DESIGN STUDY OF A TEMPORARY, EMERGENCIAL AND SUSTAINABLE SHELTER IN LIGHT WOOD FRAMING AND BAMBOO

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ABSTRACT

Objective: This article aims to present an architectural proposal for a temporary emergency shelter of a sustainable nature using Wood Frame and bamboo, which allows for easy transport, assembly and disassembly in the event of major tragedies and serves as a shelter for the needy population.

Method: This work was developed in two stages: initially data was collected on issues relating to environmental tragedies and their solutions as well as the emergency needs of the victims. In the second stage, a program of these refugees' needs was drawn up, the project was developed and the volumetric model was presented.

Theoretical framework: Currently, the socioeconomic conditions in Bolivia, the political instability in Venezuela and the natural disasters in Haiti cause the number of refugees to increase in Brazil. Bolivian immigration to the country has a more continuous flow compared to that from countries like Venezuela and Bolivia. Furthermore, with the increase in natural disasters present in the national territory, it is necessary to promote solutions to alleviate the needs of this population in a state of vulnerability.

Results and conclusion: the results presented in this work make up the research project for the development of new materials, products and constructive elements for wooden construction.

Implications of the research: along with this discussion, it is expected to expand the understanding of the concepts and design processes in emergency housing, possible renewable materials application, ease of production and execution to fit vulnerable communities in Brazil.

Originality/value: This study explores an important gap in empirical studies carried out in the context of emergency shelter projects for vulnerable communities.

Keywords: Emergency Shelter, Housing, Sustainability, Bamboo and Wood Construction, Design Methodology.

ESTUDO DE PROJETO DE UM ABRIGO DE CARATER TEMPORÁRIO, EMERGENCIAL E SUSTENTÁVEL EM WOOD FRAME E BAMBU

RESUMO

Objetivo: Este artigo tem por objetivo apresentar uma proposta arquitetônica para um abrigo emergencial temporário de caráter sustentável utilizando Wood Frame e bambu, que possibilite a facilidade de transporte, montagem e desmontagem em caso de grandes tragédias e sirva de abrigo para a população carente.

Método: Este trabalho foi desenvolvido em duas etapas: inicialmente foram levantados dados sobre questões relativas às tragédias ambientais e suas soluções bem como às necessidades emergenciais das vítimas. Na segunda etapa, foi elaborado um programa de necessidades desses refugiados, o desenvolvimento do projeto e a maquete volumétrica.

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Referencial teórico: Atualmente, as condições socioeconômicas da Bolívia, a instabilidade política na Venezuela e os desastres naturais no Haiti fazem com que o número de refugiados aumente no Brasil. A imigração boliviana para o país possui um fluxo mais contínuo se comparada àquela de países como Venezuela e Bolívia. Além disso, com o aumento dos desastres naturais presentes em território nacional, faz necessário o acolhimento e promoção de soluções para amenizar as necessidades dessa população em estado de vulnerabilidade.

Resultados e conclusão: os resultados apresentados neste trabalho compõem o projeto de pesquisa desenvolvimento de novos materiais, produtos e elementos construtivos para a construção em madeira.

Implicações da Pesquisa: Com essa discussão, espera-se contribuir tanto com a ampliação do entendimento sobre os conceitos e processos de projeto em habitações emergenciais, possíveis materiais renováveis aplicados, facilidade de produção e execução para atendimento de comunidades vulneráveis no Brasil.

Originalidade/valor: Este estudo explora uma importante lacuna de estudos empíricos realizados no contexto de projetos de Abrigo emergenciais para comunidades vulneráveis.

Palavras-chave: Abrigo Emergencial, Habitação, Sustentabilidade, Metodologia de Projeto.

