The influence of timber panels on architecture

Costa Santos, Sandra

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S. Costa Santos, PhD. Architect
University College Dublin, C.E.S.U.G.A., Feáns 152, 15090 A Coruña, Spain; PH (+34) 981 137346; FAX (+34) 981 137347; e-mail: sandra.costa@ucd.ie

Abstract
Since timber is naturally directional, timber products become directionally neutral only due to the progress in manufacture technology. This work studies timber panels with a view to analyse their influence on the architectural form. From a design point of view, two sub-categories are defined. These are solid panels, and optimised panels. Solid panels have a homogeneous and compact section and their thicknesses are relatively small. Composite panels are generally made up with two boards and an inner structure to which they are bonded. The work concludes that the two main typologies of timber panels influence design in a different way: due to their homogeneous inner structure, solid panels allow flexible cutting of the openings, and loads and supports can be placed with few limitations. In the other hand, optimised section panels require more planning and should be treated as finished elements.

Keywords: timber manufacturing, timber panel, solid timber panel, optimised section panel, timber architecture.

1 Introduction

In the mid-twentieth century, the industrial development of timber by-products begins, such as plywood (the main structural by-product). This development is closely related to that one of the adhesives. Plywood had a great effect on the light frame building system. It made possible to stabilize and stiffen the building by using it as a skin in walls, floors and roofs. Previously, timber sections joining the studs diagonally would stabilize the structure. With plywood, the structural behaviour of the building against horizontal loads was significantly improved. The first industrial factory to produce plywood (built in 1930 by the Portland Manufacturing Company-USA) used a modern manufacturing technology. This process made use of synthetic glues (urea-formaldehyde and phenol-formaldehyde resins) instead of traditional animal and vegetal-based glues for the first time. These resins were essential to the development of the manufacturing process and the timber boards [1]. The development and popularizing of the chipboard manufacturing process happened in Europe in 1951 thanks to the German manufacturer Deutsche-Novopan. Further developments and improvements to this process were a big step in the timber manufacturing industry. They gave rise to a new product: the medium density fibreboard (MDF), that was the result of research carried out in USA in the mid 1950s.

During the last twenty-five years, the timber by-products industry has been addressing the demand for prefabricated products with high mechanical properties. The timber industry research is directed towards the exhaustive use of the material, including parts that were discarded before. Today, in addition to sawn timber, a wide range of timber-based products is available and much innovative work is focused on the development of timber composite materials with new properties and increased technical efficiency. In this sense, the generic term *timber board* includes a wide range of timber-based products with different properties and uses. However, we can say that a timber board is an element in which length and width prevail over thickness and its main component is wood. These planar components are produced in several different processes in which timber of various dimensions (boards, strips, veneers, strands, chips and fibres) is pressed and bonded together with synthetic resins or mineral-based adhesives. Sometimes, the adhesive properties of timber itself are activated. These manufacturing methods result in a major improvement in quality compared with the source material, because defects such as knots, splits or twisted growth can be avoided, giving as a result a product of much greater strength. The processing of timber products follows a downward path with three main stages [2]. The first stage involves making sawn timber like boards and squared timbers. The most important products at this stage are laminated boards. The second stage reduces in size the various off-cuts from the first stage. As a result, wood strips (beadings, laths, etc.) are produced and made into multi-layered sheets. And the waste from this process is broken down even further to make high-strength boards. Finally, the third stage produces fibreboards from fine waste (i.e. sawdust): the wood is divided into fibres and lignin and pressed into sheets. In every stage in this size reduction path there is a counter-stage of composition and reshaping. Gluing is the technology that determines the make-up and consistency of the product. Also, technological development is producing more robust materials, thus enabling individual building components to be thinner.

Figure 1. Manufacturing of cross-laminated timber panels: vacuum press.

Figure 2. Manufacturing of cross-laminated timber panels: removing the resulting panel from the press.

Present manufacturing methods (frequently meaning the use of laminated materials) allow not only a more precise dimensioning of the members, but also make the production of curved and other forms easier. Also, the swelling and shrinkage of the components are usually much smaller than in solid, cut timbers. There is a huge selection of solid timber and timber composite products, where many different types exist in the individual categories (achieved varying the make-up, the type and quality of timber used and the nature of the adhesive). But, most importantly, present manufacturing methods can produce surface constructive components with very similar physical and mechanical properties in all their axes, components that are extremely homogeneous and have minimum fluctuations in their properties. But, if the generic term timber board includes planar timber-based products, the specific term *timber panel* will define those elements made from timber by-products whose structure within their plane tends to be isotropic [3].

