DETERMINATION OF FLEXURAL STRENGTH OF VELVET TAMARIND REINFORCED CONCRETE SLABS

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CERTIFICATION

This is to certify that this work "Determination of Flexural Strength of Velvet Tamarind Reinforced ConcreteSlabs" was carried out by Etteh, Emmanuel Umoh (B.Eng) with Reg. No. 20124766288 in partial fulfillment of the requirements for the award of Master of Engineering (M.Eng) degree in Civil Engineering (Option in Structural Engineering) in the School of Engineering and Engineering Technology, Federal University of Technology, Owerri, Nigeria.

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DEDICATION

This work is dedicated to the Most High God through whom it has been possible to attain this educational height and my late wife, Mrs. Grace Emmanuel Etteh whose love and support I will ever remember and cherish.

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TABLE OF CONTENTS

	Page
Title page	i
Certification	ii
Dedication	iii
Acknowledgements	iv
Abstract	v
Table of Contents	vi
List of Tables	x
List of Figures	xii
List of Plates	xiii
Notations	xiv
CHAPTER ONE – INTRODUCTION	**1**
1.1Background of Study	1
1.2 Statement of problem	3
1.3 Objectives	3
1.4 Justification of study	3
1.5 Scope of study	4
CHAPTER TWO - LITERATURE REVIEW	**5**
2.1 Reinforced concrete	5
2.2 Cement	6
2.3 Water	7
2.4 Aggregates	7
2.4.1 Classification of aggregates	8
2.5 Lightweight concrete	9
2.5.1 Workability	11
2.5.2 Density	12
2.5.3 Durability	14
2.5.4 Flexural Strength	15
2.5.4.1 Factors affecting the flexural strength of a concrete beam	16
2.5.5 Compressive strength	18

2.6 Steel reinforcement 19
2.7 Bamboo reinforcement 22
2.7.1 Interaction with water 25
2.7.2 Bonding with concrete 25
2.8 Stick reinforcement 30
2.9 Velvet tamarind stick reinforcement 30
2.9.1 Velvet tamarind 31
2.9.2 Common names 31
2.9.3 Botanic description 32
2.10 Review of research works on concrete slabs 32

CHAPTER THREE - MATERIALS AND METHODS 36
3.1 Materials 36
3.1.1 Cement 36
3.1.2 Water 36
3.1. 3 Fine aggregate 36
3.1.4 Coarse aggregate 36
3.1.5 Reinforcement bars 37
3.2 Methods 37
3.2.1 Material Preparation 37
3.2.2 Laboratory investigation of materials 40
3.2.3 Strength tests on specimen 42
3.2.4 Comparative analysis of the flexural strength of velvet tamarind stick, steel reinforced concrete slab and unreinforced concrete slab 56

CHAPTER FOUR - RESULTS AND DISCUSSIONS 57
4.1 Presentation of results 57
4.1.1 Tensile strength test result of velvet tamarind stick 57
4.1.2 Comparison strength test of concrete used 58
4.1.3 Flexural strength test result of concrete slabs reinforced with velvet tamarind stick at different spacing and loading conditions 58
4.1.4 Flexural strength test of concrete slab reinforced with velvet tamarind stick reinforced with steel and unreinforced slabs 61
4.1.5 Sieve Analysis of Aggregates 67

4.1.6 Bulk densities of aggregates 68
4.2 Discussion of Tests 68
4.2.1 Discussion of tensile strength test results 68
4.2.2 Discussion of comparison strength results 68
4.2.3 Discussion of flexural strength test 68
4.2.4 Discussion of sieve analysis, slump and water absorption test 73
4.2.5 Discussion of bulk density test 75

CHAPTER FIVE - CONCLUSIONANDRECOMMENDATION 76
5.1 Conclusions 76
5.2 Recommendations 77
5.3 Contributions to Knowledge 77

References 78
Appendices 81

LIST OF TABLES

		Page
Table 2.1	Compressive strength from the concrete made with different aggregates	13
Table 2.2	Mechanical properties of bamboo reinforcement	27
Table 4.1	Tensile strength test result of velvet tamarind stick	61
Table 4.2	28 Days compressive strength test result	62
Table 4.3	Maximum flexural strength of the slab due to point load at different spacing of stick reinforcement	63
Table 4.4	Maximum flexural strength of the slab due to line uniformly distributed load at different spacing of stick reinforcement	64
Table 4.5	Maximum flexural strength of the slab due to uniformly distributed load at different spacing of stick reinforcement	65
Table 4.6	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with point load at 75mm c/c.	66
Table 4.7	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with point load at 100mm c/c.	66
Table 4.8	Flexural Strength of concrete slabs reinforced with velvet tamarind stick steel and plain loaded with point load at 125mm c/c.	67
Table 4.9	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with point load at 150mm c/c.	67
Table 4.10	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with uniformly distributed line load at 75mm c/c.	68
Table 4.11	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and Plain loaded with uniformly distributed line load at 100mm c/c.	68
Table 4.12	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and Plain loaded with uniformly distributed line load at 125mm c/c.	69
Table 4.13	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with uniformly distributed line load at 150mm c/c.	69

Table 4.14	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, Steel and plain loaded with uniformly distributed load at 75mm c/c.	70
Table 4.15	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with uniformly distributed load at 100mm c/c.	70
Table 4.16	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with uniformly distributed load at 125mm c/c.	71
Table 4.17	Flexural Strength of concrete slabs reinforced with velvet tamarind stick, steel and plain loaded with uniformly distributed load at 150mm c/c.	71
Table 4.18	Maximum flexural strength at different loading conditions	75
Table 4.19	Grading limits for fine aggregates	78

LIST OF FIGURES

		Page
Fig. 4.1	Variation of flexural strength of the slab due to point load at different spacing of stick reinforcement	63
Fig. 4.2	Variation of flexural strength of the slab due to uniformly distributed line load at different spacing of stick reinforcement	64
Fig. 4.3	Variation of flexural strength of the slab due to uniformly distributed load at different spacing of stick reinforcement	65
Fig. 4.4	Grain size analysis graph for fine aggregate	78
Fig. 4.5	Grain size analysis graph for coarse aggregate	78

LIST OF PLATES

		Page
Plate 3.1:	Stick reinforcement in concrete	44
Plate 3.2:	Slump test	46
Plate 3.3:	Test machine	47
Plate 3.4:	Hydraulic universal test machine	48
Plate 3.5:	Slab subjected to point load	51
Plate 3.6:	Slab subjected to uniformly distributed line load	51
Plate 3.7:	Slab subjected to uniformly distributed load	52
Plate 3.8:	Failure pattern of slab subjected to point load	52
Plate 3.9:	Failure pattern of slab subjected to uniformly distributed line load	53
Plate 3.10:	Failure pattern of slab subjected to uniformly distributed load.	53

DEFINITION OF NOTATIONS

NOTATIONS	MEANING
x	The primary axis of the plate. That is the shorter of the two axes of the major plane of the plate
y	The secondary axis of the plate. That is the longer of the two axes of the major plane of the plate
a	Length of the primary dimension of the plate
b	Length of the secondary dimension of the plate
h	Thickness of the plate or the length of the tertiary dimension of the plate
P	Point load (axial)
n	uniformly distributed line load
q	Uniformly distributed load
M_X	Moment along the primary axis
M_y	Moment along the secondary axis
S	Simple support
SSSS	Four edges of plate are of simple support
W	Plate displacement.
σ	Normal Stress
A	Dimensional coefficient
E	Modulus of elasticity
ϑ	Poisson's ratio
Π	Ritz energy parameter
R	Non dimensional axis (quantity) parallel to x axis. R=x/a
Q	Non dimensional axis (quantity) parallel to y axis. Q=y/b
Z	section modulus; for a rectangle, $Z = \frac{bh^2}{6}$

ABSTRACT

The need to research into alternative reinforcement materials for use in concrete structures has become pertinent due to high cost and low availability of steel reinforcement material. Velvet tamarind sticks also serves this purpose since it is cheaper and locally available for use as a reinforcement material. This research work presents the determination of flexural Strength of Velvet Tamarind Reinforced Concrete Slabs. This was to determine the flexural strength of concrete slabs reinforced with sticks of velvet tamarind as compared to concrete slabs reinforced with steel and unreinforced concrete slabs. The mix ratio of 1:2:4 was used for the concrete; with a water - cement ratio of 0.5. A total number of forty four (44) concrete slabs of size 500 x 500 x 100mm and 10 concrete cubes were cast. The cubes were used in testing the compressive strength at 28 days curing. Slabs were used to test for point load, uniformly distributed line load and uniformly distributed load with three sets of velvet tamarind stick reinforcement spaced at 75mm, 100mm, 125mm and 150mm. This was compared with slabs reinforced with 12mm steel spaced at 200mm and unreinforced concrete. The boundary conditions for the slabs were simply supported on all sides (SSSS). It was observed that the maximum flexural strength occur when the slabs were subjected to uniformly distributed load. The maximum flexural strength of slab reinforced with velvet tamarind stick was 14,345.94kN/m^2 at 75mm. The maximum flexural strength of steel reinforced slab was 23,699.25kN/m^2 while the maximum flexural strength of unreinforced concrete slab was 11,813.34kN/m^2. From this study, it can be concluded that increment in the amount of velvet tamarind stick increased the flexural strength of the slab due to the elastic properties of velvet tamarind stick which helped in improving the tensile strength of concrete, though in comparison, steel is still preferred. The gain in stress of velvet tamarind stick reinforced concrete slab was more than that of plain concrete, but lesser than steel. Based on the result of this research, velvet tamarind stick can be used as reinforcement in concrete slabs where light loads are expected, light temporary military structures, light cover slabs for drain and pedestrian walkway.

Keywords: Flexural strength, Compressive strength, Steel bar, Velvet tamarind stick, Slab, Concrete cube.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

In Civil Engineering works, concrete is widely used for the foundation of infrastructures, which is largely because of its availability and possession of suitable building properties such as ability to support large compressive loads. However, concrete has low tensile strength, hence the need to introduce steel reinforcement bars. Steel has a relatively high tensile strength, as high as 792N/mm^2 (Neville and Brooks, 2012), thus complementing the lower tensile strength of concrete.

The overall relevance of reinforced concrete in virtually all civil engineering practices and building construction works cannot be over emphasized. Concrete in which steel is embedded behave in a manner that the two materials act together in resisting forces. The reinforcing steel rods, bars, or mesh – absorbs the tensile, shear and sometimes the compression stresses in a concrete structure. Plain concrete does not easily withstand tensile and shear stresses caused by wind, earthquakes, vibration and other forces and is therefore unsuitable in most structural application. In reinforced concrete, the tensile strength of steel and the compressive strength of concrete work together to allow the member to sustain these stresses over considerable spans.

Concrete is a combination of cement, fine aggregate, coarse aggregate and water, which are mixed in correct proportions to achieve a particular strength. The cement and water react together chemically to form a paste which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has a considerable compressive strength but little or no resistance in tension (Neville, 2011). The lack of resistance to overcome tensile stress is overcome by providing reinforcement bars e.g steel, in appropriate places (tension zone). However, as the demand for concrete structures increases geometrically, there has been a

corresponding decrease in the availability of concrete construction materials and an increase in the cost of the materials. The structural/material engineers are faced with the challenge of providing partial or total substitute materials from locally available materials to cushion the effect of high cost of construction materials, else, the cost of putting up a civil engineering structure/building may become only affordable to the wealthy which will lead to a huge housing problem especially in the developing and under-developed nations in the future (Neville and Brooks, 2012).

Over the years, steel reinforcement has been the dominating reinforcement material used for slabs and other structural members because researches made on it has guaranteed it as a good reinforcement material. However, the use of steel currently poses a serious challenge based on its low availability and high cost. Also, it has been noticed that steel reinforcements increase the self-weight of the members and consequently the structure at large, so, it is not to be encouraged in light weight constructions where heavy structural members are prohibited (Roy,2011).

In the same way, coarse aggregate commonly used in concrete construction, which include granite and river gravel also poses similar challenge as its steel counterpart. Coarse aggregate is also associated with low availability and high cost, though; it has proven to be a good and reliable structural and concreting material. Also, coarse aggregate has the challenge of long haulage distances which increases the cost and threatens the duration of project completion. It is against this background that researches have been carried out to identify other suitable materials, affordable and readily available to either serve as total or partial replacement for steel and coarse aggregate in concrete works.

There have been researches on the use of bamboo, cane etc. as reinforcement materials but the use of locally available sticks has received little attention.

1.2 STATEMENT OF PROBLEM

Steel has been an important material used for engineering construction. Following the global economic recession coupled with the market inflationary trends, steel had become costly leading to a very high cost of construction, hence, the need to research into alternative materials such as Bamboo and velvet tamarind sticks which are cheaper and locally available for use as reinforcement in concrete structures.

1.3 OBJECTIVES

The main objective of this study is the Comparative Analysis of Flexural Strength of Velvet tamarind and Steel Reinforced Concrete Slab.

The specific objectives include:

i. to examine the tensile strength of velvet tamarind stick.

ii. to determine the compressive strength of concrete used in casting slabs reinforced with velvet tamarind stick, slabs reinforced with steel bars and unreinforced slabs.

iii. to determine the flexural strength of velvet tamarind stick reinforced concrete slab and steel reinforced concrete slab respectively.

iv. to compare the flexural strength of steel reinforced concrete slab with velvet tamarind stick reinforced concrete slab.

v. to compare the flexural strength of velvet tamarind stick reinforced concrete slab with unreinforced concrete slab.

1.4 JUSTIFICATION OF STUDY

The study is being justified as follows:

i. It helps Engineers to know the flexural strength of slabs reinforced with velvet tamarind stick at different spacing.

ii. It assists Engineers to know the compressive strength of slabs reinforced with velvet

tamarind stick and steel.

iii. Equally it helps Engineers to know the difference between the strength of slabs reinforced with velvet tamarind stick and unreinforced slabs.

iv. It adds to furtherance of knowledge and availability of literature.

1.5 SCOPE OF STUDY

This study is limited to determination of flexuraI strength of velvet tamarind stick reinforced concrete slabs. Slabs with all edges simply supported were considered for the research and the following steps were taken to actualize the purposes of this research.

I. Production of slabs using mix ratio of 1: 2: 4 for velvet tamarind stick reinforced concrete slabs, this was also carried out for steel reinforced concrete slabs and unreinforced concrete slabs respectively. A total of 57 slabs of 500 x 500mm and 10 cubes were cast in this research.

II. Determination of flexural strength of the slabs under consideration experimentally.

III. Comparative analysis of conventional reinforced slabs with velvet tamarind stick, reinforced slab sand unreinforced slabs respectively.

CHAPTER TWO

LITERATURE REVIEW

2.1 REINFORCED CONCRETE

For thousands of years, humans have taken advantage of ductile materials with high tensile strength in the reinforcement of brittle materials with high compressive strength. The ductile reinforcement transfers tensile load in the structure, allowing the brittle material to crack without causing failure of the structure. Throughout the last two centuries, concrete has been developed into a construction material with ever increasing potential to support compressive forces. As the compressive capacity of concrete has increased and with it demands to support longer and larger and taller structures, stronger, more ductile, and more tensile reinforcement has been required (Kryvenko, 2020).

According to (Kryvenko, 2020), Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get a particular strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. Concrete is the most commonly used material in building structures. In itself concrete is a very brittle anisotropic material with high compressive strength and low tensile strength.

According to ACI 701 (2013), Cementitious materials, Concrete is made from a properly proportioned mixture of hydraulic cement, water, fine and coarse aggregates, and often, chemical or mineral admixtures. Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water binds the aggregates (usually sand and gravel or crushed rock) into a massive rock-like mass as the paste hardens because of the chemical reaction of the cement and water (Kosmatka and Wilson, 2016).

Adebayo (2012) further confirmed that Concrete is a construction material manufactured by mixing fine aggregate (e.g. sand), coarse aggregate (e.g. gravel, crushed stone), cement and water either in a designed or prescribed proportion. Adebayo (2012) also posited that concrete is strong in compression and has good fire resisting properties, and when steel, which is strong in tension is incorporated into it, a strong and durable material which can withstand various forms of loading and can be formed into various shapes and sizes emerges. This accounts for its widespread use in civil engineering construction works such as buildings, bridges, dams, roads and so on. Similarly sandcrete blocks made by mixing cement, sand and water are popularly used as partitions in building due to their strength and water resisting capabilities. Neville (2011) opined that concrete is the most widely used construction materials these days and as such, efforts have been made by many researchers to reduce the cost of its production.

