cement and water in their correct proportion. Coarse aggregate as one of the components of concrete is produced during quarrying of limestone which has severe negative environmental impact associated with it ranging from noise pollution, impaired air quality and emission of dust and particles into the atmosphere. Moreover, cost of concrete production has risen significantly as a result of high cost of transportation of coarse aggregate to regions where the materials are present in negligible quantities. More so, disposal of agricultural waste materials such as bamboo has constituted an environmental challenge, hence the need to convert them into useful materials to reduce their negative effect on the environment. Cost of building material such as cement, needs to be reduced to make housing affordable for teeming population of people on earth; hence the need for this research to investigate the influence of cow horn and bamboo on the mechanical properties of concrete. Several issues with the strengths of concrete blocks generated in various parts of Nigeria have been found, including the use of locally sourced aggregates and an inadequate mix ratio of cements and aggregate as a result of high cement costs and a lack of adherence to several standards (Quadri and Abdulhameed, 2020; Quadri and Ijesoh, 2017).

1.3 Justification of the Study

The growing need for sustainable construction materials has led to increased interest in alternatives to conventional aggregates. Bamboo, being readily available, lightweight, and renewable, offers a promising option for reducing reliance on crushed stone in concrete production. This study explores the feasibility of using bamboo as a partial replacement for coarse aggregate, particularly in terms of its effect on concrete workability. This approach could provide a cost-effective and environmentally friendly solution, reducing the pressure on natural resources and promoting sustainable building practices. The findings from this study will contribute to ongoing research on alternative materials in construction and may encourage further studies on bamboo's mechanical properties and long-term performance in concrete structures.

1.4 Aims of the Study

The aim of this study is to assess the effect of bamboo as a partial replacement for coarse aggregate on concrete workability

1.5 Objectives of the Study

The objectives of the study are to:

i. To determine the physical properties of bamboo.

ii. To evaluate bamboo as a potential replacement for coarse aggregate.

iii. To assess the effect of bamboo replacement on the workability of concrete.

1.6 Scope of the Study

This study focuses on assessing the effect of using bamboo as a partial replacement for coarse aggregate on the workability of concrete. It involves the selection, processing, and preparation of bamboo to meet the required aggregate size specifications. The physical properties of bamboo, such as density, water absorption, and strength, will be evaluated to determine its suitability as a coarse aggregate. Concrete will be prepared with varying percentages of bamboo replacement (e.g., 0%, 10%, 20%, etc.), following standard mix design procedures. Workability will be assessed through slump tests, and the results will be compared with conventional concrete to evaluate feasibility. The study is limited to workability analysis and does not extend to long-term durability or structural performance assessments.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

Concrete is one of the major construction materials used, which is next to the consumption of water by mankind. It is estimated that six billion tonnes of concrete is produced every year throughout the world. This is due to the availability of the abundance of raw materials, low relative cost and adoptability of concrete forming various shapes. The extraction of raw materials causes depletion of resources. In recent times, the environmentalists are more concerned regarding the cement manufacture. One tonne of cement manufacture emits approximately one tonne of CO2 into the atmosphere. This causes greenhouse effect and global warming of the planet. Hence, an emission of six billion tonnes of CO2 every year which causes an environmental impact. The way to reduce the environmental impact is the use of supplementary cementitious materials. These alternative materials are generally selected on the basis of additional functionality that they offer and their cost effectiveness. Typical examples are fly ash, slag cement formerly called ground granulated blast furnace slag, silica fume, rice fibre and egg shell, one such material is Areca nut fibre ash. The applications of bamboo leaf ash (BLA) and coconut fibre ash (CFA) are replaced in varying proportions to the cement depending on their chemical composition. The use of these materials in concrete, apart from the environmental benefits, also produces good effects on the properties of final products.

One of the waste materials used in the concrete industry is coconut fibre ash (CFA). Most of the aggregates used in our country are river sand as fine aggregates and crushed rock of quarries as coarse

aggregates. Fine aggregates used for concrete should conform to the requirements for the prescribed grading zone. Natural or river sand may not conform to all the above requirements and may have to be improved in quality. The sand mining from our rivers have become objectionably excessive in view of both economy and environment. It has now reached stage where it is killing all our rivers day by day. Hence sand mining has to be discouraged so as to save the rivers of our country from total death. The problem of how to meet the increasing demand and cost of concrete in sustainable manner is a challenge in the field of civil engineering and environmental. Because of environmental and economic reasons it requires thinking about the use of industrial wastes and naturally available waste material as alternative materials in concrete production, which not only reduces the cost of production of concrete but also controls the pollution relatively.

Concrete is the most widely employed material in the world, being used from road construction to skyscrapers. However, cement production is responsible for 5% of the annual anthropogenic global carbon dioxide (CO2) production – each ton of concrete produced generates about 1 ton of CO2. To reduce the detrimental impacts of the cement industry, researchers investigate an alternative to cement known as supplementary cementitious materials (SCM) – a vast group of materials that possess cementing properties and also contribute to the reduction of environmental problems. Agricultural wastes, for example, can be used as SCM, as shown by many researchers. Besides having pozzolanic properties, which favors their application as cement replacement, agricultural waste attract interest due to its great generation around the world, only smaller than that of industrial waste. Among the investigated agro-wastes in civil construction, there is bamboo leaf ash, coconut fibre ash, rice fibre ash, sugarcane bagasse ash, and wheat straw ash.

