REPLACEMENT OF REINFORCED STEEL WITH BAMBOO IN RCC STRUCTURE USING SBR POLYMER

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IN

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Submitted by:

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CANDIDATE'S DECLARATION

I, Pranshu Upadhyay, 2K20/STE/502, student of MTech Structural Engineering, hereby declare that the project Dissertation titled "REPLACEMENT OF REINFORCED STEEL WITH BAMBOO IN RCC STRUCTURE USING SBR POLYMER " which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "REPLACEMENT OF REINFORCED STEEL WITH BAMBOO IN RCC STRUCTURE USING SBR POLYMER " which is submitted by Pranshu Upadhyay, 2K20/STE/502 Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

The use of reinforced concrete (RC) structures is widespread in the construction industry due to their excellent strength and durability. However, the production and utilization of steel reinforcement in RC structures contribute significantly to carbon emissions and environmental degradation. Consequently, researchers and practitioners have been exploring alternative materials that offer comparable performance while being environmentally sustainable. This study investigates the feasibility of replacing reinforced steel with bamboo in RC structures, utilizing styrene butadiene rubber (SBR) polymer as a bonding agent. The research methodology involves laboratory experimentation and numerical simulations to assess the structural performance of bamboo-reinforced RC beams. Bamboo is an ideal candidate for replacing steel reinforcement due to its high strength-to-weight ratio, renewability, and minimal environmental impact. SBR polymer, a widely used bonding agent in construction applications, is employed to enhance the bond between bamboo and concrete. The experimental phase includes fabricating RC beams with different reinforcement configurations, utilizing bamboo as the primary reinforcement. The beams are subjected to load tests to evaluate their load-carrying capacity, deflection behavior, and failure modes. The performance of bamboo-reinforced beams is compared with conventional steel-reinforced beams to ascertain the viability of the proposed alternative.

Additionally, numerical simulations using advanced structural analysis software are conducted to gain further insights into the behavior of bamboo-reinforced RC structures. Finite element models are developed to simulate the response of different structural elements under various loading conditions. The simulations aid in understanding the structural integrity, deformations, and stress distribution of bamboo-reinforced RC members.

The results obtained from the laboratory tests and numerical simulations are analyzed to evaluate the effectiveness of bamboo as a replacement for steel reinforcement. The findings of this study will provide valuable information for engineers and construction professionals considering sustainable alternatives to traditional RC structures. By reducing the reliance on steel reinforcement and incorporating bamboo as a viable alternative, the construction industry can significantly mitigate its environmental impact while maintaining structural performance.

ACKNOWLEDGEMENT

I would like to express my sincere appreciation and gratitude to everyone who has contributed to the successful completion of this project. Although it may not be possible to name everyone who has helped me along the way, I would like to recognize some individuals for their exceptional support and guidance.

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CHAPTER 1

INTRODUCTION

1.1GENERAL

Introducing bamboo as a replacement for reinforced steel, along with the utilization of SBR (Styrene Butadiene Rubber) polymer, can serve as an innovative construction technique in certain applications. Bamboo, a naturally occurring material, exhibits remarkable strength-to-weight characteristics and can be harvested sustainably. SBR polymer, a synthetic rubber, provides adhesive properties and enhances structural strength.

To consider the substitution of reinforced steel with bamboo and SBR polymer, the following key aspects should be taken into account:

1 Structural properties: Bamboo possesses high tensile strength, making it suitable for load-bearing purposes. However, thorough evaluation of the specific structural requirements of the project and adherence to safety regulations and standards is crucial.

2 Preservation and treatment: Proper treatment and preservation methods are essential to enhance bamboo's durability and resistance to moisture, decay, and pests. Techniques such as pressure treatment or the use of boron-based preservatives can extend its lifespan.

3 Composite construction: Bamboo can be combined with SBR polymer to create a composite material. SBR polymer acts as an adhesive, reinforcing the bamboo structure and improving overall performance. This composite material offers improved durability and weather resistance.

4 Design considerations: When opting for bamboo as a substitute for reinforced steel, careful design considerations are important. The structural design should effectively accommodate bamboo's specific characteristics and properties, ensuring appropriate load distribution, support, and connections.

5 Cost and availability: Bamboo is generally more cost-effective than reinforced steel, making it an attractive option. Additionally, bamboo is a renewable resource that can be sustainably sourced. However, bamboo availability may vary depending on the project's location and specific requirements.

6 Compliance with codes and regulations: Prior to incorporating bamboo and SBR polymer in construction, compliance with local building codes and regulations must be verified. These codes may include specific guidelines for the use of alternative materials in structural applications.

It is crucial to note that the substitution of reinforced steel with bamboo and SBR polymer may not be applicable in all construction scenarios. Factors such as structural requirements, environmental conditions, and safety considerations should be thoroughly evaluated by structural engineers and professionals before adopting this approach.

1.2 BAMBOO AS A REINFORCEMENT

Bamboo has gained significant attention as a potential alternative to traditional reinforcements, such as steel, in construction. Its unique properties make it an attractive choice for reinforcement in various structural applications. Here are some key points about bamboo as a reinforcement:

1. Strength and Durability: Bamboo exhibits excellent tensile strength, which is crucial for reinforcing structural elements. Its fibers provide remarkable resistance to bending and stretching forces, making it suitable for load-bearing applications. Additionally, bamboo has inherent flexibility, allowing it to withstand dynamic loads and vibrations.

2. Lightweight and High Strength-to-Weight Ratio: Compared to steel, bamboo is significantly lighter while maintaining impressive strength. This characteristic makes it advantageous for reducing the overall weight of structures, especially in applications where weight is a critical consideration, such as in seismic zones or areas with poor soil conditions.

3. Sustainability and Renewable Resource: Bamboo is a highly sustainable material. It grows rapidly, with some species reaching maturity in just a few years. Harvesting bamboo for reinforcement does not require the same energy-intensive processes as steel production, contributing to lower carbon emissions. Additionally, bamboo's regenerative properties make it a renewable resource.

4. Environmental Benefits: The cultivation of bamboo requires minimal pesticides, herbicides, and fertilizers compared to other crops. As a fast-growing plant, it also contributes to carbon sequestration, helping to mitigate climate change. Choosing bamboo as a reinforcement promotes eco-friendly practices and reduces the environmental impact of construction.

5. Cost-Effectiveness: Bamboo is generally more cost-effective than traditional steel reinforcement. Its availability and affordability can significantly reduce construction costs, making it an attractive option for projects with budget constraints. This cost advantage, coupled with its excellent mechanical properties, enhances its appeal as a reinforcement material.

6. Construction Adaptability: Bamboo's flexibility allows it to be easily shaped and bent, enabling its use in various construction forms and designs. It can be utilized as individual bamboo elements or in composite structures with other materials. Bamboo-reinforced elements can be prefabricated off-site, reducing construction time and labor costs.

7. Design Considerations: When using bamboo as a reinforcement, proper design considerations are essential. Factors such as species selection, bamboo treatment for durability, and compatibility with the surrounding materials need to be evaluated. Design codes and guidelines specific to bamboo reinforcement should be followed to ensure structural integrity and safety.

