Wooden Residential Buildings – A Sustainable Approach

Article *in* Bulletin of the Transilvania University of Brasov · December 2016

CITATIONS
3

READS
821

7 authors, including:

Victor De Araujo
Research Group on Development of Lignocellulosic Products (LIGNO), Itapeva, Br…
60 PUBLICATIONS **63** CITATIONS
SEE PROFILE

Juliano Vasconcelos
UNIVESP
29 PUBLICATIONS **18** CITATIONS
SEE PROFILE

Juliana Cortez Barbosa
São Paulo State University
45 PUBLICATIONS **41** CITATIONS
SEE PROFILE

Elen Morales
São Paulo State University
40 PUBLICATIONS **45** CITATIONS
SEE PROFILE

Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 9 (58) No.2 - 2016

WOODEN RESIDENTIAL BUILDINGS – A SUSTAINABLE APPROACH

Victor A. DE ARAUJO[1] Juliano S. VASCONCELOS[2]
Juliana CORTEZ-BARBOSA[3] Elen A.M. MORALES[3]
Maristela GAVA[3] Antonio F. SAVI[3]
José N. GARCIA[1]

Abstract: *Both round and handle produced (sawn or rough-hewn), timber constitutes one of the oldest building raw materials. Wood can be engineered to produce structural beams and boards. Today, wooden housing is the most valuable and viable alternative to replace masonry. In turn, it is a modern model, whereas it presents good attributes of raw materials rationalization, water-free processing, work site cleaning, and rapid production. The strong industrialization of timber housing with prefabrication of parts should be the centre of attention in the future, consonantly with housing shortage in many countries, particularly in developing and underdeveloped ones. This paper aims to present a state of the art about timber housing topic and its aspects.*

Key words: *housing, timber, wooden construction, forest products, trends.*

1. Introduction

Wood is the oldest material for building due to its abundance, high availability and easy workability [23]. Possible privation of wood in the most common forms would imply a different civilization, whereas it was present in the ages of stone, iron and bronze, contributing directly to humanity's progress, largely by the advantage of being a renewable raw material [9].

Among the conventional materials used in construction, wood presents a good relationship resistance/weight, and it offers a great facility in the production of many industrialized objects and products [23].

Reforested wood is a noble product, with beneficial features in its use as a building part, and it has the favourable condition to generate comfort for the users [29].

Then, current market requires efficient, low-cost and sustainable goods [36].

If recent trends to substitute solid wood products were reversed, not only would energy demands be reduced, but the environment would also benefit. Where it is possible, solid wood products should replace other raw materials, such as metals, concrete, ceramic and plastics [28].

[1] Department of Forest Science, USP–ESALQ, Av. Pádua Dias no. 11, Piracicaba (SP), Brazil.
[2] Research Group on Development of Lignocellulosic Products, LIGNO, Itapeva (SP), Brazil.
[3] Wood Industrial Engineering course, UNESP–Itapeva, R. Geraldo Alckmin no. 519, Itapeva (SP), Brazil.
Correspondence: Victor A. De Araujo; email: engim.victor@yahoo.de.

The use of wood in durable products could assist in the carbon sequestration, as well as it can also displace more energy-intensive construction materials, such as metals [34]. Its correct use can widen and encourage its market, consolidating it as an environmentally sustainable material [36].

In a comparative study [17] among the main construction structures (wood, steel, concrete and brick), the wooden framing structures are the most convenient for residential building purposes, especially due to criteria such as safety, fire safety, energy efficiency, quality and aesthetics.

Whilst all wood substitutes require more energy and involve more polluting processes, the greater wood use would reduce both energy use and pollution [28].

In the reflection of other regions of the world, the application of reforested wood in Brazil emerges as a viable alternative, and it can especially be applied in the forestry regions. A complete technological development in the management area with reforested wood can mean the country's independence on expensive and usually inaccessible foreign technologies [29].

Wood as a building material is positively associated with well-being, aesthetic and eco-friendliness, which are important factors in the choice of a building. These attributes are not sufficient on their own to trigger the choice of timber as a building material [13].

Focused on the wood housing discussion, this paper elucidates its perspectives, sustainability, popularization strategies, advantages, industrialization, and trends.

2. Wood Industrialization

For timber sector entrepreneurs, forest is an important source of raw material [36].