These plants belong to the Poaceae family and are known to accumulate silica during their lifetime, thus presenting silicon (Si) content higher than calcium (Ca) content. Like other agricultural wastes from the Poaceae family, bamboo ashes can also be an alternative for cement replacement. Distributed worldwide through about 1600 species, bamboo is the fastest- growing among other plants even without fertilizers and pesticides and its great O2 release which is 35% greater than trees supports bamboo use in comparison to other plants. Although it's many advantages, there is no published paper until now concerned only to review the use of bamboo ashes as SCM in concrete production and displays its pros and cons. Chemical and physical properties of concrete made with bamboo ashes usually appear secondary in large-scale reviews of agro-waste materials used in civil construction.

Therefore, to fill this gap, this systematic review aims to answer the research question: "what are the chemical properties of bamboo ashes, and what are the mechanical and physical properties of concrete and mortar samples containing bamboo ashes as partial cement replacement?". By evaluating bamboo ashes potential use as partial cement replacement in the construction industry, this work will contribute to the scientific community synthesizing the literature regarding using bamboo ashes as SCM and rising new research topics.

2.2 Ingredients of Concrete

Cement, water and aggregate are the major ingredient of concrete materials which will be explained below

2.2.1 Cement

Cement is a binder material, a substance made of burned lime and clay which after mixing with water, set and harden independently and can bind other materials together Ezeokonkwo, (2014). According to (Onwuka and Omerekpe, 2003), cement as a hydraulic binders react exothermically with water to form hard strong masses with extremely low solubility. They consist of chemical compounds such as calcium silicate and calcium aluminates. Cement is a cementitious material which has adhesive and cohesive properties necessary to bound inert aggregates into a solid mass of adequate strength and durability. Neville, (1993) also adds that cement is the binding material constituent of concrete which reacts chemically with water and aggregate to form a hardened mass on hydrating. Iheama,

(2010) further defines it as a finely pulverized product resulting from calcination of natural argillaceous limestone at a temperature below the fusion. In addition to this Ivor, (1995), defines cement as a mixture of compounds, consisting mainly of silicates and aluminates of calcium, formed out of calcium oxide, silica, aluminium oxide and iron oxide. Hydraulic cements are of four types: Portland cement, Blended Portland Cement, and Portland cement with addictives and High Alumina Cement. Cement varying chemical composition and physical characteristics exhibit different properties on hydration. The cement of desired properties can be produced by selecting suitable mixture of raw materials. The various types of Portland cement used in the construction industry are: Ordinary Portland Cement(OPC), Rapid Hardening Portland Cement(RHPC), Sulphate resisting Portland Cement(SRPC), Low Heat Portland Cement(LHPC), Blast Furnace Portland Cement(BFPC), Portland Pozzolana Cement(PPC), Modified Portland Slag Cement(MPC).

Many authors (Ezeokonkwo, 2014: Anosike, 2010: Gupta and Gupta, 2004: Iheama, 2010) agreed to the fact that on the addition of water to cement, hydration takes place, liberating a large quantity of heat. On hydration of cement, the gel is formed which binds the aggregate particles together and provides strength and water tightness to concrete on hardening. Thus cement has the property of setting and hardening underwater by a chemical reaction with it. Portland cement is a substance which binds together the particles of aggregates (usually sand and gravel) to form a mass of high compressive strength concrete. It is a combination of limestone or chalk with clay mixed in a proportion depending on the type of cement desired. Portland cement is the most common type of cement generally used around the world because it is a basic ingredient of concrete, mortar and stucco. It is a fine powder produced by grinding Portland cement clinker more than 90%, and a limited amount of calcium sulphate which controls the set time. Portland cement clinker is a hydraulic material which consist at least two-thirds by mass of calcium silicates ($3CaO.SiO_2$ and $2CaO.SiO_2$).

Okereke, (2003), Portland cement is manufactured by firing a controlled mixture of chalk or limestone ($CaCO_3$) and substances containing silica and alumina such as shale in a kiln at 1500°c temperature. They are heated to clinker and grounded to a fine powder with a small proportion of gypsum (calcium sulphate) which regulates the rate of setting when the cement is mixed with water. Anosike, (2010) also states that the manufacture of PC consists of the following three distinct processes: Mixing, Burning and Grinding. Mixing can be done by dry-process or wet-process. The wet process is the most common. The main difference between the wet and dry production process is the larger amount of water expelled from the kiln during the production process.

2.2.1.1 Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement, good cement is supposed to have the following physical properties;

I. Soundness of cement: Soundness refers to the ability of cement to not shrink upon hardening; good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia. Free CaO and MgO may result in unsound cement (Chanadan. 2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking. (Gartener, et al. 1989), since unsoundness is not apparent until several months or years, it is necessary to provide an accelerated method for its determination which includes: Lechatelier method where only free CaO can be determined and autoclave method where both free CaO and MgO can be determined. In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm. The work of Chowdhury et al., (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

II. Consistency of cement: This refers to the ability of cement paste to flow. In acceptance test for cement, the water content is regulated by bringing the paste to a standard condition of wetness and this is referred to as "normal consistency". Normal consistency of OPC ranges from 20-30% by weight of concrete. It is measured by vicat apparatus test.

