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Using Alternative Timber in Parallel Flanges Truss Structures for Steel Roof - Slope 20º, with Spans between 16 to 26 Meters

Hyago Maurício Bremm Muller[1], Roberto Vasconcelos Pinheiro[1], Jennifer Mayara Vilas Boas da Silva[2], João Paulo Boff Almeida[1], Natalia Garcia Couto[3], André Luis Christoforo[3,*], Francisco A. Rocco Lahr[4]

[1]Department of Civil Engineering, University of Mato Grosso State (UNEMAT), Sinop, Brazil
[2]Department of Architecture and Urbanism, University of Cuiabá (UNIC), Sinop, Brazil
[3]Department of Civil Engineering (DECiv), Federal University of São Carlos (UFSCar), São Carlos, Brazil
[4]Department of Structural Engineering (SET), São Carlos Engineering School, São Paulo University (EESC/USP), São Carlos, Brazil

Abstract Timber is part of society's evolutionary process. It presents several utilities because it is versatile and easy to apply. However, it is often extracted incorrectly from nature and used in inappropriate ways. In civil construction it is predominantly applied temporarily and, when it has structural purpose, it is used without knowledge about its properties and absence of structural projects. Thus, this research aims to assess the viability of employing not so usual species, with class resistance C-20 and C-30, in its usage as component structural element of industrial sheds with truss structures for roof (parallel flange) "Howe" type (20º inclination - steel roof tile); span 16, 18, 20, 22, 24 and 26 meters; typologies of edification lateral openings - 1:1, 2:1, 6:1 and opened. Therefore, it was determined the ratio between timber volume (m^3) and constructed area (m^2) according to NBR 7190:1997 standards, making it possible to verify the applicability of C-20 and C-30 species to industrial sheds typology determined in this research.

Keywords Timber, Steel roof, Cover structure, Sustainability

1. Introduction

Timber, a natural, renewable, and easily obtained material, presents a good ratio between resistance and density when compared to other civil construction materials such as steel and concrete [1].

Due to its versatility and malleability, timber has been used by humanity for many years, meeting several purposes. In civil construction, it is verified the temporary employment of timber in forms for concrete, scaffolding, and shoring. For definitive use, it is employed in frames, ceilings, floors, bridges, footbridges, residential roofs, industrial sheds and others [2].

Like the United States and Japan, which apply timber on a large scale, reaching, respectively, 85% and 95% of homes, other countries in Europe, Asia, America and Oceania have been using it intensely in civil construction [3]. However, in Brazil, despite being a world highlight in the timber industrial sector due to its diversity of native forests and productive capacity of planted forests, the use of timber is still victim of prejudice about its quality and performance, mainly due to lack of knowledge and technological advances in the sector [4, 3].

Because of the scarcity of scientific studies about traditional timbers characteristics and exploration, the market has become restricted to few species, putting some of them in risk of extinction [5]. Thus, it is necessary to know new timber species, with the potential to replace the ones traditionally used in civil construction [6].

In Brazil, the NBR 7190 (1997) standard "Timber Structures Project" [7] establishes the premises and calculation methods for structural measurement. It also establishes the test methods to obtain the physical and mechanical properties of timber.

Timber species are gathered in classes of resistance, according to the characteristic value of resistance to compression parallel to fibers ($f_{c0,k}$). Among the classes of resistance covered in the normative reference (C20, C30, C40 and C60), there are classes which are predominantly destined to temporary use, such as C20 and C30, due to lack of knowledge about the physical/mechanical properties and the lack of specific projects that prove their efficiency when employed in roof structures.

* Corresponding author:
alchristoforo@gmail.com (André Luis Christoforo)
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Intending to contribute to the use of not so usual timber species and to minimize the prejudice that surrounds the employment of timber for structural purposes, this research aimed to present the applicability of species which belong to classes of resistance C20 and C30 in truss structures for roof through the elaboration of structural projects.

2. Material and Methods

This research was performed in five steps: (i) Setting of construction geometrical parameters; (ii) Definition of the structural conception; (iii) Definition of actions and loadings; (iv) Measurement and verification of structural elements and connections according to ABNT NBR 7190 (1997) Brazilian standard prescriptions [7]; (v) Material gathering, ratio volume per construction square meter.