2 Timber panels and panelised construction.

Panelised construction is determined by load-bearing slabs or panels which are joined to form a stable assembly and ultimately the architectural form. However, panels are not new to architecture: Loos, Rietveld, Le Corbusier, Schindler….all these architects used panels to achieve floating planes or to reconcile difficult junctions of spaces which differ in height. But in concrete construction, every step in a surface needs its own pour, thus increasing the cost and labour involved. This meant that the concrete spatial constructions of the modern masters didn't find a total broad acceptance. But the surface elements produced by prefabricated timber technology can develop new directions in architecture, such as the realization of complex spatial ensembles at an affordable price.

Modern timber technology allows the production of increasingly strong and slender panels. Panels consist of three or more layers (usually of relatively low quality wood) arranged at right angles to each other and glued together, in such way that they tend to isotropy. Since timber is naturally a directional, or anisotropic, material, this distinction has only become possible due to progress in the manufacture of semi-finished and timber-based products, such as cross-laminated timber panels. Thus, panels show high strength and rigidity, achieving the behaviour of a plate (an important characteristic that determines the design with panels is that they can span two directions). Structurally speaking, panels carry different functions (load-bearing, bracing…), therefore they do not show a structural hierarchy of primary and secondary elements. Panels are joined together without any recognizable hierarchy that articulates their formal expression. Also, panels are directionally neutral and extendable in all directions. In terms of production technology, they can be extended almost *ad infinitum* in the two surface dimensions. Thus the panel becomes indifferent to direction. Transport is the only practical limit. And not only is the physical perception of timber architecture modified, but its structural behaviour too. This becomes obvious in the treatment of openings: they can be cut out where required and do not even require a lintel, provided that there is enough material above the opening. These qualities can be considered most innovative contributions to the timber architectural form.

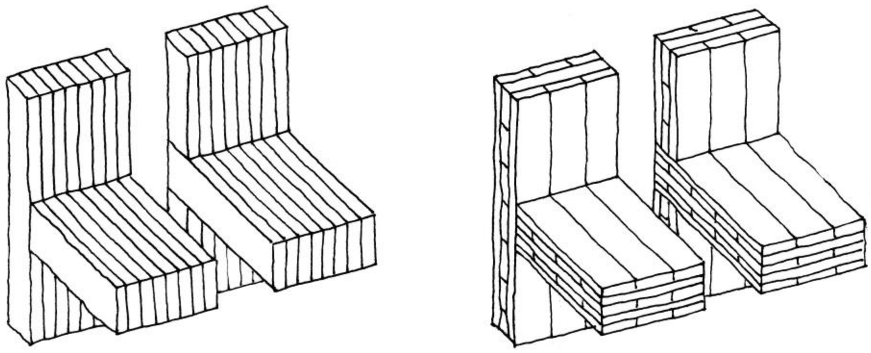

Figure 3. Edge-glued (left) and cross-laminated components (right): due to their isotropic internal structure, only cross-laminated components constitute panels.

Panelised construction distinguishes panels from those composite section elements that consist of linear members and whose internal structure does not tend to isotropy. Although these are prefabricated to form internally lined and externally clad components, they don't belong to panelised construction, where the planar nature of the isotropic load-bearing panels leads to completely new structural and design related aspects in timber architecture. Panels can have a solid or optimised section. These two typologies of panels take us to define two sub-categories within the field of panelised construction. These are *'thin wall'* construction and *'thick wall'* construction. They relate to solid panels and optimised section panels respectively.

2.1 Solid timber panels: 'thin wall panelised construction'.

Over the past few years, the use of solid or 'mass' construction systems has been introduced in Central Europe. These new products help to avoid waste and offcuts and are interesting from the ecological point of view, because while they use large quantities of timber, the tree trunk is used effectively, using different techniques and achieving different levels of quality.

