ASSESSMENT OF BAMBOO AS AN ALTERNATIVE TO STEEL REINFORCEMENT IN CONCRETE

BY

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CERTIFICATION

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DEDICATION

This work is dedicated to Almigty God my creator,the Department of Structural Engineering in the partial fufillment of the requirement for the award of Barchelor of Engineering (B.eng) Degree and also to my Parents, who have always been my pillar of strength and support for encouraging,leading and inspiring me all through this project work.

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ABSTRACT

The aim of this project is assess bamboo as an alternative to steel reinforcement in concrete structures which offers similar performance as steel reinforced concrete which can be used in areas where bamboo is abundant.

Three samples each of dimension 500×100×100mm of plain, bamboo and steel reinforced concrete beam of seven, fourteen and twenty-one days after curing were subjected to a flexural test to measure their flexural strength. This test was conducted with a four point load flexural machine, with load applied on the beams to determine the ability of the beam to withstand bending forces. The beam samples were weighed before and after curing to obtain their weight gain and water absorption rate.

The average flexural strength obtained from the plain, bamboo and steel reinforced beams of a period of seven days, fourteen days and twenty-one days was recorded. The result showed that for a period of seven days, the plain, bamboo and reinforced steel beam had a flexural strength of 9 N/mm^2, 16.67 N/mm^2 and 25 N/mm^2. Fourteen days 15N/mm^2, 23.33N/mm^2 and32.33N/mm^2. Twenty-one days 19N/mm^2, 29.67N/mm^2 and38.33N/mm^2. For water absorption the percentage is consistently higher compared to the plain and steel beam at each time interval. At seven days the water absorption was at 1.55%, and it increases further at fourteen days at 1.79% and twenty-one days 1.62%. based on the acquired results bamboo reinforced concrete can be suitable for structures such as farm sheds, rural housing and low-rise residential building for element such as walls.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

GFRP ´**-** Glass Fibre Reinforced Plastic

FRP - Fibre Reinforced Plastic

BRC - Bamboo Reinforced Concrete

BPI - Beam Performance Index

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Concrete is made up of fine (typically sand and/or crushed stone) and coarse (mainly stone or brick chips) aggregates mixed together with a binder paste (commonly Portland cement) and water. Cement hydrates to create minute opaque crystal lattices that enclose and bind the aggregate into a hard structure when it is mixed with a small amount of water(Charles N. Graham W, 1990). Silt, lignite, clay, organic contaminants, and other potentially dangerous materials should not be present in the aggregates used to make concrete. Conventional concrete mixtures can withstand compressive loads up to 4,000 psi (30 MPa). Nevertheless, any significant tension, such as that caused by bending, would rupture the microscopic hard lattice, causing the concrete to split and crack. Because of this, standard non-reinforced concrete needs to be firmly supported to stop the growth of tension. When a high-tension material, such steel, is mixed with concrete, the resultant composite material, known as reinforced concrete, is resistant to bending and other direct tensile effects in addition to compression. For use in the construction sector, a composite section with concrete that resists compression and reinforcement bars that resist tension can be created in nearly any size or shape.

Reinforcement for concrete is provided by embedding deformed steel bars or welded wire fabric within freshly made concrete at the time of casting. The purpose of reinforcement is to provide additional strength for concrete where it is needed. The steel provides all the tensile strength where concrete is in tension, as in beams and slabs; it supplements the compressive strength of concrete in columns and walls. The reinforcing steel rods, bars, or mesh absorbs the tensile, shear, and sometimes the compressive stresses in a concrete structure. Plain concrete does not easily withstand tensile and shear stresses caused by wind, earthquakes, vibrations, and other forces and is therefore unsuitable in most structural applications.

The growing interest in alternatives to steel in concrete is influenced by several factors, reflecting a shift toward more sustainable, durable, and cost-effective construction practices. These factors include:

a) Corrosion Resistance: Traditional steel reinforcement is susceptible to corrosion, especially in harsh environments or areas with exposure to saltwater.

b) Weight and Handling: Steel is heavy, and transporting and handling steel reinforcement can be labor-intensive and logistically challenging.

c) Sustainability: The production of steel involves significant energy consumption and carbon emissions.

d) Reduced Maintenance Costs: Corrosion of steel can lead to maintenance and repair costs over the lifespan of a structure.

These factors have spurred research and development of various alternative materials for concrete reinforcement:

a) Glass Fiber Reinforced Polymer (GFRP): this is a type of Fiber Reinforced Polymer (FRP) that utilizes glass fibers embedded in a polymer matrix, typically epoxy resin. GFRP provides an alternative to traditional steel reinforcement in concrete structures and offers several advantages, including corrosion resistance, high tensile strength, and lightweight properties.

b) Basalt Fiber Reinforcement: Basalt fiber reinforcement involves using fibers made from basalt rock to reinforce concrete structures. Basalt fibers are derived from the natural volcanic rock known as basalt, which is melted and then drawn into fibers. These fibers are similar to, but distinct from, glass fibers commonly used in Fiber Reinforced Polymer (FRP) materials.

c) Carbon Fiber Reinforcement: Carbon fiber reinforcement involves using high-strength carbon fibers embedded in a polymer matrix, such as epoxy, to reinforce concrete structures. Carbon fiber reinforcement is known for its exceptional strength, low weight, and resistance to corrosion.

d) Bamboo Reinforcement: Bamboo reinforcement involves using bamboo as a construction material to enhance the strength and performance of concrete structures. Bamboo has been utilized as a traditional building material in many parts of the world, and its application as reinforcement in concrete. Bamboo is a natural composite material that is helpful for constructions since it has a high strength-to-weight ratio, just like wood.Bamboo has a strength-to-weight ratio comparable to that of wood, and its strength is often akin to that of a robust hardwood or softwood (Lakkad P, 1981).

Among many uses of bamboo, Housing is one of the major areas applications especially in the wake of residential shortages around the globe. Bamboo as a building material is conventionally associated with the region of Southeast Asia and South America where climate is best suitable for its cultivation. In many of the nations, bamboo is used to hold up suspension bridges or simply make places of dwelling.

Bamboos include some of the fastest-growing plants in the world, due to a unique rhizome_dependent system. Certain species of bamboo can grow 91 centimetres (36 inches) within a 24-hour period, at a rate of almost 40 millimeters (1½ in) an hour (equivalent to 1 mm every 90 seconds).Growth up to 156 centimeters (47.6 inches) in 24 hours has been observed in the instance of Japanese giant timber bamboo.

1.2 Statement of the problem

a) Environmental Impact: The production of steel involves substantial energy consumption and carbon emissions, contributing to environmental degradation. As sustainability becomes a focal point in construction, there is a need to explore eco-friendly alternatives.

b) Cost Considerations: The cost of steel, encompassing both material and transportation expenses, can significantly impact construction budgets. Exploring cost-effective alternatives without compromising structural integrity is imperative.

1.3 Aim

The aim is to assess bamboo as analternative to steel reinforcement in concrete maintaining structural integrity and reliability in construction.

1.4 Objective

a) To determine the flexural strength of bamboo reinforced concrete beams.

b) To determine the compressive strengths of bamboo reinforced concrete columns using the rebound hammer test.

c) To assess the structural integrity of concrete beams and columns strengthened with bamboo under various loads.

d) Assess the long-term durability of bamboo-reinforced concrete, considering factors such as environmental sustainability.

e) To utilize bamboo, a rapidly renewable resource, as an eco-friendly alternative to traditional steel reinforcement.

f) Conduct a comparative analysis between bamboo-reinforced concrete and traditional steel-reinforced concrete, considering factors such as cost, environmental impact, and structural efficiency.

1.5 Scope of the study

The objective of this research is to assess alternative materials for reinforcing concrete, taking into account cost, environmental impact, and feasibility.

The study will involve durability testing, a comparative analysis with steel, and the formulation of guidelines for sustainable and economically viable construction solutions. Additionally, the research aims to uncover the inherent properties of bamboo, determine suitable bamboo species for structural purposes, and evaluate whether bamboo is a viable replacement in reinforced slabs.

1.6 Justification of the study

This is grounded in the need for sustainable and resilient construction practices. Exploring alternative materials aligns with the global push for sustainable construction practices, aiming to reduce the environmental impact of construction activities. Relying solely on steel for reinforcement creates vulnerabilities in the face of market fluctuations and supply chain disruptions. This study has the potential to make a significant contribution of more sustainable and cost-effective construction practices.

CHAPTER TWO

LITERATURE REVIEW

2.1 The use of bamboo reinforcement in various structural elements

Early studies indicated that BRC is a new area of study. Nevertheless, more experimental research is necessary before drawing any conclusions. A number of experimental studies, some of which are covered in the section that follows, have been done on the use of bamboo as a reinforcing material in various structural elements (M.Sadique Ameen, Debarati Datta, 2018).