The native forest scarcity has demanded the planned reforestation and sustainable managements for sustainable timber forestry business, not only to ensure the raw material for construction, but also the preservation of native woody forests [24].

In recent years, a diverse modern forest sector has been encouraged to adapt to the use of the "new timber" from planted forests. The range of industrial products from planted forests include: lumber, plywood, reconstituted panels and beams (MDF, OSB, Glulam, etc.), modular parts (laminates, floorings, framing, moulding, etc.), pulp and paper, and bioenergy [3, 8, 26, 35, 10].

Wood is very energy efficient, very user friendly and very versatile; it is used for as many as 100,000 different products [28].

Over time, timber was brewed in accordance with the advancements in industrialization. Firstly, the hand tools (saws, hammers, axes, scrapers, block planes, chisels, mitre boxes, etc.) emerged to confer the most rudimentary shapes on lumber through rough-hewn techniques. With the advent of a higher technology on machinery, several electrical tools (wood routers, bandsaws, circular saws, drillers, pneumatic nailers, planners, etc.) were developed to facilitate the woodworking for the people.

Through these newer technologies of wood sawing, more other wood building typologies were created, using sawn wood, standardized round-logs or squared blocks, and prefabricated wooden parts.

Nevertheless, the skilful designer and the seasoned carpenter know all these things and understand how to build with wood, so as to bring out its best qualities, while neutralizing or minimizing its possible problems [1].

The use of wood in housing can have three classes: definitive uses, definitely applied in doors, structural parts, siding, flooring, stairs, etc.; wood for auxiliary uses, only for support as braces, rules etc.; wood for transient uses, for temporary services as concrete forms, spiles etc. [12].

Thereat, wood could ideally replace steel and concrete in light construction uses, small bridges, poles, cable drums, etc. [28]. This replacement should be realized with studies focused on the timber sector, especially for the production chain expansion, because it cannot be prepared to assume this increase in future demands.

In order to enter and survive at current competitive international market, it is necessary to increase the level of logistics support for production preparation and production so as to increase the use of wood and wood material, to decrease time loss during development and acceptance of the new product, and especially to decrease the time required for production [19]. Wood allows the assembly of prefabricated parts, as well as an intensive labour [27].

The industrialization in the construction of housing units presents a profound advancement as a result of World War I, due to the global shortage of labour and materials, which increased construction costs. This fact caused an increasing interest in the development of the pre-fabrication of precast components and parts as a means of reducing the high cost of hand labour [21].

In the late 20th Century, industrialized construction costs were and are equivalent or higher than the costs of conventional buildings. Although this industrialization is associated with the time and resources optimizations, it shows there are failures in the process. The principal cause of this problem is a big mistake of methodological nature, which subsists in the basis of industrialized homes, and which affects their development adversely [22].

The structural system is established by the model for the construction, which is classified as: one-dimensional, two and three-dimensional, *i.e.*, linear (frames, arches and spatial structures), plans (plates and panels) or volumetric (modules and boxes), respectively [21]. Wood houses are commonly produced in these three types.

3. Wooden Housing Typologies

The primitive huts were built without the use of any tools or machinery; it was made only with woody branches fixed on the ground through stones and with a covering of animal skins, in order to get a refuge from the outside, cold, rain, wildlife predators, and, possibly, bad spirits [24].

Wood construction is readily adaptable to traditional, contemporary and the most futuristic building styles. Its architectural possibilities are limitless [2].

Two modern construction methods have developed: solid wood houses made with logs or planks stacked, which were found mainly in forest areas, or composed of solid panels made from wooden slats glued or nailed; houses with timbered framing, made with framing members filled with insulating and sealing materials (originally bricks, mud and stones), which are popular in urban areas. Over time, the masonry has been replaced by “sandwich” walls [4].

Today, the construction of prefabricated wooden residential units is supported by strong arguments; many innovations and improvements introduced in the early 1980s helped promote the prefabricated wooden residences around the world,

especially in most developed nations [16].

Wood architecture was multiplied in many typologies over time, *e.g.* log-home, half-timbered home (*fachwerk*), board and batten house, horizontal-blockboard house (made with tongue-and-groove planks), timberframe (post-and-beam), woodframe (balloon and platform), and modular.

The half-timbered is used in vernacular rural homes, where vertical and horizontal wood pieces are limited to the upper part of the façade [31]. The masonry is used to fill the spaces on the wall structure. This long wood structure presents large sections used on two or three-storey houses [4].