2.1. Step 1 - Geometrical and Structural Parameters

The projected edifications have the following characteristics: Howe type Isostatic truss with parallel flanges, with spans of 16, 18, 20, 22, 24 and 26 meters; Steel roof with 20º inclination; Ceiling height 5 meters; Proportion in the design around 1:3; Lateral openings (relation between the predominant one and the others): 1:1, 2:1, 6:1 and opened. In Figure 1 it is possible to observe the 3D model of the pre-set geometrical parameters.

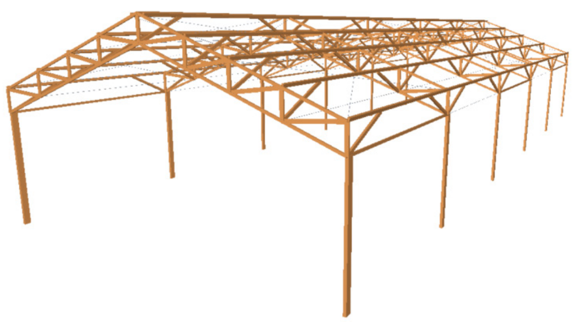

Figure 1. Representative model of industrial shed typology proposed in the research

2.2. Step 2 - Actions Definition

To the development of this project, structural, non-structural and variable permanent actions (due to the wind) were considered. Permanent actions were established according to ABNT NBR 7190 (1997) [7] and ABNT NBR 6120 (1980) [8]. In permanent structural actions there are truss bars and brackets (class of resistance C-20) and purlins (class of resistance C-30). The steel roof tile weighing 0,05 kN/m² was considered as a non-structural permanent action.

2.3. Step 3 - Measurement and Verification

Measurement and analysis of stability in truss structural elements (flanges, uprights and diagonals) and bracing system were considered compression situations and parallel traction to timber fibers (short piece, fairly thin and thin). The situation adopted to purlins was oblique simple flexion.

After measuring all structural elements, the comparison between initial estimation and the project real situation was performed, accepting a 10% difference in the structure's own weight, according to ABNT NBR 7190 (1997) prescription [7].

3. Results and Discussion

After all the calculations were performed, it was possible to analyze the results, which are represented through figures 2 to 6 and tables 1 to 4. In order to optimize the dimensioning, technical and constructive and aspects were taken into consideration, analyzing independently each structural element.

Table 1. Volume open (m³)

Span (m)	Length (m)	Truss (m³)	Purlin (m³)	Bracing (m³)	Total (m³)	m³/m²
16	45,00	3,75	0,88	1,90	6,53	0,0091
18	54,00	4,16	1,05	2,97	8,19	0,0084
20	63,00	4,32	1,47	3,72	9,51	0,0075
22	63,00	5,23	1,47	4,54	11,23	0,0081
24	72,00	10,05	1,79	4,64	16,48	0,0095
26	81,00	13,13	2,00	6,34	21,48	0,0102

Table 2. Volume 6:1 (m³)

Span (m)	Length (m)	Truss (m³)	Purlin (m³)	Bracing (m³)	Total (m³)	m³/m²
16	45,00	4,92	1,12	1,90	7,94	0,0110
18	54,00	5,54	1,49	2,97	10,00	0,0103
20	63,00	7,02	2,00	3,72	12,74	0,0101
22	63,00	8,81	1,98	4,54	15,33	0,0111
24	72,00	15,83	2,38	4,64	22,85	0,0132
26	81,00	19,26	2,64	6,34	28,24	0,0134

Table 3. Volume 2:1 (m³)

Span (m)	Length (m)	Truss (m³)	Purlin (m³)	Bracing (m³)	Total (m³)	m³/m²
16	45,00	4,14	1,12	1,90	7,16	0,0099
18	54,00	4,49	1,27	2,97	8,74	0,0090
20	63,00	5,55	1,80	3,72	11,07	0,0088
22	63,00	7,22	1,60	4,54	13,36	0,0096
24	72,00	12,24	1,95	4,64	18,83	0,0109
26	81,00	16,02	2,49	6,34	24,85	0,0118

Table 4. Volume 1:1 (m³)

Span (m)	Length (m)	Truss (m³)	Purlin (m³)	Bracing (m³)	Total (m³)	m³/m²
16	45,00	2,98	0,87	1,90	5,75	0,0080
18	54,00	3,35	1,06	2,97	7,39	0,0076
20	63,00	4,59	1,43	3,72	9,74	0,0077
22	63,00	6,20	1,38	4,54	12,12	0,0087
24	72,00	10,38	1,84	4,64	16,86	0,0098
26	81,00	13,95	2,01	6,34	22,30	0,0106

Through tables 1 to 4 it is possible to verify that, for all the openings, the timber volume is raised when span length is increased. When only trusses are analyzed, it is noticed a significant growth from the 24m span on. It occurs due to the fact that when the span is bigger, wind action area in the truss is also bigger, resulting in greater strain in the elements.