It was stated by Kosmatka, Kerkhoff and Panarese (2014) that aggregate make up about 60% to 75% of the total volume of concrete, their selection is important. The strength of concrete is limited to the strength of the aggregate. According to Kosmatka and Wilson (2016) after decades of development, the production of high strength concrete (HSC) up to grade 100 no longer presents any major difficulties. In fact, since further increase in concrete strength would be limited by the strength of the rock aggregate used and could drastically reduce the ductility of the concrete, it is not advisable to specify any higher strength concrete than grade 100.

2.2 CEMENT

Cement is a binder made from a combination of various elements at different proportions. The most common hydraulic cement used in construction today is Portland cement. Though other types exist, Portland cement is the most abundant.` Portland cement is a finely ground gray powder chemically formed by combining raw materials containing calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3), heating this mixture to a high

temperature, and then grinding the resulting material, called clinker, with a small quantity of calcium sulfate ($CaSO_4$).

2.3 WATER

Almost any natural water that is drinkable and has no pronounced taste or odour can be used as mixing water for making concrete. However, some waters that are not fit for drinking may be suitable for use in concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability.

According to ASTM C 1602 (2012), the following sources of water are approved;

i. Portable water - that which is fit for drinking.

ii. Non-portable water - other sources that are not portable, that might have objectionable taste or smell but not related to water generated at concrete plants. This can represent water from wells, streams or lakes.

iii. Water from concrete production operations - process (wash) water or storm water collected at the concrete plant.

iv. Combined water - a combination of one or more of the above defined sources recognizing that water sources might be blended when producing concrete.

2.4 AGGREGATES

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete. The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened

products. As another important application, aggregates are used in asphalt cement concrete in which they occupy 90% or more of the total volume.

The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy (Wilson and Tennis 2021).

2.4.1 Classification of aggregate

Aggregates can be divided into categories according to different criteria.

i) Classification of aggregates according to their sizes

a) Coarse aggregate: These are aggregates predominately retained on the No. 4 (4.75 mm) sieve. For mass concrete, the maximum size can be as large as 150 mm.

b) Fine aggregate (sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on the No. 200 (75μm) sieve.

ii) Classification of aggregates according to their sources:

a) Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone, gravel, periwinkle shells, palm kernel shells etc.

b) Manufactured (synthetic) aggregates: This is a kind of man-made materials produced as a main product or an industrial by-product. Some examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel).

iii) Classification of aggregates according to their unit weight

a) Light weight aggregate: According to Muller (2012), Lightweight aggregates are defined as aggregates of low density, such as: (a) expanded or sintered clay, shale slate, diatomaceous shale, perlite, vermiculite or slag; (b) natural pumice, scoria, volcanic cinders, tuff, and diatomite; or (c) sintered fly ash or industrial cinders used

in lightweight concrete. The unit weight of aggregate is less than 1120 kg/m^3. The corresponding concrete has a bulk density less than 1800 kg/m^3. (Cinder, blast-furnace slag, volcanic pumice).

b) Normal weight aggregate: The aggregate has unit weight of 1520-1680kg/m^3. The concrete made with this type of aggregate has a bulk density of 2300-2400kg/m^3.

c) Heavy weight aggregate: The unit weight is greater than 2100kg/m^3. The bulk density of the corresponding concrete is greater than 3200kg/m^3. A typical example is magnesite limonite, a heavy iron ore. Heavy weight concrete is used in special structures such as radiation shields.

2.5 LIGHTWEIGHT CONCRETE

Structural lightweight concrete is defined as concrete which:

(a) is made with lightweight aggregates conforming to ASTM C 330 (2017)

(b) has a compressive strength in excess of 2,500psi (17.25 MPa) at 28 days of age when tested in accordance with methods stated in ASTM C 330, and

(c) has an air dry density not exceeding 115pcf (1,840 kg/m3) as determined by ASTM C 567 (2014).

According to Hedjazi (2019), any concrete whose air-dry density is below 1850kg/m^3 (about 2/3 of the density of normal weight concrete) is regarded as lightweight concrete. Three means are available to achieve lightweight concrete. One way to do this is by deliberately removing the fines (fillers) from concrete mix to create large interstitial voids in the concrete. Another way is by entraining air to create large air voids within the concrete matrix. The third means is by simply using lightweight aggregate (LWA) in the place of normal aggregate in a concrete matrix. ACI 213 (2014) specifies that Structural lightweight aggregate concrete is a

concrete whose 28-day compressive strength is equal to or greater than 17 N/mm^2 with air-dry density less than or equal to $1850kg/m^3$. Spratt (1974) as cited in Hedjazi (2019) is of the opinion that some lightweight concrete has air-dry density of up to $2000kg/m^3$.

There are many types of aggregates available that are classed as lightweight, and their properties cover wide ranges. Elastic properties, compressive and tensile strength, time dependent properties, durability, fire resistance, and other properties of structural lightweight aggregate concrete are dependent on the type of lightweight aggregate utilized in the concrete (ASTM C330, 2017).

According to Hedjazi (2019),the use of lightweight concrete permits greater design flexibility and substantial cost saving, reducing dead load, improved cyclic loading structural response, longer spans, better fire ratings, thinner sections, smaller size structural members, less reinforcing steel and lower foundation cost. In addition, weight of lightweight concrete is typical 25% to 35% lighter but its strength is comparable to normal weight concrete. Furthermore, the lightweight aggregate concrete may be made of entirely lightweight aggregate or a combination of lightweight aggregate and normal weight aggregate. However, it has been a common practice to use normal sand as the filler (fine aggregate). The use and design of lightweight aggregate concrete is not as well accepted as normal weight concrete, as such no generally acceptable guideline is available for use and design of lightweight aggregate concrete. As normal weight aggregate concrete, lightweight aggregate concrete is often manufactured at site in fluid state. The properties of concrete (both normal weight and lightweight) vary with time. Properties can be classified as fresh (fluid) properties and hardened concrete properties. Properties of fresh concrete can be used to predict, to some extent, the properties of hardened concrete. This is why careful consideration should be given to fluid concrete, as any error at this stage will become a problem to hardened concrete. The major fresh concrete properties include workability and wet unit weight. On the other hand, properties of hardened concrete include strength, dry density, durability and others.

2.5.1 WORKABILITY

Workability is the ease of placing, compacting and finishing freshly mixed concrete and the degree to which it resists segregation. Concrete should be workable but the ingredient should not separate during transport and handling (Kosmatka, kerkhoff and Panarese, 2014).

Most lightweight aggregates have low density, rough texture and are porous. These features of lightweight aggregate to a large extent affect the workability of lightweight aggregate concrete. Workability is commonly measured by slump test. It is known that high slump and excessive vibration lead to drawing the heavier mortar away from the surface, where it is most needed to finishing. This is as a result of relative lightness of the lightweight aggregate compared to the mortar. In normal weight aggregate concrete, the reverse is the case. High slump and excessive vibration will bring excess weak fines to the surface. To this effect, ACI 213 (1987) recommends a maximum of 3.100mm slump for lightweight aggregate concrete.

2.5.1.1 Factors that influence the workability of concrete:

The following are the factors that influence the workability of concrete.

(i) The Method and duration of transportation,

(ii) Quantity and characteristics of cementitious materials,

(iii) Concrete consistency (slump),

(iv) Grading, shape, and surface texture of fine and coarse aggregates,

(v) Entrained air,

(vi) Water content,

(7) Concrete and ambient air temperatures and

(8) Admixtures. (Source): (Neville, 2011)

2.5.2 DENSITY

According to the American Standard for Testing Materials (ASTM, 330 - 89), Maximum unit weight prescribed for lightweight aggregate concrete is 1850kg/m^3 and minimum compressive strength at 28 day is 17N/mm^2. Hedjazi (2019) asserted that Porous aggregates are likely to form light but weak concrete. Introduction of sand as fine aggregate increases the unit weight of the corresponding concrete. Entraining of air, which improves the workability of the resulting concrete, compensates this increase in unit weight. Many research works have shown that increase in unit weight of concrete brings increase in compressive strength. However, the main factor in lightweight aggregate concrete is not the strength but the unit weight. As long as the minimum compressive strength of 17N/mm^2 will be achieved and at the same time not exceed the maximum density of 1839kg/m3, a lightweight aggregate concrete has been achieved. Ikponmwosa and Salau (2010) showed that the denser the Periwinkle shells – Palm kernel shells aggregates concrete, the higher the compressive strength. With a mix ratio of 1:21/2:2 and water - cement of 0.8 different compressive strength were obtain with different unit weight. The different unit weights were as a result of different combination of periwinkle shells and palm kernel shells, cement and sand remained constant. Concrete with density of 1934.7kg/m^3 produced a 28day compressive strength of 11.01N/mm^3: the one of 2050kg/m^3 produced 13.78N/mm^2. Muller (2012) also showed that the higher density results into higher compressive strength. He used the same mix ratio and water/cement ratio in his investigation. A total of six lightweight aggregates were used. The result of the compressive strength from the concrete made with these aggregates was as shown in Table 2.1.

Table 2.1: Compressive strength from the concrete made with these aggregates

LIGHTWEIGHT AGGREGATE	**DENSITY (Kg/m^3)**	**COMPRESSIVE STRENGTH (N/mm^2)**
Expanded Clay 1	1067	38.4
Expanded Clay 2	1650	53.1
Expanded Shale	1259	30.4
Glasswaste	260	20.90
Masonry construction and demolition waste, CD1	530	28.6
Masonry construction and demolition waste, CD2	1800	39.5

Source: ASTM C330 (1987)

The result in Table 2.1 confirmed the fact that the higher the density, the stronger the concrete. However, it will be observed that CD2 that had the highest density did not become the strongest and this might have been caused by some other factors. Thus, as periwinkle shells are suspected to be light, the concrete made with them will be light with the consequent low compressive strength (Hedjazi, 2019). The density of concrete varies, depending on the amount and density of the aggregate, the amount of air that is entrapped or purposely entrained, and the water and cement contents, which in turn are influenced by the maximum size of the aggregate. Reducing the cement paste content (increasing aggregate volume) increases density. The weight of dry concrete equals the weight of the freshly mixed concrete ingredients less the weight of mix water that evaporates into the air. Some of the mix water combines chemically with the cement during the hydration process, converting the cement into cement gel. Also, some of the water remains tightly held in pores and capillaries and does not evaporate under normal conditions. The amount of mix water that will evaporate from concrete exposed to ambient air at 50% relative humidity is about 1⁄2% to 3% of the

concrete weight; the actual amount depends on initial water content of the concrete, absorption characteristics of the aggregates, and size and shape of the concrete element (Kosmatka, Kerkhoff and Panarese, 2014).

2.5.3 DURABILITY

The durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. The major durability problems concrete faces are harsh weather condition and chemical environment. Air – entrained concrete seems to be more durable than others are. They resist freeze – thaw better than concrete without air – entrainment. The hydraulic pressure caused by explosion of water from the aggregate can be accommodated by the entrained air present in the cement mortar, thus preventing damage to the concrete. It was mentioned earlier that lightweight aggregates are porous. This means that they entrap air within them. The air they entrapped is similar to entrained air in concrete. As such, lightweight aggregates concrete has more durability potential than normal weight aggregate concrete. The ability of concrete to resist chemical attacks is a welcomed development. Ferraris et al. (1997) studied the effect of stress – relaxation, self-desiccation and water absorption on the alkali – silica – reaction in low water/cement ratio mortar. The aggregates experimented on were sprat (with more than 0.1% expansion at 14 days, ASTM C1260 (2012)), siliceous dolomite limestone and non-reactive limestone (with 0.1% expansion at 14 days, ASTM C1260 (2012)). Their result showed that the mix with the former aggregate expanded up to a maximum of 0.43% at 30 days while that of the later expanded up to a maximum of 0.02% at 30 days. The mix of the former gained more mass than the mix of the later. It can be seen that the non-reactive aggregate produced more durable mix.

2.5.4 FLEXURAL STRENGTH

When an object formed of a single material, like a wooden beam or a steel rod, is bent, it experiences a range of stresses across its depth. At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value. These inner and outer edges of the beam or rod are known as the ‘extreme fibers. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the beam or the rod fail is its flexural strength. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, also a mechanical parameter for brittle material, is defined as a material’s ability to resist deformation under load. The transverse bending test is mostly frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three-point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress (Callister, 2018).

Flexural strength is a measure of how a material will deform and strain when weight or force is applied. It describes the ability of a material with specific cross section to resist bending when placed under stress. This property is important in civil, mechanical, and aerospace engineering and design, and is frequently used to select correct materials for parts that will support loads without flexing (Callister, 2018).

The value of the theoretical maximum stress that causes crack at the bottom fiber (tension zone) of a test flexural element is known as modulus of rupture. The value of modulus of rupture depends on the dimension of the slab and above all on the arrangement of loading. For beams, the Modulus of rupture can be obtained by the flexural test of concrete element, molded as prescribed by BS 1881: Part 118: (1983).

2.5.4.1 FACTORS AFFECTING THE FLEXURAL STRENGTH OF A CONCRETE BEAM

The deflection and cracking behavior of concrete structure under flexure and minimum flexural reinforcement of concrete members depend upon the flexural tensile strength or modulus of rapture of concrete in addition to other factors. Many factors have been shown to influence the flexural tensile strength of concrete, particularly the level of stress, size, age and confinement to concrete flexural member, etc. The effect of the factors like level of stress, age, and confinement of concrete member should be giving prime importance while studying the flexural tensile strength of concrete.

Researchers have also devoted their work to study the factors causing variability in flexural tensile strength of concrete. The effect of curing of concrete member on flexural tensile strength, cured under standard testing condition, is studied by Umar and Faslih (2019). They found significant differences between the modulus of rapture of concrete specimens and this difference is varied from 35% to 100% for HPC. The effect of admixtures of the concrete on flexural tensile strength is studied by Siddiqui (2011), and Amudhavalli and Matthew (2012). They concluded that optimum amount of silica fume is 10-15% and of fly ash is about 15% for maximum compressive and flexural strength. The influence of mineral admixtures on the short- and long-term performance of concrete is that silica fume contributed to both the short- and long-term properties of concrete, whereas fly ash shows its beneficial effect in a relatively longer time, (Gonen, Yazicioglu, and Demirel 2014). A study of various properties of concrete containing silica fume was reported by *Zhao and Zhang* (2019). The effects of aggregate content, aggregate gradation, water-to-cementitious material ratio, and superplasticizer dosage rate were also discussed. They concluded that aggregate content seems to have a relatively negligible effect on the compressive strength of silica fume concrete. However, aggregates work to arrest cracks when concrete is subjected to flexural

loads; therefore, increasing aggregate content increases the flexural strength of concrete. In flexural strength of concrete incorporating hooked steel fibers and silica fume, it was noticed that flexural strengths of concrete containing 1% steel fiber is greater than those of the concrete with 0.5% steel fiber with various silica fume contents. The standard test method for the flexural tensile strength of concrete with its size dependence is proposed by Ahmed (2016). They concluded that the flexural tensile strength decreases with increase of structural element size. The concrete member size has a significant effect and an equation incorporating the effect of size of concrete for predicting the flexural tensile strength of concrete given as,

$$f_t = 0.827/h^{0.1}(f_c^{2/3}) \quad (2.1)$$

where, f_c is compressive strength and h is the depth of beam in mm (Ahmed et al,2014).

The flexural tensile strength increases with increase of age and strength of concrete. The proportional increase in the flexural tensile strength at same age of concrete goes on decreasing with increase of level of concrete strength. The flexural strength increases many folds under confinement confining condition of concrete. The percentage increase in flexural tensile strength with the increase of age of concrete under confining condition of concrete is constant at different level of compressive strength.

All factors that affect the strength of a concrete beam also affects its modulus of rupture either directly or indirectly (Neville and Brooks, 2012). Such factors include;

i. Dimension of the beam
ii. Use of reinforcement
iii. Shape of aggregates

(i) Dimension of Beam

As the depth of a concrete beam increases, it reduces its susceptibility to bending and thus higher value of flexural strength increases in the breadth also of the concrete beam (Neville and Brooks, 2012).

