Journal of Positive Psychology & Wellbeing
2023, Vol. 7, No. 1, 434-443
http://journalppw.com
ISSN 2587-0130

Sustainable Construction Of Rural Housing In Guadua: A Step-By-Step Learning For Rural Communities

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Abstract

Population growth has generated the search for fast, economical and environmental housing alternatives that guarantee the wellbeing of the population. In recent years, the use of plant-based materials in construction has increased, from ancestral practices to the technical aspects based on the Colombian Seismic Resistant Construction Regulation NSR-10. This article explains the sustainable construction systems of guadua housing for rural communities in Colombia, seeking to take advantage of the available resources, the natural properties of guadua and the low costs of the material, with the generation of a pedagogical manual for the use of this resource and the learning of rural communities so that they can make their own construction of guadua housing. The guadua construction pedagogical manual contains specifications, preparation, tools, type of cuts, type of joints, material protection, construction systems and process recommendations. Guadua construction for rural communities in Colombia is a viable alternative from an economic, environmental and social point of view, as it is a low-cost resource available in the country, and generates the possibility of solving housing problems for people affected by natural disasters, conflicts, among others.

1. INTRODUCTION

The worldwide demand for housing has forced the search for subsistence alternatives that are fast, economical and environmentally friendly, and that can guarantee people's wellbeing (Rodríguez et al., 2006). Colombia is a country that has been influenced in rural areas by the development of productive and extractive activities, however, it is inhabited by peasant, indigenous, Afro-Colombian communities, agricultural producers and rural entrepreneurs (Ropero Beltrán, 2015), which are affected by 33% and 36% by poverty, with greater

intensity in young people and with the exception of those over 55 years of age (Monroy et al., 2022).

In recent years, the growing interest in promoting the development of sustainable civil engineering and sustainable construction, with positive impact on the economy, environment and society, has stimulated the research and use of plant-based materials (Sánchez et al., 2018). Bamboo has become an important research topic because it is an alternative in sustainable construction, where its rapid growth, high strength-to-weight ratio, low harvesting and processing costs make it a suitable material for the construction of bridges, rural houses, water canals, among others (Correal et al., 2022).

Guadua angustifolia is a bamboo species that grows naturally in areas of Central and South America, playing a role in ecosystems for its ability to capture CO2, reduce soil erosion and control water cycles (Villegas et al., 2019). In rural areas, many houses have been built using ancestral practices with Guadua, however, despite the fact that it is considered as a construction material in the Colombian standard (NSR-10 of 2010), it is still not widely used, due to the lack of quality control of the material, technical difficulties and inadequate uses of the material (Moran et al., 2015).

This article explains sustainable guadua housing construction systems for rural communities in Colombia, seeking to take advantage of the available resources, the natural properties of guadua and the low costs of the material. In addition, it aims to show the inhabitants the structural and aesthetic benefits of this type of construction, generating a pedagogical manual for the use of this resource and the learning of rural communities so that they can build their own guadua housing, taking into account the regulations in Title G of the Colombian Regulation of seismic resistant construction NSR-10.

2. METHODOLOGY

It is proposed to create a pedagogical manual of guadua construction according to title G of the Colombian Regulation of seismic resistant construction NSR-10 for the rural population of Colombia with the purpose of developing an adequate learning process in sustainable construction. This study was carried out through the following phases:

- Information collection and analysis: The information for the guadua construction pedagogical manual was collected.
- Creation of the pedagogical manual: The structure of the manual is developed and the content of sustainable construction in Guadua is written.
- Graphic design of the manual: Images are added to the structure of the pedagogical manual corresponding to the step by step of the sustainable construction, for its easy interpretation by the rural communities.