Purlins present an increasing timber consumption when the span is raised. This fact is due to its function in transferring wind strains to trusses.

Bracing systems also present crescent consumption in accordance with span increase, a fact which is related to the number of components in the structural system.

When the openings influence is analyzed, it is possible to verify that the opening ratio 6:1 presents greater timber consumption when compared to other opening ratios. This fact may be explained by the increase of wind pressure coefficients, caused by the difference of air mass penetration in the shed.

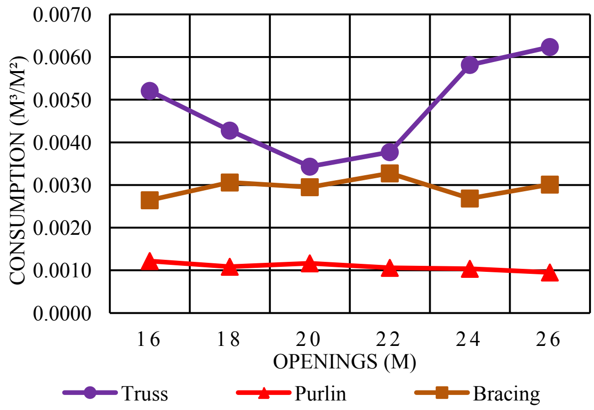

Figure 2. Timber consumption m³/m² for opening ratio – Open

Figure 2 presents timber consumption per constructed area (m³/m²) for open opening ratio. It is possible to verify that the lowest timber consumption for trusses was in 20m span and the highest one was for 26m span. The bracing presented values close to 0,003 m³/m² for all spans and purlins presented a small decrease of timber consumption in accordance with the increase of spans.

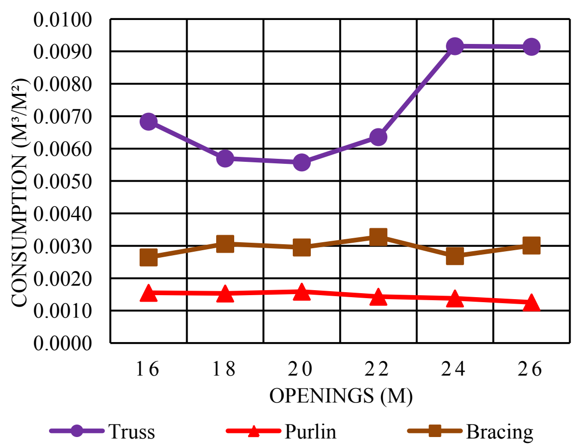

Figure 3. Timber consumption m³/m² for opening ratio – 6:1

Figure 3 presents timber consumption per constructed are (m³/m²) for 6:1 opening ratio. It is possible to observe the 18m and 20m spans presented lower timber consumption for trusses and the highest obtained results were for 24 and 26m spans. This fact may be explained due to the raise in spans length between supports, resulting in an increase in the number of structural elements needed to overpass the span. Furthermore, there is an intense wind action over the widest cover surfaces. When it is combined with the own weight, they generate significant strains in the structures, making strong parts necessary to endure such loads.

In bracings and purlins, timber consumption presented practically constant results for all spans.

