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Review Paper on Design and Analysis of Hybrid Steel-Bamboo-Concrete Truss Bridge

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Abstract-*Firstly, this study evaluates experimentally the physical and mechanical properties of the hybrid material. Then it develops an analytical model and performs the structural design of the bridge. The connection system for joining among element on a truss structure significantly influences the strength as well as behaviour of the structure, so this study will deal with different types of connection systems. The system will be tested experimentally with a full scale model, after which the truss will be constructed and tested for loading, deflection and failure.*
Keyword: *Bamboo, Low-cost bridges, Bamboo footbridges, Bridge engineering, concrete filled bamboo.*

I. INTRODUCTION

Bamboo as structural material has been extensively used to build permanent and temporary structures in past decades. Bamboo is recognized as a sustainable material that can serve as a competitive and environmentally friendly alternative to non-renewable and polluting materials such as steel and concrete due to that it is a rapidly renewable structural material and has mechanical properties similar to timber. In recent years, a large number of experimental and analytical studies on the mechanical properties of structural bamboo have been conducted. Also, several researchers have investigated the behavior of bamboo as reinforcement in structural concrete. According to the studies above, bamboo can be considered as an attractive alternative to steel in tensile loading due to its relatively high tensile strength, falling within the range of 100 MPa–400 MPa. For some species of bamboo, the ultimate tensile strength is same as the yield strength of mild steel. The present study investigates an alternative inexpensive approach for footbridges assembled out of prefabricated bamboo members. Bamboo is a natural material with remarkable mechanical properties and in abundance in many parts of the world, particularly in many areas of interests. Additionally, bamboo structures are eco-friendly and align with the goal for green and sustainable development. During the last two decades, there is a growing interest in bamboo as a construction material. Research focuses mainly on characterizing the materials and its mechanical properties. Traditional bamboo structures) can be found in Asia, Latin America and East Africa. Contemporary bamboo footbridges (mostly arch bridges) using full bamboo culms have been constructed in Colombia and Indonesia. However, in the construction industry, the usage of bamboo culms is still limited. Partly, this is because of the shortage of design codes and standards. An interesting exception is the extensive use of bamboo for scaffolding in the HK region, which is supported by pertinent guidelines and documentation.

II. LITERATURE REVIEW

1. Sandeep Bhardwaj et. al.(2014) “An Alternative to Steel: Bamboo-A review”: Bamboo material and their composites may be utilised in bridge as a replacement of steel for a IS Class A loading bridge. Steel column can be replaced with bamboo column with use of modern material like Ferro cement, steel joints, carbon fibre reinforced plastics as stiffeners.
2. Fernando Oliveira et. al.(2020) “Numerical analysis of truss elements on a sustainable bamboo bridge”: The numerical comparison between truss elements of a steel bridge and a bamboo bridge, both designed for pedestrian traffic was performed on this paper. First, an existing steel bridge in Brasilia was considered and numerically modeled using FEM. The results obtained in this model are in agreement with the Brazilian standards and the bridge design manual. Second, another FEM model was considered changing all steel elements with sustainable bamboo elements. The bamboo Dendrocalamus Giganteus with its natural geometry is considered. The design procedure closely follows the Brazilian structural timber design standard, similar to international standards. It was demonstrated that both bridges have satisfactory stiffness and load carrying capacity.
3. Wen-Tao Liet al (2017) “Axial load behavior of structural bamboo filled with concrete and cement mortar”: The axial load bearing capacities and the initial stiffness of both concrete-filled bamboo columns and

cement mortar filled bamboo columns are much higher than those of con-ventional bamboo, which verified the feasibility of the pro-posed stiffening scheme for conventional structural bamboo. Furthermore, it is more efficient to increase the axial load behavior by filling concrete than filling cement mortar. The experimental ultimate bearing capacities of concrete-filled bamboo columns and cement mortar filled bamboo columns are generally higher than the calculated values by a simple summation of the bamboo and the infilled material contributions. Hence, the confining effects of bamboo on the infilled material are significant and cannot be ignored.

4. T.S. Paraskevaet al (2017) "Design and experimental verification of easily constructible bamboo footbridges for rural areas": The present study investigates an original solution for green and sustainable footbridges as a remedy to the overwhelming lack of bridges in the underprivileged world. The proposed bamboo footbridges bypass the need for expensive materials and complex techniques. They can be rapidly assembled on site from prefabri-cated bamboo members and low-cost gusset type steel connec-tions. The present study focuses on the design, the construction, and the experimental validation of simple truss bamboo bridges.

5. Giuseppe Quaranta et al (2019) "Experimental dynamic characterization of a new composite glubam-steel truss structure": This study investigated the dynamic characteristics of a new composite glubam-steel truss structure in which the elements of upper chords and diagonal bars are made of glued laminated bamboo (glubam) while the bars of the lower chord are made of steel bars with hollow cross-sections. Such a system was conceived to facilitate its industrial production while reducing the overall cost and ensuring high environmental sustainability through efficient use of the constituent materials and structural details suitable to allow the reuse of each element. Laboratory tests were performed on a prototype structural system in order to estimate its dynamic properties.