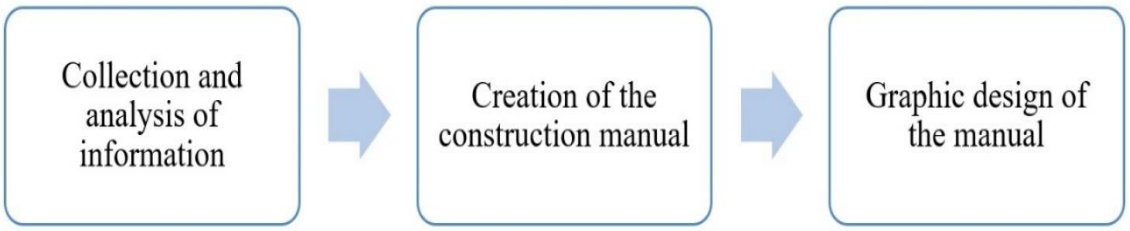

Figure 1. Methodology applied

3. PEDAGOGICAL MANUAL ON GUADUA CONSTRUCTION

3.1. Specifications of Guadua

- Not to present initial deformation of the axis greater than 0.33% of the length of the element.
- Not to present perimeter cracks at the nodes or longitudinal cracks along the neutral axis of the element.
- Cracks with cracks greater than or equal to 20% of the length of the element are not suitable.
- There should be no holes caused by xylophagous insects (that feed on wood).
- Guadua with any degree of rotting is not acceptable.
- Tender guadua with a fairly light green cane with white lines at each end of its knots and with thorns on its branches.

3.2. Preparation for use

Drying: Prior to drying, the guadua should be washed with low abrasive materials and adequate processes that do not deteriorate its surface. In addition, it must be dry at the time of manufacture, below 19%. Artificial drying methods can be used. This artificial drying must guarantee the integrity of the piece, preventing excessive cracking or crushing.

Preservation: A chemical product capable of protecting against fungal or insect attack is applied. The guadua must have at least one type of treatment of the NTC 5301. Preservation by immersion cannot make perforations that exceed 130 mm. For manual application, it must be done according to the catalog or technical sheet of the immunizing product. In no case should unimmunized guadua elements be installed.

Fabrication: The metallic elements must resist natural corrosion or present some anticorrosive treatment. The specifications of longitudinal dimensions and minimum cross-sections must be shown in the design drawings. Tolerances of no more than 2% shall be respected. All elements must be identified as specified in the drawings.

Transport and storage: Avoid overloading structural members during transport and storage. The maximum number of stacked culms is 7.

Storage in a dry place, under cover, with good ventilation, and good drainage, in a vertical position and isolated from the floor. Comply with the requirements of Law 769 of 2002.

3.3. Tools

- For cutting: Machetes, saws, saws and electric disc saws are used.
- To open the guadua: short and long axes are used.
- To drill and perforate: Augers, hand drills or berbiquí, electric drills, drills, drill bits.

- For fastening: Bolts, clamps, wires, miter box are used.
- To shape traditional assemblies: chisel, gouges, knives, shorts, etc. are used.
- To introduce concrete in the joints: Funnel is used.
- To tighten nuts: wrenches are used.
- To tap: Hammers, mallets, mallets are used.
- To polish or varnish: Compressor and paint torch, brushes are used.
- To work with cement: Trowels, trowels, shovels are used.

