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The Use of Betong Bamboo as Reinforcement of Concrete Beam Structures

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Abstract: In the endemic era, the source and cost of steel is increased. The quality of material used in the construction field is important as it determines the strength of the building. Hence, this project aims to utilize the Betong bamboo as reinforcement for concrete beam structures. There are three different sizes of bamboo strips used. Next, the chemical treatment is conducted to protect the bamboo from any insects such as termites. The test involved in this project is the flexural compression test. However, the testing found that the product is failed. This project is failed due to honeycombs found around the beam and only one test can be done. Hence, it can be solved by preparing the sample of concrete mix well. The results obtained based on the test carried out on the beam prove that the product produced is a failure because when the load is applied to the beam no value is recorded because the displayed value will disappear when then load is lifted. This proves that the product is a failure. Based on the findings, it can be concluded that the use of steel in construction buildings is better because steel is not easy to get damaged by insects compared to bamboo.

Keywords: Bamboo, Reinforcement, Treatment, Construction, Concrete

1. Introduction

Bamboo is one of the materials that have the potential to be used in the construction of buildings as easily found in many tropical and subtropical locations. Bamboo is also suitable for construction because of its high tensile strength and the ability to absorb the concussion of an earthquake. Based on previous research, giant grass known as bamboo is a local material and has the potential to use as an alternative to the conventional material, which is steel as it is more natural, sustainable, and eco-friendly than steel [1]. Nowadays, the construction of buildings is actively carried out as building structures, substructures, and superstructures such as slabs and beams are improving. Since Covid-19, the choice of material uses is determined mainly by the cost and the mechanical properties of the materials as it is important in determining the strength and load resistance of the building and the ability to comply with the client's needs and the building purpose.

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There are over 1200 distinct species of bamboo and each nature of the bamboo stalk is influenced by each different species and different growth of the environment [2]. Due to advances in processing technology, and growing market demand, it has been widely spread for domestic goods and subsequently been further expanded to industrial use and one of them is the production of bamboo chips used in ancient China. The tensile strength of several species of bamboo has been tested and makes comparison with the strength of steel shows that bamboo has greater strength and load-bearing capacity which highlights the acceptability or otherwise of bamboo as material steel as a substitute for structural members in engineering construction [3]. Building development has been temporarily prohibited because to Covid-19 from 2020 till the present to stop the outbreak from growing worse. Because steel is a non-renewable and unsustainable material, the epidemic led to a spike in steel prices as iron ore deposits became scarcer. Therefore, the scope of this project is to focus on the design of concrete beam structure using Betong bamboo strips also known as Dendrocalamus asper, DA as a reinforcement with three different sizes to make a comparison of the strength of each size. The past experiment study shows that betong bamboo showed the highest tensile strength, and the average of its tensile strength is 198.35 N/mm^2 compared to other species of bamboo because it is thicker than any other species of bamboo [4].

The dimensions of the bamboo strips used have three different sizes to make a comparison of the strength between each different size bamboo strip and it was done by discussing and analyzing previous journals which in form of (6 mm x 15 mm), (6 mm x 20 mm), and (6 mm x 25 mm) as 'thickness x width' respectively as shown in Figure 1. Bamboo strips also go through chemical treatment using borax and boric acid to prevent them from insects. The aims to utilize the Betong bamboo as reinforcement of concrete beam structures. Since the objective of this project is to test the strength of concrete beams using bamboo strips as reinforcement, the test will be focusing on the strength and the durability of the materials used and how they can comply with the beam design standards for the construction of buildings.

2. Materials and Methods

This study begins with the evolution of the design followed by the concept and design of the project embodiment. It explained more about the preferred required report paper. There are three phases that will be focused on such as design process, product treatment and assembly, and product testing and analysis.

2.1 Materials

Material selection is the next step in the process of designing any 3D product for this prototype such as betong bamboo, acid boric and borax, and concrete. Acid boric and borax used in chemical treatment because easy to handle and takes less time. The last material is concrete that usually used in the construction of reinforced concrete such as columns and beams. The ratio mix used is 1:2:4 with 0.6 water-cement ratio.

For this project, the commonly used bamboo is betong bamboo. This is because betong bamboo is usually used in construction because of its hard and strong stem. Knowing the mechanical properties of bamboo, such as moisture content, density, and shrinkage, is essential for overcoming cracking damage. To minimise dimensional changes induced by considerable shrinkage, bamboo should be processed while it has a low moisture content and a high density. Furthermore, bamboo is a hygroscopic substance, which means it absorbs and excretes water depending on temperature and humidity [5].

For treatment, the ingredients needed are acid borix and borax. the purpose of this treatment is to prevent the bamboo strips from being infected by any insects and to ensure that they last longer. the ratio used in mixing the solution is 1:1 and treatment for this bamboo takes 1 week.

