SUSTAINABLE MODULAR PROTOTYPE WITH BAMBOO FOR COMMUNITY CENTERS

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This contribution presents the results of research carried out in two areas of the Peruvian Amazon within the framework of two community projects for technology transfer and capacity development in construction with bamboo, with the objective of designing and building a modular prototype with bamboo for 1:1 scale with the function of a community center, capable of incorporating sustainable strategies, replicability and adaptability, as an architectural alternative to the deterioration of the Amazonian natural and cultural habitat. The methodology contemplates two phases of experimentation, the first of design and construction of the Model Prototype in the Southwest Amazon (Pilcopata), studying the local context, the bamboo species, the participatory construction process, to formulate the modular proposal with the function of a Center Tourist Community; the second validation of the Prototype, identifying the bamboo species and adding a module in the design format for use in the Communal Transformation Center in the Central Amazon (Native Community of Pampa Michi), both executed with the local population. Among the results, the efficiency, practicality and flexibility of the design and construction stand out, and the verification of sustainable strategies, with the use of carbon neutral materials such as bamboo, the revaluation of traditional knowledge with palm leaves and the replicability in similar conditions with models of participatory learning, which validate the Prototype. In a third phase, the construction processes are systematized, being part of the Manual for the construction of light structures with bamboo in Peru.

*Keywords*: Sustainable architecture, Bamboo, Modular Prototype, Community project.

1 INTRODUCTION

The Amazon rainforest is considered the largest tropical forest on the planet (Rodriguez 2023), a huge carbon sink that provides several vital ecosystem services, as well as cultural and spiritual value for millions of people. In Peru, tropical forests cover 60% of the territory (SPDA 2018), with great biological diversity, housing 61 indigenous peoples and 14 isolated groups (RAISG 2020). However, in recent decades, the Peruvian Amazon, have been suffering pressures and threats from anthropic actions, aggravated by the effects of climate change and the economic and social needs of habitability of the population, destroying their natural and cultural habitat. In addition to this, forest cover has been decreasing each year, which is why new sustainable productivity alternatives are urgently needed to replace the use of wood and reverse the situation.

It is essential to promote the strengthening of sustainable Amazonian communities, where Architecture also has commitments to caring for the environment, preserving the planet, energy
efficiency and comfort (Cobo Fray and Montoya Flórez 2021) as well as the protection of cultural rights. In this sense, bamboo is presented as a resource with great potential; its use in the construction sector in Latin America and the Caribbean (LAC) has been gaining more and more followers in recent years due to its numerous environmental and socio-economic advantages (Peciña-López 2023). In Peru, the areas with the largest surface area of natural bamboo forests are recorded in the southeastern Amazon with an area of 39,978 km2, between the regions of Junín, Ucayali, Cusco and Madre de Dios (SERFOR 2022), dominated mainly by the native species *Guadua Sarcocarpa* and *Guadua Weberbaueri*. As for the Central Jungle and the northeastern region of San Martín, they are characterized by the great diversity of native American bamboos (Londoño 2021). Londoño (2021) has recorded 8 native species (3 woody and 5 herbaceous) and 6 exotic woody species in the Junín region. Amazonian bamboos in Peru are a viable economic alternative, promoting sustainable constructions con prototypes that satisfy needs, such as Community Centers. The Prototype is the product of the analysis and commitment of the Amazonian natural and cultural physical environment, of the population center and/or community where it is located. It proposes a modular, sustainable and adaptable construction system to the function and contexts of similar characteristics, with the possibility of educational community work, with learning strategies in construction with bamboo. The architectural-structural Model considers sustainable and technological criteria, using mainly local bamboos, for the modular design of elements - trusses that generate volume - space and allow standardizing participatory knowledge transfer processes, saving time and material, strengthening community activities, and contributing to activate the bamboo value chain with the aim of improving family income.

2 METHODOLOGY

This work is developed in two phases - case studies, in two periods and two areas of the Amazon: 1) design and construction of the prototype, and 2) validation and adaptation of the prototype. In both, the effectiveness of the modular design and the application of sustainability criteria are evaluated, considering the main steps for its execution. And a third phase of systematization of the construction processes. To determine the sustainability criteria, the GREEN Methodology and Tool for evaluating sustainability in buildings, by Macías and García Navarro (2010) and the Environmental, Socio-cultural and Socio-economic Sustainable Principles, by Correia et al (2014), selecting 15 criteria that are used to verify its application in the Prototype, with a checklist. This evaluation responds from management, project development, planning, obtaining materials and execution of the prototype.

