

WORLD BAMBOO CONGRESS, DAMYANG,  
KOREA 2015

# PURLIN - DOWEL CONNECTION FOR BAMBOO CONSTRUCTIONS AS SUSTAINABLE PROPOSAL FOR THE AMAZON HOUSING

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T a n i a   C e r r ó n





# Problems to be addressed

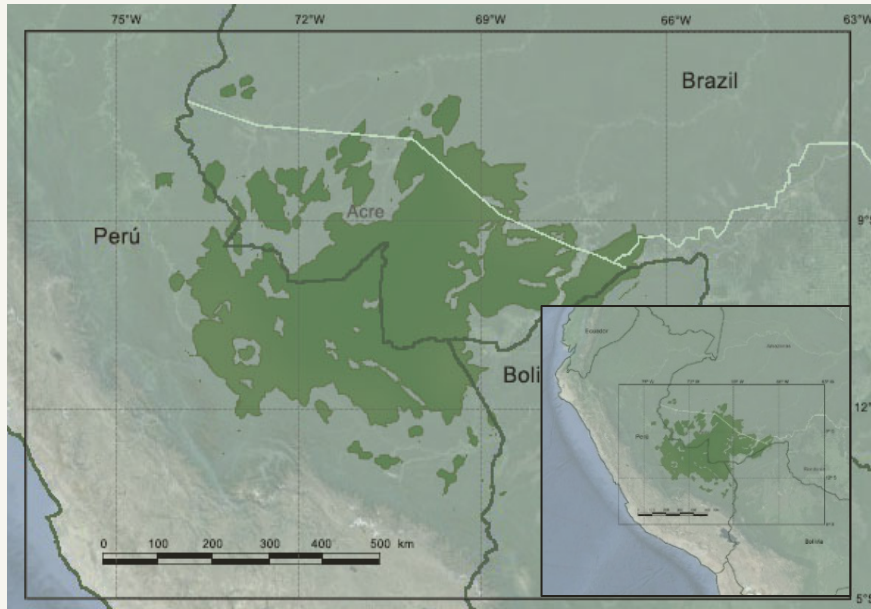


Peru is one of the 17 megadiverse countries of the world and its Eastern Tropical Andes-Amazon region is globally recognized conservation priority.





# Problems to be addressed



Peru has abundant bamboo resources with 67 species distributed in approximately 71,000 km<sup>2</sup> area, especially in the southwest Amazon where up to 30,000 km<sup>2</sup> of tropical rainforest are dominated by native *Guadua* genus bamboos.

However, local foresters and farmers lack knowledge of how to sustainably manage bamboo forest.

The natives know about bamboo, but they don't know the potential of it in construction and the possibility of industrial products



On the other hand the Amazon Indigenous groups, continue suffering the impact of colonization. They don't live in good conditions, they have health problems associated with the housing.



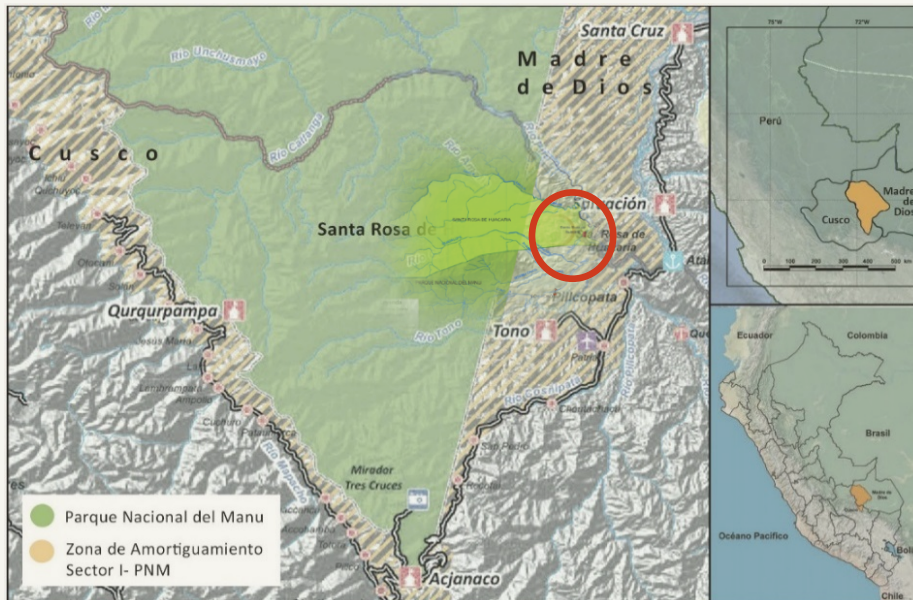
# Place and people

## Intervention Universe in potential areas

Zone	Regions	Proposal
Zone 1 North Coast	Tumbes, Piura, Lambayeque and La Libertad Regions.	
Zone 2 Northwest Center	Cajamarca, Amazonas and San Martín Regions.	
Zone 3 Central Forest	Cerro de Pasco, Huanuco and Junín Regions.	
Zone 4 Central Coast	Lima and Ica Regions.	
Zone 5 Southeast Forest	Andean Amazon, Cusco and Madre de Dios Regions.	Bamboo housing proposal for the Amazon

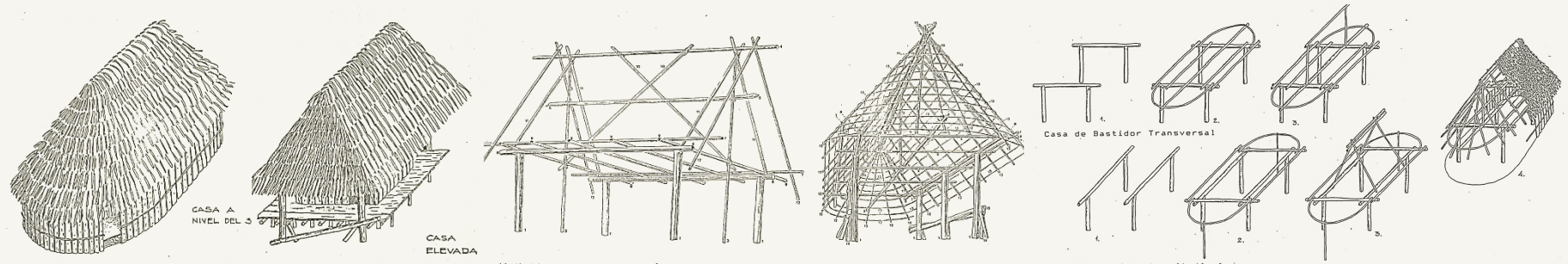
The housing project is located in the Amazon region of Peru, in the region of Cusco, in the Native Community of Santa Rosa de Huacarias in Manu National Park. The Community is populated by two ethnicities: Matsiguenga and Wachiperi.

The Matsiguenga, are one of the most representative indigenous communities in the Amazon.





# The Matsiguenga





# The Proposal

## **Eco-friendly house made of bamboo**

meets the physical, environmental, socioeconomic and cultural characteristics of the site.

**An "Appropriate construction system" with bamboo,**  
on the architectural features and structural components of Matsiguenga's techniques, natural materials, conception of their vision of housing.

*The use of bamboo is posed in different ways: cane, slats and mats.*



### **1 . P r o p o s a l C r i t e r i a**

- 1.1 Alternative and production of ecological and healthy housing for the Amazon. bam
- 1.2 Creativity with identity, design that responds to the habitat of Amazonian peoples.



### **2 . M a t e r i a l s p r o p o s e d**

Local and natural materials, mainly bamboo. Endemic species of the genus Guadua bamboo: *G.angustifolia*, *G.sarcocarpa* and/or another endemic specie.