Solid panels have a homogeneous and compact section. They can be manufactured in big sizes as open system elements, that is, without following a given module. Due to their homogeneous inner structure, this typology allows flexible cutting of the openings, without additional elements around the perimeter, and also allows loads and supports to be placed with few limitations. As a result, these components can be modified or adjusted on site. They can form solid wall, floor or roof elements by simply using metal or wood connectors or adhesive bonding. Solid timber panels can assume load-bearing, bracing, insulating and sealing functions. In other words: they are both constructive and structurally multifunctional. That involves a great simplification in the build-up of layers, compared to traditional construction systems such as timber frame construction, where internal wall surfaces are often lined with plasterboard or fibreboard that is then filled, smoothed and painted. When using solid timber panels with a visible wood surface, further finishes are not necessary, and in some cases (such as the case of cross-laminated timber) the surface finish can be of industrial or fair-faced quality. Not only a wide range of panels offered by the industry now retain the surface character and structural features of timber (in particular the grain), but the process of compaction in multi-tear heat presses can improve significantly the hardness and abrasion resistance of softwood and hardwood surfaces, and subsequent heat or oil-and-heat treatments make timber more resistant to weathering as well, allowing the structural panel to become external cladding. In addition to the continuous development of solid timber construction, heat treatment, compaction and textile reinforcement of wood products remain important areas for future work.

Solid timber panels include cross-laminated timber, panels made with composite timber boards and panels made with stacked board planks. The thicknesses of these types of timber panels are relatively small. For that reason, in the present work we introduce the term *'thin wall' panelised construction* when referring to the built form resulting from their use.

Figure 4. Holy Family Nursery in Eichstätt (Germany), designed by architect Karl Frey: cross-laminated timber panels solve vertical and horizontal structural elements.

Figure 5. Holy Family Nursery in Eichstätt: structural timber panels used with an exposed surface.

2.2 Optimised section panels: ‘thick wall panelised construction’.

Composite panels rely on the optimisation of the section once a certain panel thickness has been achieved. They are generally made up with two boards and an inner structure to which they are bonded. This inner structure, with ribs and cross-ribs, will tend towards isotropy, although it is not homogeneous as in the case of solid panels. The internal build-up of the panel dictates where loads, supports and cuts should be located: it means that although the cuts can be virtually anywhere in its surface, their perimeter has to be occupied by structural elements. Openings are then less limited in size than in the case of solid panels. However, this inner structure is easily modified in the workshop to suit different situations: there is much scope for flexibility within the internal layer.

Optimised section panels require more planning than solid panels because although they can be freely manufactured without following a module, they should not be adjusted on site but treated as finished elements. Their cavities can be filled with insulation or used to conduct services, thus making complete and finished constructive units. This typology includes structural insulated panels; box, hollow or ribbed section panels, folded panels, and board system panels. We will use the terms *alveolar or ‘thick wall’ panelised construction* when referring to the built form resulting from the use of optimised section panels.

Figure 6. Passive-Energy housing in Dornbirn (Austria), designed by architect Johannes Kaufmann: the optimised section prefabricated timber panels integrate wall openings.

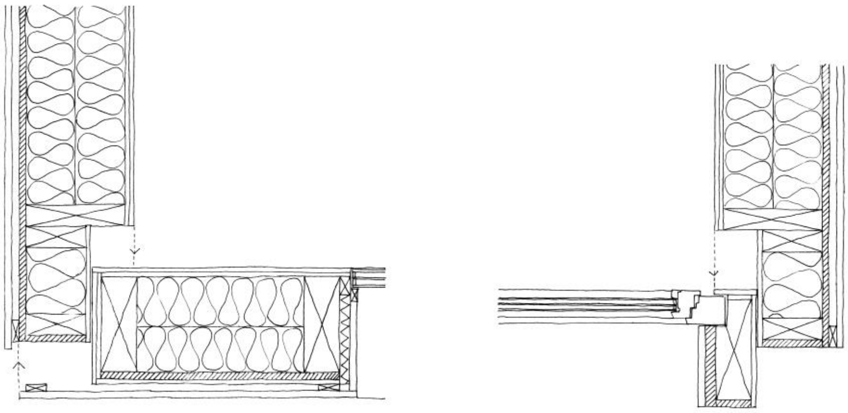

Figure 7. Passive-Energy housing in Dornbirn: horizontal sections showing assembly joints between panels.

3 Conclusion

The term *timber panel* defines various types of planar components with extremely homogeneous physical and mechanical properties in all their axes, and whose structure within the plane tends to be isotropic. Panels offer innovative contributions to timber architecture: they do not show a structural hierarchy of primary and secondary elements, therefore can be joined together without any recognizable hierarchy that articulates their formal expression; they are directionally neutral and extendable in all directions; they allow flexible treatment of openings since these can be cut out where required; and they are constructively multifunctional, thus being able to simplify the traditional build-up of layers. The two typologies of panels (with solid and optimised sections) involve two ways of implementing panelised construction: *'thin wall'* panelised construction uses elements that can be easily modified on site and *'thick wall'* panelised construction relates to complete and finished elements.

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