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Experimental Investigation on Behaviour of Well Treated Bamboo as Reinforced Concrete Beams

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ABSTRACT

In this modern fast growing world countries like India are fast growing in both technology and infrastructure. Due to an intense rapid growth in infrastructure the demand of resources for construction has reached its peak. The major component for high raise buildings are steel which is soared and expensive. But the infrastructure cannot be stopped because of the steel. So, an alternative material Bamboo as reinforcement is introduced instead of steel reinforcement in concrete structures. The demand for this materials is also less in rural areas since it is one of the fast growing grass. In this paper investigates the Bamboo is fully replaced instead of steel reinforcement. The reinforcement cannot be done with the whole bamboo for small cross section elements in construction. So it is bisected into clums and tied with binding wires. The main aim to introduce bamboo as reinforcement is preferably low cost and readily available raw material. This bamboo was the basic construction material in olden days even before cement was introduced. It does not need any investment of money and time where it easily grows and easy to transport. Bamboos can be highly recommended for the rural areas where low rise buildings are raised and with cheaper rates. Steel reinforcement was used for seismic activity and tensile property.

But the manufacturing and transport cost is expensive. So an alternate is introduced and is also investigate whether it is suitable for the replacement with lower cost. This paper investigates the feasibility of bamboo reinforcement for concrete beams. If steel is replaced with bamboo then the behavior of the structure is observed and results are recorded for improving the enhancement of the structure.

I. INTRODUCTION

1.1 GENERAL

In recent years, steel prices have soared. For developing countries, steel is difficult to obtain because of expensive prices, and for the construction industry, usage of steel is currently limited heavily. The production of steel has high consumption of fossil fuels. So, the steel discharge in the construction of structures has been presented, showing the possibilities of drastic reduction by research institutes. Meanwhile, for developing countries, it is important to make the development of buildings construction; low cost, no requirement of sophisticated technologies and reliable construction methods. Environmental destruction such as pollution of air and water has been occurring in some regions by rapid development and production of materials like iron, steel, glass, cement and aluminum that use limited mineral resources. On the other hand, plants and fibers are annually reproducible clean resources. Bamboo is a unique group of gigantic grasses the culm of which originates in underground rhizomes. It grows naturally in many parts around the world country but some species are artificially planted. Bamboo forests are found across tropic and sub-tropic zones between latitudes of about 40^{o} south, i.e .areas with mean annual temperature's of from 20^{o} C to 30^{o} C. Bamboo suitable for water pipes grows at altitudes from 20 to 3,000 meters. The plant is fully mature at an age of three to four years. In recent years, many researches around the world are begun to explore the use of low-cost and low-energy substitute construction materials. Among the many possibilities for such substitutions, bamboo, which is one of the fastest growing plants, has got a great economic potential. Bamboo has been used in constructions of bridges and houses for thousands of years in Asia. Bamboo takes less energy to harvest and transport.

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Therefore, bamboo has low manufacturing costs compared with steel; bamboo is widely expected to be possible even in countries and regions that have no advanced manufacturing technology and construction techniques.

In most countries, concrete is widely used as the foundation for the infrastructure. Concrete is used largely because it is economical, readily available and has suitable building properties such as its ability to support large compressive loads. However, the use of concrete is limited because it has low tensile strength. For this reason, it is reinforced, and one of the more popular reinforcing bars(rebar) is steel. Steel has a relatively high tensile strength, as high as 115 ksi (792 N/mm^2), complementing the low tensile strength of concrete. Steel reinforcement at some point may no longer be available.

Even today there exists a need for more economical and readily available substitute reinforcement for concrete. In some parts of the world many building are constructed only with concrete or mud-bricks. This is dangerous in case of seismic activity. These building have little hope of standing in the case of an earthquake. Steel reinforcement would be an ideal solution, but cost is a considerable problem. Scientists and engineers are constantly seeking for new materials for structural systems; the idea of using bamboo as possible reinforcement has gained popularity.

1.2BAMBOO CHARACTERISTICS

Bamboo is giant grass, not a tree. Bamboo culms are a cylindrical shell divided by solid transversal diaphragms at nodes and have some intriguing properties such as high strength in the direction parallel to the fiber, which run longitudinally along the length of the culm, and low strength in a direction perpendicular to the fiber. The density of fiber in cross-section of a bamboo shell varies with thickness as well as height. Fiber distribution is more uniform at the base than at the top or the middle. This is because bamboo is subjected to maximum bending stress due to wind at the top portion of the culm. Bamboo is a normal Functionally Graded Material (FGM) . It is a composite with hierarchical structure. The strength of bamboo is greater than most of the timber products.