M a t s u g e n g a   h o u s i n g





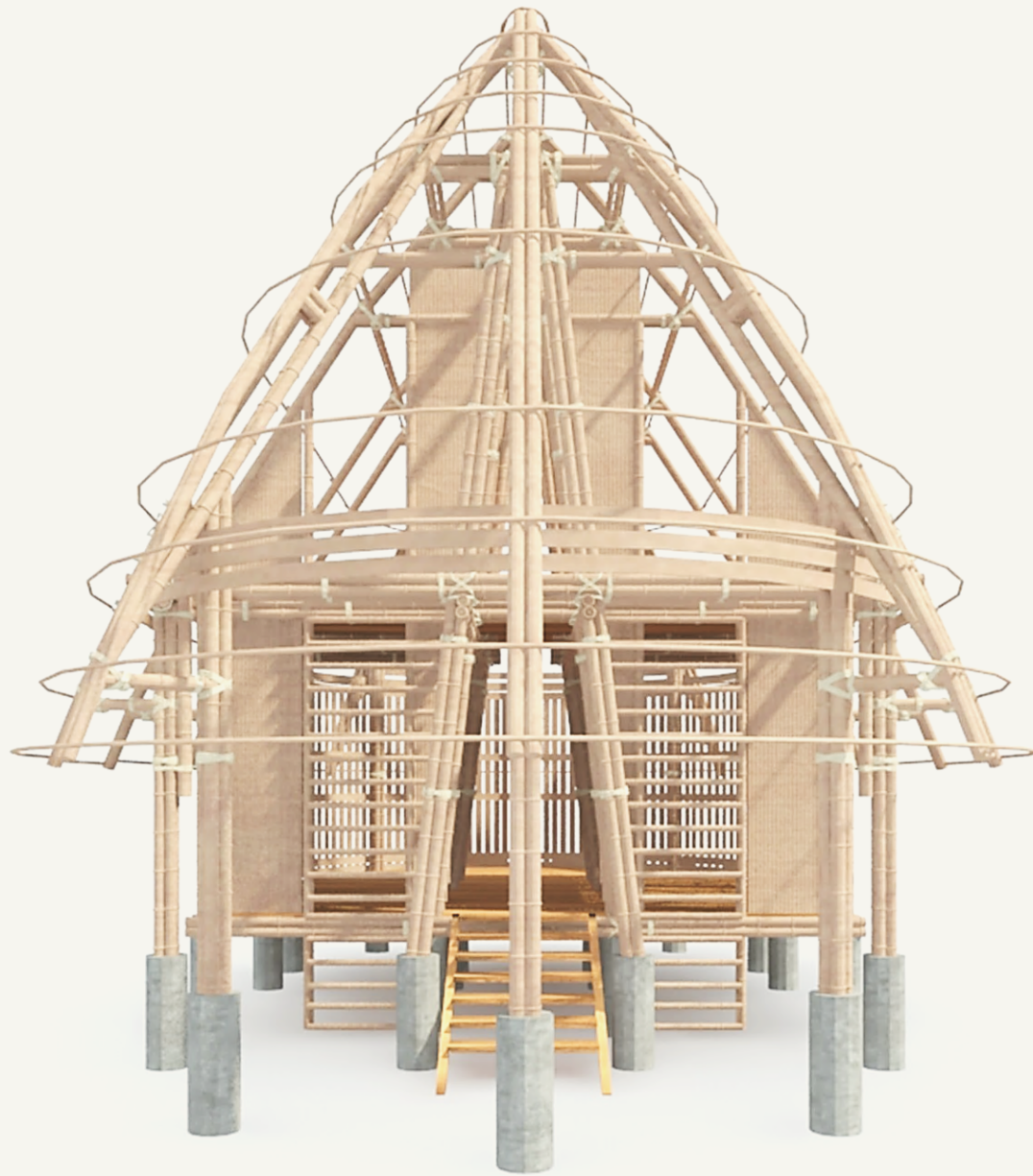
M a t s i g u e n g a   h o u s i n g





M a t s u g u e n g a h o u s i n g



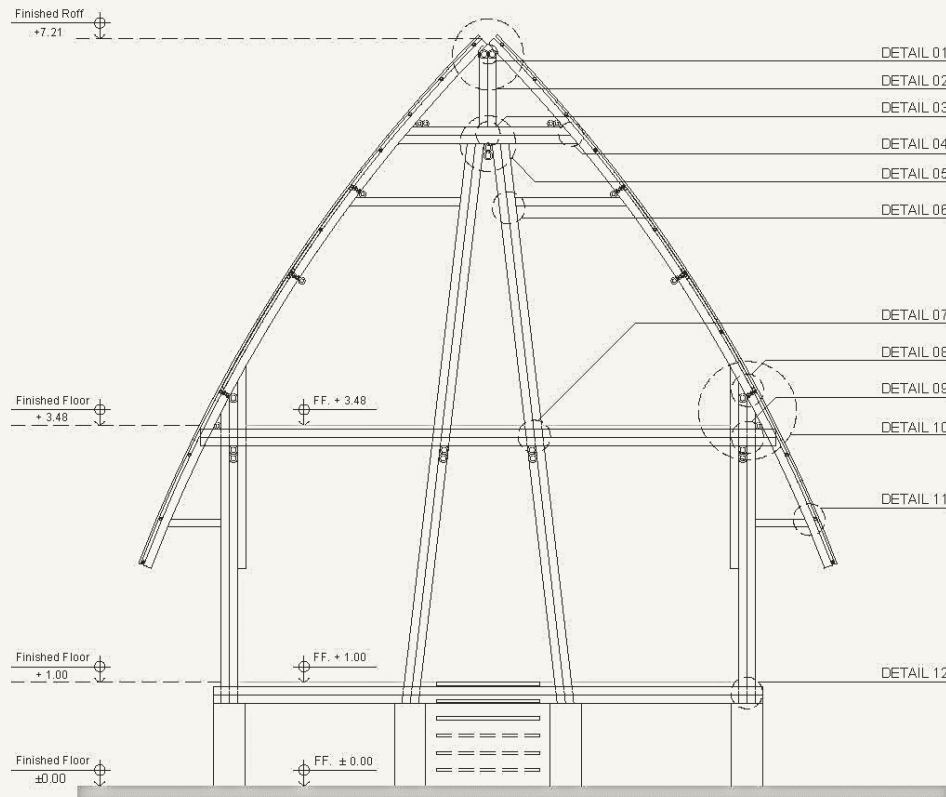


Proposal housing: Front View



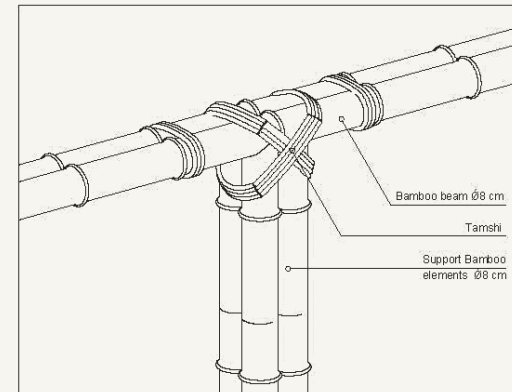
Proposal housing: Structural System



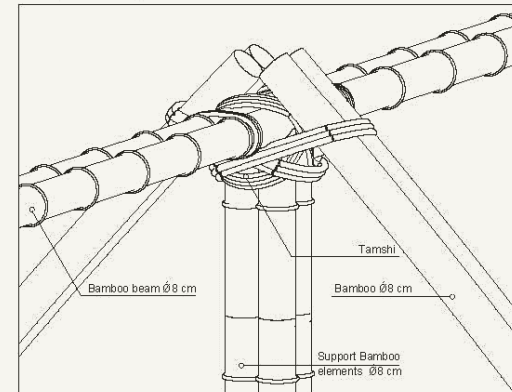


**SECTION B - B**

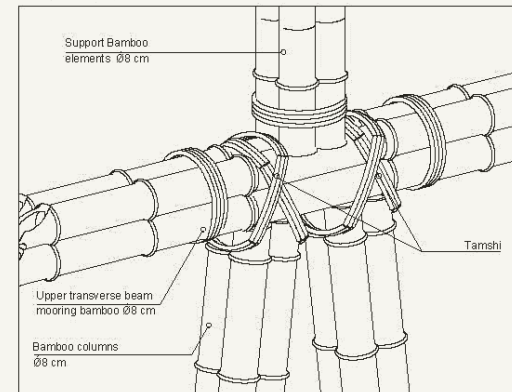
## DETAILS OF TIES WITH ROPE



**DETAIL 01**

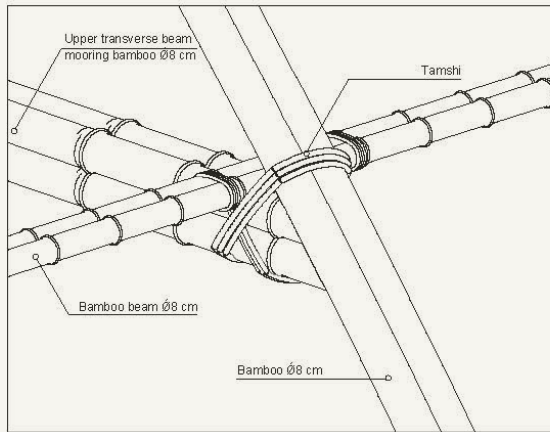