3.4. Types of Cuts

Figure 2 shows the types of cuts

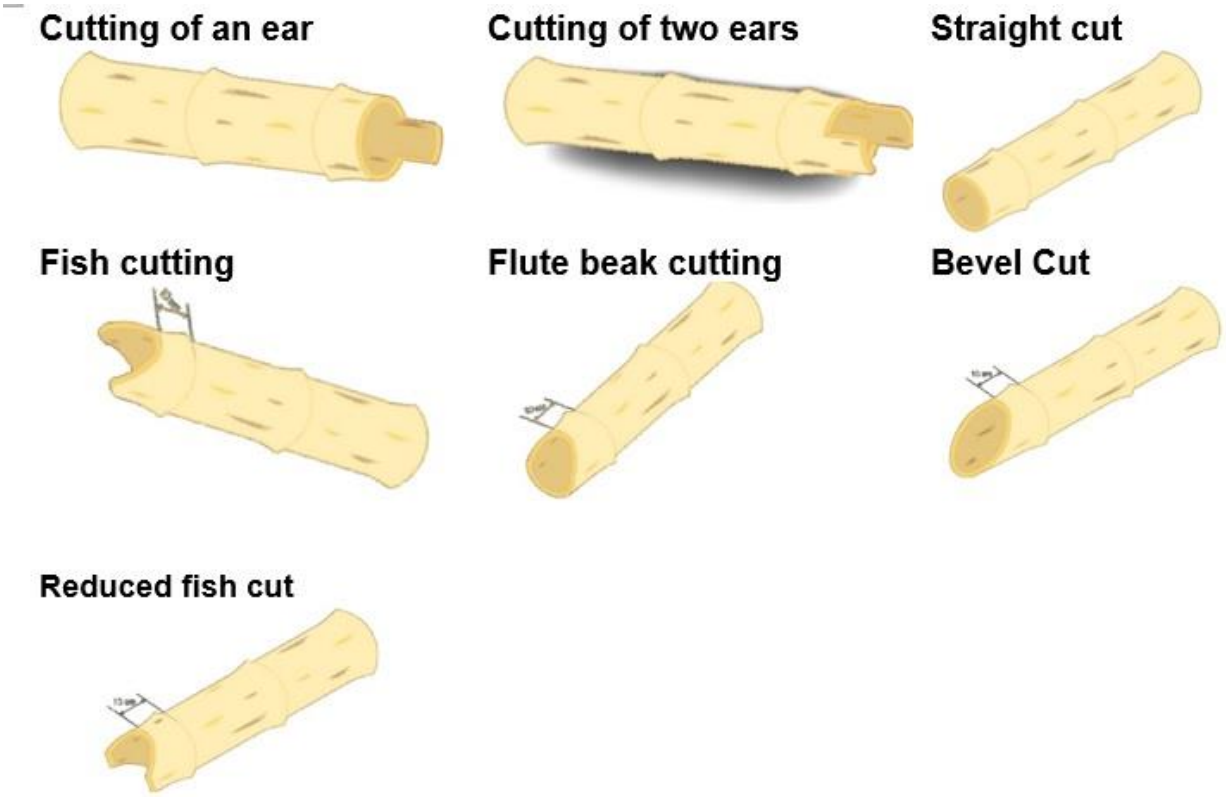

Figura 2. Types of Cuts

3.5. Types of joints

Figure 3 shows the types of joints

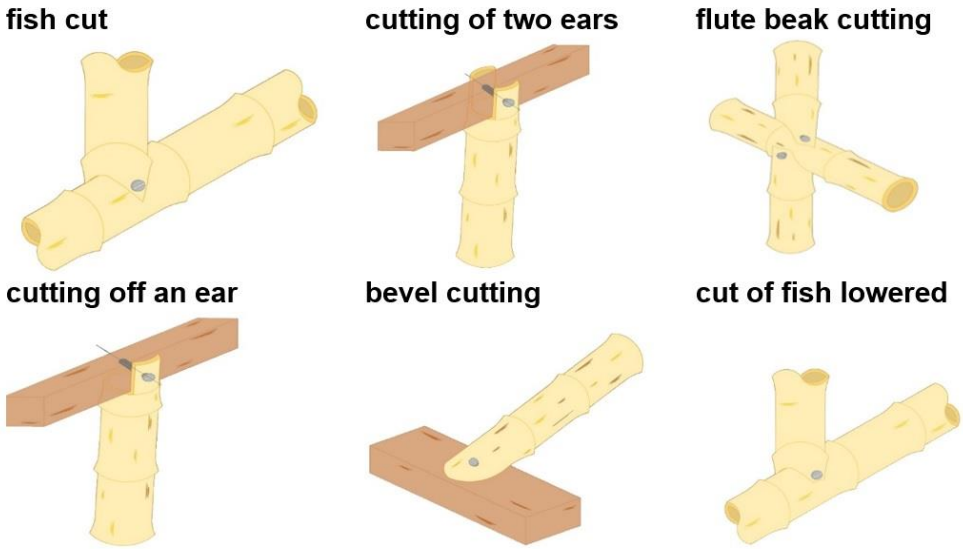

Figura 3. Types of joints

3.6. Protection of the material

- **Moisture:** Guadua should never be in direct contact with the ground; plinths or pedestals should be built and should not be exposed to the elements. In addition, poorly ventilated spaces should be avoided and surfaces should be protected with impermeable coatings (NSR-10, 2010).
- **Fungi and insects:** Guadua should be treated for immunization and stored in conditions of minimum humidity and treated with fumigants (NSR-10, 2010).
- **Fire:** Heating elements must be avoided, structures must be insulated with non-combustible materials, and the temperature of the structure must not exceed 65ºC. Fuel storage areas must be surrounded by non-combustible materials and outside the guadua structure. The use of substances that accelerate the increase of fire must be limited and adjacent structures must be separated by at least 1.20 m.