(ii) Use of Reinforcement

The strength of bond between a reinforcement and concrete arises primarily from friction and adhesion. Bond is also affected by the properties and the reinforcement and the concrete. The introduction of reinforcement improves tensile stress absorbing capacity of a concrete beam and thus it increases the theoretical value of the flexural strength of a concrete beam (Neville and Brooks, 2012).

(iii) Shape of Aggregate

Both the shape and the surface texture of aggregate influence considerably, the strength of concrete; flexural strength is more affected. Rougher texture e.g. angular arched granite encourages greater adhesion or bond between the particles and the cement matrix. Bounded natural granite on the other hand does not allow for good bond which results in poor flexural strength in concrete beam (Neville and Brooks, 2012).

2.5.5 COMPRESSIVE STRENGTH

Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. It is generally expressed in mega pascals (MPa) or pounds per square inch (psi) at an age of 28 days. One mega pascal equals the force of one newton per square millimeter (N/mm^2) or 1,000,000 N/m^2. Based on the works cited earlier, it has been observed that compressive strength of concrete is affected by the unit weight of the concrete. Also, it has been seen that more factors other than unit weight affect compressive strength of

concrete. According to Hedjazi (2019), these factors include water-cement ratio, the type of aggregate, the cement type, and the technique employed during batching and placing. Hasan and Kabir (2011), showed that the type of aggregate as well as the aggregate/binder ratio affects the compressive strength of concrete. In the research, the aggregates used were river sand, dead burnt magnesia and sintered alumina. From their result, it was discovered that the higher the aggregate-binder ratio, the lesser the compressive strength. It was also discovered that the aggregate/binder ratio of the mix made with either magnesium sand or aluminum sand had higher compressive strength than that made with river sand. They also showed that the higher the water/cement ratio, the lesser the compressive strength. Their experimental result showed that on all aggregate/cement ratios, the compressive strength was smaller with increase in water/cement ratio and vice versa. The effect of water/cement ratio on lightweight aggregate is same with normal weight aggregate concrete.

2.6 STEEL REINFORCEMENT

According to Kryvenko (2020), Steel was developed in the 19^{th} century as a stronger and more ductile alternative to iron. Steel reinforcing bars are manufactured as plain or deformed bars. It has been used to reinforce concrete since nearly its advent as a modern construction material, and is manufactured in the form of bars, plates, wire, and mesh. Ductility, strength, and chemical bond to concrete are just a few of the advantages steel provides as a reinforcing material. The advantages these improved properties would provide in concrete reinforcement were recognized and steel in the form of reinforcing bars (rebar) became an effective method of providing ductility and tensile strength to concrete. Modern steel rebar has a young's modulus of 29×10^6 psi and behaves in an elastic-plastic manner (Kryvenko, 2020).

Another advantage steel provides in reinforcing concrete is the ability to bond with the cement mortar matrix of the concrete. This bond strength is a significant property of reinforcing steel, allowing forces to be transferred through the steel and distributed evenly to

the surrounding concrete material. Bond strength between steel and concrete is a product of the adhesion between the two material surfaces, the pressure or gripping effect provided by the concrete after drying shrinkage, physical interlocking of the concrete aggregate and bar deformations, and mechanical anchors within the concrete at the rebar ends. The quality of the concrete, its strength in tension and compression, and the diameter, shape, and spacing of the rebar determine the bond properties above. The bond stress that develops at the material interface when either material is subject to stress is expressed as local shearing stress per unit area of the bar surface, and the bond stress limit can be determined by pullout test of the rebar embedded in the concrete. Much of the research and development on rebar throughout its history attempted to determine and increase the bond strength of reinforcing elements in concrete. Reinforcement is used to improve tensile properties; the most commonly used reinforcement is steel bars. However, Fibre reinforcement has been used in structures for a long time but the use is still low in comparison to conventional reinforcement bars (Karl and Tim, 2013).

One early development that increased the bond strength between rebar and concrete came in the form of projections or “deformations” rolled onto the bars in order to increase the bond surface area. In addition to the increasing of the bond surface, the deformations provided a physical mechanism for interlocking the bars with the concrete aggregates. Deformation properties are still being tested and improved on, and within the last decade experiments have shown that bond strength can be increased by enlarging the relative area of the deformations to the bar surface.

Steel is ideal for reinforcing concrete because it has high tensile strength and modulus of elasticity. These two attributes are essential if the reinforcement is to function effectively in the two principal roles that it normally has to play. These are;

i. Providing all the tensile strength required in the structural member. Since the concrete has almost no tensile strength, tensile stresses applied to the member will cause it to crack. Since the reinforcement can only comprise a small fraction of the cross section of the member, high tensile strength in the reinforcement is essential if it is to carry the total load.

ii. Minimizing the width of the cracks that exist in the concrete. Since cracks are usually inevitable in a structural member in tension, it is important to minimize their width, both for structural and aesthetic reasons. A high elastic modulus means that the full load can be borne by the reinforcement with only a small amount of associated strain, hence the cracks will only open a small amount. Limits are usually set for crack width for different purposes.

Sozen et al. (2014) went ahead to explain that in order to determine the amount of reinforcement required it is necessary to know the safe level of stress that the reinforcement can tolerate. For steel, this is relatively easy because its properties are consistent, they do not change significantly with time, and they have been very well documented. Thus, the requirements for coping with long-term loads, short-term loads and repeated loads (i.e. creep properties, strength properties, fatigue properties and so on) are well known and reliable solutions to the design problems are available.

Roy (2011) stated the Benefits of steel in reinforced concrete slabs to include;
simple placement, reduction in random cracking, reduction and control of crack width and maintenance of aggregate interlock, Displacement and curling can be minimized when steel is provided in concrete, Strength is increased with steel reinforced concrete, even the smallest cross-sectional area of steel reinforcement will provide reserve strength of 16 percent and more, most importantly steel reinforcement saves money over the life of the slab. He stated finally that admixtures are not an alternative to steel reinforcement but they both do different things in the concrete. Roy (2011) frowned at the fact that much advertising has stated that steel reinforcement can be left out and compensated with admixtures and enhancers or just

use plain (unreinforced) concrete. Much of this advertising is misleading; admixtures cannot be substituted for steel reinforcement.

Unfortunately, steel is subject to corrosion in wet and salty environments, and the resulting damage causes the steel to weaken and lose some of its valuable properties. Encasing of steel in concrete increases the length and time before initiation of corrosion starts by forcing the chlorides to diffuse through the concrete to the depth of the steel (Ward-Waller, 2005).

Several drawbacks of traditional steel rebar include loss of strength due to corrosion from moisture and chloride, and lack of resistance to severe heat and fire damage. These material weaknesses have led to American Concrete Institute (ACI) specifications that require rebar to be entirely encased in concrete, with a minimum concrete cover and spacing between bars. The concrete cover provides limited fireproofing and corrosion resistance to the steel.

2.7 BAMBOO REINFORCEMENT

According to Khatib (2020), Bamboos are giant grasses and not trees as commonly believed. They belong to the family of the Bambusoideae. The Bamboo culm, in general, is a cylindrical shell, which is divided by solid transversal diaphragms at nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers, and low strength perpendicular to the fibers respectively. The density of fibers in cross-section of a bamboo shell varies with thickness as well as height. Fiber distribution is more uniform at the base than at the top or the middle. This is because bamboo is subjected to maximum bending stress due to wind at the top portion of the culm (Khatib, 2020).

Bamboo, as an herbaceous grass plant, grows in canes. Its growth is ideal in tropical and subtropical areas (Terai and Minami, 2012).

Its height depends on the species, the climatic and soil conditions. Some species may reach 25 to 35m high or even more, with diameters ranging between 5 and 15 cm (Terai and Minami, 2012).

Bamboo has an anisotropy biological origin, and it will generate a physical and mechanic feature according to either axial tangential or radial direction. It has longitudinal fibers that offer a higher resistance on the outer part than in the inner part of the cane wall, as a consequence of the fiber density (Terai and Minami, 2012). Terai and Minami also added that a structural change during the early years (up to 3) gradually generates the formation of the canes. These canes gradually signify and the formation of silicates that give the bamboo its resistance to animal and chemical attacks begin. As of year 4, bamboo canes may be used as structure elements. Another important point to be taken into account is the bamboo's high hygroscopic value, which depends on each place's hygrothermic conditions. Therefore, bamboo's retraction is considered to be a significant physical condition for consideration.

Another bamboo major feature is its density in Kg/m^3, which ranges between 700 and 800 Kg/m^3; this variation depends on the cane's type, the origin, and position.

According to Sakaray and Togati (2012), Bamboo is a natural Functionally Graded Material (FGM). It is a composite with hierarchical structure. The strength of bamboo is greater than most of the timber products.

The mechanical properties vary with height and age of the bamboo culm. Research findings indicate that the strength of bamboo increases with age. The optimum strength value occurs between 2.5 and 4 years. The strength decreases at a later age (Terai and Minami, 2012). The function of the nodes is to prevent buckling and they play a role of axial crack arresters. The mechanical properties of bamboo reinforcement are as shown in Table 2.2.

Table 2.2 Mechanical properties of bamboo reinforcement.

Mechanical property	**Range of values (MN/m^2)**	**Typical value (MN/m^2)**	**Typical value (psi)**
Tensile strength	75-350[2]	130	18,850
Poison's ratio	0.25 – 0.41	0.32	0.32

Modulus of elasticity	10,000 – 28,000	18,000	$2.6x10^6$

Source: (Sethia and Baradiva, 2014)

According to Sethia and Baradiva (2014), Bamboo reinforcement has been well documented by Terai and Minami in 2012. To begin with, unlike steel, the properties of bamboo are not consistent but cover a wide range. This is because they depend on a considerable number of variables including such obvious ones as, species of bamboo, age of the bamboo culm, moisture content, pre-treatment (i.e. how the bamboo is stored and weathered).

Sethia and Baradiva (2014), further stated that the properties of bamboo vary a great deal. Many academic researchers have been devoted to measuring the properties of bamboos under a very wide range of conditions but, despite this, the detailed situation is not very clear because test methods have not been standardized and insufficient research has been done. Nevertheless, the broad range of likely values for the key variables of elastic modulus and tensile strength are well documented and therefore, for design purposes, realistic and safe values can probably be assumed, subject to checks made on samples of bamboo that it is proposed to use.

Despite the good properties of bamboo, Khatib (2020), went ahead to highlight the various challenges posed by bamboo being used as reinforcement. These include:

2.7.1 INTERACTION WITH WATER

In use, the interaction of bamboo with the water in the concrete is responsible for several problems. First of all, when the concrete is curing, the wet environment causes bamboo to expand, especially in the transverse direction (i.e. perpendicular to the direction of the culm) (Sethia and Baradiva, 2014). This can cause premature cracks in the concrete. Later, the bamboo shrinks back and the bond between the concrete and the bamboo is broken. Methods of dealing with these problems usually involve treating the bamboo in some way and are

likely to be expensive. Such treatments should also improve the durability of the bamboo, which is normally very poor in an aggressive or in a wet environment.

2.7.2 BONDING WITH CONCRETE

The modulus of bamboo is low compared with that of the concrete and therefore the strain in the bamboo is correspondingly high. Thus, when the concrete cracks, the bamboo allows the cracks to widen considerably. Bamboo is also inherently smooth and does not bond well to concrete. Failure of the bond will allow the cracks to widen even more than they would if the bond was good. Under service loads these cracks can be greater than one millimeter wide. This is far in excess of the width that is normally considered tolerable.

Methods of improving the bond include coating the bamboo to increase the cohesion, constructing anchors of various kinds, and attempting to minimize the problem by minimizing the volume changes in the bamboo that are the primary cause.

This can be done by controlling the initial moisture content of the bamboo and using high grade cement that cures quickly and requires low water content. None of these solutions are likely to be suitable for local, rural, resource-based construction projects.

A related problem is that the thermal expansion of bamboo in the radial direction is very high compared to that of concrete (3-5 times greater). This property has a considerable effect on the bond between the two if temperature changes are significant.

Sethia and Baradiva (2014) also stated that one major problem with bamboo is that it is a living organism which is subject to fungi and insect attacks. Bamboo is more prone to insect attack than other trees and grasses because of its high content of nutrients. In order to combat this problem, it becomes necessary to treat the bamboo to protect it from the environment. One of the amazing aspects of bamboo is the way it interacts with the environment. It has been discovered that bamboo can prevent pollution by absorbing large amounts of nitrogen from waste water and reducing the amount of carbon dioxide in the air.

After testing bamboo as reinforcement in beams by Sethia and Baradiva (2014), he came to the following conclusions:

(a) The load capacity of bamboo reinforced concrete beams increased with increasing percentages of the bamboo reinforcement up to an optimum value.

(b) The load required to cause the ultimate failure of concrete beams reinforced with bamboo was from four to five times greater than that required for concrete members having equal dimensions and with no reinforcement.

(c) This optimum value occurs when the cross-sectional area of the longitudinal bamboo reinforcement was from three to four percent of the cross-sectional area of the concrete in the member.

(d) Bamboo reinforcement in concrete beams does not prevent the failure of the concrete by cracking at loads materially in excess of those to be expected from an unreinforced member having the same dimensions

(e) When unseasoned untreated bamboo was used as the longitudinal reinforcement in concrete members, the dry bamboo swelled due to the absorption of moisture from the wet concrete, and this swelling action often caused longitudinal cracks in the concrete, thereby lowering the load capacity of the members.

(f) Members having optimum percentage of bamboo reinforcement (between three and four percent) are capable of producing tensile stresses in the bamboo of from 8,000 to 10,000 pounds per square inch.

(g) In designing concrete members reinforced with bamboo, a safe tensile stress for the bamboo of from 34,474 to 41,369 kilopascal may be used.

(h) Concrete members reinforced with seasoned bamboo treated with a brush coat of asphalt emulsion developed greater load capacities than did equal sections in which the bamboo reinforcement was seasoned, untreated or unseasoned bamboo.

(i) Concrete members reinforced with unseasoned sections of bamboo culms, which had been split along their horizontal axes, appeared to develop greater load capacities than did equal sections in which the reinforcement consisted of unseasoned whole culms.

(j) When split sections of seasoned untreated large diameter culms were used as the reinforcement in a concrete beam, longitudinal cracks appeared in the concrete due to the swelling action of the bamboo. This cracking of the concrete was of sufficient intensity as to virtually destroy the load capacities of the members.

(k) Ultimate failure of bamboo reinforced concrete members usually was caused by diagonal tension failures even though diagonal tension reinforcement was provided.

(l) A study on the deflection data for all the beam specimens tested indicated:

i That the deflections of the beams when tested followed a fairly accurate straight-line variation until the appearance of the first crack in the concrete

ii Immediately following the first crack, there was a pronounced flattening of the deflection curve (probably due to local bond slippage) followed by another period of fairly accurate straight-line variation, but at a lesser slope, until ultimate failure of the member occurred.

This flattening of the deflection curve was more pronounced in the members where the amount of longitudinal bamboo reinforcement was small

iii in all cases noted, the deflection curve had a lesser slope after the appearance of the first crack in the concrete, even though high percentages of bamboo reinforcement were used.

Also, Sethia and Baradiva (2014), concluded that bamboo reinforcement in pavement slabs fulfils no useful purpose. The reasons included;

(i) bamboo cannot prevent load induced cracking in the concrete because its modulus is too low for it to reduce the tensile stresses that might cause cracking.

(ii) because of the low modulus, bamboo is unable to keep any cracks that do develop in the concrete from opening more widely than is acceptable. Wide cracks allow access to the bamboo for water, fungi and insects, leading to rotting and disintegration of the bamboo.

(iii) pavement quality concrete with properly constructed shrinkage joints and appropriate curing techniques should only crack at the controlled joints. But, in any case, for the same reasons that bamboo cannot prevent load associated cracking, neither can it prevent shrinkage cracking.

Also, in a study reported by Muhtar, (2020), it was concluded that;

(i) bamboo can be used as the reinforcing material in light, semi-permanent concrete military structures. Ultimate strength design procedures, modified to take into account the characteristics of the bamboo reinforcement, can be used to estimate the ultimate load-carrying capacity of precast concrete elements with bamboo reinforcement.