**DETAIL 02**

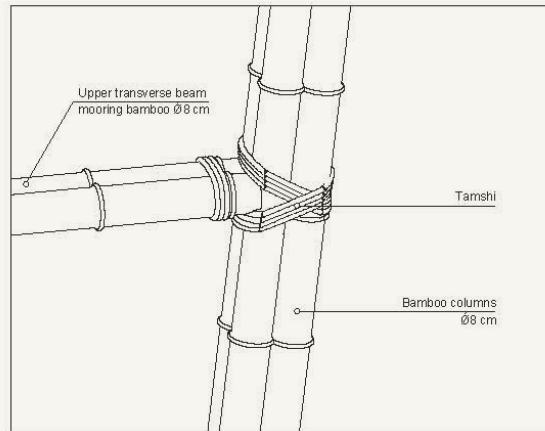


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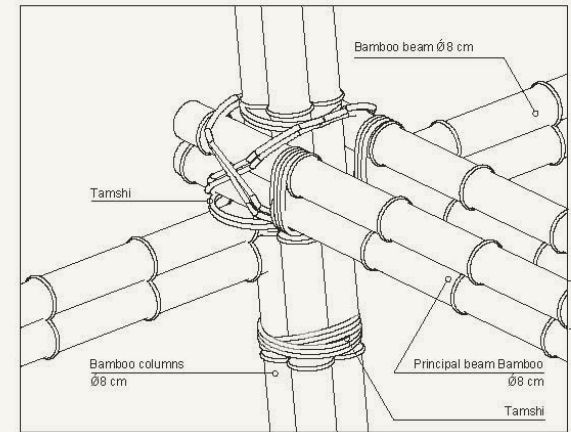




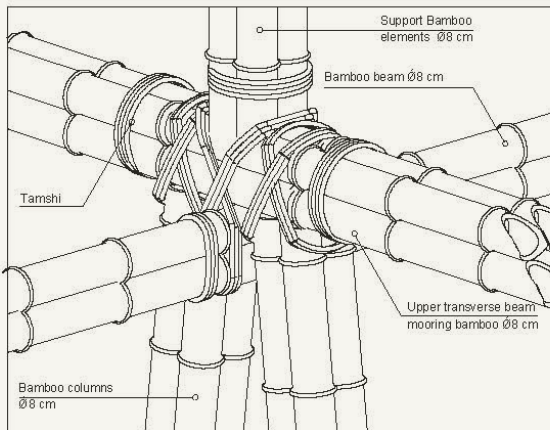
**DETAIL 04**



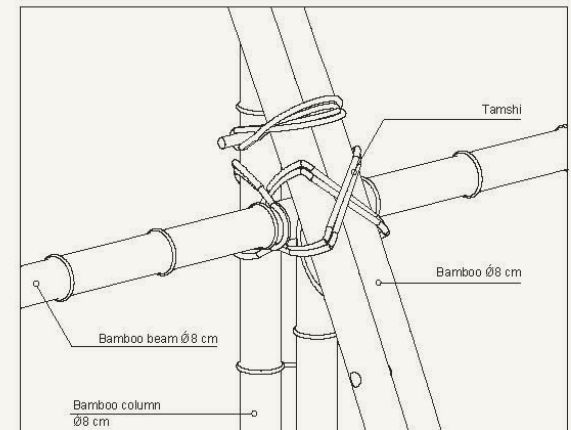
**DETAIL 06**



**DETAIL 07**



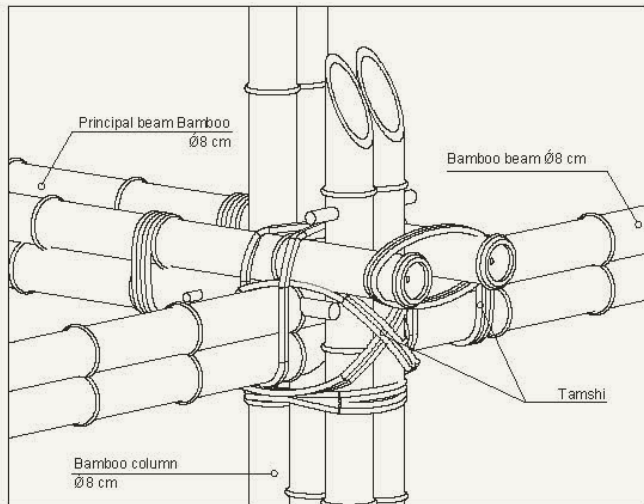
**DETAIL 05**



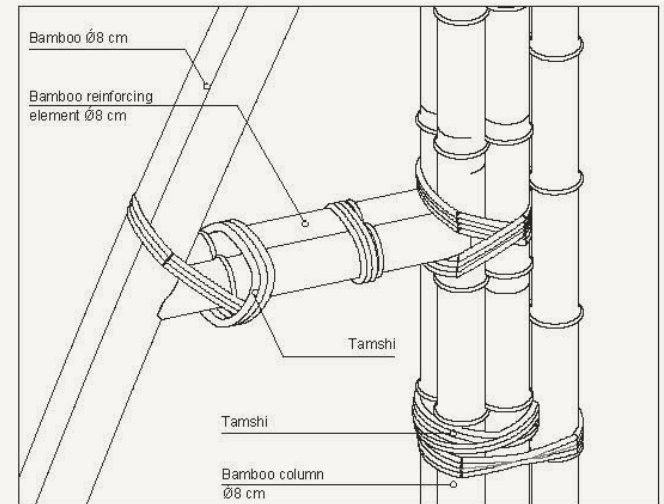
**DETAIL 08**

Purling-dowel detail proposal with “tamshi”

