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Strength Characteristics of Bamboo Reinforced Concrete

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***Abstract* - Generally steel is used in concrete structures to ensure the safety of the structure. Considering the economical point of view of the structure, cost of the steel is relatively more and it may be replaced by some other material, especially to reduce the cost in low cost housing as well as in highly seismic zones. One of the materials that can replace steel is bamboo. Bamboo is cheap and it is a natural material and the availability of bamboo is more. The properties of bamboo are good tensile strength, flexural strength, and compressive strength. Based on the above properties bamboo can certainly replace steel up to certain extent. The tensile strength and modulus of elasticity of bamboo is determined by tensile test by using UTM. The bamboo culms are cut in required size and the water proofing materials such as synthetic resin and coal tar are applied over the entire surface of the bamboo culms. The coated culms are used as reinforcing material in beams and cylinders with their percentage varying from 2 to 4. The corresponding strength achieved by the beams and cylinders after 28 days curing is compared with the plain beams and cylinders.**

Keywords: Strength, Bamboo, Reinforced Concrete, structure, natural material.

I. INTRODUCTION

Concrete is a composite construction material made primarily with cement, aggregates and water. Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges, roads, dams, pools, etc. It has relatively high compressive strength, but significantly lower tensile strength. It has various advantages such as low cost, availability, fire resistance etc. Because of its low tensile strength it is usually reinforced with materials that are strong in tension (often steel). But the high cost of steel increases the cost of construction. This problem may be overcome by using some naturally available material that has sufficient tensile strength. Bamboo is abundantly available natural material which is also inexpensive. Bamboo is a kind of giant grass and an orthotropic material. It is strong both in tension and compression. The tensile strength of bamboo is relatively high. Several studies have been carried out to evaluate the properties of bamboo to be used as reinforcing material in concrete. From the studies it was found that bamboo can potentially be used as substitute for steel reinforcement. The use of bamboo as reinforcement in Portland cement concrete has been studied extensively. Some of the positive aspects such as a lightweight design, better flexibility, and toughness due to its thin walls with discretely distributed nodes and its great strength make it a good construction material. Bamboo is used as structural material for scaffolding at construction sites in India, China and other countries as it is a tough, flexible, light weight and low cost material.

It may be used structurally and as a decorative element. In this era of industrialisation, the selection of materials is based mainly on the price and the type of facility used for production or processing. Industrialised materials, such as ordinary Portland cement (OPC) and steel, find applications in all sectors. In the second half of the 20th century, advanced materials such as synthetic polymers (e.g. Rayon, Nylon, Polyester, and Kevlar), new alloy metals and carbon fibres were developed. They were introduced in places where locally produced materials exist in abundance. In developing countries due to the modern educational system, which is mainly based on programs from industrialised nations, there are no formal educations or research programs concerning the innovative use and applications of traditional and locally available materials and technologies. Lack of reliable technical information about the local materials makes the consumers use mainly industrialised materials for which the information is freely available. The main hurdle for the application of structural composites is the lack of sufficient information about the constituents of the composites and about their durability. The focus of this study is to present a concise summary of the information about the range of material choices, which are locally available for producing concrete structural elements, reinforced with bamboo. The main hurdle for the application of structural composites is the lack of sufficient information about the constituents of the composites and about their durability. The focus of this paper is to present a concise summary of the information about the range of material choices, which are locally available for producing concrete structural elements, reinforced with bamboo.

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Bamboo is a great renewable resource and can grow very rapidly with minimal help. When substituting bamboo for steel, it could save a lot of money and energy that goes into manufacturing, shipping, installation, and the disposal of steel for construction.

History of bamboo

The word bamboo comes from Kannada term bamboo, which was introduced to English through Malay. Bamboos are some of the fastest-growing plants in the world, due to a unique rhizome-dependent system. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product. Bamboos are giant grasses and not trees as commonly believed as shown in figure 1. They belong to the family of the Bambusoideae. The bamboo Culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials. Bamboo is a tall grass, fast-growing and typically woody. The bamboo plant is a complex system, consisting of two sets of similarly structured vegetative axes: one above the ground and the other below the ground. The portion between two successive nodes is called an internode. Internodes are invariably, but not always, hollow. They are covered by sheaths at the initial stages of growth, which fall off as the plant matures.