The concrete mix used is the same as that used in the construction of ordinary structures, which is M25. The standard proportion for preparing concrete according to the JKR Construction Specification

2014 is to utilise the specified mix [7]. Treated bamboo strips are shaped into rectangular reinforcement and placed into the formwork before laying and drying the concrete to the appropriate size. The sample will be tested after 7 days. The proportions use to prepare concrete for prescribed mixes and compressive strength for prescribed mix as shown in **Table 1** and **Table 2**.

Table 1: Proportions Use to Prepare Concrete for Prescribed Mixes (JKR, 2014) [7]

Proportion (Grade)	Slump Limits (mm)	Cubic Meters of Aggregate Per 50 kg of CEM 1		Max. Free Water: Cement Ratio	Quality of Water (Litres)	Strength of Concrete	
		Fine	Coarse (20 mm)			At 7 Days (N/mm^2)	At 28 Days (N/mm^2)
1:1:2 (30P)	25 -50	0.035	0.07	0.45	22.5	20	30
1:1:5:3(25P)	25 -50	0.05	0.1	0.5	25	17	25
1:2:4(20P)	25 -50	0.07	0.14	0.55-0.6	27.5 - 30	14	20
1:3:6(15P)	25 -50	0.10	0.20	0.6	30#	11	15

or as approved by S.O

Table 2: Compressive Strength for Prescribed Mix (JKR, 2014) [7]

Grades of Concrete	28-day Strength of Concrete N/mm^2	Cube Strength at 7 Days* N/mm^2	Average Strength at 28 Days* N/mm^2
20P	20.0	14	20.0
25P	25.0	17	25.0
30P	30.0	20	30.0

*Only for CEM1

2.2 Methods

This project has four phases that have been focused on such as design process, product treatment and assembly, product testing and analysis data from testing. The design process consists of evolution, concept, embodiment, and parameter of design. Following that it is followed by product treatment and assembly continued to product testing using flexural compression testing machines. The obtained data were analyzed by StaadPro software to compare with the results obtained from product testing. This StaadPro is used to obtain product deflection while the flexural compression test is to evaluate the static compressive strength characteristics of components and material products. The data are compared, and the results show the difference in results of the two methods used is likely due to any possible errors that may occur. Usually, a flexural compression test is done until the product experiences failure and the ideal material is brittle materials as they have a very low ductile before permanent deformation. When the load is applied, three fundamental stresses are present such as tensile, compression and shear.

The concept of replacing steel load-bearing sections with concrete load-bearing members that is straightforward and consistent with any small-scale project's goals of self-reduction, cost savings, and environmental friendliness. The various properties of bamboo are used in Staadpro software, and it have been shown below to verify the mechanical strength of bamboo as tested by the Journal of Advanced Research in Materials Science [6]. The properties of the bamboo are as in **Table 3**.

Table 3: Material Properties of Bamboo

Properties	Bamboo
Shrinkage Coefficient (bulk)	0.663
Density	0.66 g/cm^3
Compressive Strength (Fcu)	78.7 MPa
Tensile Strength	206.2 MPa
Young's Modulus (E)	2000 N/mm^2
Yield Stress (Fy)	78 N/mm^2

3. Results and Discussion

This section represents the analysis of the flexural compression test machine, StaadPro software, and manual calculations.

3.1 The analysis of the flexural compression test machine.

There are several factors that cause or contribute to the failure of structural concrete in this project. Product failure, installation failure, or failure due to other factors can all be categorized as a failure. Design calculations are a major factor of concrete failure. The design calculations in this project have failed resulting in a reduction in the concrete mix until there is the appearance of beam reinforcement arising. Moreover, there is no complete review of the process once the calculations for this design are completed that can confirm that the size of the reinforced concrete section, as well as the thickness and spacing of the reinforcement, is sufficient to maintain the load combination.

Too much water or sand is one of the reasons why concrete fails to reach its intended strength. With the addition of additives and fly ash, mixing concrete becomes more difficult, and the ingredients are not well blended in the right proportions. Furthermore, the concrete is not thoroughly compressed and compacted by ramification or vibration, causing some of it to look like a honeycomb and become trapped in the concrete paste. This poor compaction of concrete poses a permeability problem, which leads to corrosion of the steel and in turn leads to a reduction in the ultimate capacity of the hardened concrete.

Other causes of the concrete failure in this project are that there is no cure in concrete for the bamboo reinforced cement of the beam. Not curing has resulted in a lack of water resulting in insufficient hydration. As a result, the capillary pores will not be able to divide, resulting in rupture and shrinkage for long periods of time. Therefore, the uncured concrete has weak strength development and is less durable.