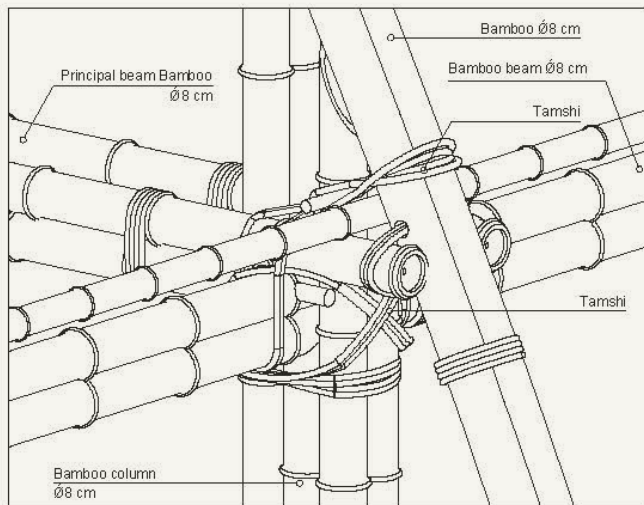




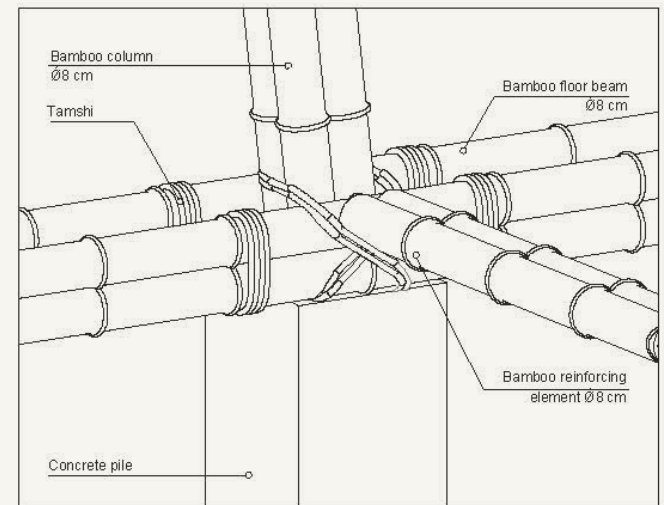
**DETAIL 09**



**DETAIL 11**

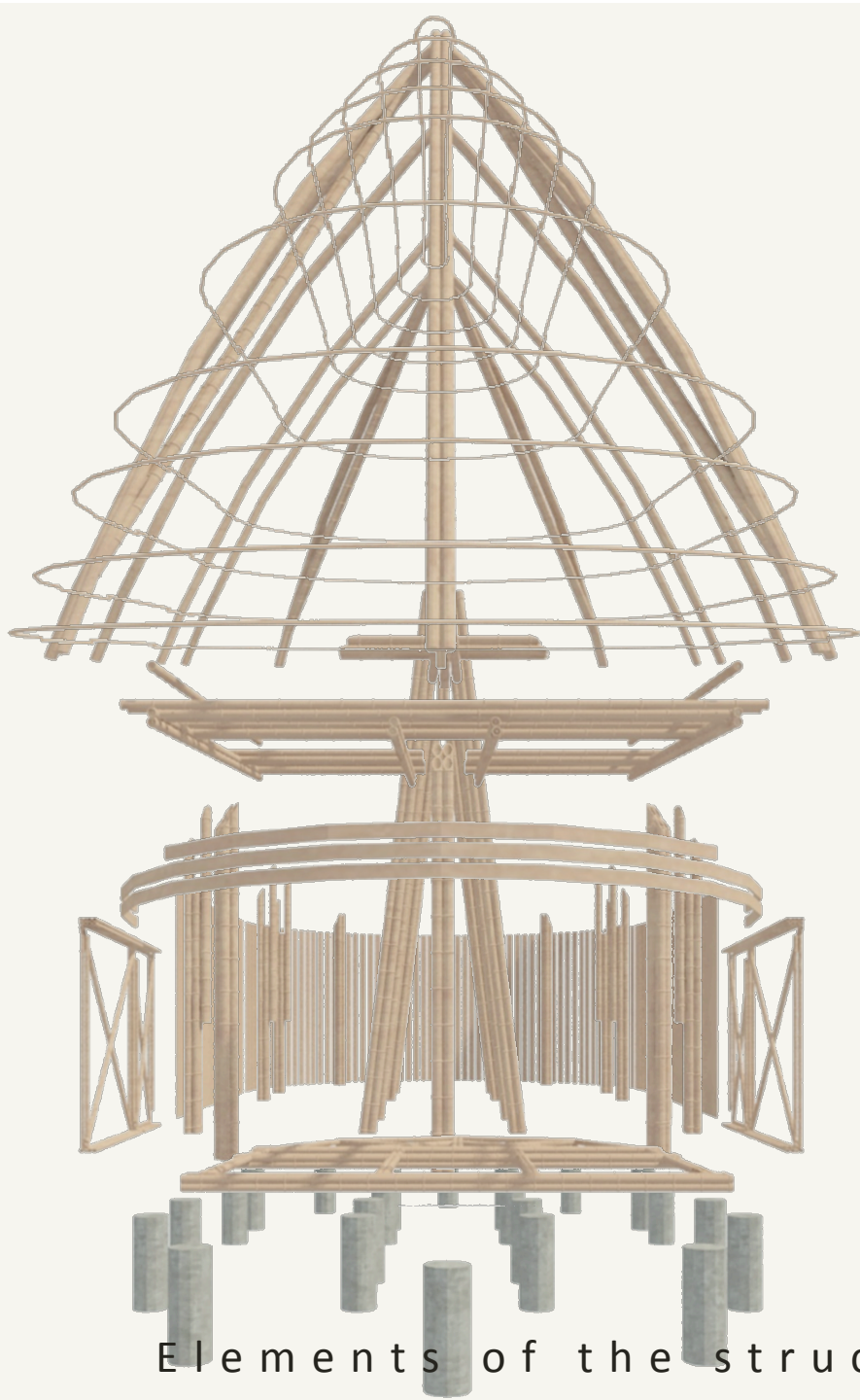


**DETAIL 10**

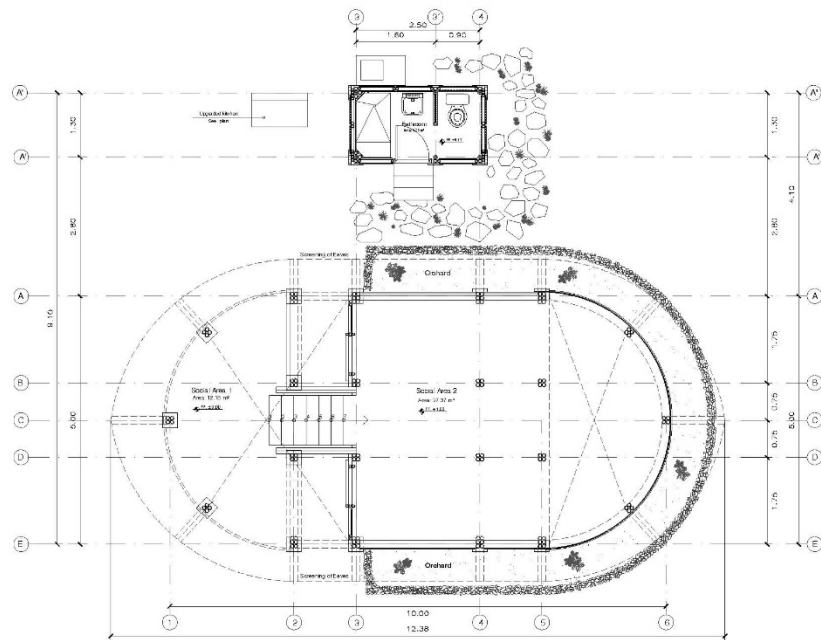


**DETAIL 12**

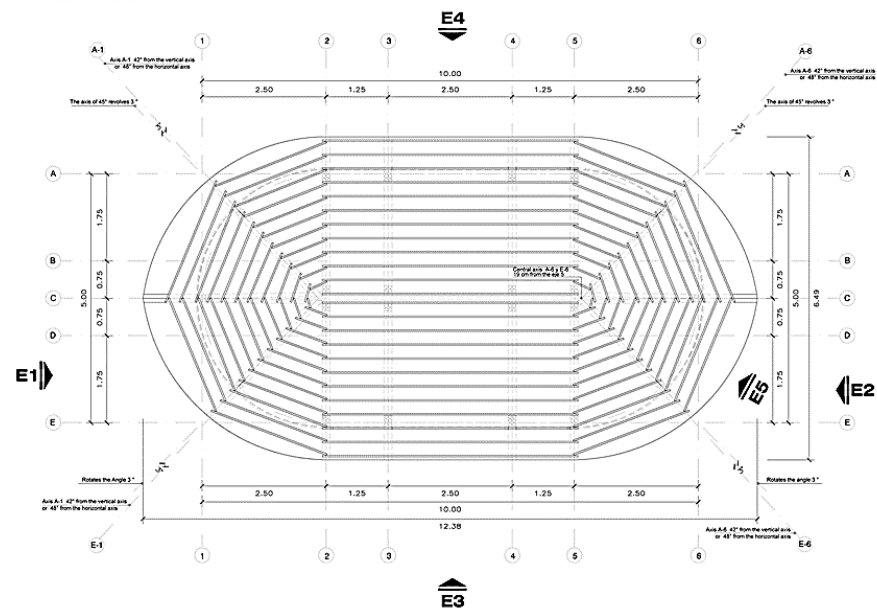




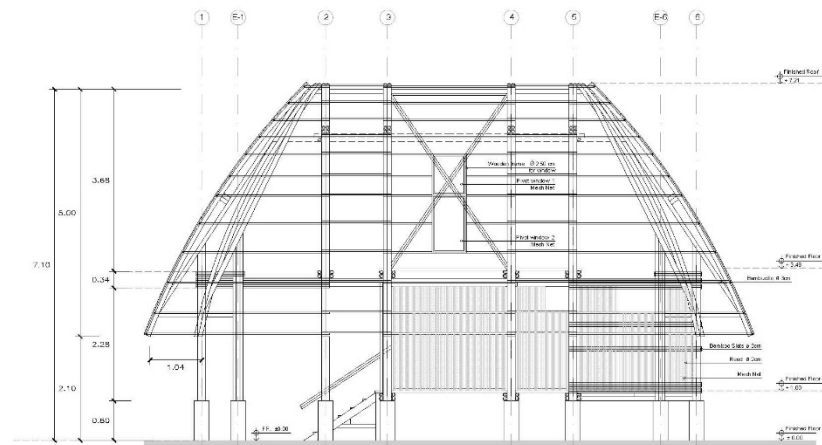
Elements of the structure and the enclosure