In conclusion, bamboo offers a sustainable, lightweight, and cost-effective alternative as a reinforcement material in construction. Its exceptional strength, durability, and environmentally friendly properties make it an appealing option for various structural applications. However, it is important to consult with experts and adhere to appropriate design guidelines to ensure the successful and safe utilization of bamboo as a reinforcement in construction projects.

1.3 SBR POLYMER

SBR (Styrene Butadiene Rubber) polymer has gained recognition as a valuable material in the construction industry due to its unique attributes and diverse applications. It provides numerous benefits, making it an appropriate choice for various construction projects.

One notable application of SBR polymer in construction is its use as an adhesive and strengthening agent. Its adhesive properties allow for effective bonding of different materials, thereby improving their overall strength and durability. SBR polymer can be employed to connect construction elements such as concrete blocks or tiles, enhancing the structural integrity of buildings.

Furthermore, SBR polymer acts as a reinforcing agent in concrete and mortar mixes. By incorporating SBR polymer into these mixtures, the resulting material demonstrates enhanced tensile strength, flexibility, and resistance to cracking. This makes it particularly valuable in regions prone to seismic activity, where the material's ability to withstand dynamic forces is crucial.

In addition, SBR polymer exhibits excellent water resistance properties, rendering it suitable for applications requiring protection against moisture. It can be utilized as a waterproofing agent for roofs, walls, and foundations, effectively preventing water penetration and subsequent damage.

The versatility of SBR polymer extends to its ability to improve the performance of asphalt mixtures. Through the addition of SBR polymer to asphalt, the resulting mixture displays improved elasticity, adhesion, and resistance to cracking. This enhancement contributes to the durability and lifespan of roads and pavements.

It is essential to note that the proper utilization of SBR polymer in construction necessitates adherence to relevant standards, guidelines, and appropriate application techniques. Determining the appropriate dosage of SBR polymer should be based on specific project requirements, and compatibility tests ought to be conducted to ensure compatibility with other materials.

To summarize, SBR polymer offers a range of advantages in construction, including its adhesive properties, reinforcing capabilities, water resistance, and application in asphalt mixtures. When employed correctly, SBR polymer can significantly enhance the strength, durability, and overall performance of construction materials and structures.

1.4 OBJECTIVES

- To determine and compare the various strength of RCC using Steel and Bamboo as reinforcement.
- To protect the bamboo from fungal and termite attack using SBR Polymer.
- To increase the Bonding strength between Bamboo surface and concrete
- To decrease the water absorption of Bamboo

1.5 SCOPE OF WORK

1.5.1 Project Planning:

- Clearly define the project objectives and requirements for bamboo reinforcement.
- Conduct a comprehensive site survey to assess the structural elements in need of reinforcement.
- Determine the precise quantities of SBR polymer and bamboo materials based on project specifications.

1.5.2 Material Procurement:

- Source and procure top-quality SBR polymer and bamboo materials from reputable suppliers.
- Ensure that the SBR polymer meets the required reinforcement standards and specifications.

1.5.3 Bamboo Preparation:

- Carefully select appropriate bamboo culms based on their strength, size, and condition.
- Cut the bamboo culms to the required lengths, removing any unwanted sections.
- Apply suitable treatments such as preservatives or coatings to enhance the bamboo's durability and resistance to decay.

1.5.4 SBR Polymer Preparation:

- Follow the manufacturer's guidelines for preparing the SBR polymer solution.
- Ensure thorough mixing of the SBR polymer solution, eliminating any lumps or impurities.

1.5.5 Reinforcement Application:

- Thoroughly clean the surfaces of the structural elements targeted for reinforcement to remove debris and dirt.
- Apply a uniform layer of the SBR polymer solution to the bamboo surfaces using brushes or rollers.
- Position the treated bamboo accurately, ensuring proper alignment and spacing according to the design requirements.
- Repeat the process for each bamboo reinforcement element.

1.5.6 Curing and Quality Assurance:

- Allow sufficient time for the SBR polymer to cure and establish a strong bond with the bamboo.
- Implement rigorous quality control measures to ensure accurate application of the SBR polymer and bamboo reinforcement.
- Conduct periodic inspections to evaluate the integrity and effectiveness of the reinforcement.

1.5.7 Documentation and Reporting:

- Maintain comprehensive documentation throughout the project, including material specifications, application techniques, and curing procedures.
- Prepare progress reports that highlight key milestones, address challenges encountered, and document any necessary adjustments made during the project.

CHAPTER 2

LITERATURE REVIEW

Adeyeye et al., (2015), extensive analysis was performed on the utilization of bamboo as reinforcement in concrete structures. The researchers highlighted the numerous advantages associated with bamboo, including its remarkable tensile strength and rapid growth rate. These properties position bamboo as a viable alternative to conventional reinforcement materials like steel.

The authors further emphasized the significance of implementing appropriate bamboo treatment techniques to enhance its durability and ensure compatibility with concrete. Through various treatment methods such as boron impregnation, heat treatment, chemical treatment, and mechanical treatment, the researchers emphasized the importance of improving bamboo's resistance to moisture, enhancing its dimensional stability, and augmenting its resistance to biological degradation. Such treatments play a crucial role in optimizing the overall performance and long-term durability of bamboo-reinforced concrete structures.

By thoroughly examining the advantages of bamboo and the necessary treatment techniques, this comprehensive review offers valuable insights into harnessing the full potential of bamboo as a reinforcement material in concrete construction. The findings contribute to the growing body of knowledge and understanding of bamboo-reinforced concrete, paving the way for its wider adoption and implementation in sustainable and cost-effective construction practices.

Suresh and Jagannathan (2014), an experimental investigation was carried out to explore the flexural behavior of bamboo-reinforced concrete beams. The objective of their research was to assess the performance of these beams in comparison to conventional steel-reinforced beams.

The researchers meticulously evaluated the load-carrying capacity and deformation characteristics of the bamboo-reinforced beams. Their findings indicated that the bamboo-reinforced beams displayed satisfactory performance in terms of load-carrying capacity. This suggests that bamboo has the potential to serve as an effective reinforcement material in concrete structures.

Moreover, the study also highlighted the deformation characteristics of the bamboo-reinforced beams, which contribute to the overall structural integrity. The results demonstrated that the bamboo-reinforced beams exhibited deformation behavior that met the required standards, further supporting the viability of bamboo as a reinforcement option.

The experimental investigation conducted by Suresh and Jagannathan sheds light on the potential of bamboo as an alternative reinforcement material in concrete structures. The positive outcomes observed in terms of load-carrying capacity and deformation characteristics emphasize the feasibility of utilizing bamboo in structural applications, while also promoting sustainability and cost-effectiveness in construction practices.

Ramli Sulong et al. , (2012), the flexural behavior of bamboo-reinforced concrete beams was analysed. The researchers explored the impact of various factors such as bamboo content, size, orientation, and arrangement on the flexural strength and cracking behavior of the beams. The findings of the study demonstrated that the incorporation of bamboo reinforcement led to improved flexural strength and better control of cracking in concrete beams.

