Facing Some Challenges on Wooden Construction in Parana State, Brazil

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Abstract: The state of Paraná is a major producer of plantation wood and forest products. The sector is responsible for one of the largest volumes of exports only behind the automotive industry. Many cities in the state were established thanks to the huge availability of natural forest timber; Peroba (Aspidospermapolyneuron) in the north and Araucaria pine (Araucáriaangustifolia) in the southern colder regions, not to mention a large number of native species with potential for reforestation. Despite this, timber construction has not been properly developed and what is observed is the complete replacement of timber for masonry construction. This paper points out some reasons for the current situation and lists some important challenges to be faced to replace wood as technically reliable and commercially competitive material for construction. Important works are presented in a number of areas already developed and under development in Paraná state, Brazil.

Key words: lumber, wooden construction, sustainable development

1. Sector Relevance

The planted area in Paraná today is estimated at 1,397,509 ha of Eucalyptus and Pine alone, not to mention other native species.

There is huge potential for forest plantation in the state and the government projection is to reach 2 million ha in 5 years. In the early 20th century, the state of Paraná had 85% of its territory covered by forests. Today there are only 3%, and there are efforts by both government and business sectors to reach 5% in 10 years.

In terms of export, the sector accounts for 5% of all exports of Paraná (only behind the automotive industry), for a total of US$ 155 million/year.

Forestry production reaches 6.6 million m³ of logs per year and 83% coming from planted forests. The sector is responsible for the production of 3 million m³ sawn timber a year.

It is composed of 3,700 companies. 75.6% are sawmills, most small and micro companies, and 24.5% of other segments generating 38,000 jobs.

With regard to the production of paper and pulp, the state produces 1,039,000 tons / year representing (6.5%) of national production.

Paraná also produces pine frames for export, especially to the United States and Canada. Just one company (Braspine), exports 200 containers of molds and frames per month to North America (US and CA).

The state is also one of the largest plywood exporters in the world and 2nd in Brazil¹.

2. Forestry

With regard to forest plantation, Paraná presents great advantages, both climatic and topographic. The state has the second largest area planted in Brazil only behind the state of Minas Gerais². Although there are various varieties of planted species, the largest area

(909,874 ha) is planted with Pine, and the second one with eucalyptus around 687,635 ha⁴.

These species, both imported, were introduced during the 60’s (Pinus spp and Eucalyptus spp) with government incentives for the manufacture of pulp and paper. At this time, the country was dependent on imports of paper, and the initiative was intended to turn the country self-sufficient in the commodity, which actually happened. Currently, Brazil has become an important exporter of paper and paper pulp.

In terms of annual wood yield in volume, there have been major advances in research and silvicultural techniques. The historical increasing in production reveals that since its introduction, the cultures of the species Eucalyptus had annual yield around 14 m³/ha/year until the 70’s. From the 90’s those figures range from 38 to 50 m³/ha/year.

Concerning Pine species, huge shifting is observed as well. In the 70’s the yield was limited to 18 m³/ha/year and yields ranging from 25 to 35 m³/ha/year are currently observed.

This increase in volume production, a combination of genetic improvement and silvicultural practice has been directed to the production of fibers for papermaking. This improvement of the annual volumetric efficiency brought however, damage to the physical and mechanical properties of the material for use in structures and construction. In the case of pine, there is a decrease in density of the material, a physical characteristic directly proportional to mechanical properties, and increase in the proportion of juvenile wood.

In eucalyptus, the growth stresses increase making the material susceptible to cracking and poor dimensional stability.

There is thus a vast field for the development of native species in reforestation. Many studies have been developed with many encouraging results. Among the potential species one can mention:

Açoita-cavalo, Angico-Vermelho, Cabreúva, Canafístula, Canjerana, Caroba, Grápia, Guajuvira, Ipê-amarelo, Ipê-roxo, Louro-pardo, Marmeleiro, Pau-marfim, Peroba, Tarumá, Timbaúva. All these species producing high quality lumber with the advantage of being native and adapted to the environment.

Of these, the Angico-vermelho and Canafistula are showing the highest potential for cultivation⁴.