III. Strength of cement: There are three types of strength in which cement are measured; compressive, tensile and flexural. Various factors affect the strength, such as water-water ratio, cement – fine aggregate ratio, curing conditions size and shape of a specimen, manner of moulding and mixing, loading conditions and age.

IV. Setting time of cement: Setting time refers to a change from liquid state to solid state. During setting time, cement paste acquire some strength (Gartener, et al. 1989). The water content has a marked effect on time of setting. Cement sets and hardens when water is added. This setting time can vary depending on multiple factors such as admixtures, chemical content, cement – water ratio and fineness of cement. Cement used in construction should have an initial setting time that is not too low & a final setting time not too high. The setting time test is carried out using the vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary

Portland cement respectively.

V. Loss of ignition: Heating a cement sample at 900o c – 1000o c (i.e., until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition. Improper and prolonged storage or during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition.

VI. Bulk density: When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage.

VII. Heat of hydration: When water is added to cement, the reaction that takes place is called Hydration. Hydration generates heat, which can affect the quality of the cement and also beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C3S and C3A present in cement and also by water-cement ratio, fineness and curing temperature. Calculation of heat of hydration of Portland cement is to determine the difference between the dry and partially hydrated cement.

VIII. Fineness of cement: Fineness is a vital property of cement which influences the rate of reaction of cement with water (hydration). The fineness of the cement affects the rate of hydration. It also affects its place ability, workability and water content of a concrete mix much like the amount of cement used in concrete. For a given weight of a finely ground cement, the surface area of the particles is greater than for a coarsely ground cement. The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last

step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

2.2.1.2 Chemical Properties of Cement

The raw materials for cement production are limestone (Calcium) sand or clay. (Silica) bauxite and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

I. Tricalcium aluminate (C3A): Low content C3A makes the cement sulphate resistant.

   Gypsum reduces the hydration of C3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength.

II. Magnesiz (MgO): The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO – based cement also causes less CO2 emission. All cement is to a content of 6% MgO.

III. Sulphur trioxide: Sulphur trioxide in excess amount can make cement unsound.

IV. Iron Oxide/Ferric Oxide: Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.

V. Free lime: Free lime, which is sometimes present in cement, may cause expansion

VI. Silica fumes: This is added to cement concrete in order to improve a variety of properties especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume. It can grant exception high strength. Hence, Portland cement containing 5 – 20% silica – fume is usually produced for Portland cement projects that require high strength.

VII. Alumina: Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical – resistant. It also quickens the setting but weakness the cement.

2.2.1.3 Water

Water used in the concrete reacts with cement and causes it to set and harden. It also facilitates mixing, placing and compacting of fresh concrete. Abruckle, (2007), states that mixing water for concrete is required to be fit for drinking or to be taken from an approved source. Findings in previous works (Ezeokokwo, 2014: Bert-Okonkwo, 2012: Neil and Ravrinda, 1996) suggest that, to achieve the required workability and strength of concrete in both its fresh and hardened state, the water used for mixing and curing needs to be of appropriate quality, that is, it should be free from impurities such as suspended solids, organic matter and salts which may adversely affect the setting, hardening, strength and durability of the concrete.

Water is used in the production of concrete, washing of aggregates, mortar and bricks formation. Water is also used for construction operations like casting, painting, terrazzo finishing, plastering and other operations. After casting of concrete, water is poured on the concrete to give it strength in a process known as curing.

After completion of the building, water is used for cleaning the building in readiness for inspection, handing-over and occupancy. As a result of these facts, it is obvious that water is very important in building construction and related activities. Neil and Ravindra, (1996) further define water to cement ratio (w/c) as the weight of water divided by the weight of cement.

According to (BS8110: Part 1, 1997), the amount of water required in a concrete mix is the minimum for complete hydration of cement. If such concrete is fully compacted without segregation, it would develop the maximum attainable strength at a given age. The BS8110, (1997) further states that the water-cement ratio of approximately 0.25 weight is required for full hydration of cement. Omuvwie and Mosaku, (2010) suggest that if the water is not properly managed, it can turn around to inflict serious structural damage to the building over time and that such damage can lead to structural failure of the building and eventual collapse aside of the economic drain on client, safety risks as well as aesthetic devaluation.

2.2.3 Aggregates

These are the inert materials that are mixed in fixed proportions with a binding material to produce concrete. These act as fillers or volume increasing components on one hand and are responsible for the strength, hardness, and durability of the concrete on the other hand. Aggregate takes up 60% - 90% of the total volume of concrete. Thus, concrete properties are highly affected by physical properties of its aggregate such as aggregate size distribution. Shape 10 and grading of aggregates can significantly influence concrete workability.

Poorly shaped and poorly graded aggregates generally show a lower packing density than well shaped and well graded aggregates, as a result more paste being required to fill the voids between aggregates. As the more paste volume needed to fill the voids is reduced, the fluidity of the paste must be increased to maintain a given workability level.