1.3B AMBOO AS A CONSTRUCTION MATERIAL

Bamboo reaches its full growth in just few months and reaches its maximum mechanical strength in just few years.its abundance in tropical and subtropical regions makes its an economically advantageous material .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 tough , flexible ,light weight and low cost material.In nature when bamboo is covered with heavy snow,it will bend until it touches the ground without breaking. This implies that bamboo has greater flexibility than wood. The energy necessary to produce $1m^3$ per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete , has been compared with bamboo.it was found that for steel it is necessary to spend 50 times more energy than of bamboo.The tensile strength of bamboo is very high and can reach 54 ksi (370 N/mm^2).This makes bamboo an alternative to steel tensile loading application. This is due to the fact that the ratio of tensile strength to specific weight of bamboo is six times greater than steel.

1.4 APPLICATIONS OF BAMBOO

Bamboo is being used in a wide variety of applications such as recreation, defense housing and construction. In regards to recreation bamboo has been used to construct a variety of musical instrument. In addition to the fact that bamboo can be used in the arts, it can also eaten. The market for bamboo shoots has grown rapidly in the last years. One of the major applications of bamboo is for construction and housing. It is estimated that one billion people live in bamboo houses. It can also be used to make furniture. Over a period of nine year the exports of bamboo furniture almost doubled in Philippines. In India and china bamboo is used in construction of temporary suspension bridges. In Tokyo and Hong Kong it is used as scaffolding in high rise buildings. Bamboo can be fashioned into many shapes leading to artists freedom as bamboo has been crafted into furniture, decorative items such as home decorative, dishware, dolls, toys, jewelry and more. Bamboo is also a popular tool for acquiring food: as bamboo fishing rods have been used to catch fish for long time. In earlier times, bamboo could be used as a blunt 7 weapon, or it could be sharpened to provide food or defense. It would also make a decent shaft for a spear. Even in the US, bamboo is beginning to gain exposure as flooring and paneling. There are companies that make plywood out of bamboo called ply-boo.

1.5 COMPARISON OF BAMBOO AND STEEL

One of the properties that would make bamboo a good substitute to steel in reinforced

concrete is its strength. The strength of bamboo is greater than most timber products which are advantageous, but it is approximately half the tensile strength of steel. Bamboo is easily accessible as it grows in almost every tropical and subtropical region, this lowers the cost of construction and increased the strength of the buildings that would otherwise be unreinforced. One major problem with bamboo is that it attracts living organisms such as fungi and insects. Bamboo is more prone to insects than other trees and grasses because it has a high content of nutrients. In order to combat this problem, it becomes necessary to treat bamboo to protect it from the environment. Steel does not have this problem but it also needs to be coated in order to protect it from rusting. Bamboo is very light in weight compared to steel. Due to its low modulus of elasticity, bamboo can crack and deflect more than steel reinforcement under the same conditions. These aspects put bamboo on the list of viable construction materials. These properties, when combined, suggest that bamboo will make a fine addition to the current selection of materials, but it is necessary that people in general be made more familiar with its strength and weaknesses.

1.6 GOALS AND OBJECTIVES

The goal of this research is to determine the feasibility of bamboo reinforcement for the concrete beams. Whereas the mechanical properties and behavior of steel reinforced concrete have been thoroughly studied and well documented, there exists no comprehensive data describing Bamboo reinforced concrete. Therefore, the aim of this study is to provide a preliminary contribution toward the collection of the mechanical properties and behaviors of bamboo reinforced beams. In concrete, reinforcement is bamboo is to be used as concrete reinforcement, it is necessary to understand how bamboo behaves in tension.

II. LITERATURE REVIEW

Masakazu Terai et al., (2011) researched about the seismic retrofit of the masonry structures in the design and construction of bamboo reinforced concrete. The test results of both RC and Bamboo RC beams are discussed. It is shown that the cracking patterns in bamboo RC beams can becomes similar to the RC beams and the predicted crack load of BRC beam give a strong effect in comparison with test data.

Adom Asamoah Mark et al., (2011)investigate about the feasibility of using bamboo as a reinforcing material in reinforced concrete members, flexural loading tests were carried out on reinforced-concrete beams in which all rebar, including the main rebar and the stirrups, were replaced with bamboo. Good load-carrying capacity, determined by when the main bamboo rebar ruptured, can be obtained if the number of bamboo stirrups is sufficient to prevent shear failure of the beam.