Dhivya and Thenmozhi (2017), the mechanical properties of bamboo-reinforced concrete beams were investigated. The researchers examined the compressive and flexural strength of these beams and made comparisons with conventional steel-reinforced beams. The findings revealed that bamboo-reinforced concrete demonstrated similar strength properties to steel-reinforced concrete, indicating the potential feasibility of bamboo as a reinforcement material.

Kartini et al., (2017), the flexural performance of bamboo-reinforced concrete beams in conjunction with steel reinforcement was examined. The research focused on analyzing the load-deflection behavior, crack width, and failure mode of the beams. The findings indicated that the simultaneous utilization of bamboo and steel reinforcement resulted in enhanced load- carrying capacity and ductility of the beams.

Ramírez-Rivera et al., (2017), the focus was on investigating the bond behavior between bamboo reinforcement and concrete. The researchers aimed to examine crucial aspects such as bond strength, slip behavior, and interface characteristics between bamboo and concrete.Through their investigation, the study revealed that the bond performance between bamboo reinforcement and concrete can be enhanced through proper surface treatment of bamboo and ensuring adequate concrete cover. These factors play a crucial role in optimizing the bond strength, which is essential for ensuring the structural integrity of bamboo- reinforced concrete elements. The findings underscore the significance of surface treatment techniques for bamboo, which can include methods such as chemical treatments or mechanical processes. These treatments are aimed at improving the compatibility and adhesion between bamboo and concrete, thereby enhancing the bond strength and reducing the potential for slippage Additionally, the study emphasized the importance of providing adequate concrete cover over the bamboo reinforcement. Sufficient concrete cover acts as a protective layer, safeguarding the bamboo from external factors and preventing premature deterioration. This, in turn, contributes to improved bond behaviour between bamboo and concrete. Overall, the research conducted by Ramírez-Rivera, Figueiredo, Barros, and Pacheco-Tergal sheds light on the significance of proper surface treatment for bamboo reinforcement and adequate concrete cover in achieving optimal bond performance. Implementing these measures can lead to enhanced bond strength, ensuring the long-term durability and structural performance of bamboo-reinforced concrete elements.

Phung-Ngoc et al., (2019) examined how the addition of bamboo fibre reinforcement affects the mechanical properties of concrete. Their research focused on evaluating the impact of bamboo fibers on compressive and flexural strength, as well as the impact resistance of concrete. The findings of the study clearly indicated that the incorporation of bamboo fibers resulted in improved mechanical properties, including increased strength and enhanced resistance to impact.

WanZ et al., (2018), the focus was on bamboo-reinforced concrete columns. The researchers employed a combination of experimental testing and numerical analysis to assess the structural behaviour and load- carrying capacity of these columns.

Through their investigation, the study demonstrated that bamboo-reinforced concrete columns exhibited satisfactory performance, showcasing their potential as an alternative to conventional steel-reinforced columns. The results indicated that bamboo, when used as reinforcement in concrete columns, can effectively withstand applied loads and contribute to the overall structural integrity.

By utilizing both experimental testing and numerical analysis, the study provided valuable insights into the behaviour of bamboo-reinforced concrete columns. This comprehensive approach allowed for a thorough evaluation of their load-carrying capacity, deformation characteristics, and structural performance.

The findings of this research highlight the potential benefits of utilizing bamboo as a reinforcement material in concrete columns. The satisfactory performance observed in the study suggests that bamboo-reinforced concrete columns can offer a viable and sustainable alternative to conventional steel-reinforced columns, contributing to cost-effectiveness and environmental considerations in construction practices.

CHAPTER-3

EXPERIMENTAL INVESTIGATION OF BAMBOO CONCRETE REINFORCED WITH SBR POLYMER

3.1 Introduction

Bamboo concrete, an environmentally friendly composite material that combines bamboo fibers and concrete, shows great promise as a sustainable option for construction. To further enhance its mechanical properties, researchers have explored the integration of SBR (Styrene Butadiene Rubber) polymer as reinforcement in bamboo concrete. This experimental study aims to evaluate the effects of SBR polymer on the performance of bamboo concrete, focusing on strength, durability, and workability.

SBR polymer is a synthetic rubber derived from styrene and butadiene copolymerization, known for its excellent adhesion and flexibility. When incorporated into concrete mixtures, it enhances tensile strength, crack resistance, and overall durability. The objective of introducing SBR polymer into bamboo concrete is to combine the advantages of both materials, creating a composite with improved properties while reducing its environmental impact.

This experimental program involves a comprehensive series of tests and evaluations to analyse the influence of SBR polymer on bamboo concrete. The research goals are as follows:

1. Material Composition: Determining the optimal dosage and proportions of SBR polymerin bamboo concrete mixtures to achieve desired mechanical properties while maintainingworkability and ease of casting.

2. Mechanical Performance: Assessing the effects of SBR polymer on compressive strength,flexural strength, and tensile strength of bamboo concrete. Experimental tests, includingcompression tests, bending tests, and pull-out tests, will quantify the load-bearing capabilities and structural behavior of the material.

3. Durability and Crack Resistance: Evaluating the resistance of SBR polymer-reinforced bamboo concrete to environmental factors such as moisture, freeze-thaw cycles, and chemical exposure. Accelerated aging tests will simulate long-term durability and assessthe material's performance.

3.2 MATERIAL TESTING

3.2.1 Cement

The concrete mixture for this project incorporated Ordinary Portland Cement as one of its primary components. Detailed information regarding the physical and chemical properties of this cement can be found in Table 3.1. It is important to note that the data presented in these tables was obtained directly from the manufacturer, ensuring its authenticity and accuracy.

Table 3.1 – Physical Properties of Cement

Fineness, m^2/kg	275
Initial setting time (in min)	154
Final setting time (in min)	261
Specific gravity	3.15
Compressive strength at 03 days (in N/mm^2)	30.5

Compressive strength at 07 days (in N/mm^2)	40
Compressive strength at 28 days (in N/mm^2)	50.5

3.2.2 Fine aggregate

For this research project, fine aggregate was sourced locally and specifically consisted of sand. The determination of the fineness modulus of the fine aggregate followed the guidelines outlined in ASTM C136 [4]. The fine aggregate was tested in a surface saturated dry (SSD) condition, yielding a fineness modulus value of 2.69.

Table 3.2 – Physical Properties of Fine aggregate

Specific gravity	2.57
Bulk Density, gm/cc	1.75
Water absorption, %	1.24
Moisture content, %	Nil
Silt content, %	4.2

3.2.3 Coarse aggregate

In the preparation of the sample beam, crushed stone was employed as the coarse aggregate. The maximum size of the coarse aggregate used was 20 mm. The gradation of the coarse aggregate adhered to the guidelines outlined in ASTM C136 [4]. The coarse aggregate was in a surface saturated dry (SSD) condition during the process.