(a) Phase 1: Design and construction of the prototype. Place: Pilcopata, Cusco Region (Southeast Amazon). Function: Community Tourist Center. The architectural proposal of the Prototype arises from the need to implement a building for tourism promotion in the buffer zone of the Manu National Park, with important areas of native bamboo specie, as well as a large population with economic needs, drug trafficking problems, precarious housing, unsustainable constructions, little tourist infrastructure, but with great potential for tourism. On the periphery are the Native communities of Santa Rosa de Huacarías and Queros of the Machiguenga and Wachiperi ethnic groups, who still preserve their traditions, and where bamboo is part of their legacy. Under this context, the first Model Prototype is developed, within the framework of a community project of the Bamboo Green Communities organization, considering the following steps: 1) analysis of the natural and cultural environment of Pilcopata and Santa Rosa de Huacarias Community, 2) selection of bamboo species and other local materials, 3) architectural and structural design of the Prototype, considering: sustainability, modularity, adaptability, teamwork and execution time, 4) socialization of the
proposal with local actors, 5) execution of the first 1/1 scale Prototype in a Community Construction Workshop with bamboo.

(b) Phase 2: Validation and adaptability of the Prototype. Place: Native Community of Pampa Michi, Junín Region (Central Amazon). Use: Community bamboo products processing center. A second Prototype is built, which allows the first to be validated, in a Native Community inhabited by the Ashaninka ethnic group, within the framework of the Project “Innovation and promotion of bamboo through action research processes for resilient agriculture in Colombia, Ecuador and Peru”, called Bambuzonía, executed by the International Bamboo and Rattan Network (INBAR), with support from the International Fund for Agricultural Development (IFAD). The main activities of the Community, of 405 inhabitants, are agriculture, fishing and tourism, the latter being what the majority is dedicated to (Santos 2022) therefore that it was contemplated to implement a Transformation Center for bamboo products, accompanied by training in construction, providing them with another alternative for economic development, protecting their habitat, taking into account the following steps: 1) study of the natural and cultural environment of Pampa Michi Native Community, 2) selection of bamboo species and other local materials, 3) socialization of the proposal with the actors involved, 4) expansion of the prototype into a 1.6 m axis module, adaptability to function, 5) execution of the second 1/1 scale Prototype in a Community Construction Workshop with bamboo.

(c) Phase 3: Systematization of Prototype construction process. Based on the two experiences, the construction processes are systematized for the preparation of a manual that allows instructions for the construction of the Prototype to be given.

3 RESULTS

3.1 Modular Design

The Modular - Structural proposal is based on a set of pairs of bamboo trusses, each truss is composed of 10 pieces (5 typical pieces, which are duplicated), which, in a mirror, forms the “pair”, covers a width of 5 m and repeats every 1.60 m on axis. In Case 1, they are repeated 4 times, in Case 2, they are repeated 5 times. Principles of order of symmetry, repetition and rhythm are applied. The 4 and 5 pairs of bamboo trusses are connected to each other by tie beams and reinforced on the sides with diagonal elements. The front and rear faces are reinforced with two arches formed by curved bamboo slats. The approach to the form responds to the climatic conditions of the Amazon – low and high jungle, generating volumetry and spatiality in the interior. In both experiences, the Modular proposal allows teamwork and learning; in the second case, performance in processes, labor and material is improved. The standardization of the truss made it possible to generate a mold for the assembly of each one on the floor. After having all the pairs of trusses, the assembly proceeded on the bases on the ground. The Prototype facilitates the possibility of expanding the space longitudinally, maintaining the horizontal measurement, the proportion of the trusses and the structural modulation (Figure 1 and 2).

3.2 Sustainability Criteria

The results show that the Prototype in Case 1 and 2 apply the 15 selected sustainability criteria, grouped into 3 components: environmental, socio-cultural and socio-economic (Table 1). In the environmental aspect, the predominant use of bamboo as a local natural material stands out, followed by the palm leaf, considering: respect for nature (1), no electrical energy was used in the extraction (2), short transfers with little fuel (3), quick execution, with little use of power tools (4), bamboo prototypes retain CO₂ (5), biodegradable waste and the small ones were reused to make crafts (6), healthy natural resources (7). In the social aspect, the participation of all actors stands
out: private, public, native communities, from the beginning (8), allowing local people to be trained (9), the architectural proposal is harmonized with the natural and cultural landscape (10), the native community are invited to weave with the palm leaf and transfer their knowledge (11), and a modular proposal is achieved (12). In the economic aspect, the Prototype was self-financed with the contribution of all those who participated (13), added value is given to local species (14), the efforts are optimized by being modular and with light materials (15). If we carried out this checklist in a conventional building, the results would probably not be the same, not all of them would be met, none of them environmentally, which shows us the virtues of the prototype, highlighting the use of bamboo as the main material, which plays an important role within sustainability strategies.

![Figure 1. Modular Construction System - Community Center (graphic elaboration by the authors).](image1)

![Figure 2. Images of the Prototypes: 1) Tourist Community Center in Pilcopata Town 2) Transformation Community Center in Pampa Michi Native Community (Photos taken by the authors, 2019-2022).](image2)
Table 1. Sustainability criteria in prototype design and construction.