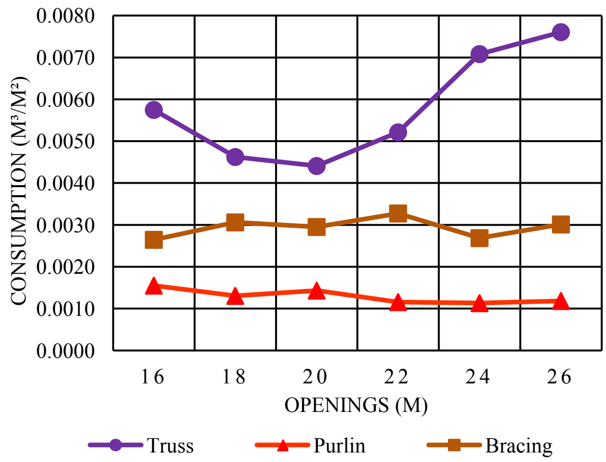

Figure 4. Timber consumption m³/m² for opening ratio – 2:1

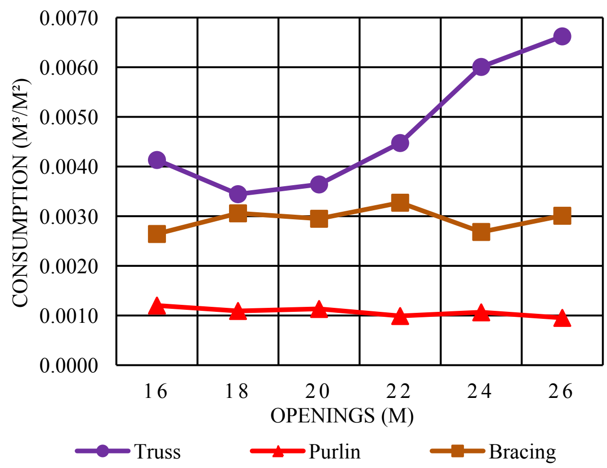

Figure 5. Timber consumption m³/m² for opening ratio – 1:1

The opening ratio 1:1 presented the lowest timber consumption in all cases as it can be seen in Figure 5. Such fact is due to the low wind pressure coefficient that hits this kind of shed, thus representing lower strains acting upon the structure, allowing less thin parts.

In Figure 6 the total consumption is represented for each span and opening type considering the total volume of trusses, purlins and bracing elements. Thus, it was possible to verify that opening ratio 6:1 presented highest timber consumption for all opening and span cases. The justification for this fact is due to higher resulting strains, which come from the wind dynamic pressure.

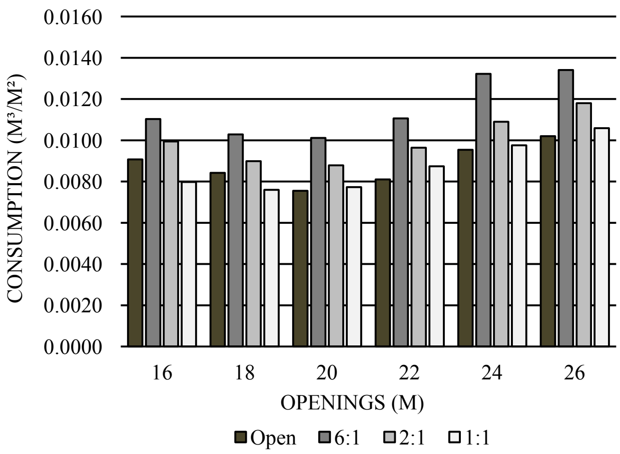

Figure 6. Total timber consumption m³/m² for all openings

It is also possible to notice in Figure 6 that the best results for timber consumption were for 18m and 20m spans, highlighting the totally open industrial shed with 20m span, which presented the highest saving of material. Analyzing all openings and spans ratios, the volumetric timber consumption ranged from 0,0075 to 0,0134 m³/m². According to Palludo et al [9], the timber consumption per constructed area ratio for rectangular sheds is about 0,020 to 0,030 m³/m², evidencing that the results presented in this research proved to be efficient and satisfactory.

In general, the opening ratio 1:1 presented the highest timber saving for most spans, except for the 20m span. When it is compared to the results from the study performed by Palludo et al [9] with 8 to 18m spans in triangular trusses, it is also possible to verify that the opening ratio 1:1 represents the best option in all cases.

4. Conclusions

Through the results obtained in the present research, it was possible to conclude:

- The technical viability of using non-conventional timbers (class of resistance C20 and C30) in parallel flanges truss structures for roof was proved through the elaboration of a project in accordance to the current standard prescriptions. Such fact contributed to valorization and commercialization of these species, consequently reducing the consumption of traditional species that may go extinct.
- The structural scheme (parallel flanges truss structures for roof) adopted for the studied spans (16 to 26m) generated timber consumption around 0,0075 to 0,0134 m³/m², approximately 60% lower than what is practiced.
- Bracing system timber consumption represented around 20 to 40% of total volume. This information is extremely relevant because it evidences the importance of bracing in securing the structure. It is worth mentioning that, in general, structures are usually made without the bracing system.
- For all studied spans (16 to 26m) the opening ratios (open, 1:1, 2:1 and 6:1) generated different values of timber consumption per constructed area. Therefore, it is suggested the use of opening ratio 1:1 whenever it is possible, since this ratio led to lower material consumption.

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