Table 3.3 – Physical Properties of Coarse aggregate(20mm)

Specific gravity	2.67
Bulk Density, gm/cc	1.56
Water absorption, %	0.53
Moisture content, %	Nil

Table 3.4 – Physical Properties of Coarse aggregate(10mm)

Specific gravity	2.66
Bulk Density, gm/cc	1.57
Water absorption, %	0.81
Moisture content, %	Nil

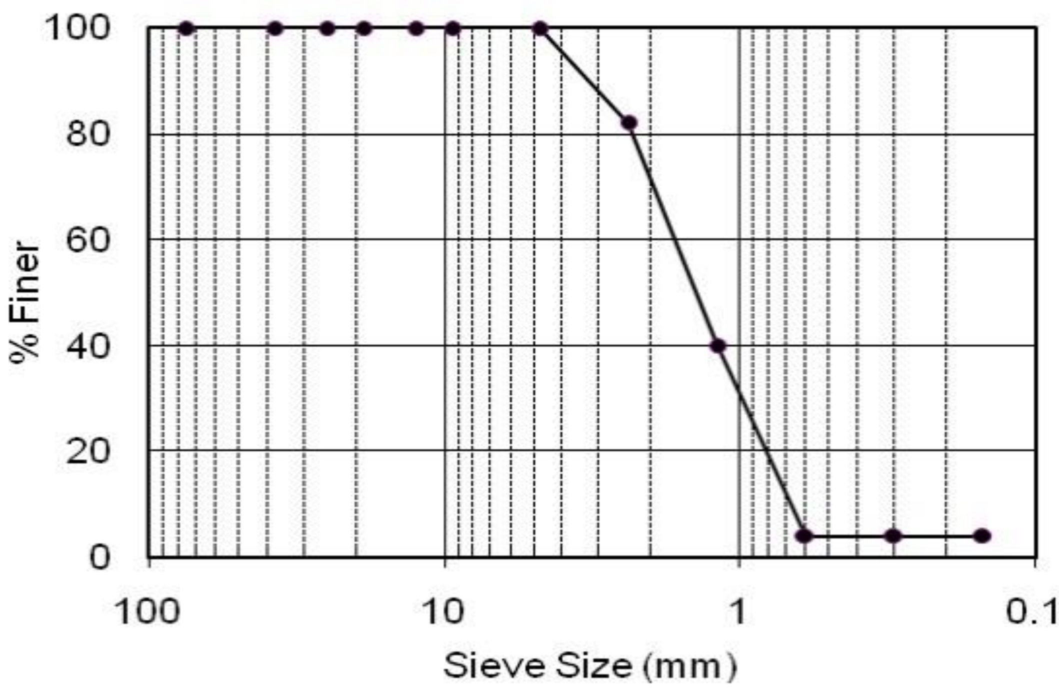

Fig. 3.1 Gradation curve of coarse aggregate

3.2.4 Bamboo

Bamboo culms possess cylindrical shells and are segmented by solid transversal diaphragms known as nodes. The distribution of strength in the bamboo culms is more consistent at the lower sections compared to the top or middle sections. This is attributed to the higher bending stress experienced by the top portion of the culms due to wind forces.

The sticks of Bamboo which are used for study are shown in Fig. 3.2.

Fig. 3.2 Bamboo Specimen

3.2.5 SBR POLYMER

For this study SBR POLYMER LATEX has been purchased from the market which is manufactured by CICO company as shown in Fig 3.3.

Fig. 3.3 SBR Polymer

3.2.6 WATER

For this research project, locally available potable water is used.

3.3 EXPERIMENTAL STUDY

3.3.1 Concrete Compressive strength (1 : 1.5 : 3)

In order to evaluate the compressive strength of concrete, we aim to produce concrete cubes with specific proportions. The mixture will consist of 1 part cement, 1.5 parts sand, and 3 parts coarse aggregates, where the coarse aggregates have a nominal size of 20mm. To enhance the properties of the concrete, Grade 43 Ordinary Portland Cement (OPC) will be utilized. Additionally, we will incorporate SBR Polymer, a synthetic additive known for improving the performance of concrete.

The objective is to assess the compressive strength of the concrete cubes at two different time intervals: 7 days and 28 days. By conducting tests at these intervals, we can examine the strength development and evaluate the long-term durability of the concrete.

The inclusion of SBR Polymer in the concrete mix is intended to enhance various aspects such as workability, cohesion, and bonding properties. SBR Polymer acts as a reinforcing agent, improving the overall strength and durability of the concrete. The compressive strength tests will provide valuable insights into the effectiveness of the SBR Polymer in enhancing the performance of the concrete cubes over time.

By analyzing the compressive strength results at both the 7-day and 28-day marks, we can draw conclusions about the rate of strength gain and determine the suitability of the concrete mixture for specific applications.

Concrete samples for compressive strength test are shown in Fig. 3.4

Fig. 3.4 Concrete Samples for Compressive Strength Test

3.3.2 Tensile Strength Test on Bamboo

Conducting a comprehensive tensile strength test on bamboo is crucial for understandingits mechanical properties and evaluating its structural suitability for various applications. Bamboo, known for its natural strength and versatility, is extensively used in construction,furniture making, and other industries.

To perform the tensile strength test, bamboo samples of standardized dimensions will be carefully selected and prepared. The samples will be conditioned to ensure consistent moisture content, eliminating potential variations in the test results. Special attention willbe given to avoiding any external factors that could affect the accuracy and reliability ofthe test.

The bamboo samples will be subjected to an axial tensile force applied gradually until fracture occurs. The force applied during the test will be measured accurately using specialized testing equipment. Simultaneously, strain gauges will be used to monitor thedeformation and elongation of the bamboo during the test.

By measuring the maximum force at which the bamboo sample fractures and analyzing the corresponding elongation, the tensile strength of the bamboo can be determined. This information is vital for assessing the load-bearing capacity and overall performance of bamboo in structural applications.

Moreover, the tensile strength test will help identify the specific failure modes of bamboounder tension, such as fiber rupture or shearing. Understanding these failure mechanisms is essential for engineering purposes and designing bamboo-based structures that can withstand anticipated loads and environmental conditions.

The results of the tensile strength test on bamboo will contribute to expanding our knowledge of bamboo's mechanical behavior and aid in its effective utilization in various fields. Additionally, the data obtained from the test will assist engineers, architects, and designers in making informed decisions regarding the appropriate applications and design considerations when incorporating bamboo as a structural material. To ensure the appropriate selection of bamboo culms for reinforcement in concrete structures, several criteria should be taken into account:

1. Age and Colour: Only bamboo culms that are at least three years old and exhibit a distinctbrown colour should be used. This criterion indicates that the bamboo has reached a levelof maturity and strength suitable for reinforcement purposes.

2. Length and Diameter: The selection should prioritize the longest culms available with a significant diameter. Longer and thicker culms possess greater structural integrity and arebetter suited for providing reinforcement in concrete structures.

3. Seasoning: It is important to avoid using green, unseasoned bamboo culms. Green bamboo, which has not undergone the drying and curing process, may possess higher moisture content and reduced strength, making it less reliable for reinforcement applications.

4. Harvest Timing: Bamboo that has been cut during spring or early summer should be avoided. This is because culms harvested during this period tend to have increased moisture content in their fibers, which can result in reduced strength.

In this particular research study, the selection process involved choosing three-year-old bamboo plants with a pronounced brown color. From each selected plant, samples measuring 1 meter in length were collected specifically from the bottom portion. The samples were taken from culms with three and five nodes, allowing for a comprehensiveexamination of the bamboo's structural properties.

In construction projects, bamboo sticks are generally more commonly used compared towhole culms. After harvesting bamboo, it is essential to undergo a drying and seasoningprocess for a period of three to four weeks before utilizing it.