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1 INTRODUCTION

Over the last 50 years, the number of people exposed to disaster risks has grown worldwide (Freitas et al, 2016), requiring a systemic understanding of causes and impacts (Freitas et al, 2012; Fakhruddin et al, 2019). Data from the period between 2005 and 2015 show more than 700 thousand deaths, 1.4 million people injured and about 23 million people displaced as a result of disasters, with 1.5 billion people affected in various ways (MELLO, 2022).

According to the United Nations (2015), Brazil is the only country in the Americas that is on the list of the 10 countries with the highest number of people affected by natural disasters between 1995 and 2015.

The country has 10 metropolitan regions, among them stand out São Paulo, with 19 million inhabitants, regarded as the largest metropolis in South America, and, next, Rio de Janeiro, with 12 million inhabitants. However, the rapid growth of large metropolitan capitals, changes in their functions, internal structures and population composition, caused changes and transformations that fragmented them. ANDERS, 2007.

In all this process, Santos (1990) and Valêncio (2008) say that the great aggrieved was poor population. It is easy to note that precarious dwellings can be found in peripheral areas, such as slums and clandestine building lots, and also in the central areas, where there are slum tenements. These precarious forms of housing are the direct consequences of economic factors, such as the policy of property speculation and political and social actions. The sum of these factors forced the poorer strata of the population to occupy peripheral areas, inadequate and risk places, such as slopes or water sources, abandoned buildings in the central regions, causing environmental degradation and urban growth based on inequality and poverty.

This shows that as a large number of developing countries and other underdeveloped countries suffer continuously from natural phenomena that severely affect cities and their settlements. The effects, many of them tragic, are not simply the result of these phenomena, but rather of the precariousness of settlements, a direct consequence of disorderly urban growth and socio-economic inequalities (ANDERS, 2007).
Occurred spontaneously, natural phenomena happen suddenly and, in any place, and transform the daily lives of many people who, directly or indirectly, are affected by them. In a comprehensive way, the term "natural phenomenon" refers to any expression coming from nature, such as hydrological, atmospheric or topological events and relate to the dynamics of the Earth: storms, tornadoes, floods, droughts or even earthquakes, tsunamis, volcanic eruptions, etc. (PERES, 2013).

For Nolli; Laroca; Varisco (2016) even with a number of increasingly frequent natural disasters, there is still no infrastructure to support the homeless. Considering the Brazilian case, which is repeated in many other countries, it can be seen that immediate attitudes are generally restricted to providing the victims accommodation in which public and/or community spaces are taken, such as sports gyms, parochial halls, exhibition centers, schools or emergency camps with improvised tents and without structures to meet the basic needs of the homeless. It could be a solution if the situation were to resolve in a short time, but it is known that the effects of serious events can take up to several years to stabilize.

In light of the above, the proposal of this work is to present a new emergency shelter solution for situations such as these, proposing the use of renewable materials, environmentally sound and easy to handle so that they can be built with the agility necessary to meet the demand in emergency cases.

With the increase in the number of natural disasters and refugees in Brazil, particularly in Mato Grosso do Sul, the country does not have an immediate housing support structure for vulnerable immigrant families. As a result, this work will address a way to protect individuals who suffer from the process and will be considered the situation in which victims do not have housing, often due to lack of financial conditions and without a social support network to which to turn, making necessary a temporary and emergency shelter, while the State is responsible for defining a permanent solution.

Faced with the increase in the number of refugees in Brazil and the occurrences of natural disasters that escape the control of the human being, this work has as its main objective to propose a sustainable model of emergency shelter using Bamboo and Wood Frame (Madeira) that serves homeless people either by a natural disaster or by an immigration process, in order to provide the victims with a sufficiently dignified, functional, welcoming and safe housing.