2.2.1 Using bamboo for slab reinforcing

Experiments were carried out on thirteen simply supported one-way slabs reinforced with babadua (Thalia geniculate) bars by (Kankam and Odum-Ewuakye, 2001). On the slabs, four-point loading was used. The findings indicated that either excessive slab deflection, the flexural failure of the babadua bars under strain, or concrete crushing was the cause of the slabs' collapse. For span-to-effective depth ratios between 12.5 and 9.3 and shear span-toeffective depth ratios between 4.2 and 6.44, a short-term factor of safety of roughly 2 against cracking and 3 against collapse was obtained. Before failing, these slabs experienced a considerable amount of deflection and demonstrated an exceptionally ductile behavior. Babadua (Thalia geniculate) bamboo bars were employed as reinforcements in two-way slabs with four sides of support. When the slabs were evaluated under cyclic and monotonic loads, there was a noticeable improvement in their punched shear and flexural strengths. Furthermore, it was noted that the concrete slab reinforced with babudua bamboo provided the proper rigidity against deflection.

(Ghavami, 2005) looked into the use of Dendrocalamus giganteus bamboo in permanentshutter concrete slab panels in 2005. Concrete was filled into half-sectioned bamboos, which served as permanent shutter shapes.

The bamboo was treated with a Sikadur 32-Gel to stop it from collecting moisture from the concrete. We looked at Dendrocalamus giganteus's shear resistance to full- and half-bamboo diaphragms. With a standard variation of 2.56 MPa, the half-bamboo exhibited a shear strength of 10.89 MPa.

Bambusa vulgaris strips were utilized by (Perera and Lewangamage , 2015) to strengthen a 600 × 60 × 100 mm slab panel. They looked into how slab panels behaved flexurally when a uniform load was applied to the center. Their results showed that the slabs with steel reinforcement and bamboo reinforcement worked better together than the specimens with steel reinforcement and the specimens with bamboo reinforcement alone.

The efficiency of BRC slab panels under impact loads was investigated by (Muda et al., 2013). The after bamboo was spliced and chopped into the required sizes of 7.5 mm, 5 mm, and 2.5 mm, it was knotted to form a mesh at a spacing of 50 mm. With an OPS-to-cement ratio of 0.45 and 0.6, oil palm shells (OPS) were substituted for conventional aggregates in the concrete mix in this experiment. They came to the conclusion that the impact strength of the first crack was significantly influenced by the diameter of the bamboo, but even more so by the thickness of the slab. The impact behavior of 300 × 300 mm BRC that merely supported one-way slabs under impact loading was investigated by (Muda et al. in 2016). Buloh kuning (Bambusa vulgaris schrad) was used to prepare the bamboo-reinforcing material.

In accordance with ASTM Type I, rice husk was added to the concrete used to make the slab panels in amounts of 5% and 10% relative to ordinary Portland cement (SSPC, 2021). The impact strengths of the slab panels were investigated during the experiment in connection to the thickness and diameter of the bamboo. The bamboo diameter and slab thickness have been found to have a linear connection with the initial and final crack strengths for both types of concrete mixes. More research is required to compare the impact strength of these BRC slabs to that of standard reinforced cement concrete (RCC) slabs.

The flexural behavior of slab panels composed of bamboo and ferro-cement, with fly ash used to partially replace the cement, was examined by (Chithambaram, Kumar, 2018). Cement for the reinforcement of one-way slabs, they employed bamboo strips and chickenwire mesh. We investigated the effects of changing the thickness of the slab and partially substituting fly ash for cement. As part of the experimental program, twelve ferro-cement slab panels, each containing six slabs, were examined. The panels had dimensions of 470 × 940 mm and thicknesses of 40 and 50 mm. While six of these slabs were made with fly ash in place of 15% of the cement, the other six were made with standard mortar at a ratio of 1:3. Each slab was allowed to cure in damp gunny sacks for a full 28 days before being tested with a uniform weight distribution. The test findings showed that the ultimate loads and early cracks in both slabs were similar. Compared to the experimental maximum load capacity, the bamboo strips raised the slab's anticipated ultimate capacity at a pace roughly three times faster than the mortar and wire mesh combined.

2.2.1 Patterns, Capacity For Absorbing Energy, And Features Of Load Deformation

It was found that the concrete slab panels reinforced with grooved bamboo strips exhibited by comparing specimens of plain cement concrete and reinforced cement concrete slab specimens.

Significantly greater load-bearing bamboo reinforced permanent shutter designs for concrete slabs(Ghavami K, 2005) were studied by Mali and Datta for BRC slab panels with semicircular grooved bamboo strips (Figure 4) as reinforcements. The water absorption capacity of the bamboo strips from the surrounding concrete was decreased by using a bondtite epoxy adhesive. A total of fifteen 600 x 600 x 100 mm concrete slab panels that were tested and molded in accordance with Eurocode EN-14488-5 (2006). Investigations were conducted on the failure modes and crack deformation capacities of substituting bamboo for the primary steel reinforcement in its entirety. Furthermore, the flexural performance of the slab's structural behavior was much enhanced, and it only slightly underperformed when compared to RC slabs with mild steel bars serving as the primary reinforcement.

The structural behavior of concrete footplate foundation slabs reinforced with bamboo under focused loading was recently studied (Haryanto et al., 2021). Three different 600 x 600 x 70 mm slab panels composed of BRC and one panel of steel-reinforced concrete (SRC) were cast and analyzed. The ultimate load, stiffness, load-deflection properties, cracking pattern, energy absorption capacity, and ductility of concrete slabs were measured in order to determine the advantages of employing bamboo for reinforcement rather than steel. Gigantochloa apus, a locally available string bamboo, was utilized, and its highest portion had an average tensile strength of 138 MPa. To lessen the bamboo strips' ability to absorb water, they were properly oiled. The SNI 1974:2011 (BSN 2011) requirements were followed in the mix design and sample testing. To make sure that the bamboo and concrete interlocked properly, the volume of the coarse aggregate was split into two nominal sizes. This was made up of aggregates in the 20 mm and 10 mm diameters with a 70:30 ratio. In comparison to steel-reinforced concrete slabs, BRC slabs can reach a strength of 82%, per the findings. Additionally, the two types of samples' verified ductility was almost identical (up to 93%). According to the authors, the steel and bamboo-reinforced slabs had comparable structural performances. After considering the aforementioned points, it was determined that slab panels reinforced with bamboo strips outperformed those reinforced with steel. Grooved bamboo strips offer more strength than ordinary bamboo strips when used as reinforcement. Furthermore, bamboo needs to be treated in order to decrease its ability to absorb water and increase its durability.

2.3 Using bamboo as beam reinforcement

One of the most crucial parts of a building's construction are its beam members. They support loads that are both vertical and horizontal. Steel has historically been used to beams as reinforcement to improve their ability to support loads. Studies have been done on the improvement of plain concrete's mechanical quality through the use of naturally occurring materials in place of steel.

The flexural behavior of BRC beams of 140 × 150 × 1100 mm was examined by testing. The flexure behavior of BRC beams was examined (Mali ,Datta, 2019) using a four-point bending test .Three different types of concrete beams were the subject of experimental investigations: beams with conventional steel reinforcement, beams with bamboo reinforcement, and simple beams made of concrete (without reinforcement). To gain a better understanding of these beams' flexural behaviors, an analysis was conducted on their energy absorption capacity, ultimate load, flexural strength, shear strength, and linear stiffness. We looked at two different kinds of BRC beams with shear and longitudinal bamboo strip stirrup reinforcements. BRC beams were manufactured and examined with 2.8% and 3.8% longitudinal bamboo reinforcements in relation to the beam cross section.Plain cement concrete (PCC) beams were found to perform much better in terms of ultimate load, first crack load, ductility, and energy absorption capacity than both types of BRC beams. Furthermore, it was discovered that the RCC (reinforced cement concrete) beam with 3.8% bamboo reinforcement and the BRC beam with 3.8% bamboo reinforcement had similar flexural strengths. 1.23 percent reinforcing steel.

The flexural strength and behavior of Babadua (Thalia geniculata)-reinforced concrete beams with varying percentages of tensile reinforcement from 2.87 12.13 were examined (Kankam, Odum-Ewuakye , 2000) in sizes of 100 × 180 × 1500 mm and 135 × 235 × 1800 mm. Eight millimeter-thick Babadua strips were used to construct stirrups.The beams were evaluated for failure under cyclic and four-point loading conditions. The findings demonstrated that the shear span's diagonal tension failure or flexural failure brought on by concrete crushing was responsible for the beams' collapse. Tests on the functionality of beams that were cast more than a year ago were also carried out. There was no evidence of any degradation in the reinforcing bars, and the flexural strength of the Babadua-reinforced beams remained intact.From the discussion above, it was determined that adding bamboo strips to the beam's reinforcement enhanced its flexural capacity. 3.8% of reinforcement made of bamboo.