(ii) as the percentage of bamboo reinforcement used in fabricating the beams increases, the estimate of the ultimate load-carrying capacity of the beams becomes less accurate.

(iii) short and long-term deflections of bamboo-reinforced concrete beams can only be approximately estimated by using the moments of inertia of either the cracked or the non-cracked transform section of the beams.

(iv) to maximize the load-carrying capability of a bamboo reinforced concrete beam, as much bamboo as can be reasonably placed in the beam should be used.

(v) to minimize long-term deflections, a minimum depth of 4 inches is recommended for flexural members.

(vi) no unusual difficulties should arise in fabricating and curing precast concrete elements with bamboo reinforcement under field conditions.

Vivas (2019), reported a study providing a set of instructions on how to properly construct a variety of structures and structural elements using Bamboo. This study suggested not to use green, unseasoned Bamboo for general construction, nor to use un-waterproofed Bamboo in concrete. Concerning Bamboo reinforced concrete, it was found that the concrete mix designs may be the same as that used with steel, with a slump as low as workability will allow. It was recommended that the amount of Bamboo reinforcement in concrete be 3- 4% of the concrete's cross-sectional area as the optimum amount. It concludes that Bamboo reinforced concrete is a potential alternative light construction method at a low cost.

Vivas (2019) gave a detailed description of the mechanical properties of Bamboo in their study. They found that the physical, as well as mechanical attributes vary with respect to diameter, length, age, type, position along culm, and moisture content of Bamboo.

Akwada and Akinlabi (2020) investigated the mechanical and physical properties of Bamboo. They conducted a thorough investigation into the structure and purposes of the nodes, which they found to strengthen the Bamboo culm. They also commented on the advantage Bamboo has over other natural building materials with its fast growth rate.

Terai and Minami (2012) as cited by Vivas (2019) conducted an in-depth study outlining the proper ways to utilize Bamboo in construction. A listing of the positive aspects of Bamboo is given, citing examples pertaining to its economical, mechanical, and environmental properties. When used as reinforcement in concrete, directions are given to insure a better performance, including discussions on waterproofing, pressure-treating, concrete design, and beam design. This study found that the Bamboo reinforcement area should be five times the typical steel reinforcement area, and that even when fine cracks develop on the surface of Bamboo, the load carrying capacity of the member is not reduced. The only negative properties of Bamboo given are its susceptibility to attack by insects, fungi and dried bamboo is prone to catch fire.

2.8 STICK REINFORCEMENT

Sticks are obtained from stems of shrubs. A shrub is a woody plant of relatively low height, having several stems arising from the base and lacking a single trunk (Encarta dictionary). A shrub can then be defined as a woody plant with several perennial stems that may be erect or may lie close to the ground. It will usually have a height less than 13 feet and stems not more than about three inches in diameter (Kuhns, 2013).

A stick reinforced concrete member is a concrete member in which sticks are used as reinforcement to carry the tensile stress caused by the load on the member. It is important to point out here that bamboo belong to the class of grass and not shrubs. In the constant search for substitute material for steel reinforcement, little or no work has been done in the area of using stick as reinforcement material.

2.9 VELVET TAMARIND STICK REINFORCEMENT

Newly developed composite materials as reinforcement system in structural concrete have the potential to revolutionize the concrete building sector. The innovative green materials can replace the expensive and environmentally unfriendly produced steel. Its advantages over steel includes;

a. Much lower production costs,
b. Lighter weight, anti-corrosion and
c. Natural renewability (no re-planting necessary).
d. Reduced environmental impact
e. Malleable, versatile and resistant

They have the capacity to bind large amounts of CO_2 due to their fast growth; they are also easily accessible and available for production in developing territories, resulting in reduced energy consumption during production. It has a wide-spread application for high impact in

the developing world; also, it is an alternative material of increased quality, lower production and transportation cost.

2.9.1 VELVET TAMARIND

Velvet tamarind is a woody plant occurs in the rain forest region of West Africa. It grows up to 15m high with dark green glossy leaves, each measuring 6cm to 8cm long and 2.5cm wide at the widest part of the leaf (Ofosu et al.,2013). The young leaves are sometimes chewed for its tangy taste. The ripe fruits are available from January till May but the peak period for harvest is between March and April (Obasi et al., 2013). The velvet tamarind pulp is eaten in South Eastern part of Nigeria (where it is known as *Icheku* or Nchichi) because of its refreshing properties & pleasant scorching taste (Obasi et al., 2013).

It is multi use tree. It is a source of timber, fruit, seeds, fodder, medicinal extracts and potential industrial components, so in terms of rural farmer the tree can provides seasonal income in periods of potential hardship. Tamarind trees are able to compensate farmers in seasons after subsistence crops have generally been harvested (pods are harvested in the dry seasons), thereby giving a potential economic return in local markets where food is scarce.

Tamarind is a tree that is easy to cultivate & requires minimum care. It is generally free of minimum pest and disease, has a life span of 80 – 200 years and can yield 150 – 500kg of pods per healthy tree/year at 20 years of age. The potential of the tamarind tree within rural farming communities has been well recognized, although unimproved wild trees are continuously being exploited to meet growing domestic and international demand.

2.9.2 Common Names:

(English): Black Velvet, velvet tamarind (Igbo): *Icheku* (Yoruba): Awin (Hausa): TsamiyarKurm (French): Tamarinier Noir (Ibibio): Ukuk (Igala):Aigele

2.9.3 Botanic Description:

Velvet tamarind is a tree of 30m high, shrubby with a densely leafy crown. Bole without buttrerres, Bark smooth, grey, slash reddish, yielding a little red gum. Leaves sometimes are finely hairy, with a common stalk of 5-13cm long with an odd terminal leaflet and usually 2 pairs of opposite or alternate leaflets, the lower pair being somewhat smaller, leaflets is mostly 3.5- 10, 2.5-5cm, elliptic to broadly elliptic, sometimes slightly obviate, blunt at the apex or abruptly and shortly acuminate, symmetrical and rounded leathery, glabrous above and with midrib slightly sunken. Flowers are usually whitish in large terminal or occasionally auxiliary panicles up to 30cm long, branches spreading out widely and more or less horizontally, the whole inflorescence at first covered with very short brownish hairs, individual flowers are with short stout stalks, the buds are about 2mm long. Fruits are densely, velvety, black, each fruit with a stalk of about 6mm long with a little collar near the apex, and a brittle shell enclosing one seed or exceptionally two as shown in Plate 2.1; embedded in a dry brownish, sweetly acidic, edible pulp as shown in Plate 2.2.

Plate 2.1 Velvet tamarind fruit

Plate 2.2 Edible pulp

2.10 REVIEW OF RESEARCH WORKS ON CONCRETE SLABS

Youssef, El-Fitiany and Elfeki, (2016) conducted a research on Flexural Behavior of Protected Concrete Slab After Fire Exposure. Their investigation was based on casting and testing 16 reduced scale (600×600×40mm) reinforced concrete slab specimens. Two concrete mixes with design 28 days compressive strengths of (30 and 38 MPa) were adopted. The specimens were exposed to fire flame temperature levels of (400°C,500°C and 600°C) at the lower surface of the slab specimens with exposure duration of one hour, then after 24 hours; they were tested in flexure to failure under uniformly distributed load while they are partially edge restrained against lateral and rotational movements. According to Youssef, El-Fitiany and Elfeki, (2016), it was found from the results that the values of ultimate load capacity, decreased for all specimens after exposing to fire flame.

They also found out that the reduction in concrete flexural strength is more pronounced than that in compressive strength after exposing to fire. The residual values of flexural strength at fire temperatures around 600 °C were (47%, 51%) for series A and B respectively.

Also, Onundi, Oumarou and Alkali (2019) studied “Effects of Fire on the Strength of Reinforced Concrete Structural Members”. He developed an Excel-based spreadsheet application for thermal analysis of concrete slabs. According to him, it accounts for different aggregate types, slab thicknesses, and fire exposures. Several analyses were performed with the spreadsheet application to examine the affect slab thickness and aggregate types have on the fire performance of concrete slabs in standard and natural fires. The results were compared with published test data and finite element software simulations to benchmark the accuracy of the proposed tool.

Hence, Fire tests represent the oldest method to evaluate the fire endurance of structural elements Onundi, Oumarou and Alkali (2019).Fire tests in furnaces are carried out by exposing certain surfaces of a test specimen to heating in a manner that simulates its exposure to heating in a fire (Wit, 2011).

According to Wit (2011), sensory and optical techniques have been developed to determine the post-fire material properties of concrete. But these methods are used in the evaluation of fire damage and cannot be applied to the assessment of concrete performance during fire conditions. Muda et al. (2012) studied the Flexural Behaviour of Lightweight Oil Palm Shells (OPS) Concrete Slab Reinforced with Geogrid. In their research, slabs were casted with varying amount of OPS with different Geogrid layers. A geogrid is geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly made polymer materials, such as polyester, polyethylene or polypropylene. They may be woven or knitted from yarns, heat-welded from strips of material or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid. Geogrids are commonly used to reinforce retaining walls, as well as sub-bases or sub-soils below roads or structures, Wikipedia. They stated that the Data from test results shows that increment in oil palm shells content will reduce the flexural strength of slab while increment in amount of geogrid can increase the flexural strength. Both materials portray their potential as replacement for granite aggregates and steel reinforcement. Slab samples casted manage to fulfill criteria of lightweight concrete but fail to achieve high strength. Slab casted portrays similar properties and behavior as conventional steel-reinforced concrete with ductility and strain hardening. By comparing to design requirement for residential floor based on British Standard, the slab samples show adequate capacity to cater for both ultimate limit state and serviceability limit, hence can be adopted in construction of residential building.

Abid and Franzen (2011) studied the Design of Fibre Reinforced Concrete Beams and Slabs. In their research, they evaluated three of the existing guidelines, namely the FIB model code, RILEM TC-162-TDF (2003) and the Spanish EHE-08, regarding design of fibre reinforced concrete. They used Mathcad to make design calculations regarding moment and shear resistance in ultimate limit state and crack width in serviceability limit state for simply supported beams with different combinations of ordinary reinforcement and fibre

reinforcement. The design results were then compared with existing experimental results to assess the accuracy of the design codes. According to Abid and Franzen (2011), the simply supported slabs were also designed in Mathcad, where two reference slabs with ordinary reinforcement were compared to concrete slabs reinforced with fibres.

They reported that the variation between the design codes and guidelines was small. However, when compared to the experimental results, underestimations were revealed in all the guidelines. The FIB model code and the Spanish EHE-08 proved to be the most accurate. Out of the three guidelines evaluated, the FIB model code was the most applicable due the fact that it was complete and clear in most regards.

The design of the simply supported slabs revealed that, it is possible to replace ordinary reinforcement with steel fibres but requires large fibre fractions, as those used in this project were not enough.

Today, fibre reinforced concrete is mainly used on industrial ground floors, where the slabs on the ground are exposed to heavy repetitive loads from e.g. trucks and lifts, in order to increase the durability of the ground slabs and increase the strength against cracking (Abid and Franzen, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

The materials used in this research work were cement, water, sharp sand, granite, velvet tamarind stick and 12mm high yield steel.

3.1.1 CEMENT

The type of binder or cement used for this research was Dangote brand of ordinary Portland cement (3X) obtained from a retail cement shop along Naze road, Owerri, which conforms to the requirements of BS 12 (1996).

3.1.2 WATER

For the mixing of the concrete into paste, the water used was borehole water obtained from a tap in Federal Polytechnic, Nekede, Owerri, Imo State according to the requirement of ASTM C1602 (2004).

3.1.3 FINE AGGREGATE

These are aggregates passing sieve no. 4 (4.75mm) and are predominantly retained on sieve no. 200 (75μm). It can also be classified according to source, either natural or synthetic.

The fine aggregate used in this work was sharp sand obtained from Otamiri River in Nekede, Owerri. The sand was free from deleterious materials.

3.1.4 COARSE AGGREGATE

The coarse aggregate used in this research work is granite. It was obtained from a quarry in Akamkpa Local Government Area of Cross River State and retailed in Owerri, Imo State. It was free from debris.

3.1.5 REINFORCEMENT BARS

i. HIGH YIELD STEEL

The reinforcement bar used was 12mm high yield steel which was obtained from the local market in Owerri.

ii. VELVET TAMARIND STICK

Velvet tamarind stick, with botanical name, mucunapruriens, was cut from the bush in Umuchima, Ihiagwa, Owerri, Imo State. The velvet tamarind stick was 12mm diameter and was carefully selected. It was peeled, dried, cut into appropriate sizes and carefully treated before being used as reinforcement.

3.2 METHODS

The methods are divided into three, preparation of materials, laboratory investigations on materials and strength test on specimens.

3.2.1 Material Preparation

i. Preparation of Mould

The mould used in this work for casting slabs was fabricated with wood to a size of 500 x 500 x 100mm. To avoid loss of mixing water to the wood, it was covered with nylon (polythene) both at the base and at the sides.

ii. PREPARATION AND ARRANGEMENT OF REINFORCEMENT MATERIALS

a. Velvet tamarind stick

Velvet tamarind was carefully cut from the bush with a diameter of 12mm in size. The stick was carefully peeled and dried before cutting them into 450mm of length. It was first dried before cutting to take care of any decrease in size due to dehydration. The stick was then treated by soaking it in a solution of sodium chloride (NaCl) for 12 hours in order to kill any

inherent rodent. It was also steamed for 24 hours to remove the inherent cellulose from the stick. Finally, the stick was sun dried and used for reinforcement of the slab.

The reinforcement sticks were arranged with the aid of binding wire and in nine sets. The spacing used was same for both the main and distribution reinforcement. The nine sets of reinforcements were spaced at 75mm, 100mm, 125mm and 150mm centre to centre respectively. The total of 36 velvet tamarind sticks reinforced concrete slabs was cast with four sets of reinforcement pattern. For every loading and reinforcement pattern, 3 slabs were used to test for flexure. Concrete "biscuits" or spacers of thickness 25mm were attached to the sides and bottom of the reinforcements to provide for adequate cover to the reinforcement.

b. Steel

The 12mm high yield steel was bought in full length of about 12m, and was cut with the help of a hack saw into 450mm lengths. It was then arranged at different spacing with the help of binding wires. The spacing was the same for both the main reinforcement bars and the distribution bars.

c. BATCHING

Batching refers to the method of measuring the different materials to be used for concrete making. The batching method adopted in this work was batching by volume. This was carefully done using a calibrated container to get the quantity of various materials for each mix. The mix ratio used was 1:2:4 (cement, fine aggregate, coarse aggregate) with a water cement ratio of 0.50.

d. MIXING

Mixing of various component of concrete was done manually with the use of spade. The coarse aggregate was soaked in water for 24 hours and air dried for 2hours before mixing to achieve saturated surface dry aggregate (SSD). Water was first poured on the mixing surface

(platform) a day before the actual mixing so as to saturate the surface to avoid it absorbing the mixing water. The fine aggregate was first measured, followed by coarse aggregate. The aggregates were mixed dry before cement was then added and also thoroughly mixed. This was followed by the addition of some quantity of clean tap water and mixed. The remaining water was then added after a short time of mixing. The whole constituents were mixed until an even paste was obtained.

e. PLACING

The moulds were set in place and insulated with water proof to avoid loss of mixing water to the ground beneath or the mould.

The reinforcement was placed inside the prepared mould with the spacers providing for concrete cover. The freshly mixed concrete was immediately transferred to the mould with the help of head pan.

f. COMPACTION

Compaction of concrete is the method adopted for expelling the entrapped air from concrete, hence reducing to amount of void, and packing the aggregate particles together so as to increase the density of concrete. The freshly mixed concrete in the mould was compacted in three layers using tamping rod along the reinforcement spacing.

The surface of the compacted slab was fine finished using the trowel and marks were made for easy identification. The specimens were kept in a secure place to acquire strength as shown in Plate 3.1.

Plate 3.1: Stick reinforcement in concrete

g. CURING

Curing is the procedure for insuring the hydration of Portland cement in a newly-placed concrete. The hardened slabs and cubes were transferred immediately into the curing tank 18 hours after casting. The slabs and cubes were completely submerged in water throughout the period of curing. Curing was done at normal room temperature and in a tank of tap water. The specimens were removed at the end of 28 days from the day of casting and dried at room temperature for 30minutes before testing.