This work, directly or indirectly, contributes to possible solutions of shelters and temporary equipment in situations of related catastrophes, expanding the range of studies on the field in Brazil - since there are few studies and prototypes for this purpose. The application of the studies in a specific city, in this case the city of Corumbá, in Mato Grosso do Sul, brings a realistic prospect for a problem of natural disasters caused by climatic or geological phenomena, and which have given Mato Grosso do Sul two negative posts. The state is the champion in the type of occurrences and the 355 cases registered from January to October 26, 2018 broke the historical record, being the state with the largest number of disasters in the country, which allows other research to develop and new solutions to emerge, for different situations encountered. (MS CIVIL DEFENSE, 2018). In addition, the number of refugees from neighboring countries entering via the national border, particularly in the city of Corumbá, is considerable. The lack of resources and difficulties related to documentation mean that many immigrants stay temporarily in Corumbá when they land in the city. The case has mobilized the inhabitants of the city, whose only hostel for people in a street situation has only 22 vacancies (LEMOS, 2018). The Corumbá experience may subsequently be replicated in other areas with similar characteristics and conditions.
2 LITERATURE REVIEW

In the prehistoric period with severe changes in climate (with the glacial period) and a consequent scarcity of food, there may have been conditions that favored the development of man and sharpened his intelligence. This meant the search for a greater source of food, the establishment and creation of the first shelters (ANDERS, 2007).

In the last decades, with climate changes in general, and among others, the increase in global temperature, and as a consequence the increasingly recurrent and intense incidence of storms, in the case of Brazil, lead to various predictable risks. First, already homeless populations are more exposed to harm; in the aftermath, those who have a roof, but precarious and finally, depending on the size of the event, even those who believe they have a safe house, especially because it was not designed for extreme situations. Increasing Rain incidence can indeed contribute to the aggravation of daily life in other layers of society that divide the city territory, socializing, so to speak, the dangers to which everyone is exposed (NOLLI; LAROCA; VARISCO, 2016).

For Peres (2013), according to his studies, the best definition of catastrophe comes from the economist named Philip O'Keefe of the Disaster Research Unit at Bradford University, who states that this is the relationship between a risk, whether natural or man-made, and a vulnerable condition.

According to Castro (1998), the disaster is the result of adverse events, natural or man-made, on a (vulnerable) ecosystem, causing human, material and/or environmental damage and consequent economic and social damage. Disasters are quantified for damage and damage in terms of intensity, while adverse events are quantified in terms of magnitude. The intensity of a disaster depends on the interaction between the magnitude of the adverse event and the degree of vulnerability of the affected receptor system. Typically, the preponderant factor for the intensification of a disaster is the degree of vulnerability of the receiving system.

Davis (1980) thus developed a risk and vulnerability diagram as shown in Figure 1 below:

![Risk and Vulnerability Diagram](image)

**Figure 1** - Risk and Vulnerability Diagram.
**Source:** adapted by the authors (2020).

Every year, disasters have a significant impact on Brazilian society. In 2013, 493 natural disasters were officially reported, which caused 183 deaths and affected 18,557,233 people in 4,433 municipalities (MINISTRY OF NATIONAL INTEGRATION, 2013).

An important period for advancing the development of the collapsible shelter technique was the periods of the wars and the post-war world. The large number of soldiers in battle, refugees, and the homeless and the difficulty in logistics with conventional materials instigated new shelter techniques that greatly improved soldiers' housing in the field and also improved medical facilities. (NOLLI; LAROCA; VARISCO, 2016).

Faced with such a context, it is possible to establish principles of a shelter, which are driven by the basic needs of the user and are subject to a permanent evolutionary process.
Quarantelli (1982, apud JESSÉ, 2015, p. 14) states that it is necessary to understand some considerations regarding temporary emergency housing, how much unity or groupings, during and after natural disasters, which may extend indefinitely until a stable and permanent situation is resolved:

1) Emergency shelter: provides weather protection. Whether it's vehicles, tents, or even debris.
2) Temporary shelter: Includes places to sleep, cook and bathe. It occurs usually in existing institutions.
3) Temporary housing: Victims are housed, preferably maintaining family groups, and can return to their normal daily routines, but in a temporary location. It is usually during the post-disaster rehabilitation phase that such housing is constructed and provided by the government. The accommodation can start with a basic unit and be expanded over time and according to the need of each situation.
4) Transient or permanent housing: It is the housing that takes the place of what was destroyed and allows victims to rebuild their usual way of life prior to the occurrence of the disaster from a basic unit that can be expanded over time.