To conduct the tensile strength test, it was necessary to prepare the bamboo samples. Thepreparation involved cutting bamboo sticks with a length of 1 meter and a width of approximately 20 mm. These sticks were then allowed to dry and season for a duration of30 days, as depicted in the accompanying figure. It is important to note that due to bambooobeing a natural material, the thickness of the sample may vary along its length, as strict control over its properties is challenging. Consequently, measurements were taken at fivedifferent points along the sample's length to determine the average dimensions of the sample.

Throughout the seasoning period, all bamboo sticks were adequately supported at regular intervals to prevent warping or distortion, ensuring that the samples maintained their structural integrity. This precautionary measure was taken to minimize any potential irregularities that could affect the accuracy and reliability of the subsequent tensile strength test.

Tensile strength test of Bamboo stick is shown below in Fig. 3.5

Fig. 3.5 Tensile Strength Test of Bamboo Stick

3.3.3 STUDY AND ANALYSE THE DIRECT EFFECT OF SBR POLYMER ON BAMBOO REINFORCEMENT

For the purpose of studying the direct impact of SBR Polymer on bamboo, a specific procedure was followed. Bamboo culms were encased with wire to ensure sufficient bond strength between the bamboo and the coating material. Subsequently, the bamboo-wire composite was coated with SBR Polymer.

To allow for proper analysis of the effects of the SBR Polymer, the treated bamboo-wirecomposites were left undisturbed for a period of 15 days. This duration was selected to provide ample time for any potential changes or interactions to occur between the SBR Polymer and the bamboo.

During this period, various factors were monitored, such as the physical appearance of the bamboo, any observable changes in its structural integrity, and the overall condition of the SBR Polymer coating. These observations served as key indicators to assess the direct effect of the polymer on the bamboo.

By examining the treated bamboo samples after the designated 15-day period, researchersaimed to gain insights into how the SBR Polymer influenced the bamboo's properties. This investigation would provide valuable information regarding the potential benefits and drawbacks of using SBR Polymer as a coating material for bamboo, particularly in terms of enhancing its strength, durability, or other desirable characteristics.

Observation setup to analyse the direct effect of SBR Polymer on Bamboo stick sample wrapped by welded wire for better bonding strength is shown below in Fig. 3.6.

Fig. 3.6 Direct effect of SBR Polymer on Bamboo

Through careful analysis and evaluation of the treated bamboo samples, I could draw conclusions and make informed decisions about the feasibility and potential applications of incorporating SBR Polymer in bamboo-related projects.

3.3.4 FLEXURAL STRENGTH TEST ON RCC BEAM (M-30)

To assess the flexural strength of an RCC (Reinforced Concrete Cement) beam, a comprehensive test is conducted. The flexural strength test is crucial in determining the beam's ability to withstand bending forces and its overall structural performance.

During the test, a sample RCC beam is carefully selected, prepared, and positioned on a testing apparatus. The beam is then subjected to a gradually increasing load at its midpointuntil it reaches failure. The applied load induces bending forces that cause the beam to deform, and the response is recorded and analyzed.

Specialized testing equipment, such as a universal testing machine, is employed to accurately measure and apply the load. Strain gauges and displacement sensors are strategically placed on the beam to monitor and capture its behavior under the applied load. These measurements provide valuable data on deflection, strain, and ultimate failure point.

The test is conducted following standardized procedures and guidelines to ensure consistency and reliability of results. Factors such as beam dimensions, concrete strength, and reinforcement details are carefully considered to simulate real-world conditions accurately.

By analysing the load-deflection curve obtained from the test, key parameters can be derived, including the maximum load sustained by the beam, the corresponding deflection, and the ultimate flexural strength. These parameters serve as critical indicators of the beam's ability to resist bending forces and its overall structural integrity.

The results of the flexural strength test on the RCC beam provide valuable information for structural engineers and designers. This data aids in optimizing beam design, determining load capacities, and ensuring the safety and performance of concrete structures in real-world applications, such as buildings, bridges, and infrastructure projects.

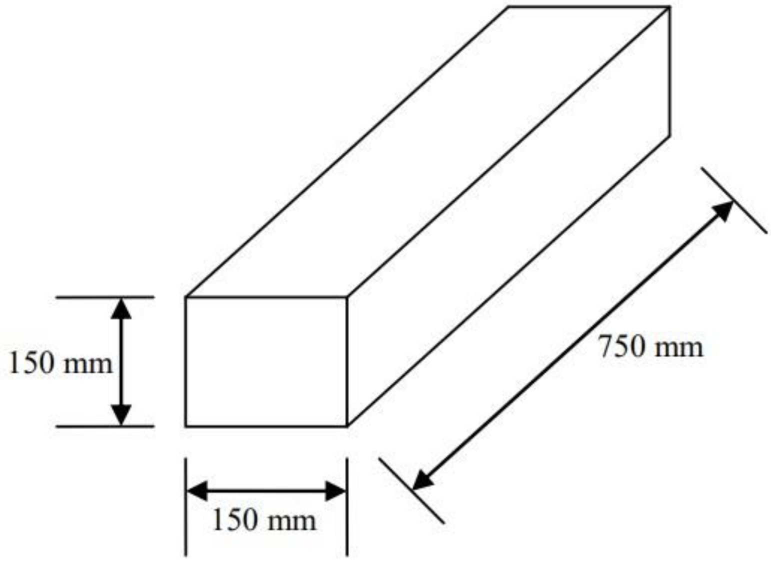

Fig. 3.7 Dimension of Sample Beam

3.3.5 Detailing of RCC Beam

RCC Beam (longitudinal reinforcement of 4number,600 mm length of 12mm dia (Fe500) and Transverse reinforcement 100mm length of 8mm dia (Fe500) at 100mm c/c spacing.