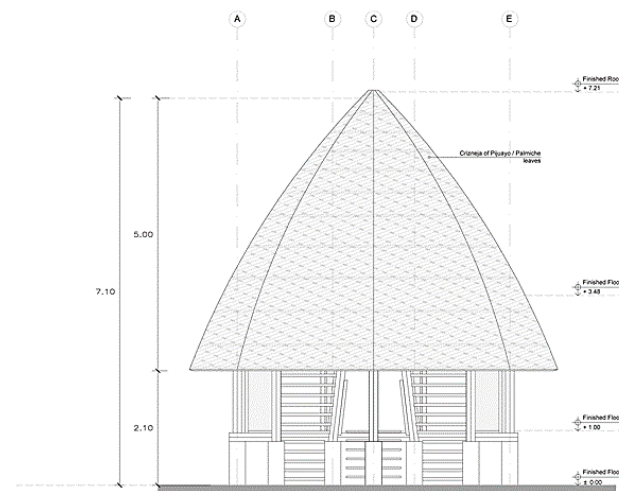
GENERAL PLANT



DECK JOISTS



ELEVATION 3 Y 4 - UNCOVERED



ELEVATION 1 - FRONTAL

Proposal housing: Area 95 m2



## Objective

- Proposition of a reinforcement method for dowel joints on bamboo canes with fiberglass.
- Improvement of embedding strength of joints on bamboo canes by proposed fiberglass reinforcement.

# 1. Test

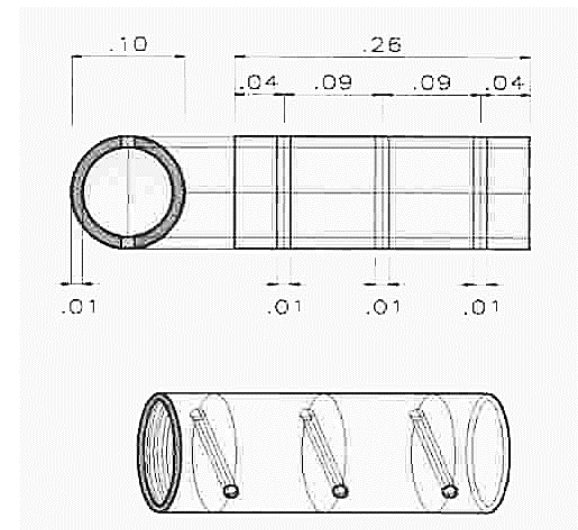
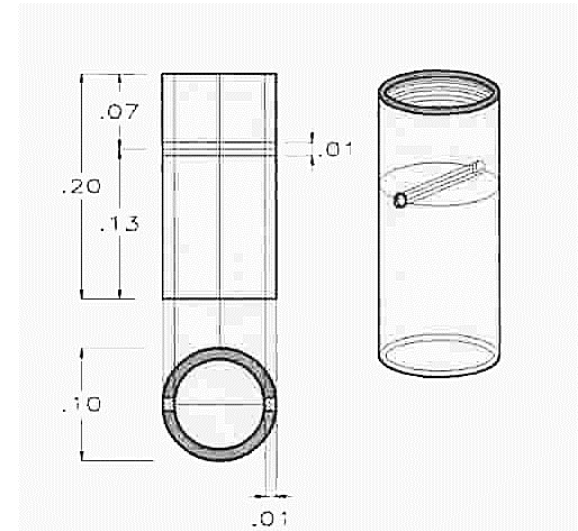
We prepared twelve specimens totally.

**Some of them were tested with compression parallel to the grain, and the others perpendicular to the grain.**

For the specimens in parallel compression to the grain, we had 6 specimens without diaphragm of 20 cm length, 10 cm diameter, and 10 mm cross section. And the experiment with compression perpendicular to the grain, 6 specimens without diaphragm of 26 cm length, 10 cm diameter, and 10 mm cross section were prepared.

Number and disposition of specimens were following:

- Three specimens with compression parallel to the grain without reinforcement.
- Three specimens with compression parallel to the grain with reinforcement.
- Three specimens with compression perpendicular to the grain without reinforcement.
- Three specimens with compression perpendicular to the grain with reinforcement.





## 2. Material

### 2.1 Bamboo

The used bamboos is of the type “Guadua Angustifolia”cultivated in Nimes - France.

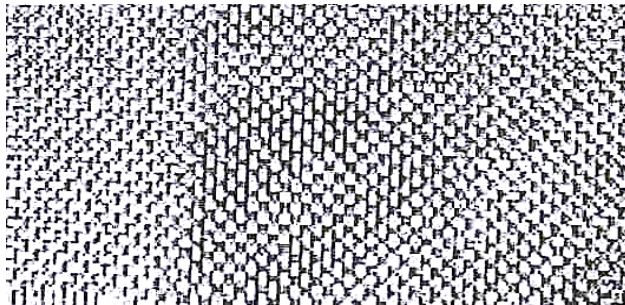
For the experiments with the reinforcement, the exterior surface of bamboo were rubbed with sandpaper to provide a better adhesion between the fiberglass and the cane of bamboo.

For the test on non-reinforced pieces, we bored directly one or three bolf-holes according to the type of experimentation.

### 2.2 Fiber

#### 2.2.3 Fiberglass

A fiber reinforced composite contains many single layers of lamina which are unidirectional or multi-directional. The properties of the composite depends on the properties of its constituent lamina. Only the two-dimensional orthotropic elasticity is applied when a lamina is thin enough to assume the properties of the axis perpendicular to plane of lamina are negligible.

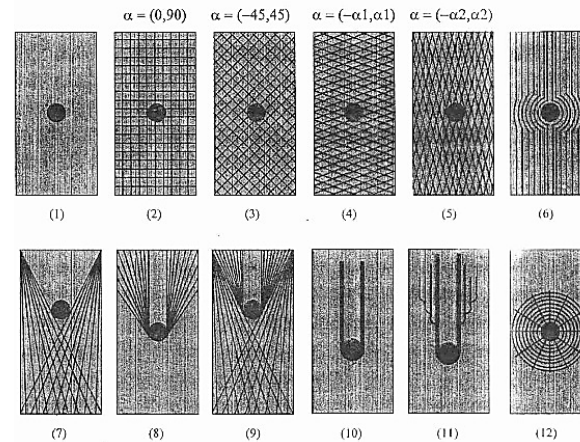


Properties	Glass S	Glass E	Carbon	Kevlar
Specific Gravity ( $\text{g/cm}^3$ )	2.54	2.54	1.80-1.95	1.45
Elasticity Modulus ( $\text{N/mm}^2$ )	87000	73000	350000	120000
Tensile Strength ( $\text{N/mm}^2$ )	4900	4300	2500	>3000
Elongation at break (%)		4.90	0.5-0.7	2.1
Price		1	7.3	4.2

Comparison of Fibers (Gay 1991)

## 2.2.3 Direction of Fiberglass

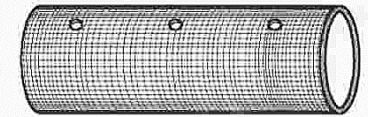
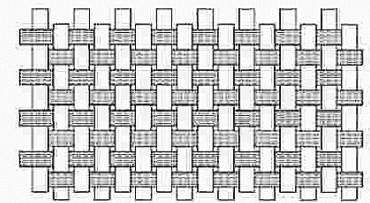
Technische Universität Dresden  
(Haller-Textile Reinforcement SFB 528)



## 2.2.4 Reinforcement

We haven employed a Type of commercialized fiberglass sheets, “Vetrotex” with 600gr/cm<sup>2</sup>, which are composed with perpendicular crossing fibers.

The sheets were glued on the exterior surface of bamboo, keeping their fibers in parallel to the bamboo are.



## 2.3 Adhesive

The reinforcement of fiberglass is glued with a commercialized Epoxy resin adhesive from “West System”.