III. METHODOLOGY

Properties of bamboo

Bamboo is strong in tension and in compression. The tensile strength of the outer fibers of Bamboo is much greater than that of steel. Bamboo exhibits great bending capacity. Its elasticity makes it a great material for construction in earthquake areas. The light weight of bamboo is one of its great advantages: it is easy to transport and easy to work with. The usage of cranes is unnecessary in most cases.

Table 1 Embodied energy of building materials with respect to their strength.

Material	MJ/m^3 per N/mm^2
Concrete	240
Steel	1500
Timber	80
Bamboo	30

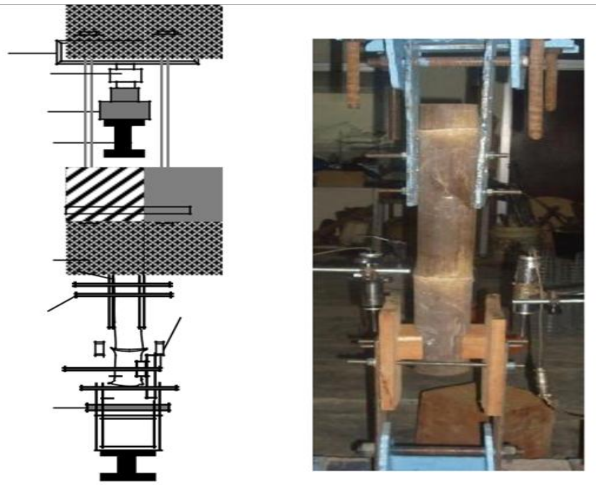

Fig. 1 (a) Test set-up for tension of the connection; (b) detail of the test set

Test to be conducted on bamboo

1. Determination of Density

The samples used in the determination of moisture content were the same used for density determination. Theoven-dry density of each sample were calculated using Equation

Density (kg / m³) = (mass / V) × 10^6 (2)
Where,
m: mass after oven dying (g) and V: volume of the sample (mm³)
2. Compression Strength

The Gigantochloa Scortechinii bamboo were cut into three sections of each culm for both untreated and treated from the bottom, middle and top part. The height of each test specimen was cut into twice of the external diameter of the bamboo culms. Compression strength were tested by using digital compression test machine. The maximum compressive stress then were calculated by using the Equation.

$$\sigma ult = Fult / A \quad (3)$$

where σult: compressive stress (MPa), Fult: maximum load (N) and A: bamboo wall cross-sectional area (mm²).

The results of the tests presented here were done on the Guadua Angustifolia species, with samples with a relative humidity of about 15%. They have been run by Dr .Simon Eicher, from the Otto- Graf-Institute.

Fundamentals of the design of Bamboo structures, thesis by 0. Arce-Villalobos 1993 Bamboo is not a homogeneous material. Inner and outer fibers have very different properties and work together to make bamboo a unique material. The inner part is softer and extremely elastic whereas the outer part is more rigid and extremely strong due to its silicate composition (Table 3.1.2). The tensile strength decreases in the nodes where the fibers run randomly. Nodes reduce the tensile strength of the whole culm. After five to six years, the tensile strength tends to decreases.

The variations in the results can be easily explained by the nature of the material bamboo. Each cane grows differently according of the amount of sun, water, and nutriments it receives. Each cane is therefore unique. Properties vary depending of the relative moisture of the bamboo: the density, for instance, varies from 500 to 800 kg/m 3 (31 to 50 pounds/ft 3).

Furthermore, the tests have been run in different places, on different samples, and under different conditions. Furthermore, the tests are done at small scale, and the samples are not always representative of the overall behavior of the culms. This explains why the design values are so small compare to the results presented above.

Mild steel:

Steel is made up of carbon and iron, with much more iron than carbon. In fact, at the most, steel can have about 2.1 percent carbon. Mild steel is one of the most commonly used construction materials. It is very strong and can be made from readily available natural materials. It is known as mild steel because of its relatively low carbon content.

Mild steel is very strong due to the low amount of carbon it contains. In materials science, strength is a complicated term. Mild steel has a high resistance to breakage. Mild steel, as opposed to higher carbon steels, is quite malleable, even when cold. This means it has high tensile and impact strength. Higher carbon steels usually shatter or crack under stress, while mild steel bends or deforms.

Concrete

According to previous research done on bamboo cavity filled with concrete, commercial self-compacting concrete was adopted to ensure the quality of casting and the uniformity of concrete properties in the specimens filled with concrete. Three plain concrete cylinders (152.5 mm in diameter and 305 mm in height) were prepared and tested in compression following ASTM C39/C39M to determine the concrete properties. The average concrete cylinder strength (f0c) was 35.91 MPa and the corresponding strain (eco) was 0.0021.

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