Interreg Sudoe

EUROPEAN UNION

IMIP_
Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels

European Regional Development Fund

D2.2.1
Report about compatible construction systems

IMIP-SOE3/P3/E0963

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PROJECT CONTEXT

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CONTENT

1. INTRODUCTION

The work is contemplated in the IMIP project of the INTERREG SUDOE Program, within Working Package 2 *Design and manufacture of interconnected modules*.

These works focus on the development of modules and construction systems to be used in rehabilitation and new construction.

In this report, the systems and products made from natural cork and wood that are currently being implemented and used are presented and analysed. The purpose is to summarize analyse the compatibility of existing construction systems with the panels designed in IMIP project.

The study is carried out within the area of the Interreg Sudoe regions and we will focus more specifically on Portugal, France and Spain.

2. OBJECTIVES

The objective of this analysis is to determine construction systems that exist in the current market and that may be compatible with the systems that are being analysed in the IMIP project.

By this way, any contractor or designer can use the systems developed in this project and make it compatible with their own system in order to complete any project in a complete and sustainable way.

On the other hand, this report describes wood-based building systems currently available on the market that will be useful for the IMIP consortium to improve existing construction systems and to identify possible market gaps to develop improvements according to technical and environmental criteria.

3. PRINCIPLES OF THE RESEARCH

This report focuses on construction systems in two main areas:

- New building projects
- Rehabilitation and renovation projects

In both cases, the construction systems this report focuses on are:

- Vertical systems
- Horizontal-Slabs systems
- Roof systems

The main reference to determine that the systems analysed are compatible with those developed in the IMIP project is that they are systems based on wood as the main element. In this report is summarized a description of them to conclude if they are possible to use with IMIP panels.

In the same way, it is established as a preference to establish compatible systems, those that within their description incorporate an insulating element of the set (preferably natural cork).

4. WALL FORMING SYSTEMS

4.1 FRAME WALL

The walls of a building have several important functions: The first one is to define the spaces within the building for privacy and zoning, and enclosing the building itself. The second one is to provide the vertical structure that supports the upper floors and the roof of the building, and the lateral structure that stiffens the building. The third function of the walls is to encase the mechanical systems (electrical wiring, plumbing, and heating). To provide all of these functions, the deep wood-framed panel is quite an achievement, so numerous decisions need to be made in the course of designing a wall system for a wood-frame building.

4.1.1 Framing style

The framing style most used is the balloon framing, with continuous studs from the mudsill to the top plate and continuous between floors (figure 1). It was developed in the 1840s and is the antecedent of the framed wall. In recent years, balloon framing has been almost completely superseded by the more labour efficient and fire-resistant platform frame construction, with studs extending only between floors. There are still situations, however, where a variation of the balloon frame system is useful. One of these situations is where the continuity of studs, longer than the normal ceiling height, is essential to the strength of a wall. Examples include parapet walls and eave (side) walls that must resist the lateral thrust of a vaulted roof. Another reason for using the balloon framing system is to minimize the effects of shrinkage that occur across the grain of joists in a platform-framed building. This framing system could be important with a continuous stucco siding that spans two floors without a control joint, or in a multiple-story hybrid building system where the floors in the balloon-framed part would not shrink equally with the floors in the platform-framed part.