3.2.2 Laboratory Investigation on Materials

The properties of materials investigated include the physical properties of fine aggregates, coarse aggregates and velvet tamarind stick.

i. **Sieve Analysis**

The fine aggregates and coarse aggregates were tested to determine gradation (sieve analysis) and water absorption. Collection of samples was in accordance to BS EN 932-1(1997) while the sieve analysis was in accordance to BS 812-103.1(1985). Sieve analysis was carried out manually using sieves arranged in decreasing size of opening and placed on a pan in order to differentiate samples of the aggregate into fractions.

The test was conducted for both fine and coarse aggregate. Quartering method was used to reduce sample to appropriate test size. The electronic weighing machine was cleaned to be free from additional weight to avoid zero error, and the weight of the tray was also recorded. The sample was weighed and recorded and poured into the topmost sieve. The sieves were arranged in decreasing order. Sieve sizes depended on the material to be tested. The test sample with the set of sieves was shaken manually for about 30minutes.

Samples collected on each of the sieves and on the pan were weighed and recorded. The results are presented in appendix A.

ii. Density

Density is the weight per unit of volume of a substance. The bulk wet density of the 28-day compressive strength was obtained since some structural characteristic depends on it. The cubes for the compressive strength test were weighed in a digital weighing balance that has accuracy of 0.01g and recorded and the bulk density of the wet samples was computed using Equation (3.1).

$$Density = \frac{Mass\ of\ wet\ Sample}{Volume\ of\ the\ wet\ sample} \qquad (3.1)$$

The dry bulk density of the sample was as well determined. This test shows how dense the components of a dry concrete mix are packed when filled in a standard manner. The test specimen used for wet bulk density test was carefully dried. It was measured and the weight recorded.

Bulk density for dry concrete is calculated with the relationship shown in Equation (3.2).

$$Dry\ bulk\ density = \frac{weight\ of\ dry\ concrete}{volume\ of\ the\ sample} \qquad (3.2)$$

iii. Slump Test

Slump test is used in determining the degree of workability of a concrete mix. This is extensively used in site work. Though it does not measure workability directly, it provides useful information regarding variation in the uniformity or consistency of a mix of a given proportion.

Slump test was done according to the specification of BS 1881: Part 102: 1983.

A homogeneous fresh concrete mix was produced with uniform color and of consistent mixture. The slump cone was placed on the base plate with the smaller opening at the top and it was held down firmly. The cone was filled in four layers; each layer was tamped with 25 blows using the tamping rod. The top surface was struck off with the trowel, and the cone was gently lifted vertically from the formed concrete cone. The actual slump was the difference between the height of the metal cone and the concrete cone. The slump was measured using the meter rule as shown in Plate 3.2.

=

Plate 3.2: Slump test

3.2.3 Strength Tests on Specimens

The strength tests carried out were; tensile strength test on velvet tamarind stick, compressive strength test on concrete cubes specimens and flexural strength tests on reinforced concrete slabs.

i. Tensile Strength Test on Velvet tamarind stick

Tensile strength test to measure the force required to break a material and the extent to which the material is elongated before breaking was carried out. Specimen of velvet tamarind stick was placed in the holding gap of a universal test machine at specified grip separation points and pulled until failure. The specimen in test machine is shown in plate 3.3 and the hydraulic universal test machine is shown in plate 3.4.

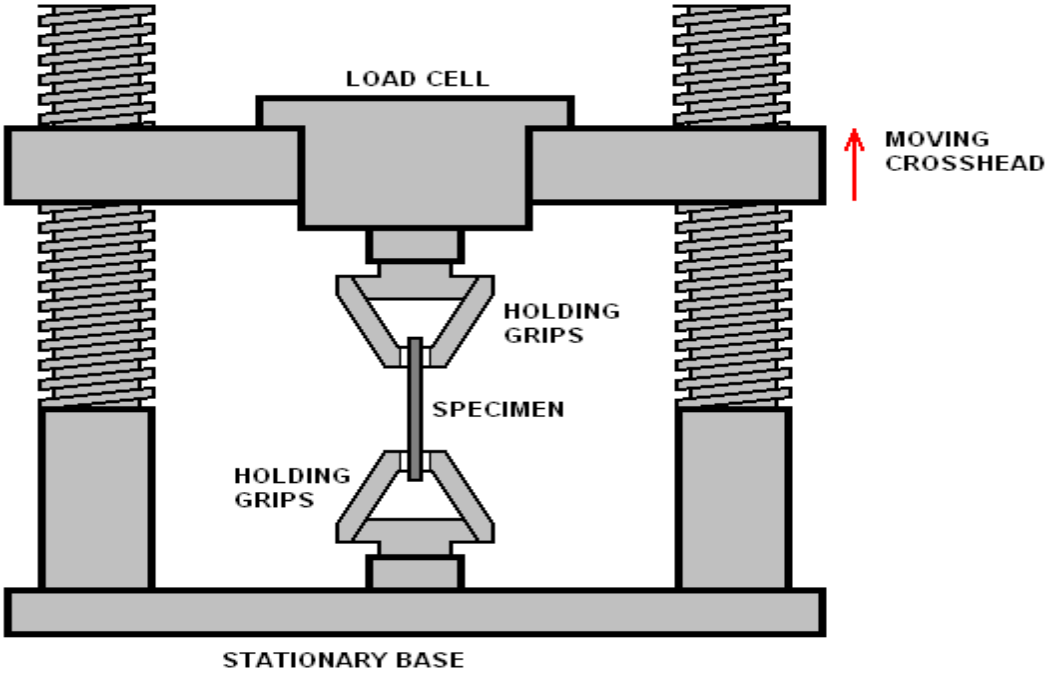


Plate 3.3: Test machine

Plate 3.4: Hydraulic Universal Test machine

ii. Compressive Strength Test on Concrete cubes

Compressive strength test was carried out in order to determine the compressive strength of the concrete used in casting slabs reinforced with velvet tamarind sticks, slabs reinforced with steel bars and unreinforced slabs.

The concrete cubes were produced using manual mixing method in a mould measuring 150mm x 150mm x 150 mm in size. The moulds were first oiled for easy of removal of the samples after setting. The concrete sample was introduced into the mould in three layers with proper vibration. A total of 10 cubes were produced from the ten batches used and the mix ratio is 0.5: 1:2:4. 0.5 represent water cement ratio, 1 stands for cement, 2 stands for fine aggregates and 4 stands for coarse aggregates. The 10 cubes were crushed at 28days and used to obtain the 28-day compressive strength. The concrete cubes were cured by total immersion and tested for 28 days and tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) thereafter. The machine conforms to the requirement of BS EN 12390-4 (2000) and has a testing range of 0-1000kN. The compression load at failure was recorded and used in Equation (3.3) to determine the compressive strength of the concrete slabs.

Compressive strength σ_c =

$$\frac{compressive\ load\ of\ cube\ at\ failure\ (N)}{cross\ sectional\ area\ of\ mould\ (mm^2)} \qquad (3.3)$$

iii. Flexural Strength Test

To determine the flexural strength of the concrete made with velvet tamarind stick reinforced concrete slab and that which is reinforced with 12mm steel, it was subjected to flexural strength test under various loadings. A total of forty-four (44) slabs specimen were used for the work. Thirty-six (36) slabs specimen was for velvet tamarind stick while nine (9) slabs specimen each was for steel reinforced concrete and plain concrete respectively.

The slab specimens were tested immediately they were removed from the curing tank i.e. when they are still in a wet condition. The test specimens were simply supported on four sides by steel beams 50 x 500mm surface area and were perfectly fixed on the testing machine.

The center of the slab was marked through drawing diagonal lines using a scriber to aid in the application of point load directly to the center. The plunger was 30mm diameter. Loading was done gradually at about one-minute interval between each thrust; this was to aid in giving time for proper distribution of load by the member.

For the uniformly distributed line load, a hardwood of 50mm x 400mm was placed on the slab to help in the distribution of the load along the centerline, since the machines plunger can only transfer point load. Also, because of the curved nature of flexural members under deflection, a sand bed was placed on the test specimen such that under deflection, the sand will aid in the transfer of load to the deflected centerline.

The same procedure was repeated for uniformly distributed load. Hardwood was used to transfer the load over the whole surface area of the slab excluding the area directly supported by the beam. A sand bed was also used to help in load distribution.

(i) FAILURE CRITERIA

The load was applied gradually at 2 strokes in a minimum of 30seconds. The load was increased until the specimen failed, and the maximum load applied to the specimen during the test was recorded.

The slab was considered to have failed once there was a visible crack beyond 2mm at the bottom fiber (BS 8110-1, 1997). It was noticed that different loading conditions had different patterns of crack at the bottom of the slab.

It was also noticed that the stress (pressure) on the slab tends to reduce when allowed for some time between loadings. This was due to distribution of load within the member. Effective distribution of load in the slab was obtained when the slab was loaded with uniformly distributed load, which makes its modulus of rupture higher than when loaded with point load.

The unreinforced slab was noticed to fail without warning that is brittle failure, unlike the steel and velvet tamarind stick reinforced slabs.

The flexural strength of the specimen is expressed as the modulus of rupture in terms of stress.

$$flexural\ stress, \sigma = \frac{6M}{bh^2} \qquad (3.4)$$

Where;

M = maximum Moment at the center of the slab (kN/m^2)

B = width of slab (mm)

h = depth of the slab (mm)

The result of flexural stresses are shown in Table 4.18

Plate 3.5: Slab subjected to Point load

Plate 3.6: Slab Subjected to Uniformly Distributed Line Load

Plate 3.7: Slab Subjected to Uniformly Distributed Load

Plate 3.8: Failure pattern of slab subjected to Point Load

Plate3.9: Failure Pattern of Slab Subjected to Uniformly Distributed Line Load

Plate3.10: Failure Pattern of Slab Subjected to Uniformly Distributed Load

(ii) MAXIMUM BENDING MOMENT ANALYSIS

Determination of Flexural Strength of Reinforced Concrete

Flexural strength is a material property, defined as the stress in a material just before it yields in a flexure test. It is a property or structural member that indicates its ability to resist failure in bending.

Flexural strength can be determined empirically. For a reinforced concrete slab that is simply supported on all sides, the flexural strength can be obtained from the failure or collapse load by calculating the maximum moment due to the load which occurs at the mid-span.

Hence, the equation for maximum bending moment based on various types of load application can be derived thus;

Where:

P is the force exerted by the 30mm plunger at the time of failure

a and **b** are the x and y-axis dimensions of the slab which is equal to 500mm (a=b=500mm).

(a) Maximum Moment Caused by Point Load

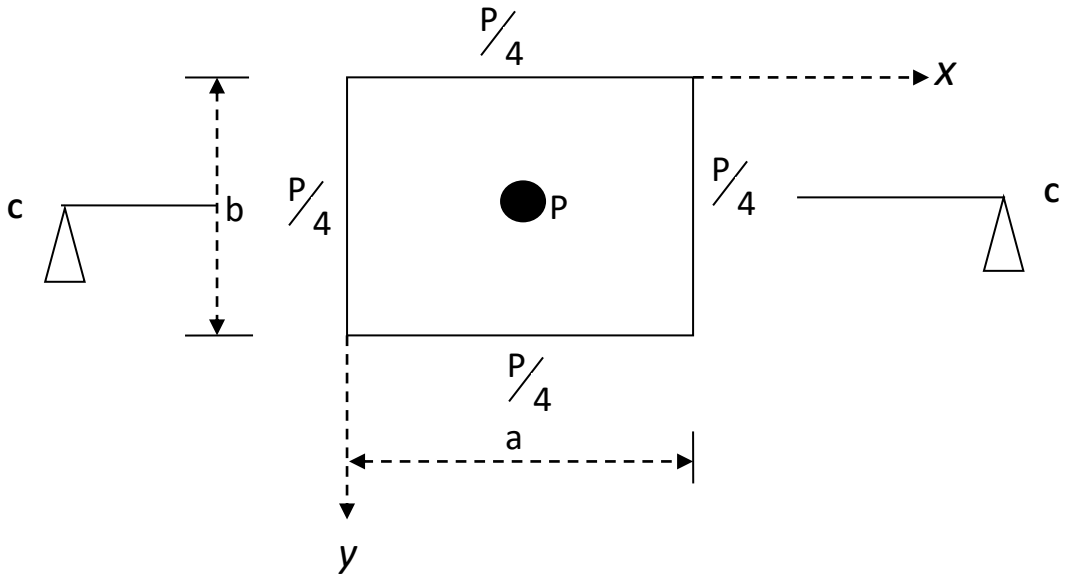
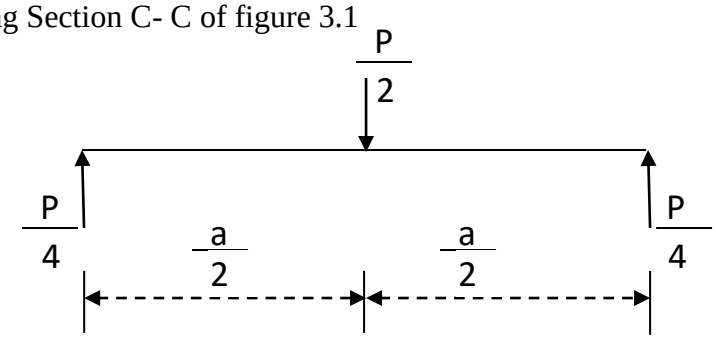


Figure 3.1: Slab subjected to point load P (plan)

Considering Section C- C of figure 3.1



Maximum bending moment will occur at mid-span in both axes

$$taking\ moment\ at\ mid-span, i.e\ {}^{a}/_{2}$$

$$M_{max} = \frac{Pa}{8} \quad (3.5)$$

$$where\ a = 500mm$$

$$M_{max} = 0.0625P(Nm)$$

(b) Maximum Moment Due to Uniformly Distributed Line Load

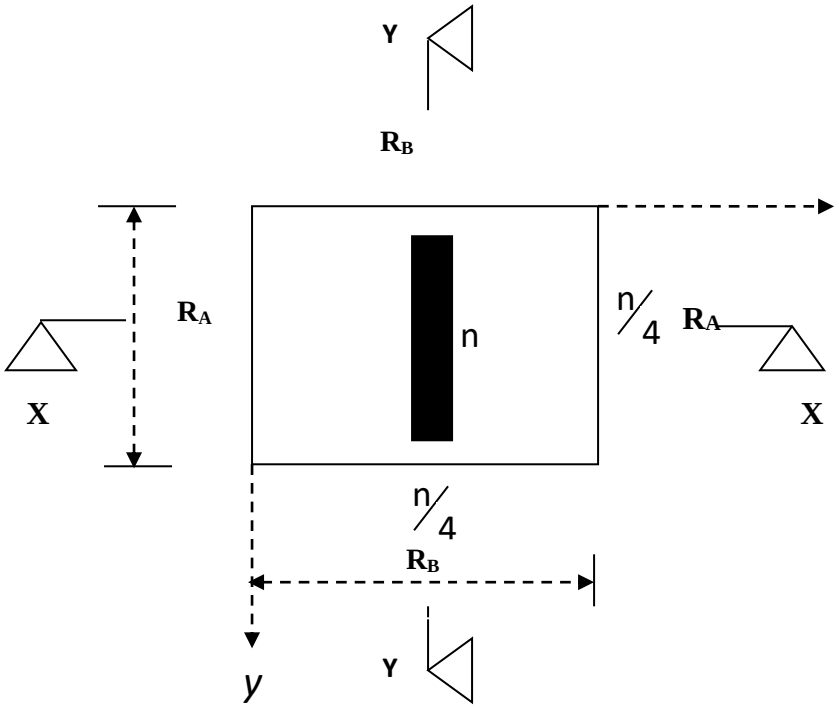


Figure 3.2: Slab subjected to uniformly distributed line load P (plan)

R_A and R_B are the support reactions in x and y directions.

