An Environmental and Economic Comparison between the use of Conventional Reinforced Concrete and the Wood Frame System Alternative

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ABSTRACT: Conventional construction systems are still present in the overall scenario of civil construction industry, with the consumption of large amounts of natural resources and the generation of significant quantities of waste. The objective of this paper is to gather information about existing conventional construction systems vis a vis the alternative use of Wood Frame. Research was carried out by using the methodology of bibliographic and documentary search to place a comparison with the environmental and economic aspects collected from various sources in order to discuss the costs of systems, using case studies carried out by different authors. The results indicate that, despite the stability of reinforced concrete in the national construction scene, it is possible to use the Wood Frame system as an alternative capable of generating economic and environmental benefits.

Keywords: Reinforced concrete system; Wood Frame; Economic viability; Environmental impacts.

Uma Comparação Ambiental e Econômica entre o Uso do Concreto Armado Convencional e a Alternativa do Sistema Wood Frame

RESUMO: O cenário atual da construção civil é marcado pelo sistema construtivo convencional, que é altamente poluente e gera uma quantidade enorme de resíduos. O objetivo deste artigo é agrupar informações acerca dos sistemas construtivos convencional e um sistema alternativo, *Wood Frame*, usando a metodologia de pesquisa bibliográfica e documental, e comparar os aspectos ambientais e econômicos colhidos, discorrendo sobre os custos dos sistemas, por meio da utilização de estudos de caso realizados por diferentes autores. Os resultados encontrados indicam que apesar da estabilidade do concreto armado no mercado nacional, é possível a utilização do sistema *Wood Frame* como uma alternativa capaz de gerar benefícios econômicos e ambientais.

Palavras-chave: Sistema de concreto armado; *Wood Frame*; Viabilidade econômica; Impactos ambientais.

1. INTRODUCTION

Conventional building systems made with ceramic blocks and cement derivatives such as concrete are still dominant in the Brazilian civil construction market, used both in large and small buildings. However, this system has a problem, which lies in the harmful damage it causes to the environment, both during its manufacturing process and in the high percentage of waste at the construction site. [1]

An alternative to this conventional construction process is the Wood Frame system. The usage of wood as a structural element is the main characteristic of this system. It is seen as a sustainable system since wood is a recyclable, renewable, and biodegradable material that requires little energy for its transformation [2]. Since this system is widely used in Northern Hemisphere countries, there is a large variety of technologies already present on the global market, thus facilitating the translation of these systems to Brazilian territories.

1.1. Conventional Reinforced Concrete System

This construction system is widely used in Brazil, because it is easy to obtain the necessary materials and does not need specialized workers. Despite the easy brought by this construction process, the concrete industry hides a high emission factor of dangerous gases to the atmosphere, being it alone responsible for 8% of global carbon dioxide emissions, arising from both the chemical process of cement formation and the generation of heat needed to process the clay and limestone that form the cement. This construction model is harmful to the environment and generates impacts, such as the high generation of waste, one of the reasons being the need to break the masonry walls for the installation of the electrical and hydro-sanitary systems of the building. [3.4]

1.2. Wood Frame System

In contrast to concrete, there is the Wood Frame system. According to Spaniol [5], it consists of an industrialized and durable construction system, which is structured in reforested (treated or not) wood profiles, forming panels for flooring, walls, and roofs. Other materials coat these panels to increase thermal and acoustic comfort, as well as protect the building from the weather and fire. As it is made from renewable raw material, this system is classified as sustainable since wood cultivation for usage in the building structures contributes significantly to the effective reduction of atmospheric carbon, storing this component as durable goods and contributing to a trend contrary to that of most materials. Other than that, it reduces the impact generated by the Civil Construction industry. [6]

Spaniol claims that it is possible to prefabricate Wood Frame construction systems partially and completely, which increases this system's quality, diminishes waste generation, and decreases the time needed to build with this material. This characteristic allows not only to have a cleaner, free-of-waste construction site but also to obtain results that are less prone to the emergence of pathologies. Among other advantages, this construction system significantly reduces the amount of labor and

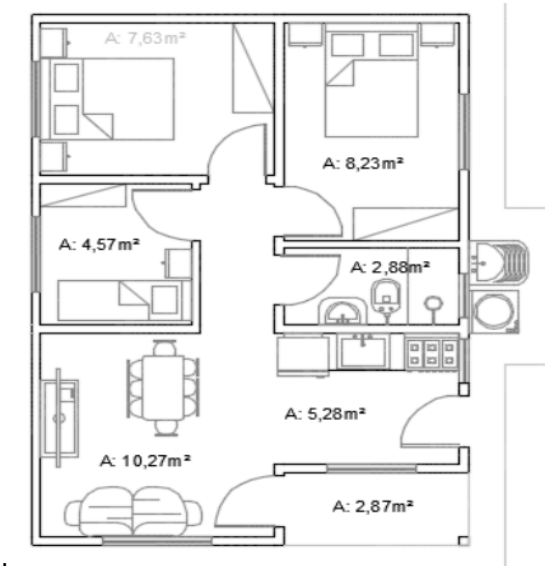
presents a favorable thermal performance, as it allows the use of a wide variety of insulators inside the panel. In addition, as they are light systems, they do not require much of a foundation and are able to adopt seller's structural solutions, with lower production costs. [5]