The main objective of this article was to understand the basic housing unit needed for a post-disaster situation or in cases of emergency immigration situation where it is necessary to accommodate a group of people in vulnerable situations, and thus offering better conditions of assistance, comfort and functionality for temporary shelters. With the intention of presenting a project with a minimum of environmental impact and easy assembly and dismantling, renewable materials such as bamboo and wood (Wood Frame) were chosen, which allow for the carbon stock, since they emit less carbon dioxide into the atmosphere, contributing to the mitigation of the greenhouse effect, and can be considered sustainable inputs.

3 METHODOLOGY

This article was prepared using two methodological approaches: in the first, the survey of needs and the choice of appropriate materials for the development of the topic were carried out. In the second stage, the architectural and technological study of the temporary, emergency and sustainable shelter was carried out with the following premises in mind:

- Create a design that allows assembly and disassembly;
- Develop a project to be quickly built to shelter families in situations of immigration (refugees) and/or natural disasters;
- Employing lightweight construction systems;
- Enable the construction of the module without the need for skilled labor;
- Employing sustainable materials, i.e. from renewable sources, manufactured using low water and energy consumption;
- Obtain an end product that can be used more than once.

4 RESULTS AND DISCUSSION

The abundance of wood and bamboo in the national territory contributes to the rapidity of the assembly process of the units, optimizing the construction time. the use of materials benefited and prepared with modular parts, mostly for sale in stores of construction materials or similar companies, was chosen. Considering a temporary situation and with few resources was defined thus, a system of single plant, not compartmentalized containing in its interior only a dormitory space, kitchen, small area of upper deposit, and in the external service and access
area. The shelter unit has a floor 25.92 m² area and can accommodate four to six people, as shown in Figure 2.

![Figure 2 - Furnished Plant Shelter](image)

Source: Authors, 2020.

The basic idea of the project is based on the development of a small number of parts system that can be mounted and dismantle constituting an assembly kit. From this kit, it is possible to generate larger spaces/shelters using the same design concept, only adding extra parts from the adopted standard. For information on the construction of the unit of 25,9m², Table 1 below has been developed, with the relevant data for those who want to build the housing.

### Table 1 - Table for construction of the Emergency Shelter.

<table>
<thead>
<tr>
<th>HOUSING IN BAMBOO AND WOOD FRAME</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FOUNDATION</td>
<td></td>
</tr>
<tr>
<td>Shoe</td>
<td>22 18L paint cans filled with sand</td>
</tr>
<tr>
<td>STRUCTURAL MASONRY</td>
<td></td>
</tr>
<tr>
<td>Hydraulic wall</td>
<td>21 structural blocks</td>
</tr>
<tr>
<td>WOOD FRAME PANELS</td>
<td>BAMBOO STRUCTURE WALL</td>
</tr>
<tr>
<td>Ceiling</td>
<td>6 Panels</td>
</tr>
<tr>
<td>Base</td>
<td>7 Panels</td>
</tr>
<tr>
<td>Walls</td>
<td>15 Panels</td>
</tr>
<tr>
<td>Port</td>
<td>1 panel</td>
</tr>
<tr>
<td>Closures</td>
<td>5 Panels</td>
</tr>
<tr>
<td>ROOF BAMBOO STRUCTURE</td>
<td></td>
</tr>
<tr>
<td>Piece 600 cm</td>
<td>4 pieces</td>
</tr>
<tr>
<td>SCREWED SOLUTION BETWEEN PARTS</td>
<td>Threaded bypass bar and fisherman system</td>
</tr>
<tr>
<td>PARTS WITH FISH MOUTH FITTING</td>
<td>16</td>
</tr>
<tr>
<td>ROOF AREA</td>
<td>54.6 m²</td>
</tr>
<tr>
<td>SOLUTION FITTING ROOF X BAMBOO</td>
<td>Fisherman's Mouth</td>
</tr>
</tbody>
</table>

Source: Authors, 2020.
The design allows great flexibility by adding more useful area, as it is modular structured as 122cm x 244 cm, which can be enlarged laterally and longitudinally, as Figure 3.