Properties	Epoxy	Polyurethane	Polyester	Phenol
Specific Gravity (g/cm <sup>3</sup> )	1.10-1.40	1.10	1.10-1.45	1.30-1.86
Elasticity Modulus (N/mm <sup>2</sup> )	4500	700-7000	4000	3000
Tensile Strength (N/mm <sup>2</sup> )	130	30	80	70
Shear Modulus (N/mm <sup>2</sup> )	1600		1400	1100
Shrinkage (%)	0.08-0.15		2.00-8.00	1.00-1.20
Elongation at break (%)	2.00-6.00	100	120-160	70-120
Heat Resistance (°C)	210-260	100	120-160	70-120
Burning Rate	Slow to self-extinguished		Slow to self-extinguished	Very slow



### 3. Procedure

#### 3.1 Boring of the cane

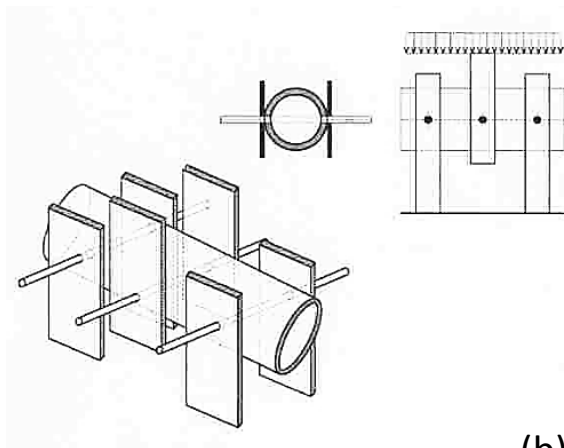
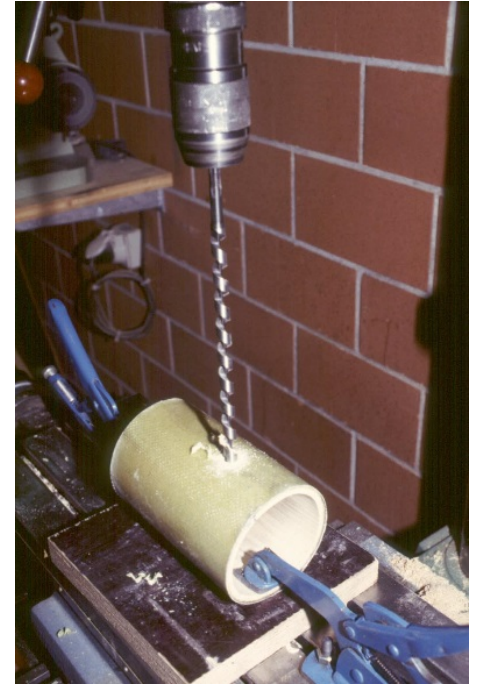
After glued the fiberglass on the bamboo cane, they were bored with 15 mm. of diameter in one line for parallel compression (a) to the grain and were the others bored in three lines with 15 mm in perpendicular compression to the grain (b)

#### 3.2 Methode

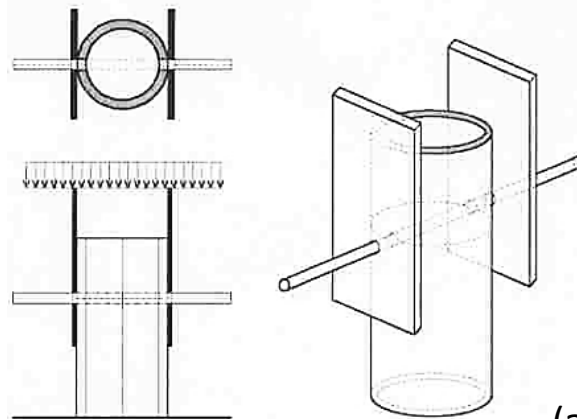
The test were carried out in the machine in the following conditions: normal

A steel-bar of 12 mm diameter was inserted in to the holes on bamboo traversing two steel plates. These steel plates work to transmit the compression load to the steel-bar.

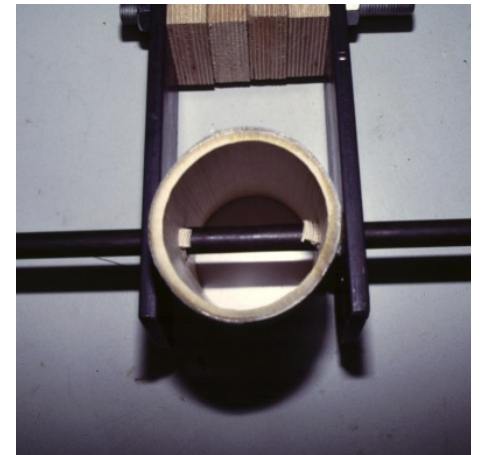
(a)



(b)

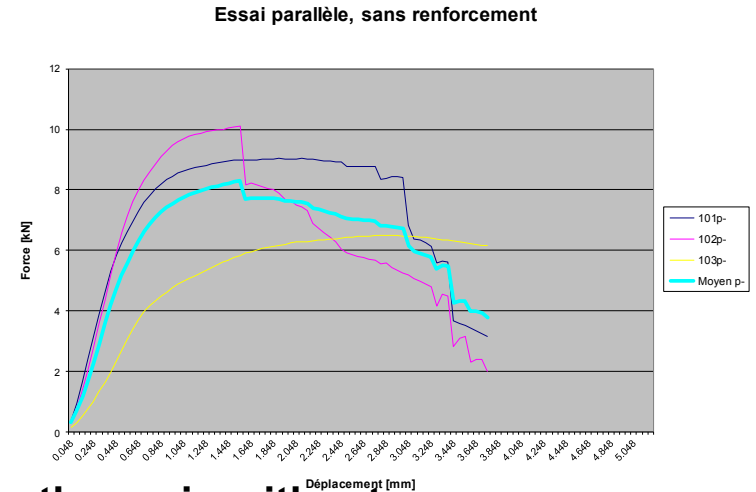
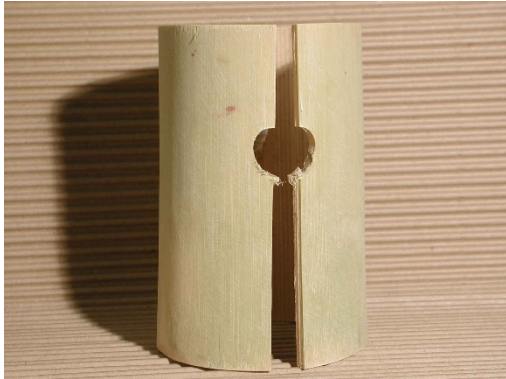


(a)

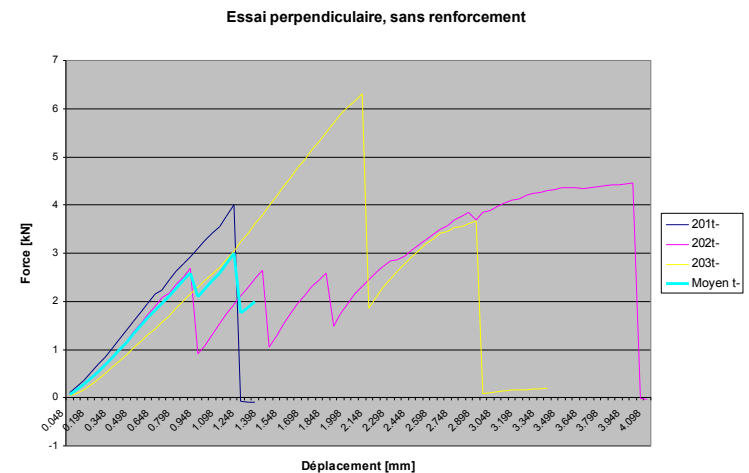


## 4. Results and discussion

4.1 From the values of compression parallel to the grain without reinforcement, we have a maximal load of about 8kN and 1.5 mm of displacement before the first crack appears.