However, this constructive system has disadvantages as a limitation of floors used with this structural model. However, according to Silver, McLean, and Evans, this can be overcome by using technologies such as glued micro-laminated wood, which may increase the structural performance with its use. It is also necessary to pay close attention to the process of waterproofing the structure, treating and maintaining the wood as a whole, as well as the need for specialized labor. [7]

2. METHODOLOGY

The research was realized through bibliographic and documentary methods, with the objective of portraying the greatest possible number of characteristics of these systems and identify the relationships between the variables of the study. For this, the researchers used papers, books, and other texts of scientific nature that were available online to deepen their knowledge about the previously mentioned building systems and to make a comparative analysis of the main aspects of these elements. In addition to this, two case studies were reviewed: the first being the work of Silvestre and Figueiredo, who brought the economic aspects in their work, using a floor plan of a simple single-family residence (Figure 1), with an area of approximately 50 m². [3]

Figure 1 - Floor plan of the single-family residence

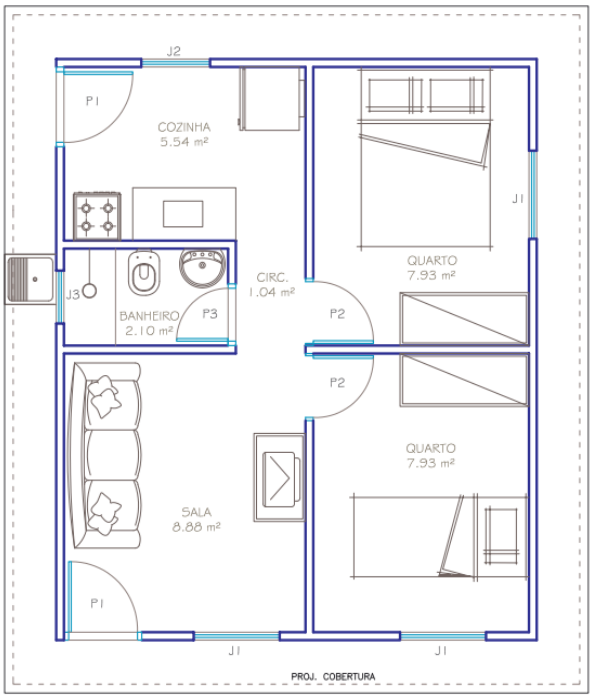


Source: Silvestre and Figueiredo, 2018

Spaniol [5], who works with a project made available by the Caixa Econômica Federal in its "Caderno CAIXA: Projeto padrão casas populares" (CAIXA Notebook: Popular Housing Standard Project), a document that lists different projects on the same floor plan together with the budget for the building, for accessibility to popular housing

in the country, was also used.

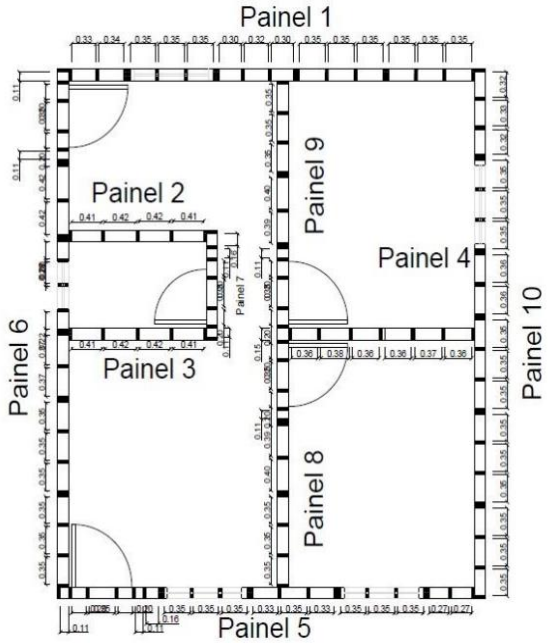
Figure 2 - Floor plan of the Caixa standard project



Source: Caixa Econômica Federal, 2006.