Bamboo has historically been used as a building material due to its inherent properties, being regenerating, Biodegradable, with high tensile strength, and light weight. It does not require sophisticated fuel/energy guzzling procedures for processing. However, despite its innumerable qualities one does not get to see bamboo houses. The conventional brick, RCC, framed structures have emerged as the prime solution for mass housing, even though they are not affordable by the majority of the sections in society. The irony is that while on one hand there is acute housing shortage, homelessness, poverty, growth and worsening conditions of slums in urban areas, on the other hand, valuable research on alternative cheaper and easy to construct solutions.

The development of science & technology is a continuing quest for improvement in infrastructure of world around us. The structures in nature are great lessons for human study only the most eco- friendly structural forms have survived. The profound capacity respond to a variety of climatic and environmental forces, makes a natural form of tremendous examples to numerous fields of structural design. A natural material which is available in bulk and ease of use in the rural areas in the developing countries. Bamboos occur mostly in tropical and subtropical areas, from sea level to snowcapped mountain peaks, with a few species reaching into temperate areas.

The major application of bamboo is for construction and housing. According to study it is estimated that one billion people in the world live in bamboo houses. Since bamboo has been used in construction and currently they are used as props, foundations, framing, scaffolding flooring, walls, roofs and trusses. Bamboos are tied together to make grid reinforcement and placed in soft clay to solve deformation problems in embankments. In rural part of India mostly bamboo is use as reinforcement in mud walls.

Bamboo is one of the oldest building materials used by mankind. The bamboo culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material.

In many overly populated regions of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing. With the advancement of science and technology and the good supply of timber, new methods are needed for the processing of bamboo to make it more durable and more usable in terms of building materials.

Bamboo is also still being looked at as a way to clean environmental pollution. It is a consumer of Nitrogen, which could soon be part of a huge effort to prevent air pollution. Durability of natural fibre concrete composites using mechanical strength and micro structural properties. Naturally and locally available materials such as jute, coir and bamboo fibre can well be used as natural fibre reinforced concrete composites.

Figure 1: Bamboo

The main objective of this study is to study the effectiveness of bamboo in replacing steel, especially for low cost housing then to study the structural properties of locally available bamboo and the compressive strength, flexural

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strength and modulus of elasticity of bamboo reinforced concrete beams and cylinders were compared.

II. SELECTION & PREPARATION OF BAMBOO

Selection:

The following factors should be considered in the selection of bamboo culms for reinforcement in the concrete structures:

1) Use only bamboo showing a pronounced brown colour.
2) Do not use the culms of green, unseasoned bamboo.
3) Avoid bamboo cut in spring or early summer. These culms are generally weaker due to increased fibre moisture content.

Basic characteristics of bamboo

Bamboos are giant grasses and not trees as commonly believed. They belong to the family of the Bambusoideae. The bamboo Culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibres and low strength perpendicular to the fibres respectively. Bamboo is a composite material, consisting of long and parallel cellulose fibres embedded in a ligneous matrix. The density of the fibres in the cross-section of a bamboo shell varies along its thickness. This presents a functionally gradient material, evolved according to the state of stress distribution in its natural environment. The fibres are concentrated in regions closer to the outer skin. This is consistent with the state of stress distribution when the Culm is subjected to wind force Drying bamboo is fundamental to its conservation for various reasons. Bamboo with low humidity is less prone to mould attacks especially when humidity content is less than 15%. Physical and mechanical properties of bamboo increase with a decrease in its humidity content. Bamboo to be treated with a preservative need to be dry to facilitate penetration and obtain a better result and reducing transport costs. Bamboo can be dried in air, green house, and oven or by fire.

Durability of bamboo

Just like timber, bamboo is vulnerable to environmental degradation and attacks by insects and moulds. Its durability varies with the type of species, age, conservation condition, treatment and curing. Curing should be initiated when bamboo is being cut in the bamboo grove. There is a strong relation between insect attacks and the levels of starch plus humidity content of bamboo Culm. In order to reduce the starch content, bamboo receives a variety of treatments including curing on the spot, immersion, heating or smoke bamboo depends strongly on the preservative treatment methods in accordance with basic requirements its chemical composition should not have any effect on the bamboo fibre and once injected it must not be washed out by rain or humidity. The preservative can be applied using simple systems such as leave transpiration, immersion.