Constructions of logs or large planks are developed especially in heavily wooded areas in Northern Europe [4]. In short, the log-home is the house based on the wood-log stacking, to form solid walls.

Board and batten houses are formed by upper and bottom frames, interconnected through pillars to the roof and additional structures such as horizontal sealing (floors and ceiling) and vertical sealing walls [6].

Post-and-beam is a self-supporting wood structure fixed by connections among parts with the structural frame set at its basis [5].

Horizontal-blockboard home is made by these materials joined together with tongue and groove, stabilized laterally by studs, and this system has been widely used for high classes, as second housing in cottages, chalets, etc. [11].

In platform woodframe, first-floor beams are completely covered to form a platform upon which the exterior/interior walls are erected. In balloon-frame housing, exterior wall studs continue through the first and second stories [2].

Modular home is derived from trailers, specifically those for permanent housing, referring to units manufactured in industry and installed anywhere [15]. It is panelized by CLT or "sandwiched" walls.

The architectural potential of wood is vast, allowing the construction of buildings with attractive performances [4].

Factory-built wood housing, which includes modular, manufactured and panelized houses, increasingly allows the homebuilders to provide consumers with homes that are less expensive than site-built housing, without sacrificing a home's quality or aesthetic appeal [30].

The first approach to achieving a strong, durable structure, involving economical use of materials, is to follow a modular plan for layout and attachment of frame parts [2]. The use of second-rate materials and the removal or shortening of building stages may result in financial savings in a short time, but it also could weaken the structure. Hence this must be considered in order to attain an efficient building.

3.1. Sustainable Wooden Houses

It is possible to use the forest without its destruction, creating work and income.

The international community has experienced a range of strategies to curb tropical deforestation and conserve biodiversity. But new logging investments in primary tropical forests, including those made in the name of sustainability, are likely to do more harm than good [7].

The boom-and-boost export pattern is often blamed on the demand by developed countries, high import barriers, and low international wood prices. In fact, it is rooted in the tropical countries' own policies related to timber concessions and wood-processing industries [33].

However, only a strong integrated action among tropical countries (native wood

suppliers) and the developed countries of the Northern Hemisphere (native wood buyers) will get to mitigate this problem, which persists to the present day.

Deforestation currently accounts for about 15% of global greenhouse-gas emissions, and some 75% of Brazil's emissions. But the government of this Latin American nation cannot get there on its own, whereas it needs its policy to have a broad support [20]. Developed nations do little to help in this chronic problem.

Conservationists should instead focus on more investments in protected areas and creative ways to prevent the logging spread in these rapidly-declining ecosystems [7].

This chronic fact still occurs often in construction, because the rich countries of the Northern Hemisphere are buying from Brazilian manufacturers, monstrous amounts of unset kits of prefabricated dwellings in native wood species, *e.g.*, roble (*Tabebuia sp.*), grapia (*Apuleia sp.*), cedar (*Cedrela sp.*), tauari (*Couratari sp.*), muiracatiara (*Astronium sp.*), mahogany (*Swetenia sp.*), bulletwood (*Aspidosperma sp.*), cumaru (*Dipterix sp.*), tatajuba (*Bagassa sp.*), cambará (*Gochnatia sp.*), itaúba (*Mezilaurus sp.*), etc.

An important policy to be explored by these developing nations – and also by developed nations – could be the massive use of wood from human planted forests in durable goods, such as housing, structures, furniture, toys, boxes, musical instruments, cellulose and paper, etc. The wooden waste from the processing of these goods could be efficiently applied for bioenergy.

Planted forests contributed a higher proportion of overall forest goods and services [10]. In terms of carbon dioxide sequestration (CO_2) in highly durable wooden building structures, the greatest environmental benefits can be achieved by the continual utilization of wood at a rate that matches the sustainable increment of forest growth [34].

The solid wood from human planted is a very energy efficient raw material. The industrial processing of solid wood is environmentally benign and should be fairly free-pollution [28].

Some industries have led the challenge of successfully use recent technologies to protect the environment [14].

The wood is readily recycled from demolished buildings for use in new ones, and when finally discarded, it biodegrades rapidly to become natural soil. It is our only renewable building material, one that will be available to us for as long as we manage our forests with an eye to the perpetual production of wood [1].