As poorly shaped aggregates show increased inter particle friction, resulting in reduced workability. The concrete mixtures having poorly shaped and poorly graded aggregates often require higher water and cementitious materials requirements than those with well- shaped and well-graded aggregates to maintain the same workability. The right selection of aggregates can minimize the increased water and cementitious materials contents needed to ensure adequate workability.

2.3 Qualities of Aggregates

i. It should be chemically inert i.e. they should not react with cement or any other aggregate or admixture.
ii. It should possess sufficient toughness to bear impact and vibratory loads.
iii. It should be capable of producing an easily workable plastic mixture on combining with cement and water.
iv. It should be free from impurities; inorganic or organic in nature, which will affect adversely on its quality.

v. It should be strong enough to bear compressive and normal tensile loads in the ordinary mixture.

vi. It should possess sufficient hardness to resist scratching and abrasion in the hardened state.

2.4 Types of Aggregates

This is classified on the basis of their grain size, origin and density.

2.4.1 Classification by grain size

i. Fine aggregates: The grain size lies between 4.75mm to 0.15mm. They pass-through from sieve with the mesh size of 4.75mm and are retained on a sieve of 0.15 mesh size. Sand is the most universally available natural fine aggregate.

ii. Coarse aggregates: They are those that are retained on the sieve of mesh size 4.75mm, their upper size is generally around 7.5mm. Gravels from river bed are the best coarse aggregates in the making of common concrete. Situations may require suitable rock types to be crushed to the desired particle sizes for making coarse aggregates.

2.4.2 Classification based on origin

i. Natural: They are those types of fine and coarse aggregates that are available in almost ready to use form, from natural resources. Examples are sand from river beds, pits and beaches, and gravels from river banks.

ii. Bye-product: They are materials obtained as wastes from some industrial and metallurgical engineering operations which possess suitable properties for being used as aggregate. Examples are cinder obtained from burning of coal in locomotives and kilns and also slag is obtained from blast furnaces as scum is the best example from this category.

iii. Processed: These form a special class in aggregates. Examples include; burnt clay, shale, vermiculites and perlite. They are essential ingredients of lightweight concrete.

2.4.3 Classification based on density

i. Standard or normal: These types of aggregates give strength and weighting to the concrete of around 2300 to 2500kg/m^3.

ii. High density: These ones are used in standard proportions yield in heavy weight concretes. Such concretes are especially useful as shields against x-rays and radiations in the atomic power plant. Examples are Baryle – a natural mineral with a specific gravity of 4.3 is an example.

iii. Light weight: They are natural and artificial materials of very low density so that the resulting concrete is also quite light in weight, generally within a range of 350 to 750kg/m^3.

2.5 Admixture

Admixtures are not a primary constituent of concrete. They are added to concrete if necessary and not all the time. Brantley and Brantley, (2004) admixtures are those chemicals that can be added to the concrete mix to achieve special purposes or meet certain construction conditions. Admixtures are mixed into the concrete to change or alter its properties.

The use of admixtures should offer improvement in the properties of concrete by adjusting the proportions of cement and aggregates. However, it should not affect adversely any property of concrete. An admixture should be used only after assessing its effect on the concrete to be used under an intended situation. It should also be known that admixtures are no substitute for good workmanship i.e. the effect of bad workmanship cannot be improved by the use of admixtures.

Gupta and Gupta, (2004) and Anosike, (2010) suggest that admixtures perform the following functions:

i. Accelerate the initial setting and hardening of concrete.
ii. Retard the initial setting of concrete
iii. Increase the strength of concrete
iv. Improve the workability of fresh concrete

v. Improve the durability of concrete

vi. Reduce the heat of evaluation

vii. Control the alkali-aggregate expansion

viii. Aid in the curing of concrete

ix. Improve wear resistance to concrete

x. Reduce shrinkage during the setting of concrete

Bamibgoye et al., (2016) undertook particle size distribution analysis, slump test and compressive strength on hardened concrete in exploiting economics of gravel as a substitute to granite in concrete production. Sulymon et al. (2017) reported that sources of gravel greatly influence compressive, flexural and split-tensile strength of concrete David, et al., (2018).

2.6 Bamboo as an Additive

Bamboo, known for its rapid growth and sustainability, has been explored as an additive in concrete. According to Bashir, Gupta, Abubakr, and Abba (2018) that bamboo fiber can be used to enhance the compressive strength of concrete, however, reported a decrease in the flexure as the amount of the fiber content increases.