3. Drying

One of the major limitations of the use of wood in construction in Brazil is the difficulty of finding commercial dry lumber.

The use of partially dried lumber, brings a number of serious drawbacks such as increased transport costs, dimensional instability, decrease of mechanical properties, and an increase in the possibility of fungal attacks among others.

Since a large part of the wood processing companies is made up of small sawmills, and since the entrepreneur lacks technical instruction on the subject and lines of credit to his business, a joint action of awareness of the problem is necessary.

On the one hand it is possible to develop low-cost kilns. The study presented by Moura et al. (2012) shows an experimental kiln of low cost assembly, and proposes drying timber at a low temperature (70°C) thus eliminating the need for boilers [1]. Also, those kilns can be potentiated with solar energy (Fig. 1).

Also, a device of this nature could be shared by several small entrepreneurs who also would share the system’s operating costs. Works like this support the small and micro entrepreneurs and would, once implanted, allow significant increase in the material quality.

On the other hand, it is necessary to market the demand for dry wood, and in this sense, the technical personnel specifying and applying wood (architects,
Facing Some Challenges on Wooden Construction in Parana State, Brazil

4. Treatment

Since Brazil is a tropical country, with elevated temperatures all year round in almost all its regions, the fungal activity and presence of insects are very high. The products available on the market although very effective, are still too aggressive. The CCA for instance, has been banned in most of the world and certainly will be in Brazil. It is time to propose more environmentally friendly treatments. Colli et al. (2007) for instance, developed treatment studies using tannin and boric acid with excellent results in the treatment of bamboo [3].

Moreover, it is important to make the prevention of fungal attack through a detailed architectural design to avoid direct contact of the wood parts to moisture taking measures such as: the use of eaves, ground elevation, thermal barriers against condensation, flashings and gutters, specifying dry wood, etc.

The detailed design may suitably prevent fungal attack completely thus significantly reducing the need for wood treatment. Inspection points, hatches for introducing preservative sprinklers, and allowing disassembly of the panels for periodic maintenance are measures to prevent insect attack and decay of the building.

5. Grading

As in the case of concrete and steel structures, timber structures are also calculated on the basis of lumber mechanical properties. Countrywide one cannot find commercially graded wood, not even visually graded. In Paraná, the situation is no different. This is an entirely undesirable situation since there are grading standards, and many works have been undertaken to improve the grading performance.

Moura et al. (2012) developed a manual for mechanical visual grading that could be used in small sawmills [4]. The document defines acceptable defects for each class of resistance. This handbook is able to assist the small and micro entrepreneur in the grading of their product adding value to the lumber.
Furthermore, non-destructive testing equipment (NDT — Non Destructive Testing) are very widespread. The ultrasound devices are particularly interesting for their versatility and relatively low cost.

Like many other countries, Brazilian lumber should bring the stamped strength class. Here again, the market demand for graded wood is required (Fig. 3). On the other hand, most sawmill entrepreneurs are completely unaware of the meaning and importance of mechanical grading.

It is therefore fundamental that this entrepreneur be informed and trained to know the available grading techniques and choose the one that would best fits his needs.

6. Development of Components for Wood Construction

One special need in wood construction in the country is the lack of specific components for the building system.

A serious problem that requires attention is the tightness around windows, particularly concerning the wood-frame system.

Tumeler (2016) deals with the problem by proposing the use of perimeter frame in the interface between the window and the panel as seen in Fig. 4 [5].

The author’s method solves the interface sealing problem. Wind tunnel tests have proven that the interface was tight even when subjected to a 300 Pa wind pressure (correspondent to 200 km/h wind speed).

In this field there are numerous product development possibilities. The partnership with the industry could put into focus not only the manufacture of these elements, but also the test in buildings in use.

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Fig. 3 Strength graded timber.\(^5\)

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\(^5\) http://stta.org.uk/Resources/Trada2.PDF.
7. Management and Utilization of Residues and Sawmill By-Products

One of the problems related to the processing of wood is the waste management.