P is the force exerted by the 30mm plunger at the time of failure

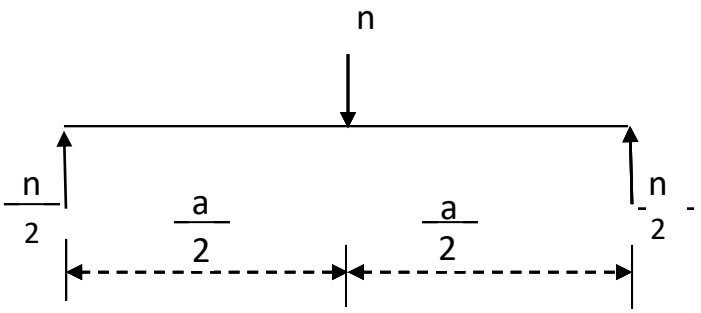
a and **b** are the x and y-axis dimensions of the slab which is equal to 500mm (a=b=500mm).

If the plunger load, P, is converted into a uniformly distributed line load, n, of length x

$$n = \frac{P}{\text{load length, x}} = \frac{P}{x}$$

$$P = nx$$

considering section $x - x$ *in figure* 3.2



taking moment at the RHS

$$R_A * a - n * \frac{a}{2} = 0$$

$$R_A = \frac{n}{2}$$

if the maximum bending moment occurs at the centre

$$M_{max} = R_A * \frac{a}{2} = \frac{na}{4}$$

$$but\ n = {}^{P}/_{x}$$

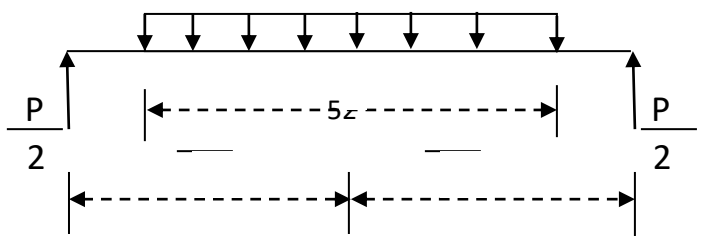
$$M_{max} = \frac{Pa}{4x} \qquad (3.6)$$

where the load length, $x = 0.38m$ *and* $a = 0.5m$

$$M_{max} = 0.3289P(Nm)$$

considering section $y - y$

taking moment about the RHS



$$R_A b - \frac{P}{x} * x * \frac{b}{2} = 0$$

$$R_A b = \frac{Pb}{2}$$

$$R_A = \frac{P}{2}$$

$for\ simply\ supported\ member\ with\ udll, maximum\ moment\ will\ occur\ at\ the\ mid - span, that\ is\ at\ {}^{b}/_{2}$

$$M_{max} = \frac{P}{2} * \frac{b}{2} - \frac{P}{x} * \frac{x}{2} * \frac{x}{4}$$

$= \frac{Pb}{4} - \frac{Px}{8}$

$$M_{max} = \frac{P(2b - x)}{8} \qquad (3.7)$$

$For\ a = b = 0.5m\ and\ x = 0.38m$

$M_{max} = 0.0775P(Nm)$

$Therefore, the\ maximum\ moment\ occurs\ along\ section\ x - x\ axis$

(a) Maximum Moment at the Centre due to Uniformly Distributed Load

The maximum moment will occur at the center of the slab as shown below;

$the\ plunger\ load, P, is\ uniformly\ distributed\ over\ x^2\ surface\ area\ of\ the\ slab$

$giving\ a\ uniformly\ distributed\ load, n, of;$

$$\mathrm{n} = \frac{\mathrm{P}}{\text{load area}} = \frac{\mathrm{P}}{(\mathrm{x} * \mathrm{x})}$$

$$\mathrm{P} = \mathrm{nx}^2$$

$$n = {}^{P}/_{x^2}$$

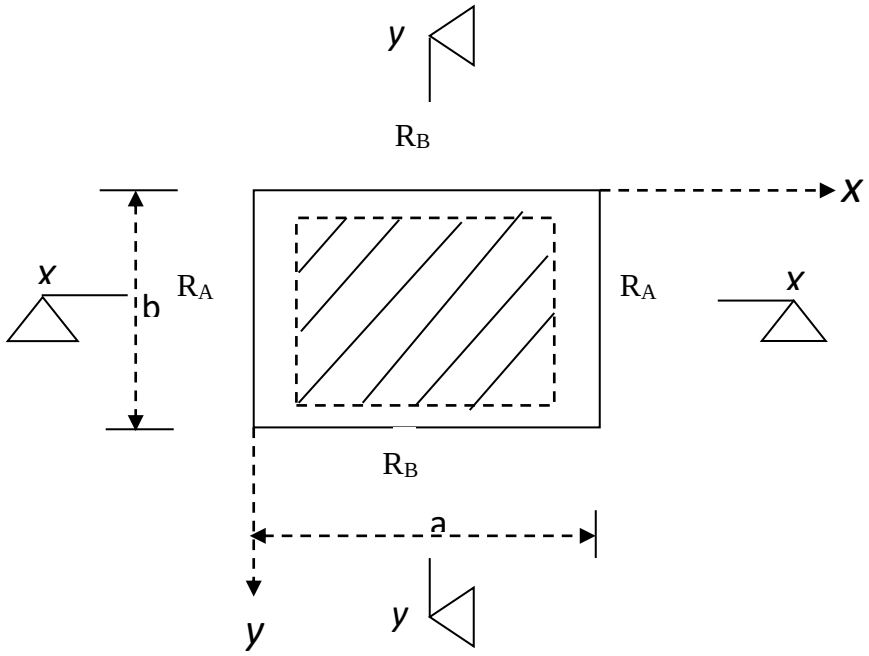
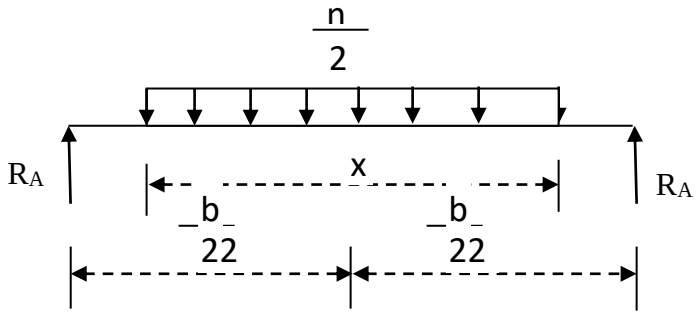


Figure 3.3: Slab subjected to uniformly distributed load P (plan)

$considering\ section\ x-x\ in\ figure$ 3.3



Taking Moment at the RHS

$$R_A * b = \frac{n}{2} * x * \frac{b}{2}$$

$$R_A = \frac{n}{4}$$

$for\ simply\ supported\ member\ with\ udl, maximum\ moment\ will\ occur\ at\ the\ mid - span, that\ is\ \ at\ {}^{b}/_{2}$

$$For\ a = b = 0.5m\ and\ x = 0.38m$$

$$M_{max} = 0.3078P(Nm)$$

(iii) FLEXURAL STRESSES FOR VARIOUS LOADS

Flexural stress, σ, is given as;

$$Flexural\ Stress, \sigma = \frac{M}{Z} \tag{3.8}$$

$Where,$

$M\ is\ the\ maximum\ bending\ moment.$

$Z\ is\ the\ section\ modulus; for\ a\ rectangle, Z = \frac{bh^2}{6}$

$Flexural\ stress, \sigma = \frac{6M}{bh^2},$

For point load

$$M_{max} = 0.0625P\ (Nm)$$

$$b = 0.5m\ and\ h = 0.1m$$

$Flexural\ Stress, \sigma = 75P\ (N/m^2)$

For Uniformly Distributed line load, udll.

$$M_{max} = 0.3289P\ (Nm)$$

$Flexural\ stress, \sigma = 394.66P\ (N/m^2)$

For Uniformly Distributed Load, udl.

$where, M = 0.3078P\ (Nm)$

$b = 0.5, and\ h = 0.1$

$$Flexural\ stress, \sigma = 369.36P(N/m^2)$$

3.2.4 COMPARATIVE ANALYSIS OF THE FLEXURAL STRENGTH OF VELVET TAMARIND STICK, STEEL REINFORCED CONCRETE SLAB ANDUNREINFORCED CONCRETE SLAB.

The results obtained from different flexural strength of velvet tamarind stick reinforced concrete slabs, concrete reinforced with 12mm steel high yield steel and unreinforced concrete were presented in Tables 4.3 – 4.18.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Presentation of Results

The results of the following tests are presented. They include:

(i) Tensile Strength test of velvet tamarind stick

(ii) Compressive Strength test of concrete used

(iii) Flexural Strength test of concrete slabs reinforced with velvet tamarind stick and steel at 75mm, 100mm, 125mm and 150mm spacing was carried out.

(iv) Sieve analysis of aggregates

(v) Bulk density of aggregates

4.1.1 Tensile Strength test result of *Velvet tamarind* stick

The result of tensile strength test of velvet tamarind stick reinforcement is presented in table 4.1.

Table 4.1: **Tensile Strength Test Result of Velvet Tamarind Stick.**

Velvet tamarind	12mm diameter
Max. Tensile Force (KN)	3.73
Tensile Strength (N/mm^2)	31.07
Yield Stress (N/mm^2)	0.00
Breaking Force (KN)	-1.28
Breaking Elongation (%)	0.00
Breaking Extension (mm)	0.00

4.1.2 Compressive Strength test of concrete used

The results of compressive strength test of concrete used are presented in Table 4.2. The area of the testing material was 150mm x 150mm.

Table 4.2: 28days Compressive Strength Test Result

SPECIMEN	Compressive load, P (KN)	Compressive Strength, P/A (N/mm^2)	Average Compressive Strength (N/mm^2)
I	554.10	24.63	25.97
II	552.92	24.57	
III	562.55	25.00	
IV	602.22	26.77	
V	560.41	24.91	
VI	610.65	27.14	
VII	595.20	26.45	
VIII	605.23	26.90	
IX	580.20	25.79	
X	620.45	27.58	

4.1.3 Flexural Strength test result of concrete slabs reinforced with velvet tamarind stick at different spacing and loading conditions

i. Point Load Condition

Under point load, the maximum flexural strength of 351.72$kN/m^2$was attained at 75mm spacing as shown in Table 4.3.

Table 4.3: Maximum Flexural Strength of the slab due to Point Load at different spacing of Stick Reinforcement

Spacing (mm)	Maximum Flexural Strength (kN/m^2)
75	351.72
100	309.36
125	293.4
150	282.84

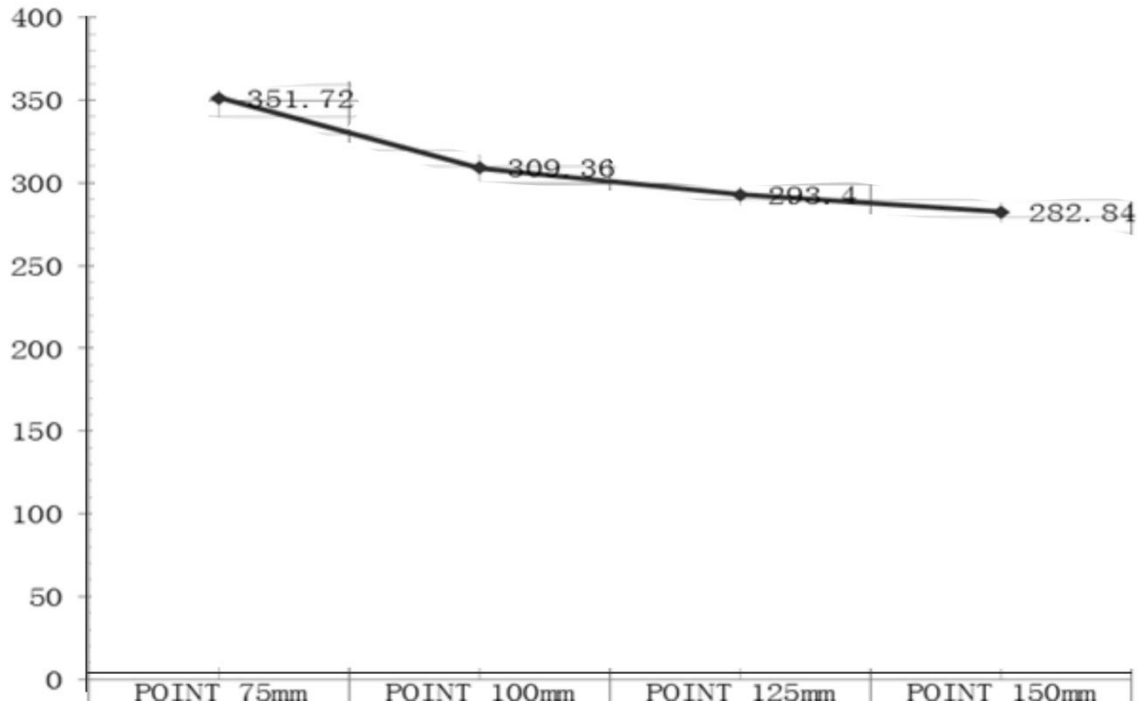


Figure 4.1: Variation of Flexural Strength of the slab due to Point Load at different spacing of Stick Reinforcement

ii. Uniformly distributed Line Load Condition

Under uniformly distributed line loading condition, the maximum flexural strength of 4846.42$kN/m^2$was attained at 75mm spacing as shown in table 4.4.

Table 4.4: Maximum Flexural Strength of the slab due to Line Uniformly Distributed Load at different spacing of Stick Reinforcement

Spacing (mm)	Maximum Flexural Strength (kN/m^2)
75	4846.42
100	4625.42
125	4576.87
150	4111.57

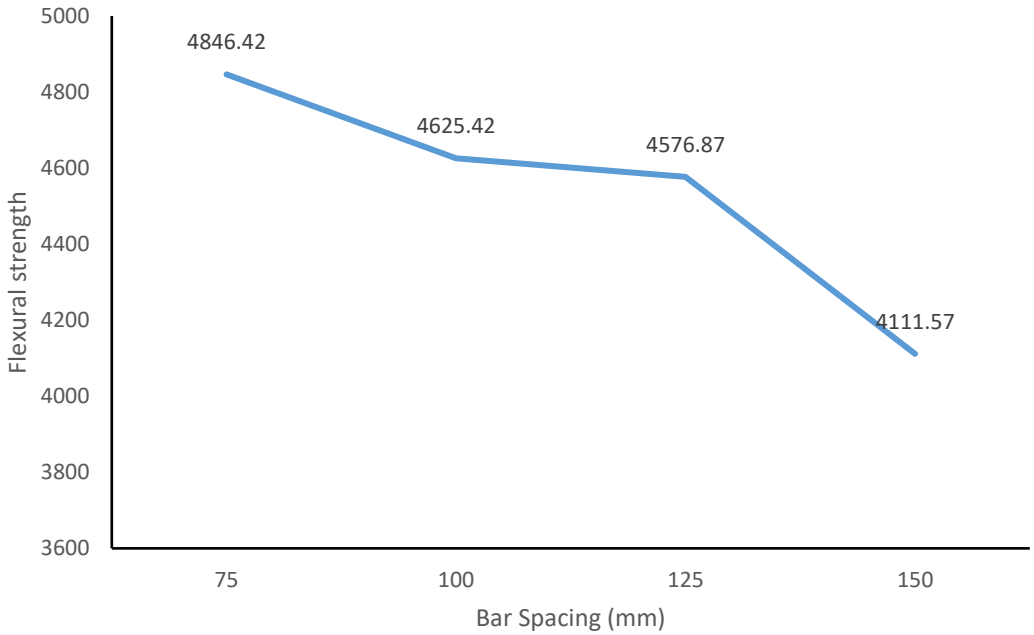


Figure 4.2: Variation of Flexural Strength of the slab under Line Load at different spacing of Stick Reinforcement

iii. Uniformly distributed Load Condition

Under uniformly distributed loading condition, the maximum flexural strength of 13742.78kN/m^{2}was attained at 100mm spacing as shown in table 4.5.