Jigar K.Sevalia (2013) investigate about the feasibility of using bamboo as a reinforcing material in reinforced concrete members,flexural loading tests were carried out on reinforced beams in which all rebar,including the main rebar and the stirrups ,were replaced with bamboo.good load-carrying capacity , determined by when the main bamboo rebar ruptured ,can be obtained if the number of bamboo stirrups is sufficient to prevent the shear failure of the beam.

Youngsi Jung (2006) investigated the feasibility of using bamboo as alternative reinforcement to steel in concrete structural elements .The researcher investigated bamboo's tensile strength and its pullout characteristics in concrete.Tensile test specimens were tested to failure and their characteristics noted.test results show that failure nodes are (1) node failure ,(2)splitting failure,(3)failure at the end tops.Also,the pullouts test results showed that the bond strengths for bamboo was lower than those for steel.

I.K. Khan (2014) presents research work bamboo sticks had been provided as reinforcement in concrete beams in place of steel bars.Different shapes of cross section of bamboo stick such as circular,square and triangular were used as reinforcement . the load carrying capacity of the bamboo reinforced beam using square cross section was higher than bamboo reinforced beams with triangular and circular cross section . Based on the limited number of tests conducted ,it was concluded that bamboo may be used as substitute of steel reinforcement in beams.

Kumar and Prasad (2003) conducted investigation on strength and deformation characteristics of six (6) bamboo reinforced conventional and blended concrete beams. Three(3) bamboo reinforced concrete beams of M25 – grade concrete and (3)of blended concrete containing 15% fly ash and 30% blast furnace slag as partial replacement of cement and coarse aggregate in the same mix were used,The result showed that the first crack load and ultimate failure load were similar for both types of beams while all the beams exhibited large ductility before the final failure with 2.40 and 2.43 times their corresponding theoretical failure loads respectively.

The united States Navel Civil Engineering Laboratory (1966,2000) reported a

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

Masani (1977) conducted an in depth study outlining the proper ways to utilize bamboo in construction .A listing of the positive aspects of bamboo is given,citing examples pertaining to its economical , mechanical and environmental properties.when used as reinnforcemen in concrete ,directions are given ti insure a better performance ,including discussions on waterproofing,pressure – treating ,concrete design and beam design.this study found that the bamboo reinforcement area should be 5 times the typical steel reinforcement area ,and that even when fine cracks develop on the surface of the bamboo ,the load carrying capacity of the member is not reduced.The only negative properties of bamboo given are its susceptibility to attack by insects,fungi and dried bamboo is prone to catch fire.

Amada and Untao (2001) studied the fracture properties of bamboo. In contradiction to other tudies , this study states that the tensile strength of bamboo fibres almost corresponds to that of steel .The main discovery is that the fracture properties of bamboo depend upon the origin of fracture.In the nodes , it is found that the average fracture toughness is lower than the minimum value of the entire clum,suggesting that the fibres in the nodes do not contribute any fracture resistance.

III. METHODOLOGY

MATERIALS AND PROPERTIES

The materials to be used in this research are
1. Ordinary Portland Cement (53 grade)
2. Coarse Aggregate
3. Fine Aggregate
4. Steel Bars (8 and 10 mm dia. of bars)
5. Bamboo Sticks (clums10mm avg dia)
6. Curing agent (CeraPoly cure-R).
7. Epoxy Resin

CEMENT

Cement is a binding substance used in construction to bind other materials together. The Ordinary Portland Cement (53grade) conforming to IS: 8112-1989 is used. Many tests were conducted on cement and results are tabled.

Table No.1 Properties of Cement

S.No	Property	Results obtained
1.	Specific gravity	3.14
2.	Consistency	32 %
3.	Initial setting time	31 min
4.	Final setting time	600 min
5.	Fineness	6%

FINEAGGREGATE

Fine aggregate also known as river sand is a natural granular mineral particle. This river is obtained from the accordance of Zone I as per IS 383-1970. The physical properties of river sand like specific gravity, fineness modulus and water absorption are tested with results:

Table No.2 Properties of FA

S.No	Property	Results obtained
1.	Specific Gravity	3.34
2.	Fineness modulus	2.73%
3.	Water absorption	5.6%

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COARSEAGGREGATE

Coarse aggregate consists of natural disintegration of rock or uncrushed gravel, as per IS: 383. Coarse aggregate used in this project is of the size 20mm.The physical properties of coarse aggregate like specific gravity, fineness modulus and water absorption are tested in accordance with IS:2386-3

Table No.3 Properties of CA

S.No	Property	Results obtained
1.	Specific Gravity	2.68
2.	Water absorption	0.5%
3.	Fineness modulus	3.35

STEEL

Steel is introduced to give tensile property to the building as concrete is strong in compression and weak in tension.it plays a crucial role on earthquake resistance due to its ductile property. The physical properties of steel like young modulus, grade, density and coefficient of expansion.