Despite the slow progress of the use of reforested wood in construction, some initiatives are being applied by modern industries, which use reforested *Pinus sp.* and *Eucalyptus sp.* in new prefabricated housing for export and also for domestic consumption. But, because of wood decay, these materials are frequently treated with chemical preservatives to enlarge this housing durability. For this specific case of housing made with treated wood, the discard must be carefully realized and respecting all the prescriptions for this kind of chemically-modified waste. The burning and direct contact with this harmful waste could cause cancer or other injuries to mammals. Withal, the treated structural wooden parts can be superficially painted – dyes, paints, stains or varnishes – to avoid the direct contact of these treated parts with skin. Recycled treated-timber could be applied in new construction uses (posts, beams, flooring or doors), furniture, and garden ornaments (dormants or barriers).

3.2. Advantages of Wooden Houses

Regardless of the wooden technique, all of them present many advantages if they are compared to other systems in different materials (steel, concrete, stone, clay etc.).

Wood popularization is due to the fact that this natural material is worked and fastened easily with small, simple, and relatively inexpensive tools [1].

In turn, masonry (bricks, concrete or stone) and steelframe use non-renewable materials, which are not sustainable, because of their irreversible extraction processes from nature.

At the construction stage of housing units on site, wood allows the assembly of prefabricated parts, in a short time, if it is compared to conventional systems, with the possibility of cost reduction, intensive utilization of labour, and low investment in capital goods [27].

However, masonry is a dirty process, because it spends larger amounts of raw material, and hardly ever could masonry offer the possibility of prefabrication processes.

Wooden housing has certain comparative advantages, as it can be designed to meet specific application requirements. These houses are available in a wide variety of sizes and durability, as well as they are designed and built to maximize the wood strength and stiffness. Wood offers warmth and natural beauty [18].

3.3. Degrading Aspects

Low utilization of reforestation wood components for buildings – particularly for social housing – can be explained by some reasons: poor knowledge of the potential of wood by businessmen and public officials; constant increase of timber prices; low competitiveness of timber sector; low wood quality from planted and managed forests; and the Iberian cultural tradition, which solely values the masonry [27].

In Brazil, wooden housing has always been associated with the use of antique techniques dating from the beginning of local colonization, *i.e.* a product for the social classes with lower purchasing power or as a second housing – beachside homes, cottages or chalets – for a population of higher economic level [25]. In other countries, this situation occurs similarly, creating an erroneous view of these wood typologies, whereas their sustainability, advantages, benefits, and competitive costs are unexplored. These situations show a general ignorance about wood properties, as well as the technological backwardness of the industries in the respective sector, which basically devalue this raw material and characterize through the aspects of low comfort and durability. It has forced all the consumers, even those with low economic levels, to choose brick houses [25].

3.4. Promotional Aspects

An important factor for the general use of wood as a construction material is promotion, which helps to raise the awareness regarding environmental and energy features of the material [32].

If the wood is managed properly as in planted forests, it should be associated with a good image of a sustainable architectural product, setting up a clean development mechanism [29].

The systematic training of technicians, engineers, architects and the interested public reflects in a necessary component to popularize the use of wood [32].

An opportune strategy to accelerate the expansion of the market of wooden housing could be the exploration of its image in the media (journals, television, and internet), emphasizing its advantages. Herewith, the inclusion of the use of these houses by artists and celebrities could stimulate the public, encouraging them to become new consumers in the future.

A massive utilization of wood houses by the governments in new popular housing could also favour their diffusion in the lower social classes, eliminating the idea that wooden housing is only a dwelling for rich people, or else, vacation homes.

Furthermore, the sustainability provided by these wooden housing must be another way to be explored in recent environmental preoccupations.

3.5. Trends

The uncontrolled world consumption of non-renewable natural resources will strongly urge the human, in the future, to seek new ways of goods manufacturing. And construction will be the most affected sector, because it still consumes a lot of non-renewable materials in its most popular building techniques such as masonry and steelframe.

An important way to be followed is the major use of wood in housing and commercial buildings, especially in the bearing structures and walls, restricting the use of cement and stones to giant structures such as skyscrapers, large bridges, water dams, dikes, sluices, tunnels, industrial floorings, etc.