(Mark, Russell, 2011) compared the performance of BRC beams with different stirrup materials for rural constructions. They made stirrups out of steel, rattan cane, and bamboo, and they reinforced longitudinal stress with strips of Bambusa vulgaris. The beams underwent four-point bending tests until they broke. The least expensive and most economical way to give shear reinforcement to bamboo-reinforced beams was examined using the performance model created in this study. Based on the beam performance index (BPI), which calculates the amount of energy absorbed per unit cost of a beam, steel stirrups were found to be the most economical choice. In addition to the literature just cited, a great deal more research has been done on BRC beams; a few of the most current studies are included in Table 2.1.

Table 2.1; Recent studies on BRC beam(Ameen and Datta, 2018)

Author	Bamboo species	Bamboo treatment	Size of beam	Test results
Anto et al. (2023)	Dendrocalamus Strictus	Untreated	140 x 150 x 1100 mm	Provided strength comparable with steel reinforced beam
Al-Fasih et al. (2022)	Bambusa Heterostachya (BH), Schizostachyum Brachycladum (SB) i Bambusa vulgaris Vittata (BV)	Untreated	150 x 150 x 1000 mm	Bamboo species BV and BH can replace steel reinforcement
Budi and Rahmadi (2019)	Dendrocalamus Asper	Untreated	110 x 150 x 1700 mm	Strips with U-shape grooves improves the flexural capacity of beams
Awoyera et al. (2019)	Locally available bamboo	Bituminous adhesive	150 x 150 x 2000 mm	flexural strength increases with increase in curing age

2.4 Using bamboo to reinforce walls

One of the most crucial parts of any construction structure is the wall. They often take up most of a building's area and need a lot of constructing supplies. Typically, walls made of brick are utilized to raise a building's dead weight. On the other hand, because they use fertile soil, bricks greatly raise the cost of walls.Prefabricated wall panels with bamboo reinforcement were examined (Puri et al., 2017) these panels are helpful for low-cost housing. They made wall panels that measured 2440 mm in length, 300 mm in width, and 50 mm in thickness. The wall panels were reinforced with Bambusa balcoa species bamboo strips, which had a thickness of 3-5 mm. Each box was roughly 50 × 50 in size and featured a crisscross pattern.

Due to the cellulose content of bamboo, termite damage and fungal growth were prevented by treating the bamboo with lime water. Sikadur 32 LP epoxy, an alternative to Sikadur 32 gel, was used to lower bamboo's water absorption capacity. The wall panels were cast using a mortar mixture that had a 1:2 cement to sand ratio. The panels were subjected to transverse loading and rebound hammer testing.It was stated that the suggested wall panel system was substantially lighter, cheaper, and more energy-efficient than traditional brick walls. It reduced the cost by 40% and the dead weight of walls by 56% when compared to a brickwall designs.

(Ganesan et al., 2019) investigated the potency and characteristics of BRC during two-way in-flight maneuvers. As reinforcement, 20 mm broad Bambusa bambo splints with thicknesses ranging from 8 to 15 mm were employed. The splints were coated with varnish to provide water resistance. To improve the splints' bond with the concrete, sandblasting was done. Three BRC wall panel prototypes were taken into consideration; they had aspect ratios of 1.667, 1.818, and 2 and thickness ratios of 12.5, 13.75, and 15. The slenderness ratio was consistently 25 in all of the samples. Examination of the failure of wall panels with different aspect and thickness ratios was conducted using a uniformly distributed inplane force applied at an eccentricity of t/6. Due to the wall panels' two-way movement, it was stated that biaxial Diagonal cracks that run from the wall's corners to the panel's center originate from bending in the planes that are parallel and perpendicular to the axis of loading. The wall panel deflection increased as the aspect ratio rose. The aforementioned study states that wall panels composed of BRC with aspect ratios between 1.667–2 and thickness ratios between 12.5–15 could support loads up to 630 kN.

It is clear from the explanation above that bamboo-reinforced wall systems are lighter and less expensive than conventional wall systems. They can support heavier loads than conventional brick walls. It is necessary to apply treatment to prevent the bamboo strips from deteriorating. All things considered, they make decent substitutes for conventional brick walls.

2.5 Different bamboo codes

Bamboo has been the subject of numerous investigations for decades by various scholars looking into its potential as a reinforcement material for structural elements. Bamboo's behavior can now be easily understood thanks to the programs developed for it thanks to these investigations. A variety of techniques are offered for testing split bamboos (IS 8242, 1976).

The physical and mechanical properties of split bamboo, including its moisture content, specific gravity, static bending, compression perpendicular to the grain, and shear perpendicular to the grain, were evaluated using this standard. In a similar vein, (IS 6874, 2008) details various test procedures for figuring out the mechanical and physical characteristics of round bamboo. This standard also includes procedures for figuring out the round bamboo's density, shrinkage, and tensile strength parallel to the grains.

When bamboo is utilized for construction purposes, it must be preserved. Preservatives and treatment methods for bamboo used for structural applications, including scaffolding, home construction, walls, trusses, and posts, are provided (IS 9096, 2006). It also provides recommendations for the optimal course of action depending on a variety of bamboo uses. Among the chemicals advised for treating bamboo are coal tar creosote, copper zincnaphthyse, copper chromearsenic composition, copper chrome-boron composition, acidcurpric-chromate composition, and boric acid-borax.

A crucial code for the structural design of concrete members reinforced with bamboo is IS 15912:2018 (Structural Design Using Bamboo - Code of Practice). This standard describes board design concepts for using structural bamboo in buildings that take into account mechanical resistance, structural resistance, and structural endurance. This specification addresses the design of bamboo panels, such as split, round, and glue-laminated bamboos, that are attached mechanically or adhesively. For quality assurance, dimensional stability, minimum strength information, and grading standards, it also contains standard bamboo joints. Bamboo-using construction elements are also incorporated, such as on-site labor, offsite component production, and on-site assembly.

This code states that over 100 different species of bamboo can be found in India; some of these are solid, but the majority have hollow structures. Following a thorough testing program, sixteen bamboo species were suggested for structural use. Table 2 lists some of the species' mechanical and physical characteristics.For structural purposes, bamboo that is at least four years old and fully developed should be utilized. Bamboos that exhibit a firm texture or for structural reasons, walls that are generally thicker and have nodes at regular intervals are thought to be advantageous. Bamboo that is broken, shattered, or crumpled needs to be thrown away. Avoid dead or immature bamboo, rot, collapses, and checks that are deeper than 3 mm. It is not advised to utilize green bamboo poles in construction. Shrinkage of green bamboo can cause joints and terminals to become loose after only a few weeks of growth. In addition, green bamboo is preferred by insects and microbes than dried bamboo. Bamboo has a low natural durability that can range from 12 to 36 months, depending on the species and climate. When bamboo is used outside and in direct contact with the ground, usually breaks down in a year or two. However, in a hidden, off-the-ground setting, bamboo can last anywhere from two to five years. When fungal degradation occurs in the sclerenchymatous fibres , the bamboo's mechanical strength quickly declines. Bamboo needs to be properly preserved in order to maximize its durability.

The IS 15912 of 2018 specifies fire safety requirements for bamboo buildings. This suggests that bamboo may be made fire-resistant through chemical treatments. Bamboo's fibrous nature contributes to its high tensile strength, according to IS 15912:2018 . It can be used as an alternative to concrete reinforcement, subject to design and construction constraints.

Some bamboo species have ultimate tensile strengths under direct tension that range from

1400 to 1400, which are nearly similar to those of steel. 2000 pounds per square centimeter. Bamboo concrete members are subject to the same design rules as steel-framed concrete

structures.

Designers and researchers can use accessible international standards as a guidance. ISO 22156 – 2004 provides information on the usage of bamboo structures, including those composed of split bamboo, round bamboo, glued laminated bamboo, and bamboo panels linked together using adhesives or mechanical fasteners. It is determined by the structure's performance as well as the design's limit state. It solely deals with the requirements for a structure's mechanical resistance, longevity, and serviceability.

The test protocols for evaluating the physical properties and strength of bamboo, such as its mass per volume, moisture content, shrinkage, compression, bending, and tension, are described in ISO 22157-1:2004 . It also includes tests carried out on bamboo samples in order to gather information that may be used to identify unique strength functions and determine allowable stresses. For quality control reasons, this data can be utilized to map out the link between the mechanical properties and variables including moisture content, mass per volume, growth site, location along the clum, and the presence of internodes and nodes.

