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Review Paper

To what extent can bamboo replace steel reinforcement in reinforced concrete slabs?

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Keywords

Bamboo reinforced concrete slab, bamboo, non-conventional materials, concrete, ultimate tensile stress

ABSTACT

This research was undertaken to investigate the feasibility of bamboo reinforced concrete and if it can replace steel reinforced concrete for future construction. Two slabs reinforced with two bamboo culms and three bamboo culms were tested under four-point loading to investigate the flexural strength or bending strength. Slab2 reinforced with three bamboo culm showed strength that is a third bigger than the strength of slab1 containing two bamboo culm. Also deflection of slab2 also showed twice the deflection of slab1. Water proofing agent should be used as this will minimize the water absorption and sand/adhesive should be applied to increase the bond strength between the bamboo and concrete. The ultimate tensile strength of bamboo is 138 N/mm2.

This is almost half the ultimate tensile strength of mild steel. Under certain condition and a strict preparation bamboo can be used as a rebar for concrete for light weight structures.

1. INTRODUCTION

The purpose of this project is to investigate the behavior of bamboo as reinforcement for concrete. Theoretical and experimental investigations will be carried out to see the feasibility of bamboo as a replacement for steel in concrete reinforcement.

Description of nature of the problem

Concrete is very important for building and the "single most widely used material in the world (Mitchell, 2008)". However, concrete is very weak in tensile and cannot be used by itself, therefore a different material needs to be used to reinforce it. Therefore, for centuries steel has been the primary reinforcement for concrete. This is because steel has high tensile strength and it compensates the low tensile strength of concrete.

Steel is strong reinforcement for concrete but steel is very expensive and is not a natural material which could have an impact on the availability of steel in the future. Therefore, an alternative material is needed to replace steel for future construction. Steel also has negative effect on the environment because it consumes a lot of energy when is produced and this results in a vast amount of carbon dioxide released into the atmosphere.

Many research is being carried out every year to find an alternative material to replace steel as a rebar. Some examples of reinforcement material other than steal are glass, carbon, basalt, aramid, synthetic and bamboo. In this project bamboo is considered as a potential reinforcement for concrete.

Bamboo has also been used as a building material on construction for many years mostly in developing countries like Vietnam and Thailand because of its low cost and availability. However, bamboo is also environmental and sustainable because of its natural material and low carbon dioxide emission.

Bamboos are strong in both tension and compression but most importantly they are strong in tension, this is very significant because concrete is strong in compression but week in tension. Therefore, the bamboo can complement the low tensile strength of concrete when used as reinforcement.

Project's scope, aims and objectives

The project's scope is to investigate the feasibility of bamboo reinforced concrete and if it can replace steel reinforced concrete for future construction. Steel has been used alongside concrete as a composite material for years. However, there is need for new materials that could be used for reinforcement for concrete but is cheaper, sustainable and friendly to the environment.

The project's aim is to investigate to what extend can bamboo replace steel reinforcement in reinforced concrete slabs.

Here are all the objectives set out for this project:

- Investigate to what extend has bamboo been used as reinforcement in concrete slabs
- Identify possible pros and cons of using bamboo as reinforcement in concrete slabs

- Develop testing regime to identify suitable bamboo for use as reinforcement
- Test concrete slabs with bamboo rebar to determine reinforcement
- Compare test results with theoretical models to asses' accuracy of models
- Identify construction uses from tests
- Comment on feasibility of using bamboo as reinforcement

2. LITERATURE REVIEW

Bamboo as an engineering material

Bamboo has been used in construction for centuries in some countries like India and Brazil. Bamboo is used for small building or parts of building like doors, windows, trusses, walling, ceiling, bridges and scaffolding. In Brazil the use of bamboo is limited to scaffolding and simple dwellings (Ghavami, 2005). They are mostly found in abundance in tropical and subtropical regions of the globe and are economical because bamboo reaches its maximum mechanical resistance in three years (Ghavami, 2005). This is one advantage of bamboo because the availability of bamboo is very high as it reaches its maximum strength in three years and also they are found in a large area of the globe.