Bamboo leaf ash, on the other hand is obtained by the burning of bamboo leaf at a controlled temperature. This has been found to possess high reactive silica, which makes it suitable for use as a supplementary cementitious material (Villar-Cociña, Santos, Savastano & Frías, 2011; Dwivedi, Singh, Das, & Singh, 2006; Arum, Ikumapayi & Aralepo, 2013). Various studies have been carried out on the use of natural fiber in SCC with supplementary cementitious material such as limestone, fly ash, silica fume, improving its workability using admixtures (Adhavanathan, 2017; Amirtharaj, 2017). The use of bamboo leaf ash in concrete exposed to a

sulfate environment has been reported (Ademola & Buari, 2012; Asha, Salman & Kumar, 2014) to enhance the resistance of concrete to sulfate attack. Adewuyi, Olusola and Oladokun (2013) reported its use as a supplementary cementitious material in the production of sandcrete blocks. A study by Dewi, Wijaya, and Christin Remayanti (2017) recommended the use of 40 g of bamboo fiber as the optimum content in a concrete mix for the control of crack and improving the quality of the concrete. However, the study pointed out that increasing the fiber content beyond the optimum content may reduce concrete workability and quality.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The method used to carry out this project work was to analyse the impact of concrete production by using crushed bamboo as partial replacement of coarse aggregate I.e. granite. This was initiated in order to achieve the objectives of this project by carrying out laboratory test on the particles of concrete materials by determine the size particles, mixing ratio and mix design, mass of materials involved, casting of cubes, curing of cubes, dry wet weight, dry density, sieve analysis, the workability of the concrete and the compressive strength of the casted cubes. These were carried out in accordance with British standard of specification.

3.2 Materials used

Cement

The cement used for this research work is Dangote Portland cement of grade 42.5R conforming to BS 8500-2 (2015), the cement was gotten from a local distribution Sawmill, Ilorin.

Fine aggregate

The fine aggregate used for this project work is sharp sand which was gotten from the nearest

Coarse Aggregate

The coarse aggregate to be used will be conforming to ACI committee 363(2011). The granite are angular in shapes and free from dust. It is bought at the nearest Quarry Company in Ilorin.

Crushed Bamboo

The bamboo was obtained mostly behind stream in Ganmo, Kwara State, Nigeria. The whole quality was clean out of the dirt material and impurities, and then crushed by machine and sieved.

Water

The water used in all mixes is potable water Conforming to BS EN 12620(2013).

3.3 Laboratory Testing of The Properties of Aggregates

3.3.1 Particles size distribution

Grading is the arrangement of the proportions of the particles in aggregate found by sieving. The sieves used should confirm to BS 410 or BS EN 933-2. The test were carried out in accordance with the procedure given in BS EN 933-1. An aggregate containing a high proportion of small particles as being coarsely graded and one containing a high proportion of small particles as finely graded.

Objective

- To determine the particle size distribution of the given aggregate
- I draw the various grading curves of the given aggregate.

Apparatus

• Test Sieves.

• Data sheet for recording results.

• The size of the different sieves used were 6•7 mm, 5.00mm, 44.75 mm, 3.6mm, 3.50mm, 2.36mm and 0.75mm respectively.

Procedure

The test sieves specified above were arranged from top to bottom in oder of decreasing aperture sizes with pan and lid to form a sieve column. The aggregate sample W then poured into the sieving column and thoroughly shaken manually.

The sieves were removed one by one starting with the largest aperture sizes, and each sieve shaken manually ensuring that no material is lost. All the material which passed each sieve was returned into the column before continuing with the operation with the sieve.

The retained material on the sieve with the largest aperture was weighed and its weight recorded with its corresponding sieve size. The same operation was carried out for successive sieves in the column and their weights recorded. The screened material that remained in the pan was weighed and its weight was recorded.

Calculations

1. The various masses were recorded in the test data sheet
2. The mass that retained on each sieve was expressed as a percentage of the original dry mass
3. The cumulative percentage of the original dry mass passing each sieve down to the smallest aperture size was calculated.

3.3.2 Design of concrete Mixes

This is the process of selecting the correct proportion of cement, fine and coarse aggregate (granite and crushed bamboo) and water to produce concrete having the properties specified and desired i.e workability, compressive strength, density and durability requirements by the means of specifying the minimum or maximum water cement ratio.

3.3.3 Principles of design

Strength Margin

Due to variability of concrete strengths, the mix must be designed to have higher means strengths than the characteristic strength. The difference between the two is the margin. The margin is based on the variability of concrete strengths from previous production data expressed as a standard deviation.

Workability

The workability of the concrete mix was determined by the slump test which is more appropriate for higher workability mixes.

Free Water

The total water in a concrete mix consists of water absorbed by the aggregate to bring it to saturated surface dry condition and the free water available for hydration of cement and for the workability of the fresh concrete. The workability of fresh concrete depends on a large extent on its free-water content. In practice, aggregate are often wet and they contain both absorbed water and free surface water so that the water added to the mixer is less than the free-water content. The strength of concrete is related to the free-water/cement ratio on this basis, the strength of concrete does not depend on the absorption characteristics of the aggregates.

Types of aggregates

Two characteristics of aggregates particles that affect the properties of concrete are particle shape and texture. Particle shape affects workability of the concrete and the surface texture affects the bind between the cement matrix and the aggregates particles and thus the strength of concrete. Two types of aggregates are considered for design on this basis crushed and uncrushed.

Aggregate grading

The design of the mixes must comply with specific grading curves of the aggregate. The curves of the fine aggregates mist comply with grading zones of BS 882.

Mix parameters

The approach adopted for specifying mix parameters will be with reference to the weights of materials in a unit volume of fully compacted concrete. This approach will require the knowledge of expected density of fresh concrete, which depends primarily on the relative density of the aggregate and the water content of the mix. This method will result in the mix being specified in term of the weights in kilograms of different materials required to produce one third (½) of finished concrete.