Table 4.5 Maximum Flexural Strength of the slab due to Uniformly Distributed Load at different spacing of Stick Reinforcement

Spacing (mm)	Maximum Flexural Strength (kN/m^2)
75	11813.24
100	13742.78
125	13261.13
150	12838.95

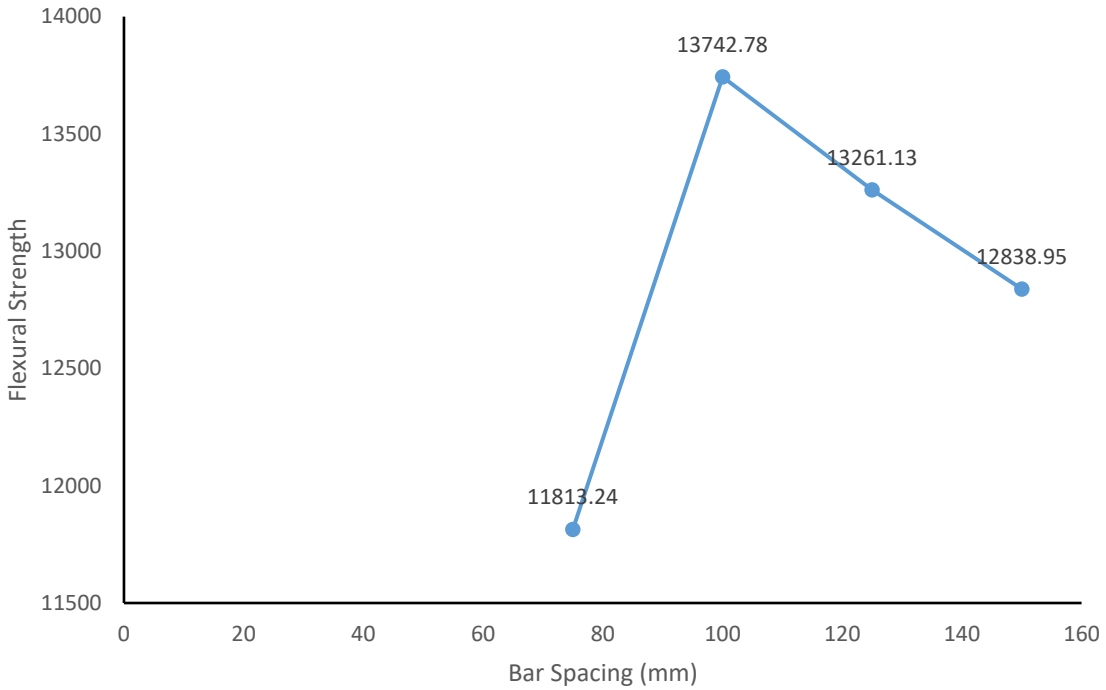


Figure 4.3: Variation of Flexural Strength of the slab due to Uniformly Distributed Load at different spacing of Stick Reinforcement

4.1.4 Flexural Strength test of concrete slabs reinforced with velvet tamarind stick, reinforced with Steel and unreinforced slabs.

Results of flexural strength test of concrete slabs reinforced with velvet tamarind stick at spacing of 75mm, 100mm, 125mm and 150mm centres, steel at 200mm and unreinforced concrete slabs subjected to loading conditions such as point load, uniformly distributed line load and uniformly distributed load are presented in Tables 4.6 – 4.17.

Table 4.6: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 75mm c/c, STEEL AT 200mm c/c AND PLAIN CONCRETE SUBJECTED TO POINT LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	AVERAGE LOAD (KN)
STICK	A1	4.595	
	A1	4.666	4.689
	A1	4.807	
STEEL	B1	6.221	
	B1	6.292	6.245
	B1	6.221	
PLAIN	C	3.676	
	C	3.747	3.841
	C	4.100	

Table4.7: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 100mm c/c, STEEL AT 200mm c/c AND PLAIN CONCRETE SUBJECTED TO POINT LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	AVERAGE LOAD (KN)
STICK	A1	4.030	
	A1	4.171	4.124
	A1	4.171	
STEEL	B1	5.868	
	B1	5.938	5.938
	B1	6.009	
PLAIN	C	3.111	
	C	3.323	3.299
	C	3.464	

Table 4.8: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 125mm c/*c*, STEEL AT 200mm c/c AND PLAIN CONCRETE SUBJECTED TO POINT LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	AVERAGE LOAD (KN)
STICK	A1	3.676	
	A1	4.100	3.912
	A1	3.959	
STEEL	B1	5.938	
	B1	5.585	5.797
	B1	5.868	
PLAIN	C	2.969	
	C	3.252	3.134
	C	3.181	

Table 4.9: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 150mm c/c, STEEL AT 200mm c/c AND PLAIN CONCRETE SUBJECTED TO POINT LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	AVERAGE LOAD (KN)
STICK	A1	3.535	
	A1	4.030	3.771
	A1	3.747	
STEEL	B1	5.726	
	B1	5.514	5.655
	B1	5.726	
PLAIN	C	3.040	
	C	3.323	3.158
	C	3.111	

Table 4.10: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 75mm c/c, STEEL AT 200mm c/c, AND PLAIN CONCRETE SUBJECTED TO UNIFORMLY DISTRIBUTED LINE LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	4.878	12.84	
	A1	4.524	11.91	12.280
	A1	4.595	12.09	
STEEL	B1	7.918	20.84	
	B1	7.635	20.09	20.527
	B1	7.847	20.65	
PLAIN	C	4.242	11.163	
	C	3.818	10.047	11.411
	C	4.949	13.024	

Table 4.11: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 100mm c/c STEEL AT 200mm c/c, AND PLAIN SUBJECTED TO UNIFORMLY DISTRIBUTED LINE LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	UDLL (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	4.595	12.09	
	A1	4.454	11.72	11.72
	A1	4.312	11.35	
STEEL	B1	7.706	20.28	
	B1	7.564	19.91	20.217
	B1	7.776	20.46	
PLAIN	C	4.030	10.61	
	C	3.605	9.49	10.980
	C	4.878	12.84	

Table 4.12: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 125mm c/*c*, STEEL AT 200mm c/c, AND PLAIN SUBJECTED TO UNIFORMLY DISTRIBUTED LINE LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	4.454	11.72	
	A1	4.242	11.16	11.597
	A1	4.524	11.91	
STEEL	B1	7.494	19.72	
	B1	7.494	19.72	19.783
	B1	7.564	19.91	
PLAIN	C	3.888	10.23	
	C	3.393	8.93	10.603
	C	4.807	12.65	

Table 4.13: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 150mm c/c, STEEL AT 200mm c/c, AND PLAIN SUBJECTED TO UNIFORMLY DISTRIBUTED LINE LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	4.171	10.98	
	A1	3.959	11.16	10.418
	A1	4.242	11.16	
STEEL	B1	7.352	19.35	
	B1	7.282	19.16	19.223
	B1	7.282	19.16	
PLAIN	C	3.676	9.67	
	C	3.181	8.37	10.043
	C	4.595	12.09	

Table 4.14: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 75mm c/c, STEEL AT 200mm c/c, AND PLAIN SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	5.938	41.12	
	A1	5.514	38.19	38.84
	A1	5.373	37.21	
STEEL	B1	9.615	66.59	
	B1	9.049	62.67	64.163
	B1	9.190	63.23	
PLAIN	C	4.595	31.82	
	C	4.737	32.80	31.983
	C	4.524	31.33	

Table 4.15: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 100mm c/c, STEEL AT 200mm c/c, AND PLAIN SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	5.726	39.65	
	A1	5.302	36.72	37.207
	A1	5.090	35.25	
STEEL	B1	9.402	65.11	
	B1	8.908	61.69	62.830
	B1	8.908	61.69	
PLAIN	C	4.242	29.38	
	C	4.524	31.33	30.190
	C	4.312	29.86	

Table4.16: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 125mm c/c, STEEL AT 200mm c/c, AND PLAIN CONCRETE SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	5.514	38.19	
	A1	5.090	35.25	35.903
	A1	4.949	34.27	
STEEL	B1	9.049	62.67	
	B1	8.766	60.71	61.20
	B1	8.695	60.21	
PLAIN	C	4.030	27.91	
	C	4.312	29.86	28.72
	C	4.100	28.39	

Table 4.17: FLEXURAL STRENGTH OF CONCRETE SLABS REINFORCED WITH VELVET TAMARIND STICK AT 150mm c/c, STEEL AT 200mm c/c, AND PLAIN CONCRETE SUBJECTED TO UNIFORMLY DISTRIBUTED LOAD.

SLAB REINFORCEMENT	MARK	LOAD (KN)	LOAD (KN/m)	AVERAGE LOAD (KN/m)
STICK	A1	5.302	36.72	
	A1	5.019	34.76	34.760
	A1	4.737	32.80	
STEEL	B1	8.766	60.71	
	B1	8.766	60.71	59.943
	B1	8.435	58.41	
PLAIN	C	3.747	25.95	
	C	4.171	28.89	27.257
	C	3.888	26.93	

4.1.5 Sieve Analysis of Aggregates

Sieve analysis result of aggregates is presented in Appendix A.

4.1.6 Bulk densities of aggregates

Results of bulk densities of concrete cubes are shown in Appendix B.

4.2 DISCUSSION OF TESTS

4.2.1 Tensile strength test results

From tensile strength test result, velvet tamarind stick can be said to be very poor in tension giving a tensile strength of 31.07N/mm² and a tensile force value of 3.73kN when compared to steel. It undergoes brittle failure. i.e., it breaks sharply without plastic deformation. This property is shown in Table 4.1of zero elongation at breaking point.

4.2.2 Discussion of compressive strength results

From this research, the concrete has a compressive strength of 25.97N/mm^2 which is satisfactory for making normal weight concrete of grade 25. After 28 days of curing, it was observed that for the three concrete cubes made from the same mix ratio, the compressive Strength increases with increase in the wet/dry bulk density and vice versa (appendix B, Table B.1 and Figure B.1). This explains the importance of adequate compaction during concrete placement. Hence, it can be said that the compressive strength of concrete is directly proportional to the level of compaction during placing. The amount of pores/air spaces is reduced during compaction, hence increasing the strength of the concrete.

4.2.3 Flexural Strength Test

i. Comparative Analysis of Flexural Strength test of Velvet tamarind stick reinforced slabs, steel reinforced slabs and unreinforced slabs (Table 4.3 to 4.17)

The steel reinforced slabs had the highest modulus of rupture in all the three cases of loadings because of the high tensile strength of steel and the perfect bond that exist between concrete paste and steel reinforcement. It was also noticed that the crack width at the bottom fiber of the steel reinforced slab was very small compared to that of the stick reinforced slab; this was due to the high tensile strength of steel compared to velvet tamarind stick, hence little tension was transferred to the concrete. In the case of uniformly distributed load, no visible crack was noticed at the bottom fiber of the slab; instead, at a point the slab could no longer take additional load. It was considered to have failed though the steel reinforcement prevented it from cracking. In the cases where the slab failed without visible crack, it could be said that it was due to “over reinforcement”.

The modulus of rupture of velvet tamarind stick reinforced slab was greater than the modulus of rupture of plain concrete slab in all cases of loadings. It was also observed that in all cases of loadings, the modulus of rupture of steel is greater than that of velvet tamarind and plain concrete.

Also, the percentage gain in stress of velvet tamarind reinforced slab over plain concrete slab was highest when subjected to uniformly distributed load with 27.53% gain over plain concrete.

The result can be seen on Table 4.3 to 4.17 (flexural strength of concrete slab reinforced with velvet tamarind stick, steel and plain)

ii. Comparative Analysis of the Maximum Flexural Strength results at Different Loading Conditions

From the results on Table 4.18, velvet tamarind stick reinforced concrete slab had an increasing percentage gain in stress over plain concrete slab when loaded with point load, uniformly distributed line load and uniformly distributed load respectively when reinforced at 75mm, 100mm, 125mm and 150mm spacing.

When compared to its steel equivalent, velvet tamarind stick reinforced slab at 75mm had 75.10% stress resistance under point load, 59.83% under uniformly distributed line load and 60.54% under uniformly distributed load. At 100mm spacing, velvet tamarind stick had 69.47% stress resistance under point load, 57.97% under uniformly distributed line load and 59.22% under uniformly distributed load. Moreover, at 125mm spacing, velvet tamarind stick had 67.49% stress resistance under point load, 58.62% under uniformly distributed line load and 58.66% under uniformly distributed load. Furthermore, at 150mm spacing, velvet tamarind stick had 66.69% stress resistance under point load, 54.20% under uniformly distributed line load and 57.99% under uniformly distributed load.

In comparison with its steel equivalent, it had a stress of 78.93%, 47.13%, and 43.67% under point load, uniformly distributed line load, and uniformly distributed respectively.

Table 4.18: MAXIMUM FLEXURAL STRENGTH AT DIFFERENT LOADING CONDITIONS

TYPE OF LOADING	TYPE OF REINFMT./ SPACING	FAILURE LOAD	MAX. MOMENT KNm	MAX. FLEXURAL STRENGTH kN/m^2	% GAIN IN STRENGTH OF VELVET TAMARINDOVER PLAIN CONCRETE	%age STRENGTH COMPARISON 0F VELVET TAMARINDR.SLAB TO STEEL R.SLAB
POINT	STICK/ 75mm	4.689	0.2931	351.72	22.07	75.10
	STEEL/200mm	6.245	0.3903	468.36		
	PLAIN	3.841	0.2401	288.12		
LINE UDL	STICK/ 75mm	12.280	0.7675	4846.42	7.61	59.83
	STEEL/200mm	20.527	1.2829	8101.19		
	PLAIN	11.411	0.7132	4503.47		
UDL	STICK/ 75mm	38.84	1.5051	14345.94	21.45	60.54
	STEEL/200mm	64.163	2.4863	23699.25		
	PLAIN	31.983	1.2393	11813.24		
POINT	STICK/ 100mm	4.124	0.2578	309.36	25.02	69.47
	STEEL/200mm	5.938	0.3711	445.32		
	PLAIN	3.299	0.2062	247.44		
LINE UDL	STICK/ 100mm	11.72	0.7325	4625.42	6.73	57.97
	STEEL/200mm	20.217	1.2636	7978.84		
	PLAIN	10.980	0.6863	4333.37		
UDL	STICK/ 100mm	37.207	1.4418	13742.78	23.24	59.22
	STEEL/200mm	62.830	2.4347	23206.89		
	PLAIN	30.190	1.1699	11150.98		

MAXIMUM FLEXURAL STRENGTH AT DIFFERENT LOADING CONDITIONS						
TYPE OF LOADING	TYPE OF REINFMT./ SPACING	FAILURE LOAD	MAX. MOMENT KNm	MAX. FLEXURAL STRENGTH kN/m^2	% GAIN IN STRENGTH OF VELVET TAMARIND OVER PLAIN CONCRETE	%age STRENGTH COMPARISON 0F VELVET TAMARIND REINFORCED SLAB TO STEEL R.SLAB
POINT	STICK/ 125mm	3.912	0.2445	293.40	24.81	67.49
	STEEL/200 mm	5.797	0.3623	434.76		
	PLAIN	3.134	0.1959	235.08		
LINE UDL	STICK/ 125mm	11.597	0.7248	4576.87	9.37	58.62
	STEEL/200 mm	19.783	1.2364	7807.56		
	PLAIN	10.603	0.6627	4184.58		
UDL	STICK/ 125mm	35.903	1.3912	13261.13	25.01	58.66
	STEEL/200 mm	61.20	2.3715	22604.83		
	PLAIN	28.72	1.1129	10608.02		
POINT	STICK/ 150mm	3.771	0.2357	282.84	19.40	66.69
	STEEL/200 mm	5.655	0.3534	424.08		
	PLAIN	3.158	0.1974	236.88		
LINE UDL	STICK/ 150mm	10.418	0.6511	4111.57	3.73	54.20
	STEEL/200 mm	19.223	1.2014	7586.55		
	PLAIN	10.043	0.6277	3963.57		

MAXIMUM FLEXURAL STRENGTH AT DIFFERENT LOADING CONDITIONS						
TYPE OF LOADING	TYPE OF REINF/ SPACING	FAILURE LOAD	MAX. MOMENT KNM	MAX. FLEXURAL STRENGTH kN/M^2	% GAIN IN STRENGTH OF VELVET TAMARIND OVER PLAIN CONCRETE	% STRENGTH COMPARISON OF VELVET TAMARIND R. SLAB TO STEEL R. SLAB
UDL	STICK/ 150mm	34.760	1.3470	12838.95	27.53	57.99
	STEEL/200 mm	59.943	2.3228	22140.55		
	PLAIN	27.257	1.0562	10067.65		

$$\%\ gain\ in\ stress\ of\ velvet\ tamarind\ reinforced\ concrete, \sigma_o, over\ plain\ concrete, \sigma_p = \frac{100(\sigma_o - \sigma_p)}{\sigma_p}$$

$$stress\ resistance\ of\ velvet\ tamarind\ reinforced\ concrete, \sigma_o, as\ a\ \%\ of\ steel\ reinforeced = \frac{100\sigma_o}{\sigma_s}$$

4.2.4 Discussion of Sieve Analysis, Slump and Water Absorption Test

Based on the sieve analysis result for sand (appendix A.1) and granite (appendix A.2), the grain size distribution curve plotted on Fig. A.1 and A.2 respectively shows that aggregate was well graded and the fine aggregate contains no silt, according to BS 812: 103:1985.