Dumping of eucalyptus bark is one of the most serious. The bark is too acidic to be discarded in landfills. It is very aggressive to be used as poultry litter, giving off vapors that can suffocate the animals, and has low calorific value to be burned.

The disposal has been done in landfills, which can reach and contaminate the water table.

One possibility being studied is the manufacture of OSB panels (structural or not) using eucalyptus bark. This project is being developed by Mazzeto and Moura with mostly encouraging preliminary results.

8. Short Pieces

For various reasons, sawmills produce a series of short pieces (up to 1.20 m). This lumber which in many cases is of good quality and grading ends up being transformed into wood with low added value. An alternative is the use of this material in laminated wood, either glued or nailed. In situations where gluing is difficult, a good alternative to the use of this material is lamination through nailing.

Recco (2015) presents a study on the use of short pieces of pine in light trussed rafters to spans up to 6 meters with nail laminated timber-NLT [6].

In previous studies [7-9], it was found that failure of these rafters always occurred in the bottom chord in the vicinity of the supports, the location of the highest stresses. The author first studied the behavior of nailed connections subjected to tensile stress, in order to choose the most suitable type of nail. Once the nail was chosen, the author tested 6 samples of trussed rafters made out of graded wood, all six with similar mechanical properties. To assess the grading impact on the performance of the structure, a seventh sample with ungraded wood, was also tested.

All samples showed similar behavior during the test and the failure occurred in the splice closest to the lateral post. The results obtained concerning the tensile strength were quite high, averaging 60 KN and low coefficient of variation.

With the application of service load (6 KN) vertical deflections were below 1.4 cm lower than the required (both by the current NBR 7190-97 and the in-revision text of the standard; 30 mm and 20 mm, respectively). The service limit state has occurred under the load between 29 and 35 KN corresponding to a deflection of 30 mm, and under the load ranging from 22.50 and 27 KN to a deflection corresponding to 20 mm.

The vertical deflections and at the splices (horizontal displacement at connections) were higher in the sample with ungraded lumber, showing that grading benefits the performance of the structure.

From the ultimate load standpoint, the weakest point of the structure is the connection. Regarding the rigidity, the quality of wood had some influence, since

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Fig. 5  Eucalyptus bark in the sawmill ground and OSB walled house.6

the sample with ungraded timber showed higher deflections. The results could prove that the provision of adequate amounts of nails is able to convey effectively the efforts and significantly increase the performance of the structure.

Fig. 6 Internal layer and external Layers of NLT trussed rafter [6].

Fig. 7 Experimental apparatus [6].
The performance of the system was far above the required, allowing for the resizing of parts and consequent saving of lumber and nails.

In short, the results were extremely encouraging: The trussed rafters exceeded the load capacity by almost 6 times that for which it was designed. As well as for stiffness, deflections were much lower than expected, by almost five times.

9. Eucalyptus Pith CLT

A large volume of wood comes out of sawing operations as low-added value products. One of these products is the core of eucalyptus logs. Material composed most of juvenile wood has low density, relatively low mechanical properties and a high degree of cracking. This wooden contingent is disposed of as firewood and often becomes a problem for sawmills.

ALENCAR (2015) proposed a project to use this material as CLT panels.

The Cross Laminated Timber construction system or CLT (cross-glued laminated timber) first developed in Austria and Germany has recently emerged as an excellent alternative for the construction industry. CLT structural panels can have 3 to 10 layers glued together transversely. CLT can also be produced with two different wood species, which represents an opportunity to employ short pieces as done by Recco (2015) [6].

Fig. 8  CLT construction.

Fig. 9  Structural panel tests.

The work consisted of the testing of structural CLT panels. 16 CLT 3-layered panels composed with two species, Pine (Pinus spp.) and Eucalyptus (Eucalyptus grandis), were tested in bending. The samples were grouped into four types: one with only pine (PPP), and another with eucalyptus (EEA). The two remaining groups combined the two species; pine in the inner layer (EPE), and eucalyptus in the inner layer (PEP).

The tests showed values above the ones referenced in the literature and the standard regulating the CLT (ANSI/APA 320. 2012). The panels made up of pine showed better MOR values, but lower values of MOE,
i.e., panels with pine were more resistant and less rigid than those with eucalyptus.