This product failed based on the results obtained. When the test is performed on the beam, there is no data value because when the load is applied to the beam, the recorded value is not permanent and will disappear when the load is lifted back up. This proves that the product produced is a failure. This failure happened to 2 product beams that have bamboo strips of size 25 mm and 20 mm for the 15 mm bamboo strip failed to be tested on it because the concrete mix produced was not able to cover the entire bamboo reinforcement. The beam before and after the Flexural Compression Test is as n **Figure 1** and **Figure 2**.

Figure 1: The beam is to be tested using Flexural Compression Test Machines

Figure 2: The beam test results were failed using Flexural Compression Test Machines

3.2 The analysis of reinforcement beams using StaadPro software.

The StaadPro software is developed by Bentley Systems for analysis and design of construction building such as dams, bridges, and highway structures. It is one of the software applications made for the purpose of helping to ease the engineer to analysis their work. The bending test also called flexural testing is measures the behavior of materials subjected to simple beam loading. Data analyses were done to obtain deflection of product that go through flexural compression test to get theoretical data to be able to compare to experimental data.

Table 4 shows the results of reinforcement beams using bamboo were analyzed using StaadPro software.

Table 4: Results of Reinforcement Beams Using StaadPro Software

Sample No.	Beam Dimension (mm x mm)	Diameter (mm)	Deflection (mm)
1	160 x 130	20	0.147
2	150 x 130	25	0.086

As shown in **Figure 3**, the deflection is calculated by comparing the original position of the neutral axis of the beam with the deflected position of the neutral axis of the beam at any place y. The results of the graph test show that different bamboo diameters give measurable changes in deflection, with the bigger the diameter of the bamboo resulting in a lesser deflection to be employed. This deflection is the degree to which parts of the structural elements are displaced under the same load of 20kN/m.

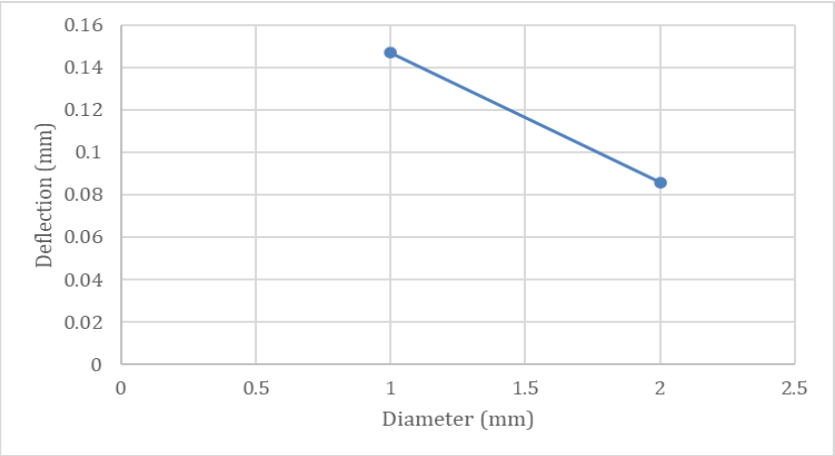

Figure 3: Deflection-Diameter Graph for Bending Test Beams Using StaadPro Software

3.4 The analysis of reinforcement beams by manual calculation

Data obtained from both manual calculation and StaadPro software were compared as shown in **Table 5.** To fulfill the objective of this study, this method was used to obtain the deflection of the product while applying the same load of 20kN/m on the product to get the result of the deflection product. For the 20 mm size bamboo strips, the deflection of the product is 0.147 mm and 1.18 mm while deflection results for 25 mm size are 0.086 mm and 1.28 mm result from StaadPro software and manual calculation respectively. Table 4 shows the results of reinforcement beams using bamboo were analyzed using manual calculations.

Table 5: Results of Reinforcement Beams by Manual Calculationstabl

Sample	Beam Dimension (mm x mm)	Diameter (mm)	Deflection (mm)
1	160 x 130	20	1.18
2	150 x 130	25	1.28

4. Conclusion

Based on the study conducted, it can be concluded that the first and second objectives are achieved but for the third objective is not achieved due to honeycombs found around the beam walls that affect the strength of the concrete. Honeycomb can occur due to mistakes that are often made are uneven tamped and evenly mixed concrete. Following that the only one flexural compression test can be done due to the lack of machines in the workshop.

There are several recommendations that can be made to improve the product which is using the size of the strip bamboo and the number of links corresponding to the standard of building construction to be able to withstand the applied load. Another recommendation is using concrete vibration and a concrete mixing machine to solve the issue of honeycomb and concrete not mixing well. The last recommendation is to test the product from various aspects to get a more accurate result such as tensile strength of bamboo, static bending, and shear testing.

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