![Figure 3 - Model - Shelter Studies. Source: Authors, 2020](image)

The module fulfills the shelter function, the plant free and without obstacles, allowing multiple support functions to the set. The structure has bamboo parts underneath the wooden boards and screwed to increase the rigidity of the assembly.

![Figure 4 - Details - Bamboo parts underneath the wooden boards for increased rigidity. Source: Authors, 2020](image)

Among other possibilities, the systems can accommodate modules for medical care, administrative area, infirmary, etc. To meet the needs of the families, it is indicated a minimum furniture, preferably dismountable and that above all basic functions. Furniture can be used as elements of separation between rooms.

To meet the basic needs of homeless families, the project included two community modules with toilets (female and male), as shown in figures 5 and 6.
These modules shall be installed at a proportion of one for each 8 to 12 Shelters as shown in Figure 7. It is suggested that these sanitary modules be installed close to each other, concentrating wherever possible the greatest number of them in order to facilitate the disposal of sewage.
The industrialization process started after World War II caused the depletion of natural resources and concern for the environment and the health of individuals. As a result, in many fields of human activity, the search for alternatives was verified and, in architecture, it was no different. Several architects went on to design villas that combine comfort and respect for the environment (SOUZA, 2004).

The choice of bamboo and the Wood Frame Construction system takes into account its qualities as a renewable, economical, durable material of unquestionable aesthetic feature; its physical and mechanical properties make this material suitable for civil construction. (SOUZA, 2004).

Due to the need to protect the bamboo against soil moisture and also rain water, the type of foundation chosen was that of shoe using paint cans with sand in its interior content, raising the construction to 0.30m above ground level. The choice of 18L paint cans, becomes an option to reuse materials that are discarded and avoids the use of concrete in the foundation not generating waste, becoming environmentally correct.

The construction system in Wood frame for building houses is a lightweight system, structured in pieces of treated plantation wood, which allows for the use in conjunction with various materials, besides allowing for rapidity in assembling and total control of expenditures already in the design phase for being industrialized. The structural behavior of the Wood frame is superior to that of structural masonry in strength, thermal and acoustic comfort (CALIL;MOLINA,2010).

The vertical panels function as double wall creating a mattress of air that works as sound and thermal insulation, and depending on the bioclimatic zone to be implanted can still use thermal insulation. The panels are connected through 2x4” pieces of pine and the slab panel is fixed on the walls, creating an airtight and stiffer housing. Two movable windows (maximum-air) are provided for cross-ventilation.

The design of structural panels in Wood frame can be follows the criteria established by the American standard WFCM 2018 also by European standards DIN 1052 (1998) and EUROCODE 5 Part 2 (1997) (WFCM,2018).

The design used the Wood Frame construction system, the platform-like system, with structural walls, supporting the roof load and transmitting the loads to the foundations through the floor. The walls are mesh panels covered on both sides with oriented strand board sheets (OBS).
Although not a commonly used material in Brazil, bamboo is used in several construction processes in several countries. In China, for example, bamboo is widely used to manufacture and assembly of scaffolding in buildings, and in India, with an excellent level of engineering, it has built one of the most important monuments of humanity: the Taj Mahal, a historical monument built in the seventeenth century (BONINI, 2010).