The results observed in the study, even the less significant ones, achieved similar average values as found in the literature, as well as above the minimum values published. Thus it was found that Eucalyptus pith, material considered unsuitable for structural use (according to the NBR 9487 standard) reached acceptable values for MOE and MOR in the composition of CLT panels, showing that the technical feasibility of using this material of low-added value in the preparation of structural CLT panels actually exists.

10. Education

Education is the main challenge that Paraná and the country will have to face for the development of a productive wood construction chain.

With respect to wood building, there is an important gap in training among both technical and high education personnel. Carpenters today had no formal training and base their practice on empirical teachings of generations preceding theirs. Much is lost: the constructive and structural understanding has given way to the empirical experimentation lacking theoretical basis. The material has changed: instead of native low-growth wood of high mechanical properties, the available material is now very young reforestation timber (18 to 25 years old), developed primarily for the manufacture of pulp and paper as stated, and whose mechanical properties are much lower.

On the other hand, the curricula of technical courses in high level architecture and civil engineering, has seen their workload significantly decrease with regard to wood construction.

The result is that there are few qualified professionals able to design, implement and maintain wooden buildings.

To reverse the situation, a broad conviction of the need to increase the workload of the superior education in the field at the federal level will be necessary. The installation of experimental construction sites for wood construction in the universities will help greatly.

With regard to technical education, SENAI (National industry service — A technical school in several professional fields country-wide) will play a key role in the development of the sector. The institution has national prestige and is present in all regions of the country. In Paraná, the SENAI Wood Institute in Arapongas (Parana state) already has an infrastructure capable of offering training of the like.

Paraná is very well placed in terms of higher education: there are 7 state universities and 5 federal universities in the state, not to mention a large number of private universities. There are several courses in Architecture and Urbanism, Civil Engineering, Electrical Engineering, Wood Engineering, etc.

In relation to teacher education, the state counts several graduate programs; several in technological fields and in particular one in Architecture and Urbanism with a research line focused on wood construction.

Although still very young, the program has trained teachers and a new generation of researchers prepared to develop the area, feeding the demand for undergraduate teachers.

11. Research — Network Collaboration

Today’s world demands development of research on a global basis. The cooperation of various expertises in research can be highly effective in the treatment of common problems.

This is the case of ZEMCH project — Zero Energy Mass Custom Home [10] — Developed by teams from different countries: University of Melbourne, British University in Dubai, Federal University of Rio Grande do Sul, São Paulo University, Ryerson University, Università del Salento, Università di Trento, University of London, School of Architecture McIntosh.

This project is concerned with the development of energy efficient construction and still proposes housing

7 http://www.ppu.pos.uel.br.
designs adaptable to the changing needs of its residents, allowing modifications over the years. In addition, projects must present aesthetic and technological appeal compatible with the best existing design.

Considering the Brazilian housing deficit of about 5 million units, the Paraná team decided to address the social housing in the context of the PMCMV (Programaminha casa minhavida — federal program of mass low-cost housing).

The production of social housing in Brazil is characterized by massive construction with government funding. The most common types are small apartment buildings and single or semi-detached single-family homes. Regarding the house design, one of the main features is the repetition of housing units built mostly with conventional construction techniques that invariably result in urban monotony and the mere repetition regardless of the residents’ profile.

This research assumes that the incorporation of technological solutions for mass production optimization, along with the possibility of customization can bring significant improvement in the quality of housing. The research problem was to meet the requirements and budget of rather restrictive government programs. The process consisted of social
housing design based on quality architecture, controlled budget, optimization of materials, energy efficiency of the building, the possibility of customization and mass production. The approach to the design process began with a series of procedures to check the conditions to establish and prioritize requirements, among them, conducting a post-occupancy evaluation in an existing housing complex, application of principles of target costing, workshops with experts, virtual and physical prototyping and simulation of thermal performance.

12. Culture Shifting: Dissemination of Information and Training

The biggest obstacle to the development of wood construction in Brazil is related to the negative perception of the user. Over the years, the timber construction has always been perceived as provisional one that should be discarded when the conditions (financial, technical, etc.) changed. Even in Paraná where early housing was based on wood construction, this perception is still very strong.