Table 2.2 Physical and mechanical properties of bamboos (IS 15912, 2019)

Species		**In air dry condition**				**In green condition**			
Properties		**Maximum compressive strength** [N/mm^2]	**Modulus elasticity x 10^3** [N/mm^2]	**Modulus of rupture** [N/mm^2]	**Density** [kg/m^3]	**Maximum compressive strength** [N/mm^2]	**Modul elastičnosti x 10^3** [N/mm^2]	**Modulus of rupture** [N/mm^2]	**Density** [kg/m^3]
		Group A							
1	Bambusa glancescens (Syn. B. nana)	-	-	-	-	53.9	14.77	82.8	691
2	Dendrocalamus strictus	69.1	15	119.1	728	35.9	11.98	73.4	631
3	Oxytenanthera abyssinicia	-	-	-	-	46.6	14.96	83.6	688
		Group B							
1	Bambusa balcooa	60.6	-	-	-	46.7	7.31	65.4	783
2	B. pallida	-	-	-	-	54	12.9	55.2	731
3	B. nutans	47.9	10.72	52.4	673	45.6	6.62	52.9	603
4	B. tulda	68	10.07	66.7	722	40.7	7.98	51.1	658
5	B. auriculata	54.3	21.41	89.1	670	36.7	15.01	65.1	594
6	B. burmanica	65.2	17.81	105	672	39.9	11.01	59.7	570

7	Cephalostachyum pergracile	49.4	19.22	71.3	640	36.7	11.16	52.6	601
8	Melocanna baccifera (Syn. M. bambusoides)	69.9	12.93	57.6	751	53.8	11.39	53.2	817
9	Thyrsotachys oliveri	58	12.15	90	758	46.9	9.72	61.9	733
			Group C						
1	Bambusa arundinacea (Syn. B. bambos)	53.4	8.96	80.1	663	35.3	5.95	58.3	559
2	B. ventricosa	-	-	-	-	36.1	3.38	34.1	626
3	B. vulgaris	-	-	-	-	38.6	2.87	41.5	626
4	Dendrocalamus longispathus	61.1	6.06	47.8	684	42.1	5.51	33.1	711

2.6 Durability of Bamboo Reinforced Concrete

When using natural fibers as building materials, durability is crucial to comprehending their long-term behavior. While bamboo has demonstrated good short-term performance in concrete structures, its long-term performance has to be understood. The use of bamboo in concrete may raise issues because of its sensitivity to insect damage and deterioration. As evidenced by several studies, these hazards can be considerably decreased with the right care and protection (Mohr, Kateeb, 2020). For instance, boron can be used to treat bamboo to make it resistant to rot and insects. Furthermore, different species of bamboo have different levels of durability.The longevity of the concrete should also be taken into account.

Concrete is susceptible to several types of degradation over time. as corrosion, cracking, and spalling of steel reinforcements. These procedures have the potential to impair long-term performance and degrade the structure.

The durability of bamboo employed as reinforcement in concrete was examined by Lima et al. For this investigation, a total of 500 specimens of Dendrocalamus giganteus bamboo were employed. To comprehend the behavior of the bamboo fibers, the inner cross section of the plant was also examined. The barker, or topmost layer of bamboo, is made up of epidermal cells, some of which include a waxy covering called cutin. Bamboo culms are segmented by diaphragms or nodes, which separate the composite material that makes them up. Sclerenchyma cells comprised the deepest layer. Parenchyma, a tissue-like matrix, envelops the sap conductors, veins, and fibers. They are positioned haphazardly in the transverse section to form the middle layer. The average composition of culms is 30% parenchyma, 60% fibers, and 10% sap conduction. These percentages have a direct impact on bamboo's mechanical and physical properties, which differ among species. It was discovered that most bamboo fibers were completely encased in parenchyma and were not in direct contact with the cementitious matrix's alkalinity. By adjusting the bamboo's tensile strength and Young's modulus, the durability was evaluated. After that, the specimens were put through a setup that involved cycles of soaking and drying. Afterwards, each sample was left to dry for a full day. The concrete samples were put in the tap, water, while individuals without concrete were submerged in a solution of calcium hydroxide. We measured the tensile strength and Young's modulus at 7, 15, 30, 45, and 60 cycles. The mechanical characteristics of the bamboo did not significantly alter.

PREVIOUS WORKS DONE

(Moh, Khatib, 2020) claimed that coatings and protective finishes that keep bamboo from soaking can boost its resistance to fungal. Another technique for treating biological deterioration is heat treatment. Bamboo becomes more resistant to fungus and insects when it is heated.

(Awolusi et al., 2022) recent research examined the flexural strength and durability of BRC prisms. They looked into BRC's ability to withstand harsh working circumstances, such as hot, salty, and acidic settings. Prisms made of BRC and steel-reinforced concrete that are rectangular in shape and measure 150 by 150 × 550 mm and M 25 grade concrete were employed in the research. The BRC samples were exposed to unfavorable working conditions for 60 days during the curing period before the flexural strength and weight loss of the concretes were assessed. With a strength loss of 0.407 N/mm2 for the BRC and 5.5 N/mm2 for the steel-reinforced concrete, it was discovered that the BRC samples had a lower slope of strength loss in the high-temperature tests than the steel-reinforced concrete samples. The BRC samples lost weight and strength more slowly, according to the tests for acid and chloride attacks. For acid assault, the weight loss for steel reinforced concrete and BRC beams was 0.95 kg and 0.54 kg, while for chloride attack, it was 0.893 kg and 0.087 kg. in that order. Even though BRC typically has less favorable working circumstances than steel-reinforced concrete, it nonetheless has a number of positive characteristics. Although these studies offer some indications of BRC's long-term effectiveness, more investigation is necessary to completely comprehend its behavior over protracted lengths of time. The longterm performance of BRC structures can be impacted by variables such loading patterns, maintenance procedures, and exposure to external conditions.

To summarise, a significant component of this research involves examining the long-term behaviour of BRC. While some studies have yielded encouraging findings, more investigation is necessary to completely comprehend the long-term effectiveness and longevity of BRC constructions.

(Chow,1914) at the Massachusetts Institute of Technology carried out the first study that was reported on the use of bamboo as a reinforcing element in concrete. Because bamboo has a high tensile strength, researchers have come up with the concept to put bamboo to the tension side of beams. As seen in Figure 1, four beams were cast; two were tested with a single concentrated load at the center, and the other two were examined in a beam-testing machine 60 days after casting with a two-point loading test. The highest load at which the bamboo and steel beams collapsed was 13.87 kN and 19.57 kN, respectively, according to the results. The safety factor for the actual maximum load divided by the theoretical load was 2.3 for the bamboo beam with a focused load at the center and 3.2 for the steel beam. The highest load at which the steel and bamboo beams failed was 30.69 kN and 20.46 kN, respectively, for the second setup where the beam was subjected to a two-point load. The steel and bamboo beams' respective factors of safety for the actual load to predicted load were 2.25 and 3.37.The behavior of bamboo was found to be similar to that of steel in concrete, suggesting that it could be utilized in small constructions in place of steel. It has been advised, therefore, that additional experimental data be needed before developing bamboo beams for practical use. Following (Chow,1914) the practicality of using bamboo as a substitute for researcher testing has been done on reinforcing in structural concrete. Bamboo has been utilized by numerous experts to fortify concrete structures for more than a century. Bamboo splints, or semiround strips, or bars, or complete culms with moderate sizes, were employed in those investigations.

One type of structural element that shifts the compressive load from a superstructure to a substructure is a column. In a study conducted under concentric stress, (Leelatanon et.al, 2010) investigated the compressive strength and ductility of small concrete columns (125 × 125 × 600 mm) that had bamboo stirrups for both longitudinal and shear reinforcement. The bamboo strips were coated with a material (Sikadur-31 CFN) that repels water. This treatment improved the ductility and strength of columns reinforced with treated strips as compared to untreated strips utilized in columns. Furthermore, in a column with comparable behavior, strength, and ductility, 3.2% treated bamboo reinforcement might take the place of 1.6% steel reinforcement.

(Akinyemi and Omoniyi, 2020) investigated the use of treated bamboo-reinforced square concrete columns measuring 150 × 150 × 600 mm for strengthening and restoration. Thirty columns were poured, ten of which were constructed with normal and modified concrete and tested to see if they would fail. Ten additional concrete columns from each concrete design mix were placed through an axial test after being preloaded to 75%, 50%, and 25% of the final load and fixed with a ferro-cement jacket. Prior to axial testing, the final ten concrete columns were ferro-cement jacketed. Both axial and lateral deflections were to be measured during the tests. Comparing the column with cement and polymer addition to the control column, it was discovered that the latter showed an average ultimate load that was 60% higher. The ferro-cement material-repaired columns exhibited the lowest axial and lateral deflections, at 72% and

93%, respectively.The concrete columns' failure patterns were typified by peeling and bulging mortar. When ferro-cement jackets and acrylic polymer were used to reconstruct the columns, their strength was almost equal to that of the original columns.