3.7. Construction System

3.7.1. Contemporary Bahareque

This is the only system included in the standard and with a construction permit. This system must comply with the minimum requirements given in NSR-10, guaranteeing optimum structural performance for the development of its useful life.

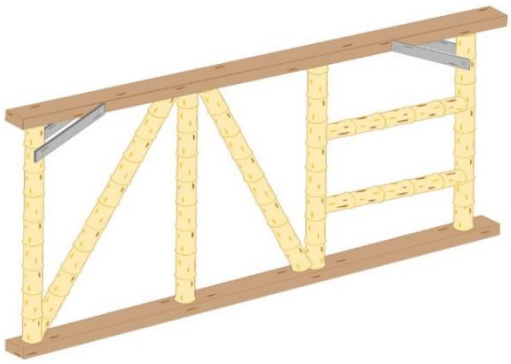

Figure 4. Contemporary Bahareque

Construction method: The construction begins by installing the lower sill, then the right feet are fixed, these must have a spacing of between 40 and 50 cm between them and be fixed with bolts to the sill. Along with this, the installation of the upper sill is carried out, thus checking the verticality of the right feet installed and helping its complete structural fixation. In order to give rigidity to the structure, the bracing is made with metallic plates of the right feet that go in the corners of the sills and the installation of the guadua braces that go in the spaces between the right feet.

Wattle and daub is presented in two ways, although it is worked with the same structure: inlayed or matted.

to being contained in 4 cm wide guadua cans that help keep the filling in place, which are installed along the structure formed horizontally and with an approximate separation of 8 cm between them.

Embedded

In this system, the interior of the frame contains a filler commonly made of mud or wet clay, usually mixed with straw. In addition

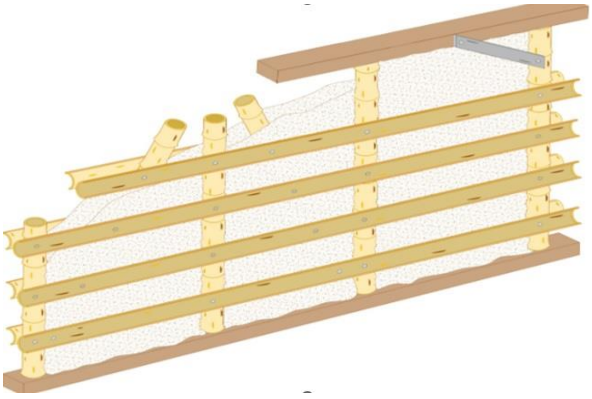

Figure 5. Contemporary Bahareque: Embutido (inlaid)

As these are installed, the backfill mixture should be introduced into the structure and pressed into the structure. Once the process is completed up to the top of the wall, the filler

should be allowed to dry for a month or more and then the chosen coating should be applied.

Matting

This system can be either hollow or embedded. The filling in its interior is the same as that of the embedded wattle and daub. The guadua mat is a light guadua grid joined together, in a horizontal position, which will serve to confine the frame made of bahareque, which is installed on the outside of the constructed frame and is anchored to the right feet that are inside it.

Figure 6. Contemporary Bahareque: matting.

In the case of backfill, the backfill is applied as the mats are installed and compacted with small tampers, and must be advanced until it reaches the top of the structure, followed by allowing it to dry for at least one month before applying the chosen covering. On the contrary, if it is hollow matting, no waiting time is needed before applying a coating after the mat is installed on the structure.

3.7.2. Classic Bahareque

This type of bahareque is the one that was used in old buildings, and its way of working is very similar to that of contemporary bahareque. Among the differences to the contemporary system are the use of modern tools and accessories such as bolts, plates and clamps that guarantee the functioning of the structure and its adequate anchorage together with its seismic resistant design.

3.7.3. Tendon Wall

The structure consists of a system of tendons made with barbed wire, to which a woven sack of fique with large eyes is fixed, which is then filled with mortar of 1:14 proportions of cement and sand. In this system the guaduas can be arranged in different ways, since the figures will be visible as part of the finishing of the structure.