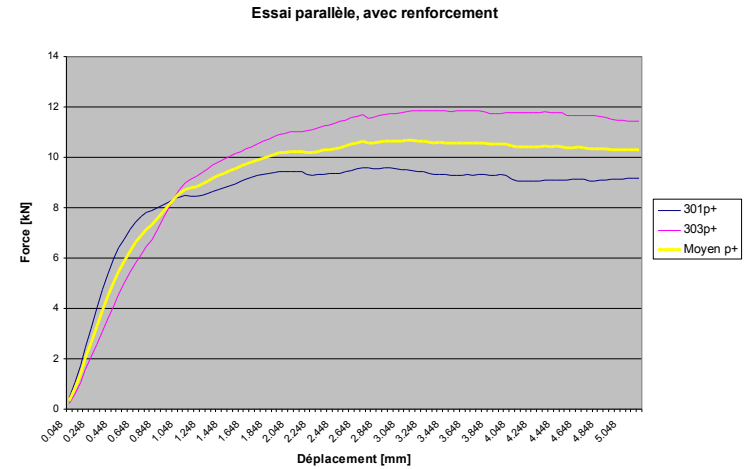


4.2 In case of the compression perpendicular to the grain without reinforcement, we have a displacement of 0.95 mm for a force of 3kN average before the first crack appears.

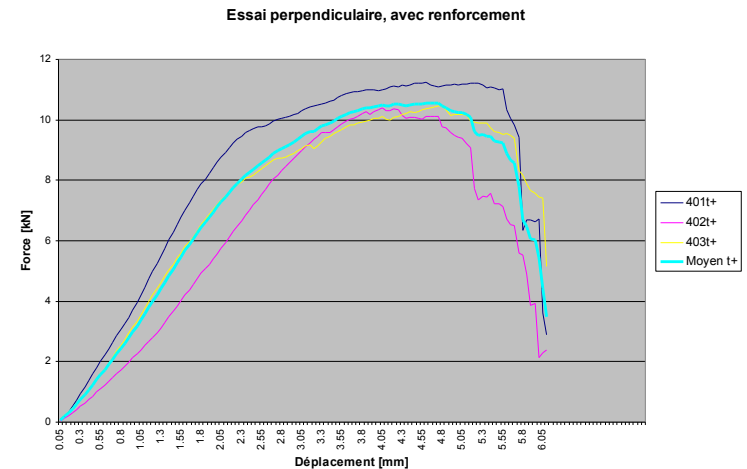
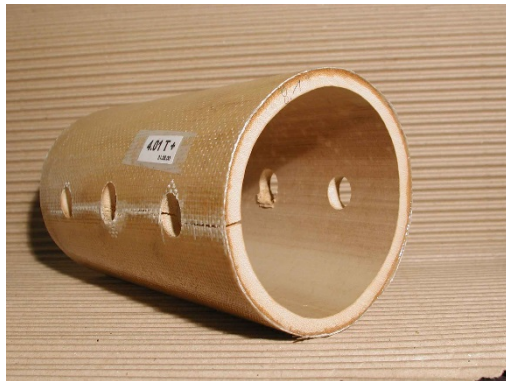




4.3 From the test of **compression parallel to the grain with the reinforcement**, we have maximal load of about of 11kN before the plastic flow caused by embedding of dowel, having a displacement of 1.85mm approx..



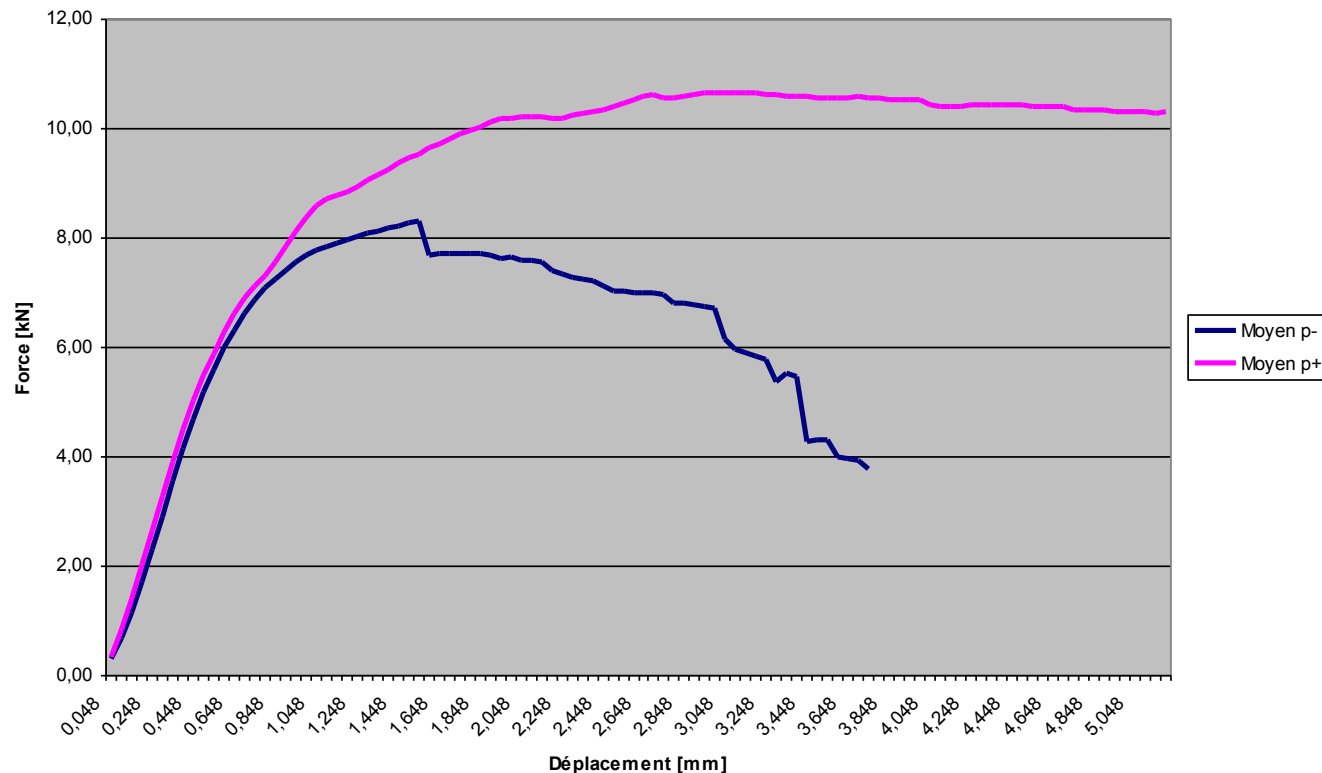
4.4 In case of the **perpendicular compression to the grain with reinforcement**, we have a displacement of 3.95 mm. for an average force of 10 kN.



## 5. Test conclusions

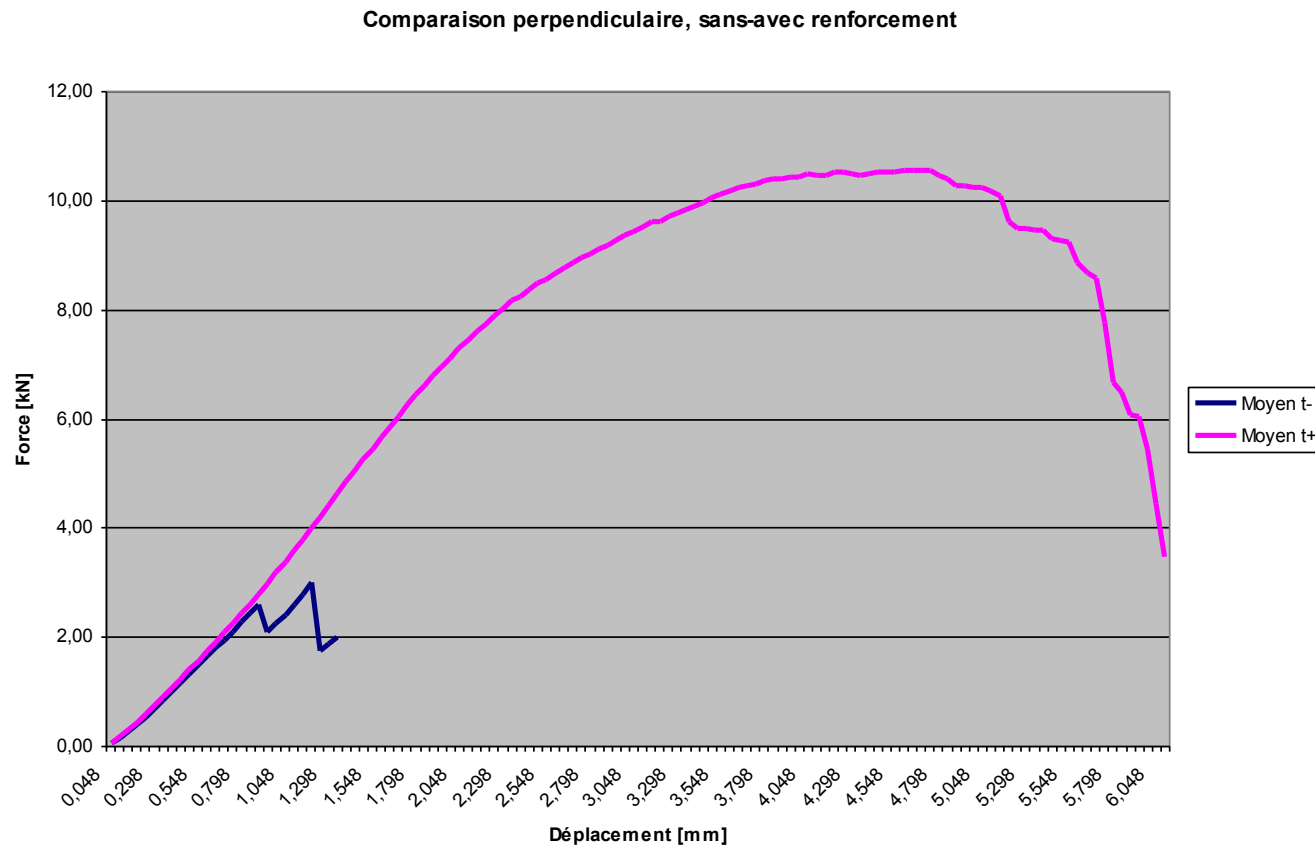
- 5.1 In case of the parallel compression on reinforced specimens, a slight improvement of embedding strength, was observed, about 130% for non reinforced specimens but no improvement on elastic module. **The application of fiberglass sheet prevented effectively occurrences of crack, and showed a remarkable ductility.**