3.3.4 Stages in mix design

STAGE 1: Selection of target water/cement (w/c) ratio.

STAGE 2: Selection of free water content.

STAGE 3: Determination of cement content.

STAGE 4: Determination of total aggregate content.

STAGE 5: Selection of fine and coarse aggregate content.

STAGE 6: Mix proportioning.

3.4 Batching of Concrete Materials

Following the mix design process, concrete materials (cement, fine and coarse aggregates) should be prepared early enough before the concrete works begin. This allows the smooth running of the project. Batching of materials was done by weight basis. The advantage of weight method is that bulking of aggregates (especially fine aggregates) does not affect the proportioning of materials by weight unlike batching by volume method. Bulking of sand results in a smaller weight of sand occupying a fixed volume of the measuring container thus the resulting mix becomes deficient in sand and appears stony and the concrete may be prone to segregation and honeycombing. Concrete yield may be reduced.

Batching of concrete materials by weight is expressed as follows:

We. (C) + Wt. (CA) + Wt. (FA) + Wt. (Air) = Wt. (CC)

Where;

Wt. (C) = weight of cement

Wt. (CA) = weight of coarse aggregate

Wt. (FA) = weight of fine aggregate

Wt. (Air) = weight of entrained air

Wt. (CC) = weight of compacted concrete

3.5 Water Absorption

Water absorption is the amount of water that an aggregate can absorb. Water Absorption tends to be a excellent indicator of the strength of the aggregate. The absorption of the aggregate can influence such properties of concrete as the bond between it and the cement paste and may thus exert some influence on the strength of the concrete, chemical stability and resistance to abrasion. The method of measuring water absorption in aggregate was is described in B.S 812.

Objective

To determine the water absorption of crushed bamboo.

Procedure

Approximately 400g of aggregate sample was added to a clean container filed with water. The material was soaked for 24 hours after which the water was drained to achieve a saturated surface dry state. Wet sample of 300g was removed and then placed in an oven for 2 hours to dry after which it was weighed and mass of 238g was obtained.

Calculation

The water absorption was calculated by the weight of wet aggregate less the weight of oven dry aggregate over the weight of the oven dry aggregate and expressed as a percentage.

Water absorption = Weight of wet aggregate - Weight of oven dry aggregate / Weight of oven dry aggregate × 100

3.6 Slump Test

Slump test is used extensively in site work to detect variations in the uniformity of mix of given proportions. It is useful on the site as a check on the variations of materials being fed to the mixer. An increase in slump may mean that the moisture content of aggregate has increased or a change in grading of the aggregate, such as the deficiency of the fine aggregate. Too much or too low slump gives an immediate warning and enables the mixer operator to remedy the situation. The test was done according to BS 1881-102:1983 that described the determination of slump of cohesive concrete of medium to high workability. The slump test is sensitive to the consistency of fresh concrete. The test is valid if it yields a true slump, this being a stump in which the concrete remains intact and symmetrical.

Objective

To determine the slump of fresh concrete mix.

Apparatus

- A standard mould which is a frustum of a cone complying with BS 1881-102:1983
- A standard flat plate preferably steel.
- A standard tamping rod.

- Standard graduated steel rule from 0 to 300mm at 5mm intervals.
- A scoop approximately 100mm wide.

Procedure

The inside surface of the mould was cleaned and oiled to prevent adherence of fresh concrete on the surfaces. The mould was placed on the base plate and firmly held

The cone was then filled with fresh concrete in three layers with each layer compacted with 25 strokes of tamping rod. After filling the mould, the top layer was struck off by means of rolling action of the tamping rod. Immediately after filling, the cone was slowly and carefully lifted and after removal of the mould the slump of the unsupported concrete was measured and recorded.

Figure 3.1: Compaction of concrete

Figure 3.2: Measurement of slump value for sample A

Figure 3.3: measurement of slump value for sample B

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Physical Properties of Bamboo

The table below shows the summary of the results obtained from the various preliminary tests carried out on the crushed bamboo used in this study.

Table 4.1: Physical Properties of Bamboo

Properties	Value
Coefficient of curvature C_c	1.06
Coefficient of uniformity C_u	0.8
Specific gravity	1.25
Water absorption capacity (%)	1.9
Aggregate impact value (%)	5.02
Aggregate abrasion value (%)	5.32
Bulk density (Kg/m^3)	636.44

4.1.1 Specific gravity

A dry clean measuring cylinder density bottle of 155g was weighed W_1, small quantity of the air dry bamboo sample was introduced into the density bottle and was weight W_2. Distilled water was then added to the sample in the density bottle and stirred very well to allow the trapped air to be released and weighed as W_3. The bottle was then emptied and dried. Finally, the bottle was filled completely with distilled water and weighed as W_4.

$$S.G = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_1)} \quad (3.5)$$

Where:

W_1 = Weight of empty cylinder (g)

W_2 = Weight of saturated surface dry sample (g)

W_3 = Weight of sample + cylinder + water (g)

W_4 = Weight of cylinder + water (g)

The results of the specific gravity of the crushed bamboo is shown in Table 4.2

Table 4.2: Specific Gravity of Bamboo

Description	Value
Weight of empty cylinder (g)	155
Weight of saturated surface dry sample (g)	1000
Weight of sample + cylinder + water (g)	961
Weight of cylinder + water (g)	938
Specific gravity	1.25