The slump was measured using the meter rule and found to be 100mm.

For coarse aggregates used in this work, the percentage of water absorption was 2.72% and according to BS 812-109 (1990), aggregates should generally have water absorption not greater than 3%. Hence the aggregate was okay for concrete making. The grading limits for fine aggregates are as shown in Table 4.17.

Table 4.19: Grading Limits for Fine Aggregates

IS Sieve designation	Percentage Passing			
	Grading Zone 1	Grading Zone 11	Grading Zone 111	Grading Zone 1V
1.18mm	30 - 70	55 - 90	75 - 100	90 – 100
600µm	15 - 34	35 - 59	60 - 79	80 – 100
300µm	5 - 20	8 - 30	12 - 40	15 – 50
150µm	0 - 10	0 - 10	0 -10	0 -15

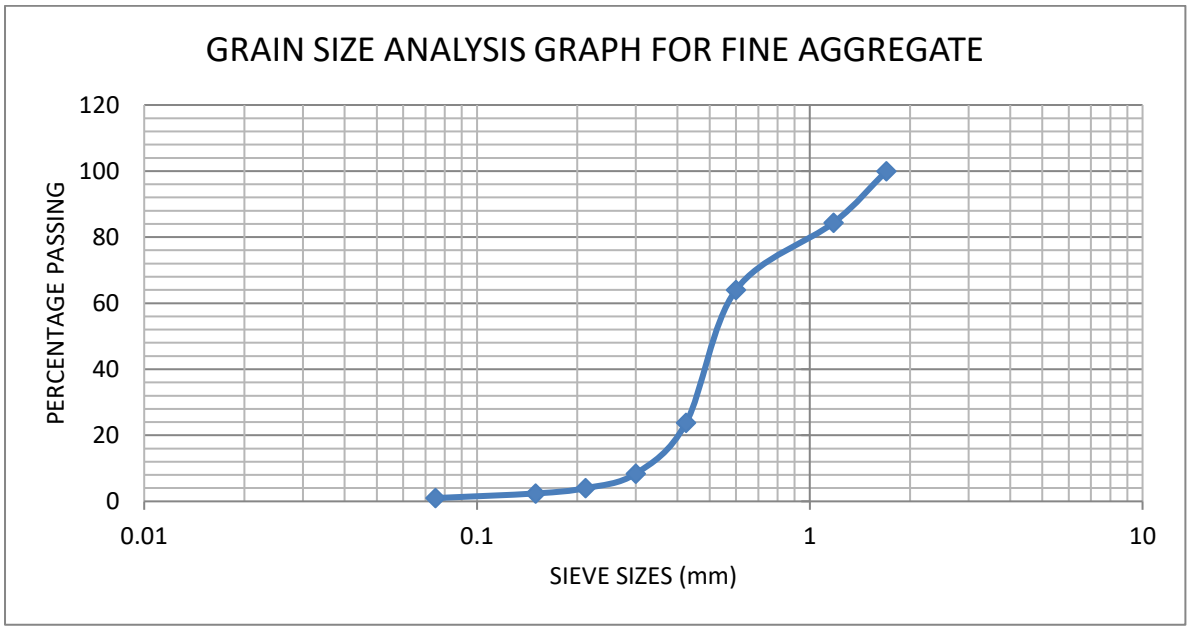


Figure A.1 Grain size analysis graph for fine aggregate.

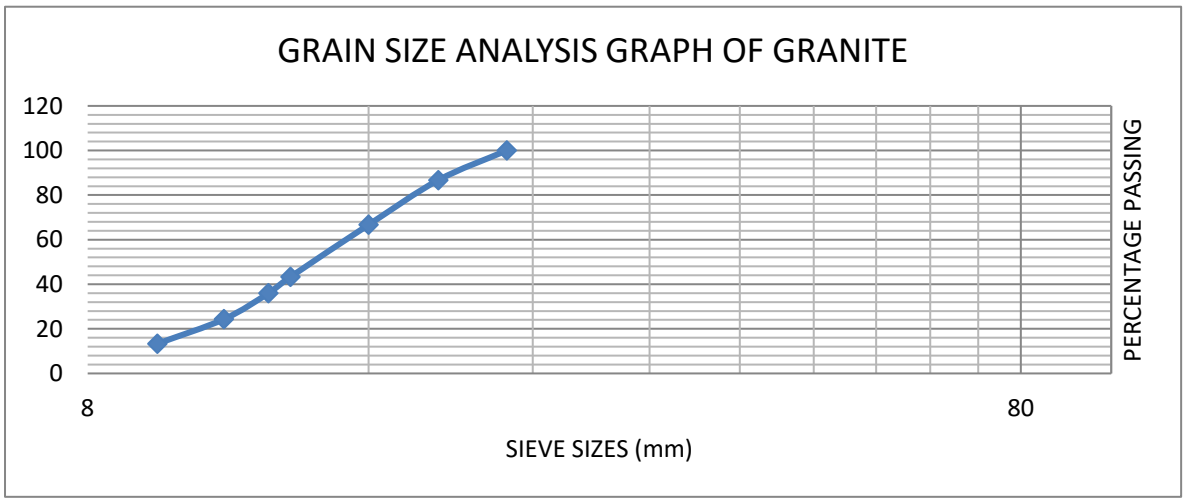


Figure A.2 Grain size analysis graph for coarse aggregate (granite).

4.2.5 Discussion of Bulk density Test

The bulk wet density of the 28-day compressive strength was obtained since some structural characteristic depends on it. The cubes for the compressive strength test were weighed in a digital weighing balance that has accuracy of 0.01g and recorded and the bulk densities of the wet samples were computed.

The dry bulk density of the sample was as well determined. This test shows how dense the components of a dry concrete mix are packed when filled in a standard manner. The test specimen used for wet bulk density test was carefully dried. It was measured and the weight recorded.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The flexural strength of velvet tamarind stick reinforced concrete slabs at different loading conditions such as point load, uniformly distributed line load and uniformly distributed load were determined.

The maximum flexural strength when velvet tamarind stick reinforced concrete slab was subjected to point load was 351.72kN/m^2 at 75mm reinforcement spacing. The maximum flexural strength when velvet tamarind stick was subjected to uniformly distributed line load was 4,846.42kN/m^2 at 75mm reinforcement spacing. Similarly, the maximum flexural strength of velvet tamarind stick was 14,345.94kN/m^2 at 75mm reinforcement spacing when subjected to uniformly distributed load. Steel reinforced concrete slabs had its maximum flexural strength at 200mm reinforcement spacing when subjected to a uniformly distributed load while unreinforced concrete (plain) slabs had a maximum flexural strength of 11,813.24kN/$m^2$when subjected to uniformly distributed load.

Velvet tamarind stick reinforced concrete slab has flexural strength of 50% and above when compared with its steel equivalent and possess similar properties when subjected to load.

The percentage gain in stress of velvet tamarind stick reinforced concrete slab over unreinforced concrete slab under uniformly distributed load was 25.01% and decreased when loaded with uniformly distributed line load and point load respectively. However, a loss in strength was observed when loaded at 150mm reinforcement spacing. Its strength can be enhanced by increasing the quantity of reinforcements. In comparing the flexural behavior of velvet tamarind stick to its steel equivalent, velvet tamarind stick was 57.99% to 66.69% close to its steel reinforced concrete slab.

It is important to note that limitations of velvet tamarind stick reinforcement and, in particular, its low elastic modulus are a limiting factor in many reinforcements uses of velvet tamarind stick for heavy construction works.

5.2 RECOMMENDATIONS

Based on the result of this research, the following recommendations are made:

i. Velvet tamarind stick can be used as reinforcement in concrete slabs where light loads are expected, light temporary military structures and cover slabs for drain, pedestrian walkway etc.

ii. For better flexural strength, the quantity of velvet tamarind stick used as reinforcement should be greater than the steel equivalent. Example, at 75mm reinforcement spacing under point load, the flexural strength of velvet tamarind stick was 351.72kN/m^2 and 468.36kN/m^2 for steel (Table 4.18).

iii. Further research should be carried out on flexural strength of velvet tamarind stick reinforced concrete when doubly reinforced.

5.3 CONTRIBUTION TO KNOWLEDGE

From this research work, the followings are the contributions to knowledge;

i The flexural strength of velvet tamarind stick reinforced concrete slab has been determined.

ii The difference between the flexural strength of velvet tamarind stick reinforced concrete slabs, reinforced concrete slabs and unreinforced concrete slabs has been determined.

iii Since there are scarcity or dearth of literature in this area, this research work has contributed to its availability.

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APPENDIX A

SIEVE ANALYSIS

SIEVE ANALYSIS RESULT

The result of the sieve analysis for sand is shown in Table A.1 and granite is shown in Table A.2. Also in Figure A.1 and Figure A.2.

Table A.1: GRAIN SIZE ANALYSIS OF FINE AGGREGATE. MASS OF SAMPLE=500G

SIEVE SIZE (mm)	MASS RETAINED (g)	%age MASS RETAINED	%age MASS PASSING
1.7	-	-	100
1.18	78	15.6	84.4
600µm	102	20.4	64.0
425µm	201	40.2	23.8
300µm	77	15.4	8.4
212µm	22	4.4	4
150µm	8	1.6	2.4
75µm	7	1.4	1
Pan	5	1.0	
TOTAL	500	100	

Table A.2: GRAIN SIZE ANALYSIS OF COARSE AGGREGATE (GRANITE). MASS OF SAMPLE=3000g

SIEVE SIZE (mm)	MASS RETAINED (Kg)	%age MASS RETAINED	%age MASS PASSING
22.5	-	-	100
19	0.40	13.33	86.67
16	0.60	20.0	66.67
13.2	0.70	23.33	43.34
12.5	0.22	7.33	36.01
11.2	0.35	11.67	24.34
9.5	0.33	11.0	13.33
Pan	0.40	13.33	-
TOTAL	3.0	100	

APPENDIX B

B.1 Bulk Densities and 28 Days Compressive Strength

SPECIMEN	SATURATED DRY Kg/m^3 (uncured)	28 DAY SATURATED SURFACE DRY Kg/m^3	COMPRESSIVE STRENGTH N/mm^2
I	2571.85	2562.96	24.63
II	2539.26	2524.44	24.57
III	2663.70	2651.85	25.00
IV	2491.85	2477.04	26.77
V	2542.22	2524.44	24.91
VI	2823.70	2814.81	27.14
VII	2441.48	2429.63	26.45
VIII	2752.59	2737.78	26.90
IX	2743.70	2728.89	25.77
X	2731.85	2722.96	27.58

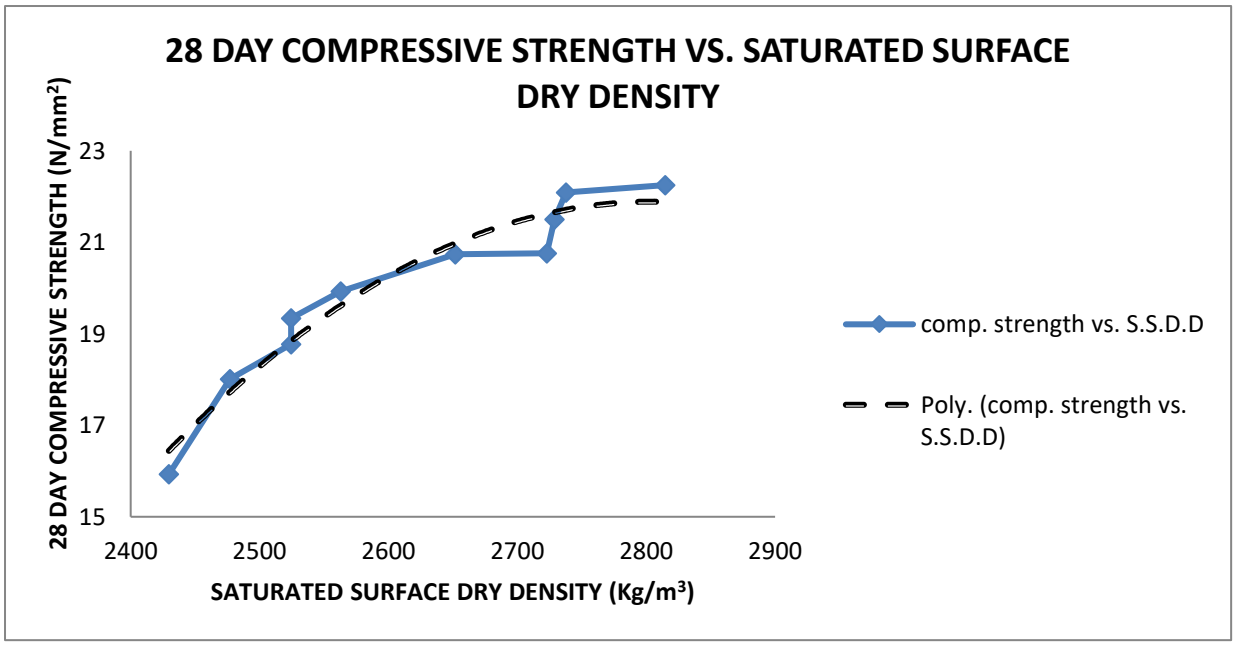

Figure B.1 28 Days compressive strength test vs. saturated surface dry density

B.2 Bulk Densities

SPECIMEN	SATURATED WET Kg/m^3	SATURATED DRY Kg/m^3	28 DAY SATURATED SURFACE DRY Kg/m^3
I	2580.74	2571.85	2562.96
II	2554.07	2539.26	2524.44
III	2675.56	2663.70	2651.85
IV	2500.74	2491.85	2477.04
V	2554.07	2542.22	2524.44
VI	2841.48	2823.70	2814.81
VII	2459.30	2441.48	2429.63
VIII	2764.44	2752.59	2737.78
IX	2758.52	2743.70	2728.89
X	2749.63	2731.85	2722.96

APPENDIX C

C.1 AVERAGE FAILURE LOAD OF SLABS REINFORCED WITH STICK AT 75mm, STEEL at 200mm AND PLAIN CONCRETE

LOADINGS	AVERAGE LOAD		
	STICK	STEEL	UNREINFORCED
POINT LOAD (KN)	4.689	6.245	3.841
LINE UDL (KN/m)	12.280	20.527	11.411
UDL (KN/m^2)	38.840	64.163	31.983

C.2AVERAGE FAILURE LOADS ON SLABS REINFORCED WITH STICK AT 100mm, STEEL AT 200mm AND PLAIN CONCRETE

LOADINGS	**AVERAGE LOADS**		
	STICK	**STEEL**	**UNREINFORCED**
POINT LOAD (KN)	4.124	5.938	3.299
LINE UDL (KN/m)	11.720	20.217	10.980
UDL (KN/m^2)	37.207	62.830	30.190

C.3AVERAGE FAILURE LOAD OF SLABS REINFORCED WITH STICK AT 125mm, STEEL AT 200mm AND PLAIN CONCRETE

LOADINGS	**AVERAGE LOAD**		
	STICK	**STEEL**	**UNREINFORCED**
POINT LOAD (KN)	3.912	5.797	3.134
LINE UDL (KN/m)	11.597	19.783	10.603
UDL (KN/m^2)	35.903	61.200	28.720

C.4AVERAGE FAILURE LOADS ON SLABS REINFORCED WITH STICK AT 150mm, STEEL AT 200mm AND PLAIN CONCRETE

LOADINGS	**AVERAGE LOADS**		
	STICK	**STEEL**	**UNREINFORCED**
POINT LOAD (KN)	3.771	5.655	3.158
LINE UDL (KN/m)	10.418	19.223	10.043
UDL (KN/m^2)	34.760	59.943	27.257