Bamboo is relatively strong in tension with tensile strength reaching 370 N/mm^2 and requires 50 times less energy to produce than steel. Furthermore, the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel. Therefore, bamboo is potential alternative to steel in tensile loading applications (Ghavami, 2005).

"The structural advantage, over other engineering materials is studied in terms of modulus of elasticity, E, and density, q, using the material selection method developed at Cambridge University shown in Figure 1(Ghavami, 2005).

Durability of bamboo as an engineering material

Bamboo just like timber is vulnerable to insects, molds and environmental degradation. The durability of bamboo varies with age, type of species, treatment, conservation condition and curing. Curing should be initiated when bamboo is being cut in the bamboo grove. There is a strong link between the amount of starch pulse humidity content of bamboo culm and insect attack. However, bamboo can receive treatments like curing on the spot, immersion, heating or smoke in order to reduce the level of starch content. Also low humidity bamboo is less prone to mold attacks and increase the physical and mechanical properties of bamboo (Ghavami, 2005). Drying bamboo is fundamental to its conservation for various reasons, however bamboo can be dried in air, oven or by fire (Kharagpur, 2011).

Basic characteristics of bamboo

Bamboos are tall grasses and not trees. They belong to the family of the Bambusoideae and grow mostly in tropical and subtropical regions of the globe. They are the fastest growing plant in the world and could reach full grow in less than a year.

As seen from figure 2 bamboo consists of two sets of similarly structured vegetative axes: one grows above the ground called culm and the other below the ground called rhizome. The culm which is cylindrical shell is the main stem of the bamboo and is made up of jointed segments called nodes. These nodes are solid and contain solid plates which give the bamboo the strength to with stand buckling. The area between the nodes is called internode. The internode is usually hollow and gives the bamboo the flexibility to with stand wind stress (Shelton, 2009). The length of the internode varies considerably between species of bamboo and also the internode length increases from the bottom to the middle of the culm and then decreases from the middle to the top of the culm. The mechanical properties of bamboo vary because of climate change, nature of growth and the moisture content of the soil (Sakaray, Togati and Reddy, 2012).

Mechanical properties of bamboo

It is important to know the mechanical properties of bamboo in order to understand the behavior of bamboo withstanding stresses and strains. Also it is important to understand the mechanical properties of bamboo for construction and design phase to save time, cost and most importantly safety. Most of the literature review has conducted the following tests to determine the mechanical properties of bamboo. Tensile test, compressive test, modulus of elasticity, shear test, pull-out test and water absorption test.

(Sakaray, Togati and Reddy, 2012) have used the above tests on moso bamboo to determine the mechanical properties of bamboo. For the tensile test they have used universal testing machine to determine the average ultimate tensile strength of bamboo. They have conducted that the average ultimate tensile strength of moso bamboo is 125N/mm^2, which is half the strength of mild steel. Also is worth mentioning that moso bamboo is one of the high tensile strength species of bamboo. This is important when choosing the type of bamboo to reinforce concrete. They have also showed the failure type of moso bamboo is mainly node failure due to brittle nature at nodes. However other failures have been observed like split failure or combination of both node and split failure.

Behaviour of bamboo in structural concrete

Kankam tested the behavior of bamboo in structural concrete in 1986 and in 1988. (Kankam, 1986) tested ten simply-supported one-way bamboo reinforced concrete slabs subjected to concentrated line loads. The experiment showed three different modes of failures on the one way slabs; concrete in compression, both shear and concrete in compression, and bamboo in tension. (Kankam, 1986) also conducted the theoretical results for the three slabs and found out the experiment results showed 180 per cent of the theoretically results. These results show the slabs are stronger than the predicted values; this is something that is going to be looked at for the slab experiment that is going to be conducted for this project.

The author followed the bamboo reinforced concrete slabs with bamboo reinforced concrete beam tests. (Kankam, 1988) tested six and ten bamboo reinforced simply supported beams subjected to long and short term loading. The ten bamboo reinforced beams failed due to diagonal tension failure of the concrete in the shear span (Kankam, 1988).