The bamboo is a versatile material for construction that can be used in its natural form as culms, as well as slatted, as mats, and planned. All construction techniques using bamboo are light and resistant and require only low cost and easy handling equipment (UBIDIA, 2016).

For the emergency housing, the bamboo in the structure, covering and bracing the species *Dendrocalamus asper* due to its high mechanical strength in pillars and roofs was chosen.

According to Calil Junior; Molina (2010), the roof is the crown of the construction and its function is to protect the construction from the weather (rain, dust, sun, winds, extreme temperatures), without losing its structural stability throughout its entire useful life. In this way, the structural, thermal and acoustic performance must be observed; the level of fire safety; the functionality and accessibility; and, the conditions of durability and serviceability.

The roof was structured to a one-slope roof covering the length of the prototype. When building with bamboo, it is recommended to use large eaves to protect the structure against windy rains. To do so, 0.60m eave of was designed, and the roof will overtake the rafters by 0.20m. The roof structure was 20 degrees inclined and was built with bamboo of the species *Dendrocalamus asper* due to its high mechanical strength adopted also for the columns for the same reason.

For the construction of the roof structure, first were made "mouth of fish" connections (Figure 8) in the pillars, and fitted the two beams to support the roof structure that received the rafters providing thus greater stability.

The tiles will be eco-friendly type. The ecological tile meets the environmental and public health interest, considering the effects of stimulated recycling, since it is made with materials for which the most common destinations would be landfills.

doors and windows of the building provide heat exchanges, ventilation and hygienization in the environments. The solution for the frames was wooden with 5cm X 10cm columns, which allow the installation and notching of the hinges in metal profiles allowing the sheets to rotate.

It is important that the site has basic infrastructure, electrical and hydraulic facilities. A suitable environment for setting up the camps are the squares in the cities. Camps can also be set up in parking lots, football stadiums, etc.

Brazil is a privileged country in terms of energy generation, because of its geographical location and its natural reserves. And the Renewable Energies that can be obtained from Hydrelcic Power Plants, Biomass, Tidal, Wind and Solar.
the shelter uses solar energy generated through photovoltaic plates, installed on the roof. Water, previously considered an infinitely renewable and abundant resource, currently defines and limits the aspirations for economic and social development. The increasing vulnerability of the waters to the predatory actions of man justifies the reuse of water, in its various modalities. (DL Dantas, AWC Sales, 2009)

The shelter is also endowed with rainwater collection by means of a very simplified system. The roof collects rainwater and sends it, through a gutter to plastic drums. Water thus collected can be used for various purposes that do not require potability.

For drinking water, it is proposed to install a 500L water reservoir installed over the sink and washing area of each dwelling.

The sewage is taken to the septic tank where it receives adequate treatment.

For the agility of transport, shorter distances are necessary, therefore it becomes advantageous the utilization regional materials from Mato Grosso do Sul. The dimensions and weights of the parts should facilitate transportation and it is convenient that the assembly be subject to great agility in its construction stages so that the housing availability is reached in a short time, with minimum effort.

5 CONCLUSION

As seen in the present study, it can be considered that, currently, emergency housing is essential and of extreme importance and the use of accessible natural materials, such as bamboo, various types of wood and its products introduce a new format for immediate attention to the population in a rational manner and valuing environmental principles.

The main positive considerations for the construction of the shelter were the possibility of assembly/disassembly, rate in the implementation of the model, and the use of sustainable materials. Considering that the availability of *Dendrocalamus asper* bamboo parts are not easily accessible, a suggestion to alleviate the problem would be the creation of emergency municipal stockpiles for future utilization. In addition, structural pieces can be replaced with similar materials without compromising the structure, provided the assembly steps are respected.

The combination of the various chosen materials allows for several different set-ups and layouts, expanding the range of options. It also allows for the adaptation of the modules in an organic way, being able to compose a great diversity of services to the population.

The use of wood transmits an affective welcome in addition to all its mechanical and environmental benefits.

REFERENCES