(Agarwal et al. 2014) investigated the lateral deflection, load-carrying capacity, and failure mode patterns of unreinforced, steel-reinforced, and bamboo-reinforced columns using axial compression and transverse loading trials. Brownish-looking Muli Bamboo (Melocanna bambusoides) culms were obtained when the plants were 3–4 years old. Its average tensile strength was 185.93 MPa, and its modulus of elasticity was 24.46 GPa. Bamboo was subjected to various chemical adhesives, including Tapcrete P-151, Anti Corr RC, Araldite, and Sikadur 32 gel, in order to assess their effects on the bond strength at the interface of the composite bamboo-concrete.Twenty-four 150 x 150 x 1000 mm columns were cast using concrete of M20 grade. Three columns consisting of untreated bamboo (reinforced with 8%, 5%, and 3%), treated BRC (reinforced with 8%, 5%, and 3%), and a plain column with 0.89 % steel reinforcement were cast. Based on the aforementioned findings, the strongest average binding between the bamboo and concrete was found in the Sikadur 32 gel. A weight equivalent to that carried by a steel-reinforced column might be supported by an 8 percent reinforced treated bamboo column. Due to inadequate concrete-to-bamboo adhesion, the untreated bamboo-reinforced columns supported substantially less weight than the treated columns strengthened with bamboo.

(Glenn, 1950) oversaw a US War Production Board-funded study on bamboo-reinforced concrete (BRC) in 1950. The project involved the construction of test structures and mechanical testing. Glenn drew a number of inferences from the test findings that aided in creating the design specifications for using bamboo splints as reinforcement in concrete. According to Glenn, there are problems with BRC beams under load, including as large deflection, poor ductility, and early brittle cracks. In addition, he saw bonding issues brought on by the severe swelling and cracking. of bamboo, the need to use asphalt emulsions, and a reduced ultimate load-carrying capability compared to the steel-reinforced components.

Glenn recommended employing bamboo tensile stresses of 34–41 MPa, based on the maximum stress values of 55 to 69 MPa for concrete beams with 3.4–6% bamboo reinforcement. A 4%–6% bamboo reinforcement was recommended in order to keep the beam deflection below l/360 of the span. In order to help the field crew design and construct BRC using an allowable stress technique—a procedure akin to that outlined in (ACI 318 , 1956) for steel reinforced concrete—a report was prepared in 1966 by Brink and Rush [5]. They proposed a 124 MPa ultimate capacity and a bond strength of 0.34 MPa. a reasonable 28 MPa bamboo tensile stress. It was suggested that bamboo have an elastic modulus of 17.2 GPa for the serviceability criteria.

Following the hybrid design technique developed by (Geymayer and Cox, 1970), a BRC flexural component was created as an unreinforced concrete component with a maximum tensile stress of 0.67 $\sqrt{fc'}$ (compressive strength of concrete in MPa). They discovered that a total safety factor of 2-3.5% could be attained with 3.4–5% bamboo reinforcement.

A multitude of research works detailing bamboo-reinforced flexural elements have offered proof in favor of the design approaches put out by Geymayer and Cox. Furthermore, a concrete flexural member that would otherwise be unreinforced demonstrated a capacity gain of at least 2.5 times at optimal longitudinal bamboo reinforcement ratios of 3-5 percent within one.

(Kurian and Kalam, 1977) examined structural elements composed of soil-cement material reinforced with bamboo in their early research conducted in India. That study's primary goal was to find an affordable substitute for rural homes in India. A mixture of ground soil with modest amounts of Portland cement (four to ten percent by weight of soil and water) is called soil-cement. In the middle of the 1930s, this material was frequently employed to build airports and road bases. The study looked into building walls, pavements, and soilcement foundations strengthened with bamboo. The bamboo was waterproofed by applying a layer of white lead paint after being treated with a 40% rosin in alcohol solution. It was stated that the strength of soil cement increases noticeably with age. The reason bamboo is less useful as a compressive reinforcement is its fibrous character, which contributes to its low compressive strength. The findings demonstrated that when the bamboo-reinforced soilcement material was used, the structural models performed well in terms of flexure resistance. Furthermore, it was noted that adding bamboo reinforcement to soil cement gives flexible pavements a significant amount of rigidity. Additionally, it was discovered that the bamboo reinforcement of the plain soil-cement section performed well in the resistive moment without attempting to lower the section's depth. The study concluded that the utilization of bamboo-reinforced soil cement in rural construction holds promise, particularly for the construction of walls, foundations, and pavements.

An experimental study on the feasibility of using woven bamboo mesh as cement mortar reinforcement was carried out by (Mansur and Aziz, 1983). The inclusion of The mortar's ductility, toughness, and tensile, flexural, and impact strengths were all enhanced by the bamboo mesh. Research has indicated that in a four-point bending test with 2-3% bamboo reinforcement, BRC beams perform noticeably better at supporting weights than ordinary concrete beams (Ghavami. K, 1995).

CHAPTER THREE

3.0. METHODOLOGY

In scientific experiments, various investigation methods are employed to collect, analyze, and interpret data. The choice of methods depends on the nature of the experiment and the specific research objectives which are:

a) Field Trials: Field trials refer to experiments or tests conducted in real-world, outdoor environments that closely simulate the conditions under which a product, intervention, or treatment will be used.

b) Observation: Observation is a fundamental research method involving the systematic and intentional recording of behaviors, events, or phenomena as they naturally occur in their natural setting.

c) Experimental Design and Statistical Analysis: Statistical analysis involves the application of mathematical techniques to analyze and interpret the data collected during an experiment. The goal is to draw valid and reliable conclusions from the data, assess the significance of observed effects.

3.2. Methodological Approach

The methodological approach to studying the alternative of steel with bamboo in concrete involves a systematic and structured plan to investigate their respective roles as reinforcement materials, these are:

a) Comparative Analysis: Compare their mechanical properties, durability, cost implications, and environmental impact.

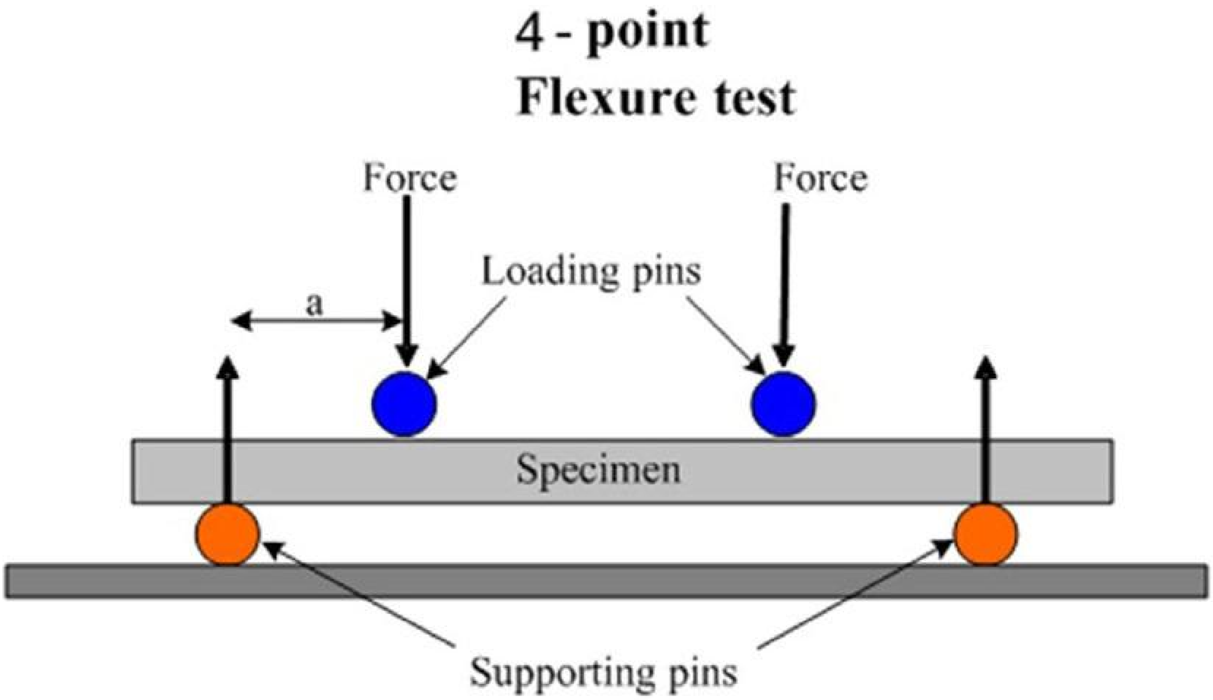
b) Testing Specimens: We Determine the types of test specimens (e.g., cubes, columns, beams) to be cast for assessing various properties such as compressive strength, tensile strength, flexural strength, and durability.

3.3.Tests Performed

a) Flexural Test: This test provides insights into how a material responds to applied bending loads, offering information on its structural performance, ductility, and failure modes. For bamboo-reinforced concrete, this test helps assess the ability of the material to withstand bending forces, simulating conditions encountered in real-world structural applications like beams and slabs.

The test was conducted on the specimen immediately after it is taken out of the curing condition. The age of the test was measured on the 7th, 14th and 21st day, and specimens for each test was prepared. The flexural test measures the force required to bend a beam under three-point loading conditions and is often used to select materials for parts that will support loads without flexing. The test is stopped when the specimen reaches 5% deflection or the specimen fails.