4.1.2 Water absorption capacity of Bamboo

Table 4.3: water absorption capacity result of the Bamboo

Description	Value
Weight of the oven dried sample (g)	1000
Weight of the saturated sample after 24-hrs	1190
Water absorption capacity	1.9%

4.1.3 Aggregate impact value (AIV)

Table 4.4: Aggregate Impact Value of the Bamboo

Description	Value
Weight of empty mould (g)	2582
Weight of mould + BAMBOO sample (g)	2861
Weight of the BAMBOO sample (g)	279
Weight of BAMBOO sample passing 2.36mm sieve (g)	14
Weight of BAMBOO sample retained	265
Aggregate impact value	5.02%

4.1.4 Aggregate abrasion value

Table 4.5: Aggregate Abrasion Value of the Bamboo

Description	value

Weight of Bamboo sample passing 1.70mm sieve (g)	266
Weight of Bamboo sample retained on 1.70mm sieve (g)	4734
Aggregate abrasion value	5.32%

4.1.5 Bulk density

The result of the bulk density of bamboo is presented in table 4.6. The dimension of the mould used in the experiment is: r = 50mm and h = 115mm

Table 4.6: Bulk density of Bamboo

Description	Value
Volume of the mould (m^3)	0.0009036
Weight of the empty mould (g)	2977
Weight of the bamboo sample (g)	575
Bulk density = $\frac{mass\ of\ the\ PKS\ sample}{volume\ of\ the\ mould}$ (Kg/m^3)	636.44

4.2 Sieve Analysis

The particle size distribution is the analysis of soil samples which involves the determination of the percentage by mass of particles within the different size ranges. The particle size distribution of coarse aggregates used was determined by the method of sieving. 3000g of air-dried samples of palm kernel shell passed through series of standard test sieves having successively smaller mesh sizes. The mass of sample retained in each sieve was determined and the cumulative percentage by mass passing each sieve was calculated. This was used in analyzing uniformity and gradation of samples. The sieve analysis results for bamboo is shown in Table 4.7, while the graphical representation is shown in figure 4.1

Weight of the sample = 3000g

Table 4.7: Sieve Analysis of Bamboo

S/N	Sieve sizes (mm)	Weight of empty sieve (g)	Weight of sieve + sample (g)	Weight of sample retained (g)	% retained	% passing	Cumm. % retained
1	37.5	1584	1584	0	0	100	0
2	20	1455	1455	0	0	100	0
3	14	1340	1458	118	3.93	96.07	3.93
4	10	1380	2306	926	30.87	69.13	34.8
5	6.35	1453	3051	1598	52.27	12.93	87.07
6	4.75	495	695	200	6.67	6.21	93.79
7	pan	820	978	158	5.27	1.0	99
	Total			3000			

From the sieve analysis chart below, the Coefficient of uniformity and the coefficient of curvature is calculated as shown below;