Apart from the timber literature, some developed countries as United States, Canada, New Zealand, Germany, Sweden and France, have realized many documents to explain, diffuse and regulate wooden residential construction and its respective elements and components, especially for the most rationalized wood techniques. These documents comprise laws, technical reports, guidelines, standard normative, etc. United States is the most advanced country in this respect, whereas several organizations are focused on this initiative such as International Log Builders' Association (ILBA), Forest Products Society (FPS), American Forest & Paper Association (AF&PA), American Wood Council (AWC), and Engineered Wood Association (APA). In the same way, Canada already possesses Canadian Wood Council (CWC) with its documents on wood construction. Some countries also present building codes for wooden housing such as New Zealand, United States and Canada. These codes are focused both on the structural parts as building details of wooden residences. Several developing nations, such as Brazil, are producing local standard documents focused on wooden structural elements and components. But there is still verified a deficiency in relation to the regulation of wooden techniques, whereas these documents will not include this kind of information. Even with these important attitudes, it is still needed a major policy to enlarge the use of wooden houses, insofar as the people are not fully informed about all the benefits of these modern and sustainable housing.

Current housing shortage and the reliability of planted timber and wood composites productions are other facts which the Governments could explore to proliferate these timber houses.

4. Summary Comments

For many families, the home is the major investment of a lifetime. While in a mobile society, people will have lived in several homes, each one serves as a prized property, capable of providing comfortable shelter to satisfied occupants [2].

For that reason, the house must be chosen to accommodate comfortably all users; likewise, it should be pleasant, with large spaces and with a rational number of rooms to ensure all the necessities of a human. Furthermore, other aspects could be evaluated, such as construction raw material, architectural typology, design style, ground size, energy efficiency, acoustic, recreational spaces, etc.

In terms of technological development and industrialization, the increase of the wood volume in construction will contribute to the possibility for this material to compete with other traditional building raw materials [9].

The most popular construction model is becoming outmoded in the new times of sustainable production, because masonry is still a technique with higher levels of water consumption, utilization of non-renewable resources and waste generated on construction site. Because of the current need for housing, the product wood-house could emerge as an important option of durable goods, especially in countries with housing shortage.

References

1. Allen E., Iano J., 2009. Fundamentals of Building Construction: materials and methods. John Wiley, 996 p.
2. American Wood Council, 2001. Details for Conventional Wood Frame Construction. AF&PA, 55 p.
3. Barbour J., 2004. Wood Quality. In: Burley J., Evans J., Youngquist J. Encyclopedia of Forest Science. Elsevier, pp. 1840-1845.
4. Benoit Y., Paradis T. 2008. Construction de Maisons à Ossature Bois. (in French). Eyrolles, 303 p.
5. Benson T., 1997. The Timber-Frame Home: design, construction, finishing. Taunton Press, 240 p.
6. Berriel A., 2009. Arquitetura de Madeira: reflexões e diretrizes de projeto para concepção de sistemas e elementos construtivos. PhD Thesis. (in Portuguese). UFPR, 363 p.
7. Bowles I.A., Rice R.E., Mittermeier R.A., Fonseca G.A.B., 1998. Logging and Tropical Forest Conservation. In: Science, vol. 280(5371), pp. 1899-1900.
8. Bowyer J.L., 2004. Environmental Benefits of Wood as a Building Material. In: Burley J., Evans J., Youngquist J. Encyclopedia of Forest Science. Elsevier, pp. 1863-1869.
9. Calil Júnior C., Dias A.A., 1997. Utilização da Madeira em Construções Rurais. (in Portuguese). In: Agriambi, vol. 1, pp. 71-77.
10. Carle J., Holmgren P., 2008. Wood From Planted Forests: A Global Outlook 2005-2030. In: Forest Products Journal, vol. 58(12), pp. 6-18.
11. Cesar S.F., 2002. Chapas de Madeira para Vedação Vertical de Edificações Produzidas Industrialmente. PhD Thesis. (in Portuguese). UFSC, 302 p.
12. Fritz-Durán A., 2008. Manual La Construcción de Viviendas en Madera. (in Spanish). CORMA, 635 p.
13. Gold S., Rubik F., 2009. Consumer Attitudes towards Timber as a