This test measures the force required to bend a beam under a four point loading system. This test can be used for reinforced or unreinforced materials.



This test was conducted with creating a conctere beam of plain, steel and bamboo reinforcement. In this test the beam is placed between the supporting pin and the loading pins.

Flexural test machine

Beam dimension of 500×100×100mm

a) Water Absorption Test: This test provides insights into the porosity and permeability of reinforced concrete, which are crucial factors in assessing its durability and resistance to environmental conditions.

Procedures include:

i. Prepare a samples of beam, either by cutting a piece from a concrete structure or by making a new sample.

ii. Clean the surface of the concrete sample thoroughly to remove any dirt, oil, or other contaminants.

iii. Weigh the concrete sample.

iv. Immerse the samples in water for 7,14 and 21 days with specific number immersed in water for 7, 14 and 21 days.

v. After 7, 14 and 21 days, remove the concrete samples from the water.

vi. Re-weigh the concrete samples.

vii. Calculate the water absorption percentage using the formula:

$$water\ absorption\ (\%) = \left(\frac{final\ weight - initial\ weight}{initial\ weight}\right) \times 100$$

b) Density Measurement: These measurements provide insights into the material's mass and volume, helping evaluate properties such as strength, permeability, and durability. Allow the specimens to air-dry or use a drying oven to remove any moisture from the surface, Weigh each dry specimen accurately using a scale. Record the mass of each specimen.

D = (Mc – Mm) / Vm

D = Density of the concrete

M = Weight of beam

V = Volume

3.3. Materials Used

a) Bamboo

The bamboo specimens employed in this study were sourced from the age range of 3 to 4 years, a developmental stage characterized by the optimal peak in their density, strength, and modulus of elasticity. Following the evaluation of these mechanical properties, the bamboo samples were utilized in the construction of reinforced concrete beams.

b) Water

Clean water was obtained from the water tank beside civil engineering laboratory.
It was used in all mixes during experiments as specified by BS 3148: 1980

c) Fine Aggregate

The fine aggregate used was gotten from a borrow pit in Benin City, Edo state, Nigeria

d) Coarse Aggregate

In this research, natural crushed granite sourced from Isihor in Benin City, Edo State, was employed. The sieve analysis determined a maximum particle size of 12.5 mm. The material exhibited a sharp and coarse texture, devoid of organic impurities. The grading adhered to the guidelines outlined in ASTM C330.

e) Cement

The cement investigated in this study was Ordinary Portland Cement (OPC) supplied by Dangote Cement. This Ordinary Portland Cement (OPC) adheres to the specifications outlined in BS EN 197-1:2000.

f) Steel

The study utilized 8mm mild steel rods, cut into 400mm lengths, to reinforce the structure. This specific length was selected to improve the flexural strength of the beams and to facilitate analytical procedures throughout the investigation. Additionally, a 5mm thick cover was applied to align with the 100mm width of the beams. The steel reinforcement was securely tied using wire gauges, positioned 50mm away from both ends..

g) Epoxy Resin

Epoxy resin is a two-part compound known for its strong adhesive properties and resistance to water. When applied to bamboo, epoxy resin penetrates the fibers, creating a solid, waterproof barrier that strengthens the bamboo structure. It provides excellent protection against moisture, rotting and insect damage.

h) Formwork (Mould)

Following the mixing process, the mold was loaded with a mixture of fine aggregate, coarse aggregate, cement, and water, ensuring proper compaction. Various machines and molds are accessible for beam production, such as the electric vibrating machine, hand press machine, and local steel wooden hand mold. Each molding machine yields beams of differing quality due to variations in compaction levels. The electric vibrating machine generates blocks of higher quality and strength compared to other molding methods. The utilized molds were wooden molds measuring 500×100×100.

3.4. Apparatus

a) Steel Bar Bender and Cutter: Shapes and cuts steel bars according to the required dimensions.

b) Compaction Machine: Assessing the compressive strength of concrete specimens to study material properties, behavior, and the effects of different factors on compression resistance.

c) Flexural Testing Machine: Applies bending loads to the beams, measuring the response and determining flexural properties which was noted.

d) Water Absorption Setup: Involves containers for immersing specimens in water, a scale, and equipment for measuring water absorption.

e) Measuring Tape: It was used in collecting measurement of the bamboo, moulds, steels and other materials when necessary.

f) Weighing Balance: A weighing machine was used to weigh the different materials according to their mix proportion and the cubes after curing.

g) Vibrating Machine: A vibrating machine located in the structural laboratory was used to vibrate the fresh concrete. This is done to eliminate air voids.

h) Clamps: Used to secure the formwork panels together and maintain their desired shape. Clamps are used to secure the beam to the testing apparatus and apply the desired load at specific points.

i) Concrete Mixer: The concrete material was mixed with the aid of a concrete mixer located in the structural lab of the Civil Engineering Department, University of Benin.

j) Wire Gauge: Used to for tying reinforcing bars together e.g. bamboo and steel bars.

k) Water bucket: Creates a mobile movement of water for mixing of concrete

3.5. Experimental Procedure

Bamboo-reinforced concrete building follows the same project, mix proportions, and construction techniques as those used for steel-reinforced structures.

a) Orange-brown bamboo, indicating at least 3 years of age, is selected for reinforcement. The bamboo culms are split into required dimensions using a saw cutter.

b) Bamboo-reinforced concrete beams are constructed and supported at both ends. Various aggregates (normal, lightweight, and laterite) with a maximum size of 20mm are used. Testing follows Eurocode 2 (EN 1992-1-2:2004).

c) A reference beam is reinforced with steel bars, and plain cement concrete is used for comparison. C-30 grade mix concrete is employed as recommended by Eurocode 2 (EN 1992-1-2:2004).

d) Normal concrete has a weight ratio of 1:2:3 with a water-cement ratio of 0.45.

e) Concrete compressive strength is established using cylinders with diameters of 15cm and heights of 30cm.

f) Bamboo culms with smooth 30mm-wide rectangular sections are prepared by cleaning, roughening slightly, coating with epoxy resin, sanding, wiring at 40mm intervals and re-coated.

g) After applying fine aggregate, the bamboo splints dry for 24 hours before placement in the formwork. A curing period of 14 days is observed.

h) The beam's dimensions are 500×100×100mm with a 300cm free span, cast within a form in 10cm layers and vibrated according to Eurocode 2 (EN 1992-1-2:2004) recommendations.

TABLE 3.1

Number of beams at the various testing period for the various combinations

Beams / Mix Ratio	7 Days Test	14 Days Test	21 Days test	Number of Beams
Bamboo Reinforced 1:2:3	3	3	3	9
Plain Concrete 1:2:3	3	3	3	9
Steel Reinforced 1:2:3	3	3	3	9
Total Beams	9	9	9	27

CHAPTER FOUR

4.1 RESULTS

The results represent experimental investigation, providing a comprehensive analysis of the data obtained from our laboratoryprocedures.

Table 4.0: This experiment was comducted with a ratio of 1:2:3:0.5 with beam dimensions of 500×100×100mm.

MATERIAL	WEIGHT (Kg)
Cement	78.3
Fine Aggregate	156.6
Coarse Aggregate	234.9
Water	39.15

DENSITY OF BEAM

The weight of the beams were measured to determine the initial density and the final density after curing. This invilves using the formula:

$$density = \frac{\text{mass}}{\text{volume}}$$

CONTROL BEAM

Table 4.1.1: Weight (kg) and Density(Kg/m³) of beam before and after curing for seven days

BEAM	BEFORE CURING (Kg)	DENSITY (D1) (Kg/m³)	AFTER CURING (Kg)	DENSITY (D2) (Kg/m³)
1	12.80	2560	12.95	2590
2	12.25	2450	12.40	2480
3	12.52	2504	12.67	2534

Mean density before curing (D1) = 2504.66 Kg/m³

Mean density after curing (D2) = 2534.66 Kg/m³

STEEL REINFORCED BEAM

Table 4.1.2: Weight (kg) and Density (Kg/m ³) of beam before and after curing for seven days

BEAM	BEFORE CURING (Kg)	DENSITY (D1) (Kg/m³)	AFTER CURING (Kg)	DENSITY (D2) (Kg/m³)
1	12.65	2530	12.80	2560
2	13.30	2660	13.50	2700
3	12.97	2594	13.15	2630

Mean density before curing (D1) = 2574.66 Kg/m³

Mean density after curing (D2) = 2630 Kg/m³

BAMBOO REINFORCED BEAM

Table 4.1.3: Weight (kg) and Density (Kg/m³) of beam before and after curing for seven days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING (Kg)	DENSITY 2 (Kg/m³)
1	12.60	2520	12.80	2560
2	12.85	2570	13.05	2610
3	13.10	2620	13.30	2660