Bonding strength

A reinforcing bar in concrete is prevented from slipping by adhesion or bond between them. The main factors which affect the bond between the reinforcing bar and concrete are: adhesive properties of the cement matrix, the compression friction forces appearing on the surface of the reinforcing bar due to shrinkage of the concrete and the shear resistance of concrete due to surface form and roughness of the reinforcing bar. The dimensional changes of bamboo due to moisture and temperature variations influence all the three bond characteristics severely. During the casting and curing of concrete, reinforcing bamboo absorbs water and expands. The swelling of bamboo causes micro cracks in the bamboo reinforced concrete structures.

Preparation:

Sizing:

1) Split culms are more desirable than whole culms.
2) Splitting the bamboo can be done by separating the base with sharp knife and then pulling a dulled blade through the culms as shown in figure 2.
3) The dulled blade will force the stem to split open, then this is more desirable than cutting the bamboo since splitting will result in continuous fibres and nearly a straight section.

Figure 2: Bamboo cutting machine

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Water proof coatings:

1) When seasoned bamboo, either split or whole is used as reinforcement it should receive a water proof coating to reduce swelling when in contact with concrete.
2) Without some type of coating, bamboo will swell before the concrete has developed sufficient strength.
3) A coat of synthetic resin and coal tar were applied on the entire surface of the bamboo.
4) A sample of Synthetic resin shown in figure 3.
5) Bamboo coated with resin and tar was shown in figure 4 and figure 5.
6) Only a thin coating should be applied, a thick coating will lubricate the surface and weaken the bond with the concrete.

Figure 3: Synthetic resin

Figure 4: Bamboo coated with coal tar

Figure 5: Bamboo coated with resin

III. EXPERIMENTAL METHODOLOGY

The cement used in present study is Portland pozzolana cement of specific gravity 2.88 and consistency of 35%. M20 grade concrete with mix proportion of 1:1.64:3.16 was used to cast specimens.

Placement of bamboo:

1) Bamboo reinforcement should not be placed less than 3.75 cm from the concrete section.
2) The clear spacing between bamboo splints should not be less than the maximum size of aggregate plus ¼ inch.
3) In cylinders the main reinforcement is provided with bamboo and the helical reinforcement is provided with palm toddy.
4) In beams longitudinal reinforcement is provided with bamboo was shown in figure 6 and figure 7.

Figure 6: Bamboo coated with coal tar placed in beam

Figure 7: Bamboo coated with resin placed in the beam

IV. RESULTS AND DISCUSSION

The testing results for Compressive strength of cubes, Modulus of elasticity of cylinders and flexural strength of beams are shown in below.

Table 1: Compressive strength of cubes

S. No	Identification	28 days' cube compressive strength (N/mm^2)
1	Cube -1	34.66
2	Cube -2	34.66
3	Cube -3	34.66

Table 2: Modulus of elasticity of cylinders

S. No	Identification % of bamboo reinforcement	Modulus of elasticity (N/mm^2)
1	0%	22489
2	2% bamboo coated with resin	25629
3	4% bamboo coated with	27782

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	resin	
4	2%bamboo coated with tar	25478
5	4%bamboo coated with tar	27827

Table 3: Flexural strength of beams

S. No	Identification % of bamboo reinforcement	28 days' flexural strength of beams (N/mm^2)
1	0%	3.9
2	2%bamboo coated with resin	4.71
3	4%bamboo coated with resin	7.84
4	2%bamboo coated with tar	4.71
5	4%bamboo coated with tar	7.06

Discussion:

Compressive strength

The average cube compressive strength is 34.66N/mm^2 which is greater than the target strength value 26.6N/mm^2.

Modulus of elasticity

The modulus of elasticity of M20 concrete without reinforcement is 22489N/mm^2 which is greater than the target value 22360N/mm^2.

The modulus of elasticity is improved about 14% with 2% bamboo reinforcement and 23% with 4% bamboo reinforcement, with resin coating on it.

The modulus of elasticity is improved about 14% with 2% bamboo reinforcement and 24% with 4% bamboo reinforcement, with coal tar coating on it.

Flexural strength

The flexural strength of M20 concrete without reinforcement is 3.9N/mm^2 which is greater than the target value 3.13N/mm^2.

The flexural strength is improved about 23% with 2% bamboo reinforcement and 100% with 4% bamboo reinforcement, with resin coating on it.

The flexural strength is improved about 23% with 2% bamboo reinforcement and 91% with 4% bamboo reinforcement, with coal tar coating on it.

V. CONCLUSION

- The target compressive strength has been achieved.
- The flexural strength of concrete has improved by using bamboo reinforcement.
- The modulus of elasticity of concrete has improved by using bamboo reinforcement.

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