Table No.4 Properties of Steel

S.No	Property	Results obtained
1.	Grade	Fe415
2.	Young's modulus	2×10^5 N/mm^2
3.	Density	7850 Kg/m^3
4.	Co-eff. of thermal expansion	12×10^{-6} /^{o} C

BAMBOO

Bamboo is a fast growing grass species which is high in strength, flexibility and toughness and is used as a substitute for steel as reinforcement in rural areas and after a few years of research it will be introduced in the urban areas after well seasoning and treated with various techniques. Its properties such as weight, specific gravity, modulus of rupture and modulus of elasticity are resulted and tabulated.

Table No.5 Properties of Bamboo

S.No	Property	Results obtained
1	Specific gravity	0.6
2	Average weight	0.675 Kg/m
3	Modulus of elasticity	1.8×10^5 N/mm^2

WATER

The strength workability and durability of a concrete depends on the water added to the mix. The strength is also dependent on the days of curing the concrete. Normally portable water is used in construction with a w/c ratio of 0.5

CURING AGENT

Since bamboo is a vegetation species is expands and contracts when it comes in contact with water so epoxy resins are used to bond the bamboo and concrete. Since bamboo expands and contracts when in contact with water the beam cannot be placed for curing.so a curing compound is added to avoid curing and to gain strength of the beam in earlier age. The curing agent used in this project is Cera poly cure-R

Properties of curing agent:

Water loss after 72 hrs. :<0.35 Kg/m^2
Appearance :Translucent White
Dry film colour : White
Viscosity : 5 to 10 cps
Reflectance :>85% of MgO
Min. temp : 4^{o}C

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Fig. No.1 Cera Poly cure

EPOXY RESIN

Epoxy resin is used as a coating for bamboo to avoid the decomposition of bamboo and to provide a good bonding strength between bamboo and concrete.

Properties of epoxy resin

- ✓ Colour :pale yellow liquid
- ✓ Mix Density : 1.05 Kg/Litre
- ✓ Mix Ratio : 77:23
- ✓ PotLife : 50 minutes at 25^{o}C.

IV. MIX DESIGN

4.1 Introduction

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required as strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labor. The variation in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view, the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure.

This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job.

The cost of labor depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labor to obtain a degree of compaction with available equipment.

4.2 Requirements of concrete mix design

The requirements which form the basis of selection and proportioning of mix ingredients are:

- ➢ The minimum compressive strength required from structural consideration.
- ➢ The adequate workability necessary for full compaction with the compacting equipment available.
- ➢ Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions.
- ➢ Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

4.3 Types of Mixes

4.3.1 Nominal Mix

In the past, the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes.

These offer simplicity and under normal circumstances, have a margin of strength above that

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specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

5.3.2 Standard Mix

The nominal mixes of fixed cements-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been include in many specification. These mixes are termed standard mixes.

4.3.3 Design Mix

In these mixes, the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However , the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

4.4 Factors affecting the choice of mix proportions

The various factors affecting the mix design are:

4.4.1 Compressive strength

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete.

4.4.2 Workability

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used.

4.4.3 Durability

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete.

4.4.4 Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate.

4.4.5 Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used.

4.4.6 Quality control

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix will be the cement-content required. The factor controlling this difference is termed as quality control.

4.4.7 Mix proportion designations

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates.

5.4.8 Factors to be considered for mix design

- The grade designation giving the characteristics strength requirement of concrete

The type of cement influences the rate of development of compressive strength of concrete.

- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of section
- Quantity and spacing of reinforcement and technique used for transportation.

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V. CONCLUSION

The experimental work shows the various results

- The preliminary tests for bamboo and concrete materials are completed.
- Conventional and bamboo reinforced concrete beans were casted and tested.
- The shear strength of the reinforced bamboo sections is comparatively lower than that of the completely steel reinforced beams.
- Replacement of steel with bamboo in a larger amount will make the structure lighter as the percentage of bamboo reinforcement that has given increases and the density of bamboo reinforced concrete beam decreases.
- As this is a lighter structure it will be less vulnerable to earthquake loads. Replacement of steel by bamboo makes the structure most economical and making easy to lower income families to build houses.