Comparaison parallèle, sans-avec renforcement





5.2 In case of the perpendicular compression without reinforcement  
Splitting failure with low load level was observed. The fiberglass sheets covering the bamboo surfaces played a role of transmitting the shear stress on bamboo **and high strength was recorded**. The reinforcement improved the embedding strength on joints 376 % to the non-reinforced specimens.



# Conclusion of the presentations

- **As a structural system have been satisfactorily approved, confirming a sufficient structural capacity for their use in housing.** Results have certified that the behaviour of the purling-dowel connections for bamboo constructions corresponds to the behaviour of a composite structure.
- **A ductile behavior has been achieved in bamboo used as material thanks to fibre reinforcement, that preventing collapse.** It has been shown that textile fibres such as glass and jute can improve the behaviour of bamboo until ductile behaviour is obtained.
- **This important contribution can be employed for wide-span structures in which bamboo is subjected to great stresses.**
- **The wisdom of the inhabitants with regard to habitat provides various contributions to population management** within a context of globalization generating development dynamics that can be applied to improve the acceptance of bamboo.
- **Finally, bamboo means a simple technology with a positive impact when used for economic housing**



# Future work

- **From the construction mechanics point of view, it is important to continue research by means of digital modelling using the Finite Element Model (FEM); to carry out a study to identify the maximum resistance capacity of bamboo diaphragms subjected to horizontal displacement; to identify and model shear strain in the connection areas; and to identify the maximum fire resistance value.**
- **From the construction point of view, it is necessary to discover the appropriate methods for an assisted and participative self-construction that identifies, via case studies, the different variations of agreement with different realities. An economic feasibility study of the production process is required, permitting the creation of local companies. A Life Cycle Assessment (LCA) is required to discover the environmental impact of housing production.**

# Recommendations of the presentations

## 1. For architects

Building with bamboo is building with a material of plant origin that requires discipline and precise construction knowledge, regardless of construction scale. All construction materials - whether combustible or not - must be protected against fire.

## 2. For inhabitants

**Bamboo is gaining validation to the point that its use for economic housing can be guaranteed. This means being prepared to take up challenges, even if it is known that this material offers a high degree of economic and social development potential.** From the economic development point of view, producing machitgengas housing can provide a source of income through small-scale production, investment in equipment being minimal since it is limited to the cost of supplies.



# Recommendations of the presentations

## 3. For local governments

Local governments must initiate proposals for change through interdisciplinary projects aimed at organising awareness campaigns, training workshops, and exchange of experience in the field of development management for the use of bamboo. They should encourage the supply of and demand for economic housing based on bamboo through the presentation of prototypes for public use.

## 4. For Cooperation organisms

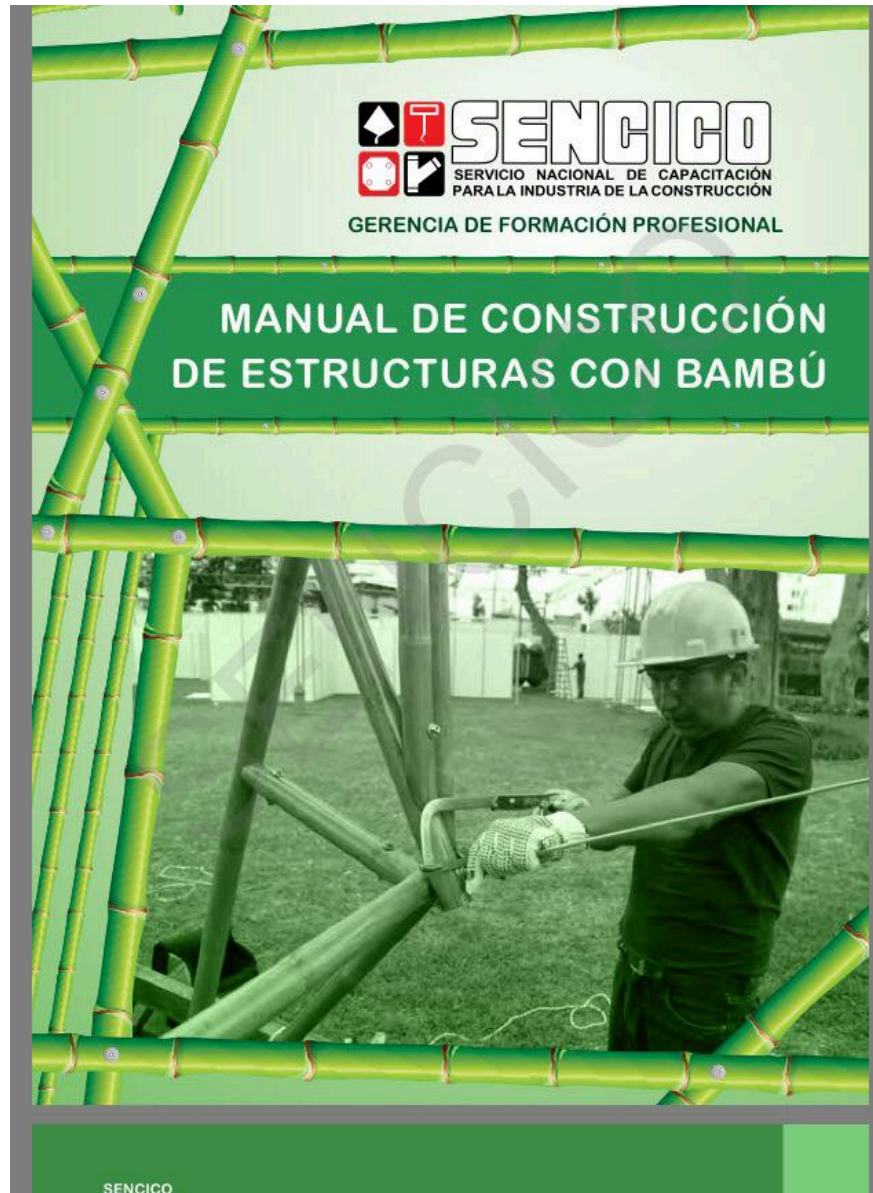
From the cooperation point of view, it is essential to create centres of competence and innovation - in addition to wood development centres – in places where bamboo can potentially grow, permitting the transfer of technology since it is vital to learn about experiences concerning wood and wooden.

It is also important to have North-South and South-South knowledge transfer and cooperation in order to build bridges and development networks.

# Tradition with modernity







<http://www.sencico.gob.pe/formacion/descargar.php?id=78>



Thank you





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