Construction Material and Towards Timber Frame Houses-Selected Findings of a Representative Survey Among the German Population. In: Journal of Cleaner Production, vol. 17(2), pp. 303-309.
14. Grobe C., 2008. Construire une Maison Passive. (in French). L'Inédite, 148 p.
15. Gutierrez R.M., 2008. Casas Móveis: experiência na região oeste do Paraná. Master's Thesis. (in Portuguese). USP, 182 p.
16. Kuzman M.K., Grošelj P., 2012. Residential Building Using the Analytic Hierarchy Process. In: Wood Research, vol. 57(4), pp. 591-600.
17. Kuzman M.K., Hrovatin J., Grošelj P., 2010. Usporedba različitih tipova konstrukcija stambenih zgrada. (in Croatian). In: Građevinar, vol. 9/10(63), pp. 869-874.
18. Lignum, 2013. Construcción en madera: la opción eficiente. (in Spanish). Editec. Year 23, no. 143, pp. 1-76.
19. Matičević G., Lovrić T., 2008. Upravljanje proizvodnjom u konceptu digitalnih poduzeća za preradu drva i proizvodnju namještaja. (in Croatian). In: Drvna Industrija, vol. 58(4), pp. 199-206.
20. Nature's Editorial, 2011. Defend the Amazon. In: Nature, vol. 480(7378), pp. 413-414.
21. Novas-Cabrera J.A., 2010. Sistemas Constructivos Prefabricados aplicables a la Construcción de Edificaciones en Países en Desarollo. Master's Thesis. (in Spanish). UPM, 62 p.
22. Oliveri G.M., 1972. Prefabricación o Metaproyecto Constructivo. (in Spanish). Gustavo Gili, 179 p.
23. Pfeil W., Pfeil M., 2003. Estruturas de Madeira. (in Portuguese). LTC, 241 p.
24. Rampazzo S.E., Sponchiado M., 2000. O Uso da Madeira de Reflorestamento na Construção Civil com Enfoque na Habitação. (in Portuguese). In: Revista de Pesquisa e Pós-Graduação, vol. 2000(1), pp. 131-148.
25. Santos A.C., Szücs C.A., 2009. Sistema estrutural de piso em madeira composto de chapas de OSB e vigas I. (in Portuguese). In: Ambiente Construído, vol. 9(3), pp. 75-93.
26. Sedjo R.A., 2004. International Trade in Wood Products. In: Burley J., Evans J., Youngquist J. Encyclopedia of Forest Science. Elsevier, pp. 1857-1863.
27. Shimbo I., Ino A., 1997. A Madeira de Reflorestamento como Alternativa Sustentável para Produção de Habitação Social. In: I Encontro Nacional Sobre Edificações e Comunidades Sustentáveis. Canela, Brazil, (in Portuguese). pp. 157-162.
28. Sutton W.R.J., 2010. Wood – The World's Most Sustainable Raw Material. In: New Zealand Journal of Forestry, vol. 55(1), pp. 22-26.
29. Szücs C.P., 2006. Sistema Stella-UFSC: avaliação e desenvolvimento de sistema construtivo em madeira de reflorestamento voltado para programas de habitação social. In: Bonin L.C., Amorim S.R. (Eds.). Coletânea Habitare. (in Portuguese). Antac, pp. 66-115.
30. Temkin K., Hong G., Davis L., 2007. Factory-Built Construction and the American Homebuyer: perceptions and opportunities. US-HUD. 127 p.
31. Tosolini P., 2008. Other Itineraries: modern architects on countryside

roads. In: The Journal of Architecture, vol. 13(4), pp. 427-451.
32. Užar J., 2013. Drvo – materijal u suglasnosti s prirodom. (in Croatian). In: Technical Journal, vol. 7(3), pp. 258-262.
33. Vincent J.R., 1992. The Tropical Timber Trade and Sustainable Development. In: Science, vol. 256(5064), pp. 1651-1655.
34. Werner F., Taverna R., Hofer P. et al., 2010. National and Global Greenhouse Gas Dynamics of Different Forest Management and Wood use Scenarios: a model-based assessment. In: Environmental Science Policy, vol. 13, pp. 72-85.
35. Youngs R.L., 2004. History and Overview of Wood Use. In: Burley J., Evans J., Youngquist J. (Ed.). Encyclopedia of Forest Science. Elsevier, pp. 1852-1856.
36. Zenid, G.J., 2009. Madeira: uso sustentável na construção civil. (in Portuguese). IPT, 99 p.