Mean density before curing (D1) = 2570 Kg/m³

Mean density after curing (D2) = 2610 Kg/m³

CONTROL BEAM

Table 4.1.4: Weight (kg) and Density (Kg/m ²) of beam before and after curing for fourteen days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING(Kg)	DENSITY 2 (Kg/m³)
1	12.15	2430	12.30	2460
2	12.07	2414	12.22	2444
3	12.00	2400	12.15	2430

Mean density before curing (D1) = 2414.66 Kg/m³

Mean density after curing (D2) = 2444.66 Kg/m³

STEEL REINFORCED BEAM

Table 4.1.5: Weight (kg) and Density (Kg/m³) of beam before and after curing for fourteen days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING(Kg)	DENSITY 2 (Kg/m³)
1	12.40	2480	12.60	2520
2	12.40	2480	12.55	2510
3	12.40	2480	12.57	2514

Mean density before curing (D1) = 2480 Kg/m³

Mean density after curing (D2) = 2514.33 Kg/m³

BAMBOO REINFORCED BEAM

Table 4.1.6: Weight (kg) and Density (Kg/m³) of beam before and after curing for fourteen days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING (Kg)	DENSITY 2 (Kg/m³)
1	12.05	2410	12.25	2450
2	12.32	2464	12.53	2506
3	12.60	2520	12.85	2570

Mean density before curing (D1) = 2464.66 Kg/m³

Mean density after curing (D2) = 2508.66 Kg/m³

CONTROL BEAM

Table 4.1.7: Weight (kg) and Density (Kg/m ²) of beam before and after curing for twentyone days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING (Kg)	DENSITY 2 (Kg/m³)
1	12.30	2460	12.45	2490
2	12.23	2446	12.37	2474
3	12.33	2466	12.47	2494

Mean density before curing (D1) = 2457.33 Kg/m³

Mean density after curing (D2) = 2486 Kg/m³

STEEL REINFORCED BEAM

Table 4.1.8: Weight (kg) and Density (Kg/m³) of beam before and after curing for twentyone days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING (Kg)	DENSITY 2 (Kg/m³)
1	12.45	2490	12.60	2520
2	12.70	2540	12.90	2580
3	12.54	2508	12.75	2550

Mean density before curing (D1) = 2512.66 Kg/m³

Mean density after curing (D2) = 2550 Kg/m³

BAMBOO REINFORCED BEAM

Table 4.1.9: Weight (kg) and Density (Kg/m³) of beam before and after curing for twentyone days

BEAM	BEFORE CURING (Kg)	DENSITY (Kg/m³)	AFTER CURING (Kg)	DENSITY 2 (Kg/m³)
1	12.82	2564	13.02	2604
2	12.91	2582	13.13	2626
3	13.04	2608	13.25	2650

Mean density before curing (D1) = 2584.66 Kg/m³

Mean density after curing (D2) = 2626.66 Kg/m³

4.2 WATER ABSORPTION TEST

$$water\ absorption\ (\%) = \left(\frac{final\ weight - initial\ weight}{initial\ weight}\right) \times 100$$

Table 4.2.1: **SEVEN DAYS CONTROL BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.17
Beam 2	1.22
Beam 3	1.19

MEAN VALUE = 1.19

RANGE = 0.05

Table 4.2.2: **SEVEN DAYS STEEL REINFORCED BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.18
Beam 2	1.50
Beam 3	1.38

MEAN VALUE = 1.35

RANGE = 0.32

Table 4.2.3: **SEVEN DAYS BAMBOO REINFORCED BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.58
Beam 2	1.55
Beam 3	1.52

MEAN VALUE = 1.55

RANGE = 0.06

Table 4.2.4: **FOURTEEN DAYS CONTROL BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.23
Beam 2	1.24
Beam 3	1.25

MEAN VALUE = 1.24

RANGE = 0.02

Table 4.2.5: **FOURTEEN DAYS STEEL REINFORCED BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.61
Beam 2	1.20
Beam 3	1.37

MEAN VALUE = 1.39

RANGE = 0.41

Table 4.2.6: **FOURTEEN DAYS BAMBOO REINFORCED BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.65
Beam 2	1.70
Beam 3	1.98

MEAN VALUE = 1.78

RANGE = 0.33

Table 4.2.7: **TWENTYONE DAYS CONTROL BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.22
Beam 2	1.14
Beam 3	1.13

MEAN VALUE = 1.16

RANGE = 0.09

Table 4.2.8: **TWENTYONE DAYS STEEL REINFORCED BEAM**

BEAM	WATER ABSORPTION %
Beam 1	1.20
Beam 2	1.57
Beam 3	1.67

MEAN VALUE = 1.48

RANGE = 0.47

Table 4.2.9: **TWENTYONE DAYS BAMBOO REINFORCED BEAM**

BEAM	**WATER ABSORPTION %**
Beam 1	1.56
Beam 2	1.70
Beam 3	1.61

MEAN VALUE = 1.62

RANGE = 0.14

FLEXURAL TEST

FLEXURAL TEST FOR PLAIN CONCRETE BEAM AT SEVEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	10
2	9
3	8

Mean fleural strength = $9N/mm^2$

FLEXURAL TEST FOR PLAIN CONCRETE BEAM AT FOURTEEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	15
2	14
3	16

Mean fleural strength = $15N/mm^2$

FLEXURAL TEST FOR PLAIN CONCRETE BEAM AT TWENTY-ONE DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	18
2	20
3	19

Mean fleural strength = $19N/mm^2$

FLEXURAL TEST FOR STEEL REINFORCED BEAM AT SEVEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	24
2	25
3	26

Mean fleural strength = 25N/mm^2

FLEXURAL TEST STEEL REINFORCED CONCRETE BEAM AT FOURTEEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	32
2	31
3	34

Mean fleural strength = 32.33N/mm^2

FLEXURAL TEST FOR STEEL REINFORCED CONCRETE BEAM AT TWENTY-ONE DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	37
2	38
3	40

Mean fleural strength = 38.33N/mm^2

FLEXURAL TEST FOR BAMBOO REINFORCED CONCRETE BEAM AT SEVEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	17
2	16
3	17

Mean fleural strength = 16.67N/mm^2

FLEXURAL TEST BAMBOO REINFORCED CONCRETE BEAM AT FOURTEEN DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	22
2	23
3	25