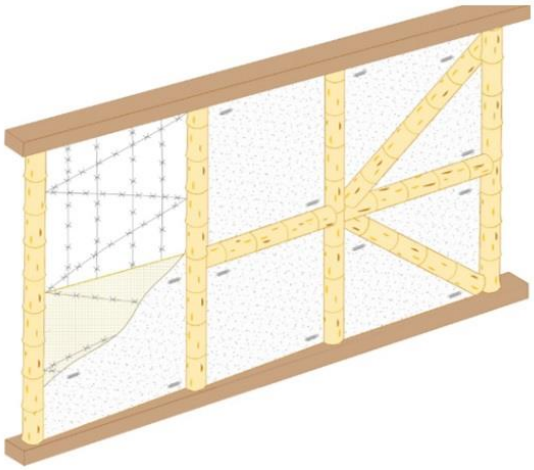

Figure7. Tendon Wall.

Construction method: We start by building the frame, which can be made in simple rectangular panels or in figures for a better finish. Once the guadua frame is built, the tensioned barbed wire is installed and fixed with screws. Then, the woven sack of fique is installed, stretched and tied to the barbed wire. Then, the mortar mixture is applied and several layers are applied until a thickness of between 3 and 6 cm is completed.

3.7.4. On-site assembly

This system is the most used and well known in construction, where all the components of the structure and necessary materials are taken to the place where the construction will be carried out to be stored and used progressively. In this way, construction and operating costs are optimized.

3.7.5. Prefabricated or preassembled

In this system, most of the structure's components and materials are used in a different location than the construction site, carried out by specialists, with specific instructions on how to assemble the structure on site. Once the prefabricated panels are placed on site, the technical data sheet must be reviewed and installed according to specifications. Since most of the construction process is done off-site and prior to the completion of the construction, it saves execution time and facilitates to a certain extent the work performed.

3.8. Recommendations for the construction process

- Have workers with sufficient experience and training, with adequate tools and safety equipment.

- Have assembly drawings with indications of assembly and location of the elements, final bracing and special precautions.

- Avoid damage due to crushing, cracking and perforations, and avoid overloading during transportation, loading and unloading of the elements.

- Storage close to the erection site and protected against rain and humidity. Anchoring, bracing and splicing to ensure strength and rigidity. Specify in the drawings the type of anchorage, its dimensions and spacing according to the structural design.

- Temporary bracing that guarantees adequate support to the structural elements (NSR-10, 2010).

4. ADVANTAGES OF SUSTAINABLE CONSTRUCTION

Sustainable construction arises from the need to seek technical and material alternatives with a socio-environmental approach seeking to reduce environmental, economic and social impacts, in addition to supplying the population's need for housing and infrastructure (Ortiz & Rozo, 2021), because the traditional construction industry is responsible for the demand of non-renewable energy resources, anthropogenic emissions such as carbon, sulfur dioxide, nitrogen oxide and benzene due to the use of asphalt (Ebolor et al., 2022).

The implementation of sustainable construction contributes to limiting the consumption of resources and maximizing their reuse, increasing the use of renewable resources, protecting nature, creating a healthy environment and improving the built environment (Shashi et al., 2022). For this reason, its advantages are: reduction of energy, water and waste costs, avoiding the large-scale generation of atmospheric pollutants and minimizing the use of raw materials.

5. CONCLUSION

The depletion of natural resources generates the search for alternatives in construction to make it sustainable, with the purpose of reducing the impacts on the environment. Guadua construction for rural communities in Colombia is a viable alternative from an economic, environmental and social point of view, because it is a resource that is available in the country, its harvesting and processing is low cost, and it solves housing problems for people affected by natural disasters and conflicts, among others.

This pedagogical manual contains information on the guadua construction process with illustrations that will serve as a guide for the topics addressed, in addition to the technical considerations according to the Colombian seismic resistant construction regulation NSR-10. For the construction of guadua houses, it is recommended to carry out a structural design prior to the construction work, in order to obtain resistance and construction specifications according to the type of terrain, avoiding unnecessary expenses.

6. ACKNOWLEDGMENTS

To the students Fayli Dayana Navarro Carrascal and Laurin Yineth Quintero Angarita for their support in the elaboration of the 3D drawings and their support throughout this research.

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