<table>
<thead>
<tr>
<th>Sustainable Criteria</th>
<th>Prototype (Figure 2)</th>
<th>Check list</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To respect nature</td>
<td>Analysis of the natural context, climate. Inclined roof - 60%, ventilation and natural lighting</td>
<td>√</td>
</tr>
<tr>
<td>2. To reduce non-renewable energy incorporated in construction materials</td>
<td>Manual tools for harvesting bamboo. Preserved with Borax Salts.</td>
<td>√</td>
</tr>
<tr>
<td>3. To reduce non-renewable energy in the transportation of construction materials</td>
<td>Bamboo and palm leaf: 5km - 15km. Other materials: local town.</td>
<td>√</td>
</tr>
<tr>
<td>4. To reduce non-renewable energy consumption during construction phase</td>
<td>Execution time: 5 days. Hand tools, little use of power tools.</td>
<td>√</td>
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<tr>
<td>5. To reduce impact of construction materials: Use of local natural materials that retain CO₂</td>
<td>Native bamboo: <em>Guadua Sarcocarpa</em></td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>Exotic bamboo: <em>Guadua takahashiae</em> / <em>Phyllostachys Aurea</em></td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>1.098 m bamboo poles (9cm Ø) / retains: 2.86 T CO₂</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td>1.150 m bamboo poles (9cm Ø) / retains: 3.004 T CO₂</td>
<td>√</td>
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<tr>
<td>6. To reduce pollution and waste materials</td>
<td>Biodegradable waste, small bamboo pieces: crafts, charcoal.</td>
<td>√</td>
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<tr>
<td>7. To contribute to health quality</td>
<td>Healthy natural materials, cross natural ventilation.</td>
<td>√</td>
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<tr>
<td>8. To encourage social cohesion</td>
<td>Government and local population, native community involvement</td>
<td>√</td>
</tr>
<tr>
<td>9. To strengthen local capacities</td>
<td>60 trained people</td>
<td>√</td>
</tr>
<tr>
<td>10. To protect cultural landscape</td>
<td>Analysis of Amazonian culture. Vernacular architecture</td>
<td>√</td>
</tr>
<tr>
<td>11. To transfer construction culture</td>
<td>I use traditional palm leaf techniques.</td>
<td>√</td>
</tr>
<tr>
<td>12. To enhance creativity</td>
<td>Design creativity and modulation</td>
<td>√</td>
</tr>
<tr>
<td>13. To support autonomy</td>
<td>Collaborative community self-support project</td>
<td>√</td>
</tr>
<tr>
<td>14. To promote local activities</td>
<td>Activate local value chains: bamboo and palm leaf.</td>
<td>√</td>
</tr>
<tr>
<td>15. To optimize construction efforts</td>
<td>Local transportation, short execution time, 2 - 3 qualified people, 2 assistants.</td>
<td>√</td>
</tr>
</tbody>
</table>

### 3.3 Capacity Building in Bamboo Construction

It was possible to train the population in construction with bamboo, in the first case, 60 people and in the second case, 50 people. Once the structure was completed, it was handed over, as appropriate, to the local government and/or the community, and the locals made the final enclosures applying their traditional techniques, reinforcing the identity of the people and their sense of belonging.

### 3.4 Technical Manual

After evaluating the two case studies, the Communal Prototype is validated, in relation to (a) the modular design, and (b) the application of sustainability criteria, adding the teaching method developed in the training, which allows the construction processes to be systematized of the Prototype in a Technical Manual, which facilitates its execution for other areas of the Amazon, which is part of the “Manual for the construction of light structures with bamboo for Peru” that can be downloaded on the INBAR web portal.
4 CONCLUSION

The Community Center Prototype presented for the Amazon demonstrates the application of modularity concepts with sustainability criteria with the use of local bamboo, adapting to different uses and maintaining the geometric composition. It is an alternative to build prefabricated Centers with local resources with minimal impact on the environment from the production phase to their entire useful life and that in turn contribute to the dialogue and strengthening of the community. Modular prefabricated construction allows you to save time and material in the construction processes. With the use of bamboo, a light structure is achieved, with elements that are easy to manipulate and transport. The typology and proportion of the "truss" is the basis of the design, which is repeated in a mirror and this in turn is repeated to generate form and space. It is important for the construction process to know the species of bamboo to be used, its morphology in terms of diameter, thickness of the walls and distance between nodes. Being a Prototype for the Amazon, the research highlights the issue of joints, it would be important to study alternatives with plant fibers, to replace the steel elements, which would further reduce the carbon footprint. In the first case, some tests were carried out on non-structural joints with tamshi fiber, however, a more in-depth study of resistance is required. It also opens the possibility of proposing different types of coverings on walls and ceilings with local materials that can also be modulated as "covering panels". More prototypes are expected to be executed to continue studying its possibilities, as well as promoting the benefits of bamboo and strengthening capabilities in construction.

References