The floor plan worked on is presented in Figure 2, of a simple single-family residence with 36.84 m² of built area, two bedrooms, one bathroom, and a kitchen. In his work, Spaniol translated the plan to the Wood Frame model, as presented in Figure 3, with wood panels used for structuring and sealing the building. [5]

Figure 3 - Wood Frame Spaniol's Project



Source: Spaniol, 2018

3. RESULTS AND DISCUSSION

From the dimensions presented for these constructions, it was possible to create cost tables for the two construction models studied. The SINAPI (National System of Prices and Indexes for Civil Construction) table of the first semester of 2018 provided labor and material cost used in each service, for the Brazilian state of Mato Grosso do Sul.

The CYPECAD® Software's Price Generator collected input quantities and performed the budget. The results of the budgets for conventional masonry and Wood Frame systems for the work of Silvestre and Figueiredo [3] are shown in Tables 1 and 2, respectively.

As different processes are required for the execution of these construction models, there were different services' breakdowns for the wood frame and the reinforced concrete system in the tables presented by the authors, such as the exclusion of superstructure and finishing services in the wood construction system, with the inclusion of the facade cladding service.

The greatest expenses for the construction process with the masonry with the reinforced concrete system were labor costs for the execution of the foundation, and the price of materials for the execution of the superstructure, especially the electrical and hydraulic installations, which need to be "ripped out" for placing the inputs related to these services. [2]

Table 1 presents data regarding the costs of this house's construction model portrayed during Silvestre and Figueiredo's case study, separating the expenses with materials and employees according to the services required for this construction process. [3]

Table 1 - Cost estimation using conventional reinforced concrete masonry.

ALVENARIA CONVENCIONAL DE CONCRETO ARMADO				
ITEM	DESCRIÇÃO	VALOR (MATERIAIS)	VALOR (MÃO DE OBRA)	VALOR TOTAL
1	FUNDAÇÃO	R$ 2.514,38	R$ 2.468,50	R$ 4.982,88
2	SUPERESTRUTURA	R$ 3.133,24	R$ 1.559,84	R$ 4.693,08
3	PAREDES EXTERNAS E INTERNAS	R$ 1.634,69	R$ 952,58	R$ 2.587,27
4	COBERTURA	R$ 2.413,14	R$ 493,80	R$ 2.906,94
5	IMPERMEABILIZAÇÃO	R$ 540,06	R$ 304,08	R$ 844,14
6	ESQUADRIAS	R$ 2.053,67	R$ 357,40	R$ 2.411,07
7	INSTALAÇÕES ELÉTRICAS	R$ 2.197,01	R$ 1.984,80	R$ 4.181,81
8	INSTALAÇÕES HIDRÁULICAS	R$ 2.045,53	R$ 1.160,92	R$ 3.206,45
9	REVESTIMENTOS INTERNOS	R$ 2.570,28	R$ 1.361,02	R$ 3.931,30
10	ACABAMENTOS	R$ 1.189,01	R$ 247,49	R$ 1.436,50
11	PINTURA	R$ 1.062,58	R$ 1.298,07	R$ 2.360,65
12	SERVIÇOS COMPLEMENTARES	R$ 249,87	R$ 372,07	R$ 621,94
TOTAL		R$21.603,46	R$12.560,57	R$ 34.164,03

Source: Adapted from Silvestre and Figueiredo, 2018.

Table 2 shows the estimated costs of this building using the Wood Frame system, presenting data regarding the costs of materials and labor needed for each service, as well as the total value of each service. The greatest expenses perceived at this stage are the wall services, external and internal, and the external cladding, highlighting the reduced costs of the installation services. [3]

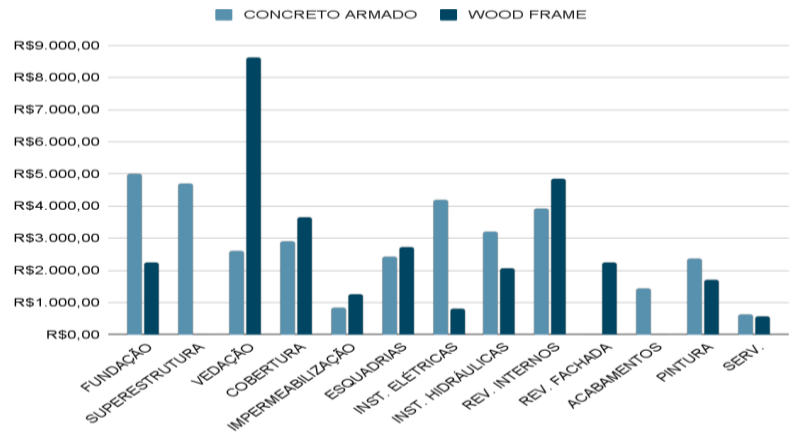
Table 2 - Cost estimation using Wood Frame.