Fig. 3.8 Beam Samples for flexural Strength Test

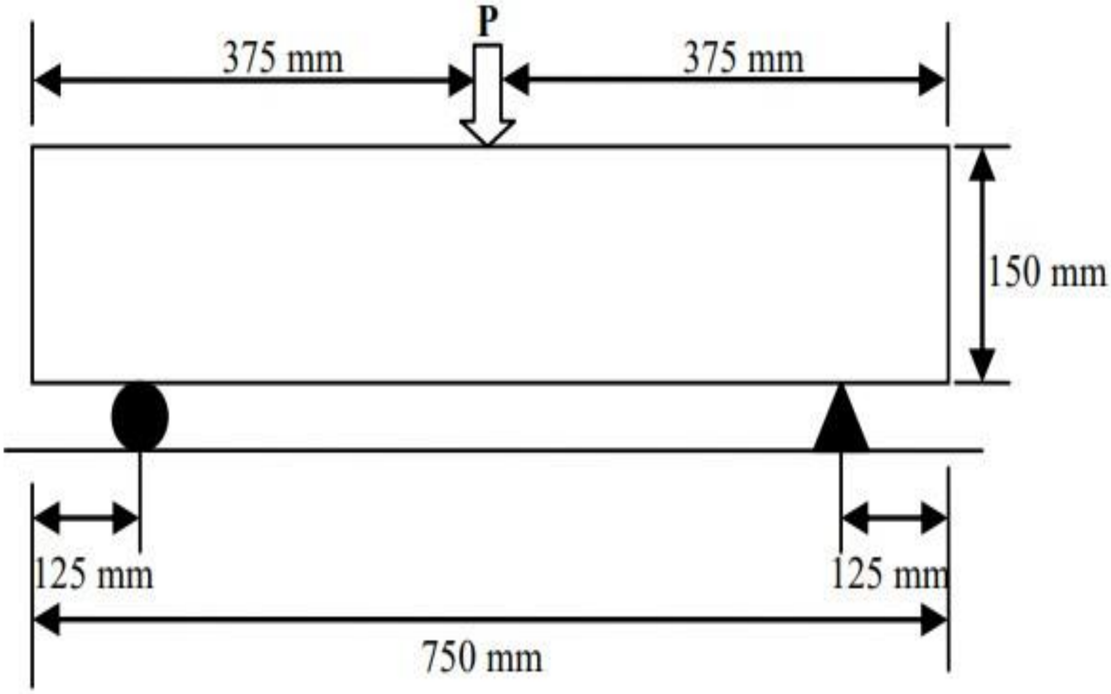

Fig. 3.9 Test Setup for flexural strength test of RCC Beam

3.4 FLEXURAL STRENGTH TEST ON BAMBOO CONCRETE BEAM USING SBR POLYMER

To evaluate the flexural strength of a bamboo concrete beam reinforced with SBR Polymer, a comprehensive testing procedure is conducted. This test aims to assess the beam's ability to withstand bending forces and determine its overall structural performance.

In preparation for the flexural strength test, a bamboo concrete beam is meticulously fabricated. The beam is constructed by incorporating bamboo as the primary reinforcement material along with the concrete matrix, which includes the addition of SBR Polymer. The SBR Polymer acts as an enhancing agent, providing improved bonding and cohesion within the concrete mixture.

Once the bamboo concrete beam is prepared, it is carefully positioned on a testing apparatus specifically designed for flexural strength evaluation. The beam is subjected to a gradually increasing load applied at its midpoint, simulating real-world bending conditions. The applied load induces bending forces on the beam, causing it to deform and deflect.

During the test, specialized equipment such as a universal testing machine is utilized to accurately measure and apply the load. Strain gauges and displacement sensors are strategically positioned on the beam to monitor and capture its behavior under the applied load. These measurements provide valuable data on deflection, strain, and ultimate failure point, which are crucial in determining the beam's flexural strength.

The flexural strength test is conducted in adherence to standardized procedures and guidelines to ensure consistency and reliability of results. Factors such as beam dimensions, concrete mixture proportions, bamboo reinforcement details, and the inclusion of SBR Polymer are meticulously considered to simulate real-world scenarios.

By analyzing the load-deflection curve obtained from the test, key parameters such as the maximum load sustained, the corresponding deflection, and the ultimate flexural strength of the bamboo concrete beam can be determined. These parameters serve as essential indicators of the beam's ability to withstand bending forces and its overall structural integrity.

The results obtained from the flexural strength test on the bamboo concrete beam provide valuable insights for structural engineers and designers. This data aids in optimizing beam design, determining load capacities, and ensuring the safety and performance of bamboo reinforced concrete structures in various applications such as construction projects and infrastructure development.

3.4.1 Detailing of Bamboo Concrete Beam

Bambcrete beam (using SBR Polymer) of 4no. Longitudinal Reinforcement – 600mm * 20mm*8mm, Transverse Reinforcement100mm*20mm*8mm, Spacing of Transverse reinforcement – 100mm Centre to centre.

Fig. 3.10 Reinforcement Detailing of Bamboo Concrete Beam

Fig. 3.11 Flexural strength Test Setup for Bamboo Concrete Beam

3.5 STUDY AND ANALYSE THE WATER ABSORPTION OF BAMBOO USING SBR POLYMER

In order to thoroughly examine the water absorption characteristics of bamboo when treated with SBR Polymer, a comprehensive study is conducted. This research aims to analyze how the incorporation of SBR Polymer influences the water absorption properties of bamboo.

To initiate the study, bamboo samples are carefully selected and prepared for testing. The samples are treated with SBR Polymer, which acts as a coating or impregnating agent on the surface of the bamboo. This treatment is known to enhance the bamboo's resistance to water absorption and potentially improve its durability in wet environments.

Once the bamboo samples are treated with SBR Polymer, they are subjected to controlled water immersion or exposure to moisture. Throughout the testing period, the samples are monitored to observe any changes in weight or dimensions, as well as the rate of water absorption.

Measurements of water absorption are taken at regular intervals to analyze the behavior and performance of the treated bamboo. Factors such as the time duration, environmental conditions, and the extent of water absorption are carefully recorded and analyzed to draw meaningful conclusions.

The study also involves comparative analysis, where untreated bamboo samples serve as a reference for evaluating the impact of SBR Polymer treatment on water absorption. This allows for a clear assessment of the effectiveness of the polymer in reducing water absorption and enhancing the bamboo's resistance to moisture.

The findings of this study provide valuable insights into the water absorption behavior of bamboo when treated with SBR Polymer. The data obtained helps in understanding the potential benefits and limitations of using SBR Polymer as a protective coating or treatment for bamboo in applications where moisture resistance is critical, such as in outdoor structures or humid environments.

By conducting a detailed analysis of the water absorption characteristics, researchers and engineers can make informed decisions regarding the appropriate use of SBR Polymer-treated bamboo, ensuring the longevity and performance of bamboo-based products in various industries, including construction, furniture, and other applications.

In this experiment, a total of eight bamboo sticks were utilized, consisting of four sticks measuring 600mm in length and four sticks measuring 100mm in length. Among these, two sticks from each length category were selected for coating with SBR Polymer, and these treated sticks were labelled as Sample "A." The remaining four bamboo sticks, designated as Sample "B," were left untreated as a control group.

After the SBR Polymer coating was applied, both Sample "A" and Sample "B" were submerged entirely in water for a duration of 24 hours. Following the immersion period, the bamboo samples were removed from the water and allowed to dry for an additional 2 hours.

The subsequent step involved weighing the bamboo samples to determine any changes in weight caused by water absorption during the immersion process. This assessment was conducted to understand the impact of SBR Polymer treatment on the water absorption properties of the bamboo.

By comparing the weights of Sample "A" (coated with SBR Polymer) and Sample "B" (untreated), researchers could analyze the effectiveness of the SBR Polymer in reducing water absorption in the bamboo. The difference in weight gain between the two samples would provide insights into the water resistance capabilities conferred by the SBR Polymer coating.

These measurements were taken after the 2-hour drying period, which allowed for a more accurate assessment of the water absorption characteristics of the bamboo samples. By carefully documenting and analysing the weight data, researchers can draw conclusions about the efficacy of the SBR Polymer treatment in reducing water absorption and enhancing the moisture resistance of the bamboo.

Fig. 3.12 Weighing of Bamboo Sample for Water Absorption test

The results of this experiment contribute to a better understanding of the water absorption properties of bamboo when subjected to SBR Polymer treatment. Such insights are valuable for various applications where moisture resistance is crucial, such as in the construction industry, where bamboo may be used for structural purposes or in humid environments.

CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1 RESULTS OF CONCRETE COMPRESSIVE STRENGTH WITH OR WITHOUT SBR POLYMER 7 Days Result

The compressive strength of concrete cubes was tested using two different samples: one with 15% SBR polymer mixed in the concrete and another without any SBR polymer. The samples were tested at both 7 days and 28 days to assess their strength. The experimental results are presented in Table 4.1 and Table 4.2, respectively.

Table 4.1 Compressive strength test (7 days)

	Sample No.	Compressive strength	Average Compressive strength
	S1	16.22	
Without SBR	S2	17.2	**16.41**
	S3	15.83	
With SBR(15%)	P1	19.38	
	P2	18.53	**19.19**
	P3	19.68	

4.2 RESULTS OF CONCRETE COMPRESSIVE STRENGTH WITH OR WITHOUT SBR POLYMER (28 Days Result)

Table 4.2 Compressive strength test (28 days)

	Sample No.	Compressive strength	Average Strength
	SA1	22.23	
Without SBR	SA2	27.60	**25.41**
	SA3	26.40	
SBR(15%)	PA1	28.30	
	PA2	30.50	**29.66**
	PA3	30.20	

4.3 RESULT OF TENSILE STRENGTH TEST OF BAMBOO

Tensile strength tests were conducted on two bamboo samples, one with 3 nodes and another with 5 nodes. The results of these tests are presented in Table 4.3

Table 4.3 Tensile strength test of bamboo

SAMPLE NO.	NO. OF NODE	AREA (mm^2)	WEIGHT (gm)	ULTIMATE LOAD (KN)	STRESS (MPA)	AVERAGE STRESS(MPA)
1		201.4	160.0	23.87	118.52	
2	3	257.3	217.2	28.53	110.88	110.66
3		229.7	171.0	23.56	102.57	
4		251.6	181.5	24.39	96.94	
5	5	274.6	223.0	29.35	106.88	102.54
6		260.1	201.0	27.00	103.81	

Table 4.3 reveals that the specimens exhibit varying properties, including differences in area and weight due to the natural characteristics of bamboo. Additionally, the presence of nodes in the bamboo specimens does not appear to have a significant impact on stress levels. Therefore, it is reasonable to consider an average stress of approximately 105 MPa while disregarding the influence of nodes.

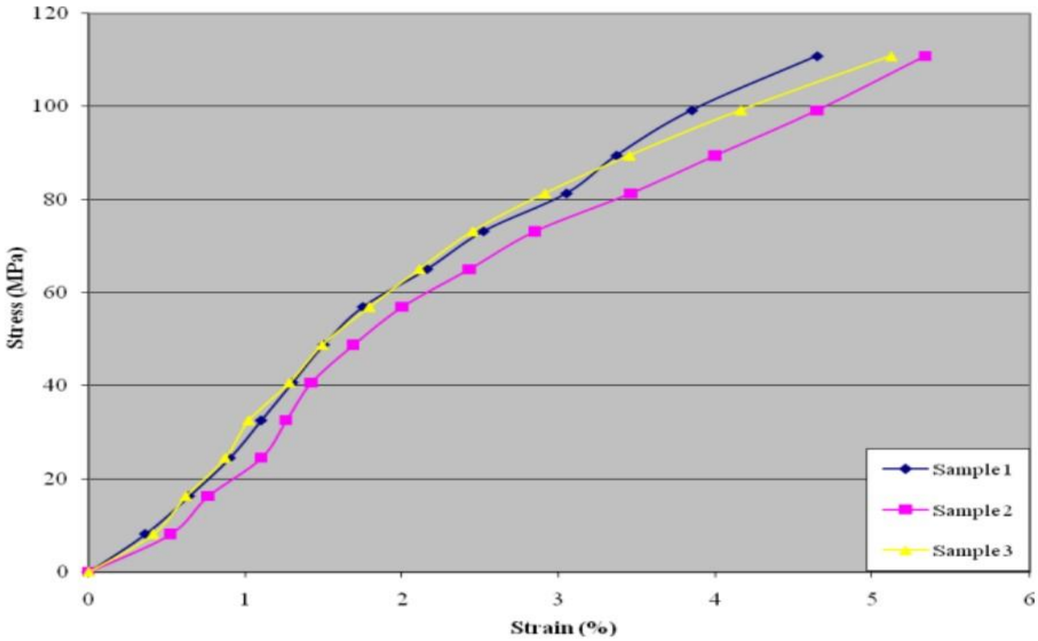

Fig. 4.1 Stress- Strain Diagram for Bamboo Sticks with 3 – node

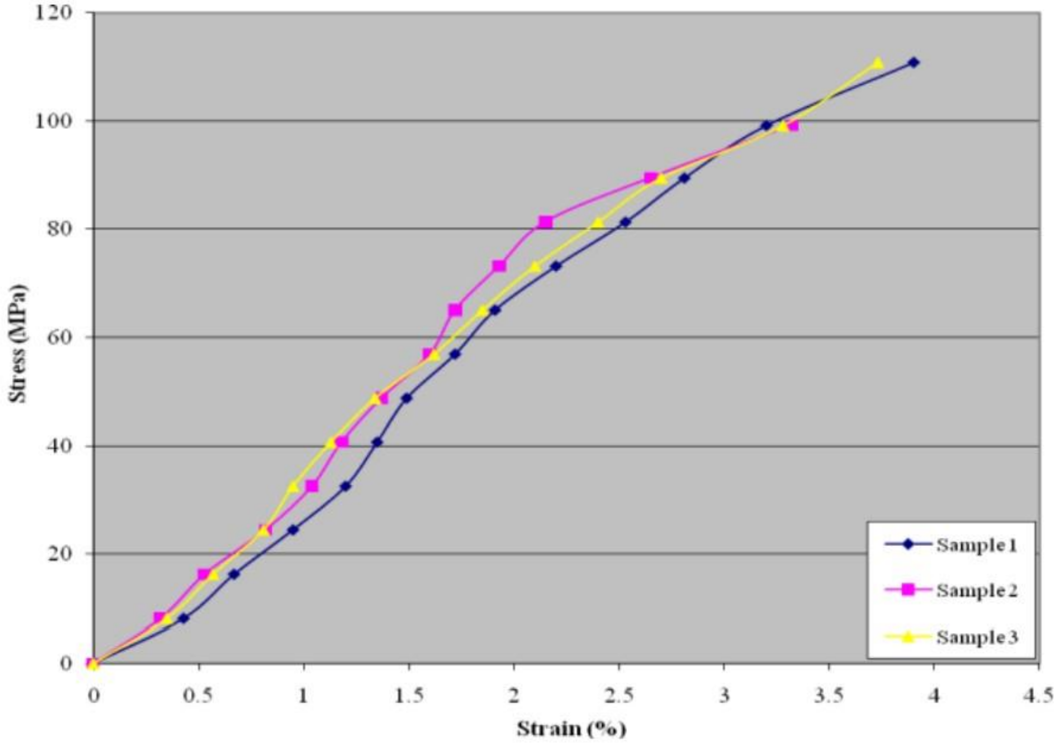

Fig. 4.2 Stress- Strain Diagram for Bamboo Sticks with 5 – node

Figure 4.1 and 4.2 demonstrate that all the samples display similar trend lines. Despite a moderate variation in the total strain measured in percentage, the maximum stress remains nearly identical for all three samples.