(Khare, 2005) tested six bamboo reinforced concrete beams on four-point load to failure. The six bamboo reinforced beams are then compared with plain concrete and steel reinforced concrete beams. Concrete beams reinforced with bamboo showed 250 per cent more load carrying capacity than plain concrete beams. The result also shows on average the ultimate load capacity of bamboo reinforced concrete is 0.35 per cent of ultimate load capacity of steel reinforced concrete (Khare, 2005).

3. CONCLUSION AND RECOMINDATIONS:

Conclusion:

1. From literature it is found out that bamboo has high tensile strength reaching up 370 N/mm^2 and low young modulus of around 1.5 x 10^4. The ultimate tensile strength conducted from this experiment is 138 N/mm^2. This is almost half the ultimate tensile strength of mild steel. Since concrete is week in tension, bamboo is potential reinforcement for concrete. Therefore, including bamboo as a rebar for concrete will increase the loading capacity of concrete slab. From the four-point flexural test it shows that the strength of slab2 is a third bigger than the strength of slab1. And also the displacement of slab2 showed twice the displacement of slab1
2. The low young modulus show that the bamboo will deflect more than steel under the same condition. This could be advantageous because the bamboo will absorb stress and deflect before falling and this will stop concrete from sudden failure if used as rebar. However, this could also be disadvantages because under maximum load it will not stop cracking of concrete.
3. The experimental results showed low strength compared to theoretical results. However, this is due to the bamboo culm absorbing fresh concrete water during curing and bond failure. Water proofing agent should be used as this will minimize the water absorption and sand/adhesive should be applied to increase the bond strength between the bamboo and concrete.
4. Durability is one of the disadvantage of bamboo for long time construction. Therefore, a strict preparation has to be done to ensure that bamboo culm is at its strongest state as possible and lasts as long as possible. For this to be achieved bamboo should be treated against insects and molds. Bamboo can receive treatments like curing on the spot, immersion, heating or smoke in order to reduce the level of starch content.
5. Under certain condition and a strict preparation bamboo can be used as a rebar for concrete for light weight structures.

Recommendation

Here are some of the recommendations for future research.

1. Further research needs to be conducted on different species of bamboo in order to pick the best bamboo culm as a rebar. It is appreciated that some species of bamboo are better at different mechanical properties. However, there is a need to have more bamboo tested in order to know what each individual species of bamboo is good for in construction e.g. some species might have high tensile strength and some species might be able to absorb less water.
2. Further research also needs to be conducted for bond strength between bamboo and concrete. At the moment sand is used to improve the bond strength; however, more materials or adhesive needs to be experiment in order to find out what material could be used to improve bond strength.
3. The behavior of bamboo reinforced concrete should be investigated under seismic wave.
4. Further research could be conducted on the straightness of bamboo shoots and compressive strength. Lack of bamboo shoots growing straight causes the culm to fail by buckling before reaching their maximum compressive strength.
5. Cover dimension could be altered since bamboo doesn't rust like steel.
6. Just like steel the percentage of bamboo in concrete should be investigated. For this project the percentage of bamboo was not an issue because the amount of bamboo used was not sufficient to cause over-reinforced concrete. However further research will clarify the percentage needed to reinforce concrete.
7. Different materials of stirrups should be investigated.
8. The behavior of bamboo in three-point bending test was investigated but was not included in this project. However, it will be interesting for future research to investigate four-point bending test in order to see the behavior of bamboo under such condition.
9. Characteristic strength should be made for the design of future bamboo rebar.
10. Durability of bamboo should be investigated in depth over a long time. Durability is a big problem for bamboo and better understanding will help towards the life expectancy of bamboo in construction.
11. The thickness and diameter of bamboo should be investigated further to understand the relationship between thickness or diameter and ultimate tensile strength of bamboo.
    Different temperatures should be investigated on bamboo to have better understanding the influence it will have on the tensile and compressive strength of bamboo.

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