WOOD FRAME				
TEM	DESCRIÇÃO	VALOR (MATERIAIS)	VALOR (MÃO DE OBRA)	VALOR TOTAL
1	FUNDAÇÃO	R$ 1.668,50	R$ 562,50	R$ 2.231,00
2	PAREDES EXTERNAS E INTERNAS	R$ 6.056,85	R$ 2.575,77	R$ 8.632,62
3	COBERTURA	R$ 2.705,90	R$ 951,25	R$ 3.657,15
4	IMPERMEABILIZAÇÃO	R$ 773,27	R$ 473,74	R$ 1.247,01
5	ESQUADRIAS	R$ 2.298,78	R$ 412,00	R$ 2.710,78
6	INSTALAÇÕES ELÉTRICAS	R$ 430,00	R$ 360,00	R$ 790,00
7	INSTALAÇÕES HIDRÁULICAS	R$ 1.254,89	R$ 798,57	R$ 2.053,46
8	REVESTIMENTOS INTERNOS	R$ 3.075,90	R$ 1.782,30	R$ 4.858,20
9	REVESTIMENTO FACHADA	R$ 2.236,42		R$ 2.236,42
10	PINTURA	R$ 741,62	R$ 958,65	R$ 1.700,27
11	SERVIÇOS COMPLEMENTARES	R$ 281,88	R$ 294,16	R$ 576,04
TOTAL		R$21.524,01	R$ 9.168,94	R$ 30.692,95

Source: Adapted from Silvestre and Figueiredo, 2018.

Through the analysis, it is noticeable that the costs of materials and labor for the foundation services and electrical and hydraulic installations are lower in the Wood Frame system, while it has considerable expenses with coatings and internal and external walls. When compared to the conventional building system, Wood Frame costs about 10% more in materials, but the reduction in labor reaches 50% compared to masonry, with a reduction in construction time by at least a third. [3]

Figure 4 - Comparison of total costs per service



Source: Adapted from Silvestre and Figueiredo, 2018

Figure 4 shows the difference between the costs generated by the two systems, especially during the foundation and sealing processes of external and internal walls, as well as the electrical installations in this building. That is a direct consequence of

the reduced weight of the wood frame system, which allowed the use of simpler foundations. The ease in obtaining materials for sealing the reinforced concrete system, and the prior planning for the building's electrical system installation present in the wood system also avoid breaking the walls of the conventional system.

Considering the total values of the two systems, a difference of 10% in the use of conventional masonry concerning Wood Frame is noted, with an increase of 27% in the amount spent on labor in the reinforced concrete system. It is worth noting that the work of Silvestre and Figueiredo brings data only on the materials and labor used, disregarding the logistical problems and the availability of the material in the area studied. [3]

Table 3 - Cost estimation of construction systems

SERVIÇOS	ALVENARIA (R$)	*WOOD FRAME* (R$)
Serviços Preliminares	766,81	766,81
Fundação	4.063,23	4.063,23
Alvenaria/Estrutura Painéis	6.786,46	5.434,13
Revestimento	8.925,57	8.433,84
Cobertura	5.969,50	5.354,23
Pintura	4.783,13	3.951,24
Esquadrias	4.169,51	4.169,51
Instalações Elétricas	2.664,55	2.664,55
Instalações Hidráulicas	2.287,95	2.287,95
Instalações Sanitárias	3.955,19	3.955,19
Limpeza Final	126,65	126,65
Custo Total	**44.498,54**	**41.207,33**

Source: Spaniol, 2018

Analyzing the work done by Spaniol [5] and referring to Figures 2 and 3, a comparison between the two systems was performed, as seen in Table 3. It is possible to perceive that they corroborate with those presented by Silvestre and Figueiredo [3], demonstrating an economic advantage of the Wood Frame system whilst compared to the conventional reinforced concrete system. It is worth noting that the budgeting performed by Spaniol considered only data from the SINAPI table about the conventional masonry system, and for the Wood Frame one, he used the set of SINAPI tables plus local market prices.

4. CONCLUSION

As seen from the case studies analyzed, the wood construction system can have an economic advantage in small residences when compared to the conventional reinforced concrete system. However, since it is not widely used in Brazil, it is difficult to find qualified labor to execute this construction model, as well as the lack of specific norms for the work using this material as a structural element. Despite the perceived differences while comparing these building systems in different papers, the Wood Frame system's eco-efficiency is proven, especially when it comes to economic feasibility, making it an excellent substitute in environmental terms but also in relation to costs. Analyzing the current scenario of civil construction, it is noticeable the need for investment in research and innovation for the implementation of building systems

less harmful to the environment. This study aims to contribute to a reflection about constructive systems and promote the research for new construction alternatives. Thus, it will be possible to have lighter, cheaper, and, mainly, more ecological constructions.

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