Mean fleural strength = 23.33 N/mm^2

FLEXURAL TEST FOR BAMBOO REINFORCED CONCRETE BEAM AT TWENTY-ONE DAYS

BEAMS	FLEXURAL STRENGTH (N/mm^2)
1	30
2	28
3	31

Mean fleural strength = 29.67 N/mm^2

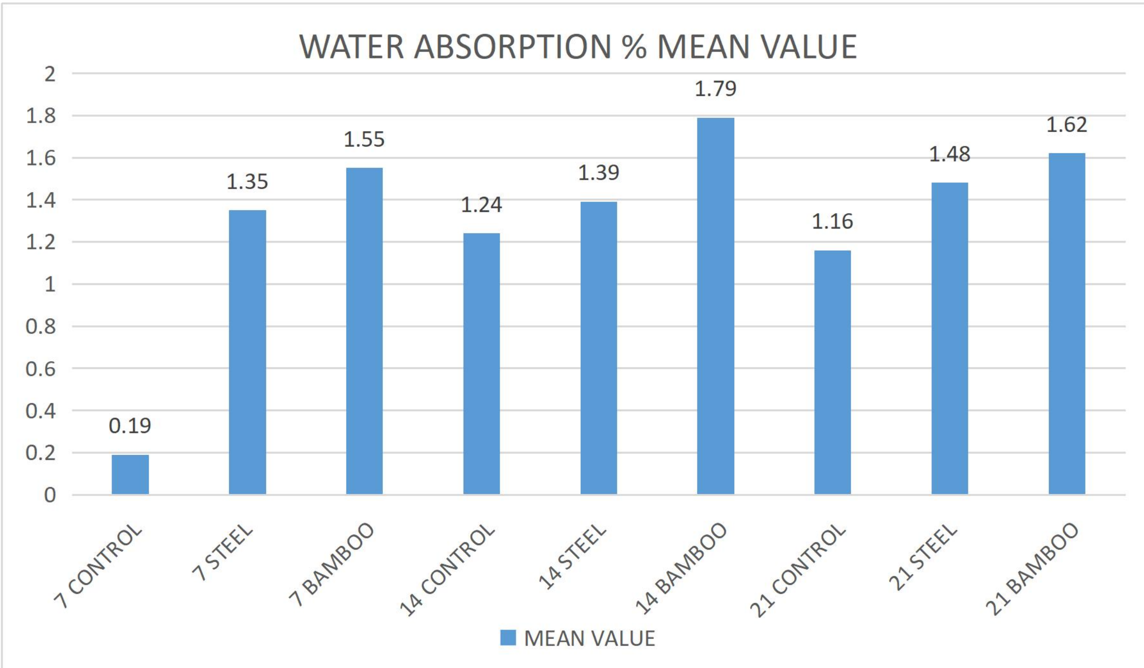
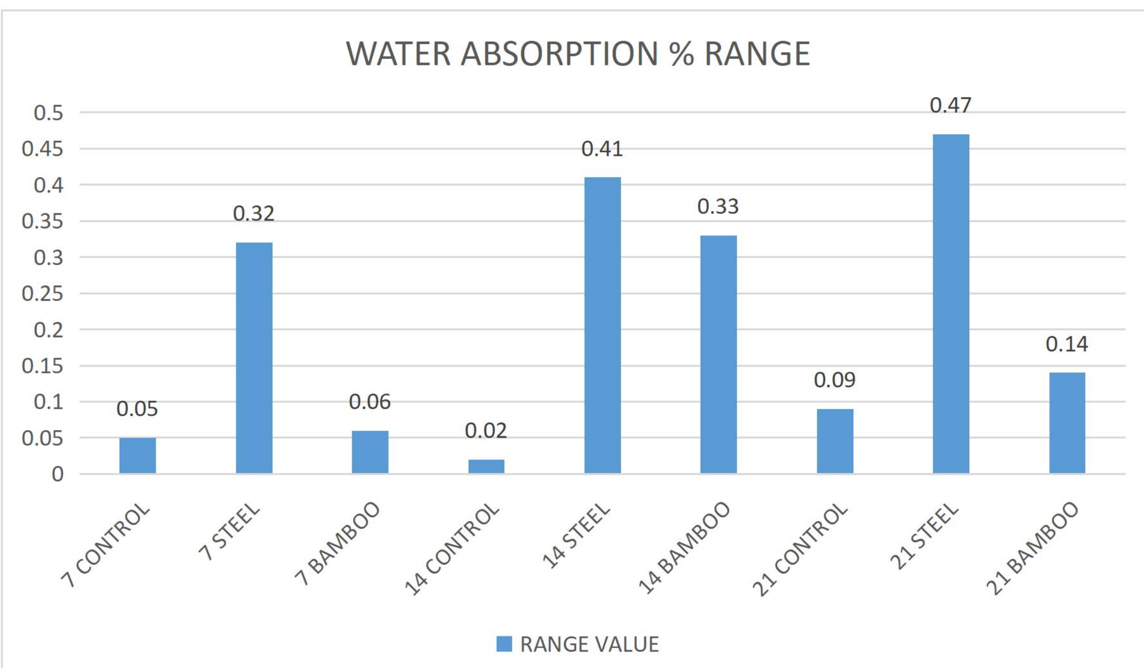
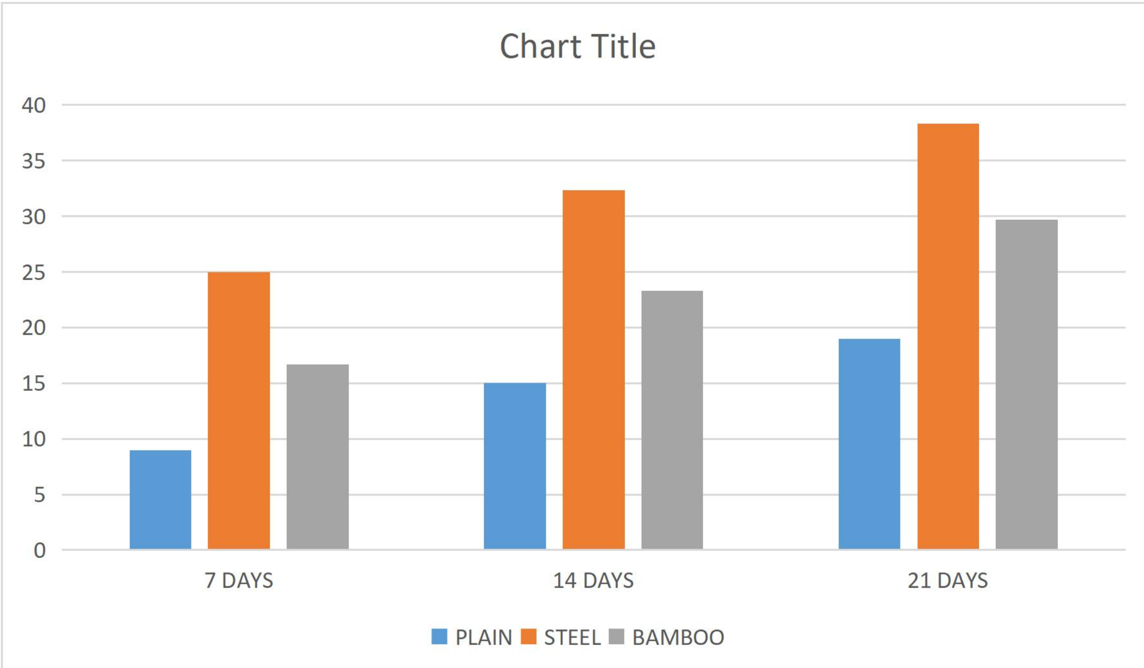


FIGURE 4.1 CHART ANALYSIS OF WATER ABSORPTION

FIGURE 4.2





AVERAGE FLEXURAL STRENGTH CHART (N/mm^2)

4.3DISCUSSION

CONTROL BEAM

The water absorption percentage mean value generally decreases over time, indicating that the concrete is becoming more resistant to water penetration as it continues to cure.

At seven days, the water absorption is relatively low (0.19%), and it increases slightly at fourteen days (1.24%) before decreasing at twenty –one days (1.16).

STEEL REINFORCED BEAM

The water absorption percentage mean value is consistently higher compared ot both the control and steel beams at each interval.

At seven days, the water absorption is relatively high (1.35%), and it remains relatively consistent at fourteen days (1.39%) and twenty-one days (1.48%).

BAMBOO REINFORCED BEAM

The water absorption percentage mean value is consistently higher bompared to both the control and steel beamat each time interval.

At seven days, the water absorption is relatively high (1.55%), and it increases further at fourteen days (1.79%) and twenty-one days (1.62%).

This results shows that bamboo reinforced beam absorbs more water than steel reinforced beam. Excess water absorption can weaken the bamboo, reducing their ability to provide reinforcement to concrete.

FLEXURAL STRENGTH

The flexural strength performed shows that for a period of 7, 14, and 21 days for steel reinforced beams the flexural strength had an average of 25N/mm², 32.33N/mm² and 38.33 N/mm².

Bamboo reinforced concrete result shows for a period of 7, 14 and 21 days. The fleural strength had an average of 16.67N/mm², 23.33N/mm², and 29.67N/mm².

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

A thorough examination of the flexural strength and water absorption properties of steel-reinforced beams and bamboo-reinforced concrete beams, offers valuable insights into how these materials perform in structural applications. Firstly, our results clearly show that steel-reinforced beams are stronger than bamboo-reinforced concrete beams at all tested time intervals (7, 14, and 21 days). This emphasizes the well-known strength advantages of using steel as a reinforcement material in concrete structures. We also noticed that both types of beams become stronger over time due to ongoing structural development and cement hydration, although this process occurs at different rates.

Our comparison of water absorption rates revealed significant differences between the two materials. While both types of beams absorbed more water than the control group, bamboo-reinforced beams consistently absorbed more water than steel-reinforced beams at all time intervals. This highlights the natural porosity and moisture-absorbing properties of bamboo, which could potentially impact its long-term durability and resistance to environmental factors like moisture and weathering.

These findings are crucial for structural engineers and construction practices. While steel-reinforced beams offer superior strength, bamboo presents an attractive option for sustainable construction, especially in regions where it's readily available and cost-effective. However, it's important to consider the higher water absorption rate of bamboo and its potential effects on long-term performance. Further research is needed to optimize bamboo's properties and address any drawbacks.

Despite its higher water absorption rates, bamboo reinforcement presents promising opportunities for sustainable construction, especially in regions where bamboo is abundant and cost-effective. Engineers and researchers should further explore and develop techniques to optimize the properties of bamboo reinforcement, potentially through treatments or modifications to enhance its durability and performance. research and development efforts are necessary to advance the understanding and application of alternative reinforcement materials like bamboo. This includes investigating techniques to mitigate the effects of higher water absorption rates, improving bonding between bamboo and concrete, and enhancing overall durability and performance.

Steel reinforcement remains a preferred choice for structural applications where high strength and durability are paramount. Engineers should continue to leverage steel reinforcement in concrete structures, particularly for projects with stringent performance requirements.

In conclusion, creating and revising industry rules and building regulations to include alternative reinforcement materials can make them more widely accepted and ensure they're used safely and effectively in construction projects. It's important for regulatory groups, industry organizations, and research institutions to work together to set standards and criteria for using bamboo reinforcement.

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APPENDIX

Binding of steel rods

Miximg of concrete

Beams

Flexural Test ongoing