4.4 RESULT OF WATER ABSORPTION OF BAMBOO USING SBR POLYMER

Experimental results of water absorption of bamboo is shown below in Table 4.4

Table 4.4 Water absorption of bamboo using sbr polymer

SAMPLE	600 mm Length Bamboo	Weight before submerged in water(in gram)	Weight after submergedin water(in gram)	100mm Length Bamboo	Weight before submergedin water(in gram)	Weight after submergedin water(in gram)	Remarks
SAMPLE A(SBR)	A1	88	92	A3	18	19	Water absorption is less in sample A as compared to Sample B
	A2	104	109	A4	22	24	
SAMPLE B	B1	92	101	B3	18	22	
	B2	96	107	B4	16	19	

4.5 Comparison of flexural strength of Bambcrete Beam with RCC Beam

Sample of 1)RCC Beam (longitudinal reinforcement of 4number, 600 mm length of 12mm dia and Transverse reinforcement 100mm length of 8mm dia at 100mm c/c spacing and 2)Bambcrete beam (using sbr Polymer) of 4no. Longitudinal Reinforcement – 600mm * 20mm*8mm ,Transverse Reinforcement100mm*20mm*8mm ,Spacing of Transverse reinforcement – 100mm Centre to centre was casted for comparison of the flexural strength at 7 Days .

The results for comparison of flexural strength for both the samples is shown below in Table 4.5

Table 4.5 Comparison of Flexural strength (7 Days)

Sample No	Dimension in cm	Position of Fracture	Tested Beam Length in mm	Load in KN	Flexural Strength in N/mm^2	Average flexural Strength	Remarks
A1	70*15*15	24.5	600	45	8.0		Flexural strength is 17% more of Bambcrete beam as compared to RCC Beam
A2	70*15*15	21.5	600	49	8.71	8.11	
A3	70*15*15	23.0	600	43	7.64		
RCC							
B1	70*15*15	24.5	600	38	6.75		
B2	70*15*15	23.5	600	39	6.93	6.93	
B3	70*15*15	21.5	600	40	7.11		

CHAPTER 5

CONCLUSIONS

1 A significant improvement of 16.94% in compressive strength was observed in a 150 mm x 150 mm x 150 mm concrete cube when it was tested with the addition of 15% SBR Polymer. This increase in strength indicates the effectiveness of incorporating SBR Polymer as an additive in the concrete mixture, resulting in enhanced structural integrity. The test results demonstrate the positive impact of SBR Polymer on the compressive strength of the concrete, highlighting its potential as a valuable component in construction materials.

2 The relationship between the number of nodes and tensile stress suggests that a more streamlined and node-free bamboo structure can withstand greater tensile forces. These findings emphasize the importance of considering the presence and arrangement of nodes when evaluating the tensile strength of bamboo materials. In conclusion, a decrease in the number of nodes in bamboo results in an enhanced capacity to withstand tensile stress, highlighting the significance of node distribution in the mechanical properties of bamboo.

3 The flexural strength of Bambcrete beams with the incorporation of SBR polymer is significantly higher, with a notable increase of 17% compared to traditional Reinforced Concrete (RCC) beams. This implies that the utilization of SBR polymer in Bambcrete construction enhances the beam's ability to resist bending forces, resulting in superior flexural performance. The observed difference in flexural strength underscores the advantageous impact of SBR polymer as an additive in Bambcrete, offering improved structural integrity and durability.

In conclusion, the addition of SBR polymer to Bambcrete beams leads to a substantial enhancement in flexural strength, surpassing that of conventional RCC beams. This highlights the potential of SBR polymer as an effective solution for reinforcing bamboo-based construction materials, providing greater resilience and reliability in structural applications.

4 The use of SBR polymer effectively reduces the water absorption of bamboo. By incorporating SBR polymer into bamboo materials, the ability of bamboo to absorb water is minimized. This means that bamboo treated with SBR polymer exhibits improved resistance to water absorption compared to untreated bamboo.

5 The use of welded wire around bamboo creates a strong connection between the bamboo and the surrounding materials, resulting in increased bonding stress. This enhanced bonding stress contributes to better load transfer and improved resistance to external forces. Additionally, the welded wire reinforcement helps to mitigate the risk of separation or detachment between the bamboo and other components.

FUTURE SCOPE

The research conducted on replacing steel reinforcement with bamboo using SBR Polymer paves the way for further exploration and development in this field. There are several potential areas of focus for future research and development:

1. Optimization of reinforcement techniques: Future studies can delve into refining and improving the methods of reinforcing bamboo with SBR Polymer. This includes exploring different techniques for coating or impregnating the bamboo, experimenting with various polymer formulations, and developing innovative bonding approaches. These efforts aim to enhance the strength and durability of the bamboo-concrete composite.

2. Long-term performance assessment: It is crucial to conduct studies that evaluate the long- term performance and durability of bamboo reinforcement with SBR Polymer. These assessments involve monitoring the behavior of the composite over an extended period under sustained loads, exposure to environmental factors, and cyclic loading conditions. The findings from such studies provide valuable insights into the structural integrity and service life of the composite.
3. Standardization and code development: Developing standardized guidelines and codes specific to the use of bamboo reinforcement with SBR Polymer is essential. This involves establishing design criteria, testing protocols, and quality control measures that ensure the safe and reliable implementation of these composite materials in construction projects. Standardization efforts help regulate the production and usage of these composites.

4. Structural design considerations: Further research can focus on developing design methodologies and software tools that take into account the unique characteristics of bamboo reinforcement with SBR Polymer. This includes analyzing the behavior of these composites under different loading conditions, providing guidance on selecting appropriate reinforcement configurations, and optimizing structural designs to maximize performance.

5. Expansion to other applications: While the current research primarily focuses on structural applications, there is potential to explore the use of bamboo reinforcement with SBR Polymer in other fields such as furniture manufacturing, landscaping, and architectural elements. Investigating the feasibility, performance, and benefits of these composites in diverse applications can open up new avenues for sustainable and eco- friendly solutions.

6. Cost-effectiveness analysis: Conducting cost-effectiveness studies that compare bamboo reinforcement with SBR Polymer to traditional steel reinforcement can provide valuable insights into the economic viability of this alternative. These studies consider factors such as material costs, production processes, and potential savings in construction expenses. Such analyses enable stakeholders to make informed decisions regarding the adoption of these composites.

7. Environmental impact assessment: Evaluating the environmental impact of bamboo reinforcement with SBR Polymer compared to traditional steel reinforcement is crucial. Life cycle assessments (LCAs) can be conducted to assess the carbon footprint, energy consumption, and overall environmental sustainability of these composites. These assessments contribute to green building practices and sustainability certifications.

By pursuing these future research directions, the field of bamboo reinforcement with SBR Polymer can continue to evolve and contribute to sustainable construction practices. The research offers viable alternatives to traditional materials and promotes the development of a eco-friendlier and more resilient built environment.

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