$C_{u}=\frac{D_{60}}{D_{10}}$,

$C_c = \frac{D_{30}^2}{D_{10} * D_{60}}$,

D_{60}= the grain diameter at 60% passing

D_{10}= the grain diameter at 10%

D_{30}= the grain diameter at 30%

C_u= coefficient of uniformity

C_c= coefficient of curvature

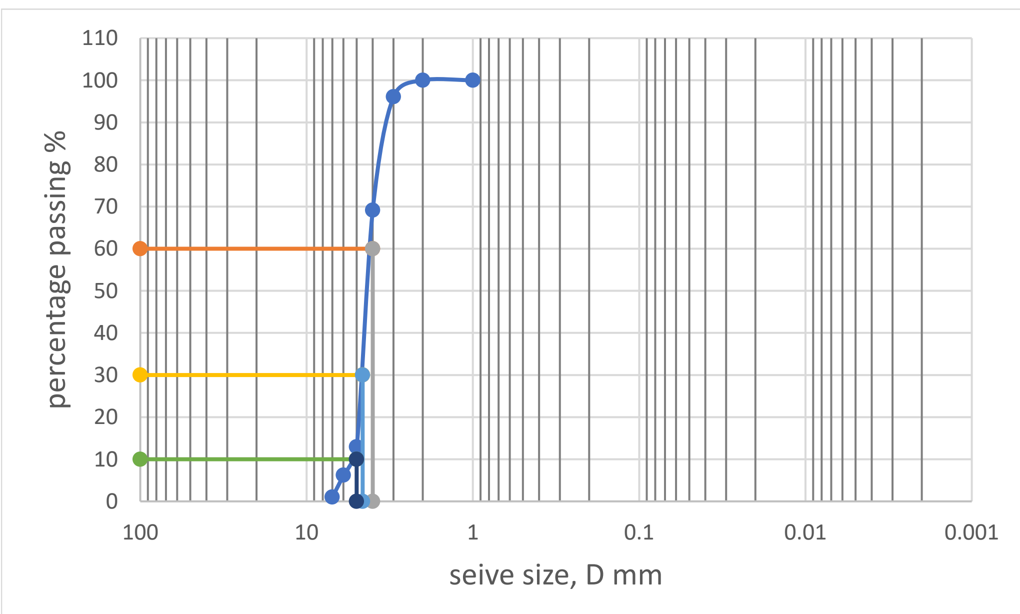

Figure 4.1: Sieve analysis chart for Bamboo

From the chart $D_{10} = 5.0$ mm

$D_{30} = 4.6$ mm and

$D_{60} = 4.0$ mm

Coefficient of curvature $C_c = \frac{(D_{30})^2}{(D_{10}) \times (D_{60})}$

$$= \frac{(4.6)^2}{5.0 \times 4.0} = 1.06$$

Coefficient of uniformity $C_u = \frac{D_{60}}{D_{10}} = \frac{4.0}{5.0} = 0.8$

4.3 Workability (Slump Test) Results

The slump test is carried out to evaluate the consistency and workability of freshly mixed concrete. This tells us how easy it is to work with during the pouring, and spreading of the concrete before it hardens. In this project, concrete was batched by weight, and different replacement of bamboo (0%, 10%, 20%, and 30%) were incorporated into the mix. A nominal mix ratio of 1:2:4 was used with a water-to-cement ratio of 0.4. The corresponding test results are presented in Table 4.8.

Table 4.2: Slump Test

Replacement of Bamboo (%)	Slump Value (cm)
0	3
10	6
20	7
30	13

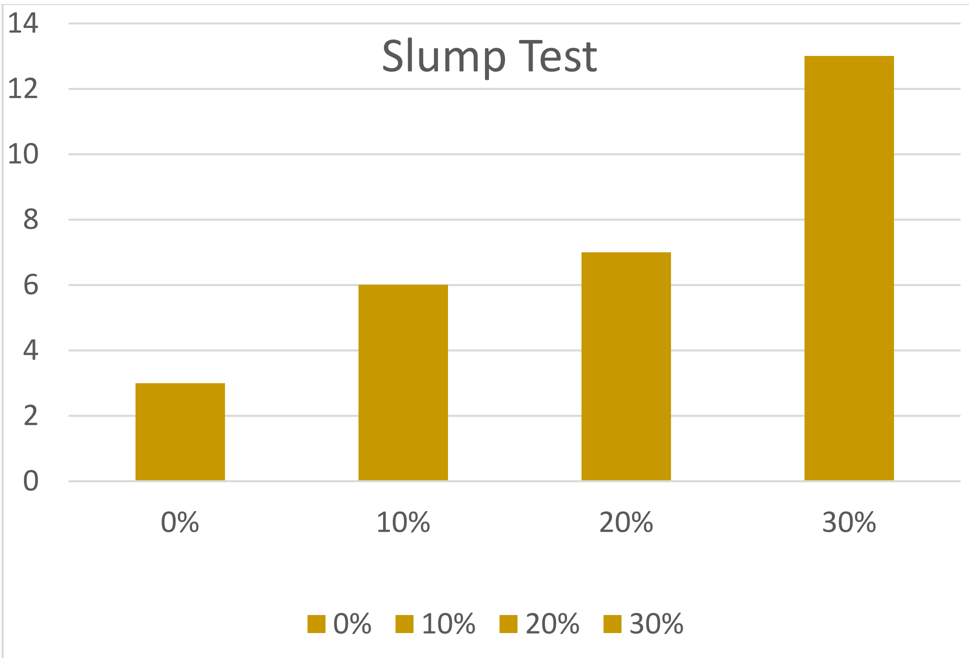

Figure 4.2: Workability chart

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results obtained during this study, the following conclusion can be made:

- The bamboo used in this research exhibited a specific gravity of 1.25, a bulk density of 636.44 kg/m^3, water absorption capacity of 1.9%, aggregate impact value of 5.02%, and abrasion value of 5.32%. These values indicate that bamboo possesses lightweight characteristics with relatively low strength compared to traditional granite, making it more suitable for non-structural and lightweight concrete applications.

- From the physical property tests, bamboo showed a gradation that was not entirely uniform (C_u = 0.8, C_c = 1.06), suggesting it is less well-graded than conventional aggregates. However, its low impact and abrasion values signify it can be used as a partial substitute for coarse aggregate, especially in situations where reduced density and sustainability are desired over high strength.

- The slump test showed an increase in workability as the percentage of bamboo increased, this trend confirms that concrete mix becomes more workable as bamboo content increases, due to its low density and high water absorption rate. However, excessively high bamboo replacement (30%) may result in segregation or bleeding due to over-workability and reduced cohesion.

5.2 Recommendations

Based on the findings from this research, the following recommendations are made:

1. Use crushed bamboo in non-load-bearing structures or lightweight concrete elements where workability is a major requirement, and structural strength is not the primary concern.
2. An optimum bamboo replacement level of 10–20% is recommended to achieve balanced workability without compromising too much on strength and cohesion.
3. Prior to usage, bamboo should be properly processed and dried to reduce variability in moisture absorption which could affect the consistency of concrete mix.
4. Further studies should be conducted to examine the long-term durability and compressive strength of bamboo-replaced concrete under various environmental conditions.
5. Policy makers and stakeholders in the construction industry should consider sustainable alternatives like bamboo to reduce the environmental and economic burden of concrete production.

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