Not without reason; the wooden buildings when first appeared in Paraná, had simple enveloped walls; boards nailed side by side to the structure and the gap between them spanned by slats. The roof, not very well insulated, did not offer much comfort to the residents. Without treatment, the wood was very vulnerable to fungi and insect attack and fire, especially Pine constructed buildings. This is just the opposite of the global situation of the wood frame construction that has systematically incorporated a number of technological improvements significantly increasing the system performance.

To reverse the situation a similar approach is necessary. The domestic industry is able to manufacture the materials used abroad with the same quality. The technology is also available.

It is possible to create websites containing updated useful information about wood construction sponsored by industries, government, industry associations, universities, research institutes, etc.

One can also envisage to establish a portal offering information, training, publications, organization of events just like the American Wood Council-AWC\(^8\), or the Canadian Wood Council, CWC or the Brazilian CBCA\(^9\) for the steel construction.

It is with optimism that one can see initiatives creating technical committees for timber deployment in the country (FIEP — Smart House Program).

The first national technical document was issued by SINAT (national system of technical building assessment) establishing the quality of the wood frame system (DATEC No. 13) of timber construction in Brazil paving the way for official funding for wood-frame construction.

Recently an ABNT (Brazilian Association for Technical Standards) meeting created a committee to organize and establish standards for wood frame construction. At the same time, we have witnessed a rather modest but increasing number of timber construction companies. We are moving forward, but much remains to be done.

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\(^8\) http://www.awc.org.

\(^9\) http://www.cbca-acobrasil.org.br/.
13. Conclusions

The state has very favorable climate for forest cultivation. The availability of land and good climate, is a Parana as set to wood and forest product production. 1.4 million ha of forest with potential to be used in construction is already available in Paraná alone. Several high quality native species under study have shown great potential for planting with the advantage of being adapted to the climate and soil.

The industrial potential and the processing capacity of the domestic industry in the sector already place the state as a major producer and exporter of paper and wooden boards (plywood, particle board, MDF, OSB, etc.) besides a number of other forest products.

There is a wide variety and availability of human resources to be developed.

In addition, the housing deficit ratios are enormous, demanding new options for building systems, more agile, more versatile, cheaper and more efficient.

All these factors constitute a highly favorable scenario for the development of wood construction. What is observed, however, is the atrophying of wood construction and lack of supply of reliable systems. What is needed then?

First of all, focus on education. The training of human resources in the field is urgent and already late. Technical schools for training technicians and specialized personnel need to be enhanced and in this case the performance of SENAI can be a great asset in national education.

University courses, in particular architecture and engineering in its various modalities, need to provide adequate training in their curricula in order to prepare the future professionals in the development of the sector.

Second, it takes investment in research and development for the proper application of the material, taking into account environmental and climatic characteristics of the wood species planted in the state.

It is essential to establish partnerships among research institutions and industry to allow the research developed at the academy to be effectively applied, causing the timber to become technologically and commercially competitive to other construction systems.

Third, it requires the development of specially designed accessories for this construction such as special screws, various connections, frames, frameworks, adhesives, insulation sheets, etc. to offer the designer and contractors a range of technical solutions compatible with the currently required levels of functionality, durability, performance and beauty of the building.

In the fourth place, a correct management of by-products generated in the processing of wood can transform those that can be re-employed with added value.

Once this scenario is built, a shift of culture is needed. For this, we need an organization of the whole production chain offering practical information, easily obtained, about the possibilities, advantages and facilities of wood construction. Sites offering continuous training, technical information, several publications on a wide range of topics, promoting events, are crucial.

Finally, we live in a very favorable moment for the utilization of wood, especially thanks to its environmentally sustainable feature. If we Know how to seize the opportunity, we can turn wood construction into a perfectly viable option in Paraná and countrywide. For that it is necessary that the products/building systems in wood to be reliable and of good quality.

References

Facing Some Challenges on Wooden Construction in Parana State, Brazil