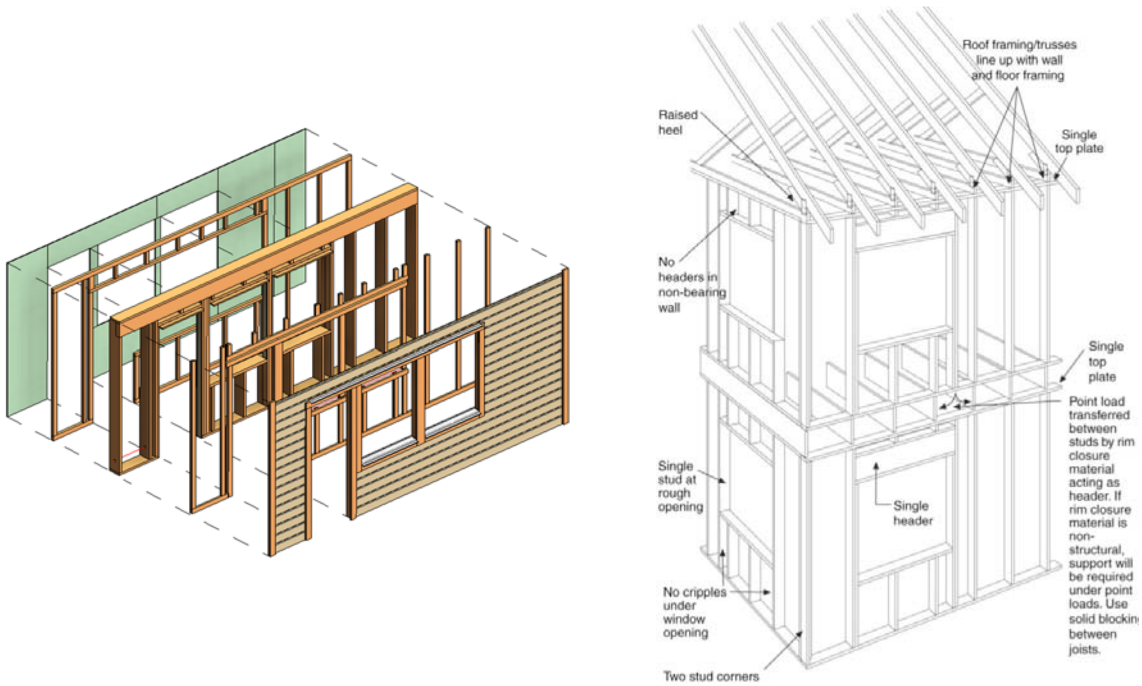


Figure 1. Ballon framing

4.1.2 Wall system

Once the study size and spacing and the framing system have been selected, it is time to consider how to brace the building to resist the forces of wind, earthquakes, and eccentric loading. Will diagonal bracing be adequate, or should the building be braced with structural sheathing and/or shear walls? This question is best answered in the context of the design of the building as a whole, considering the other materials that complete the wall system (figure 2) and where can be considered the use of IMIP panels. The details relating to these issues are addressed in this chapter with some suggestions for their appropriate use. How these various details are assembled into a complete wall system depends on local climate, codes, tradition, and the talent of the designer.

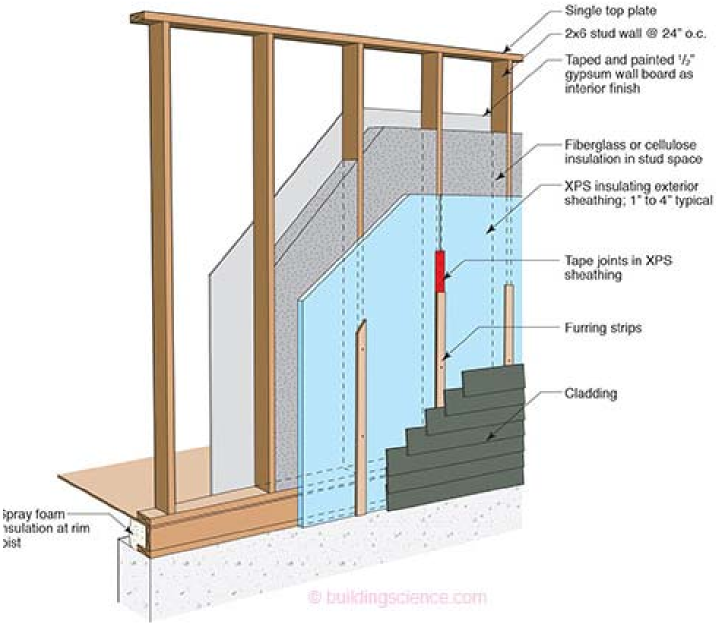


Figure 2. Wall systems

Header size depends on wood species and grade, loading, header design, and rough-opening span (figure 3). Following there is a rule of thumb for sizing a common header type.

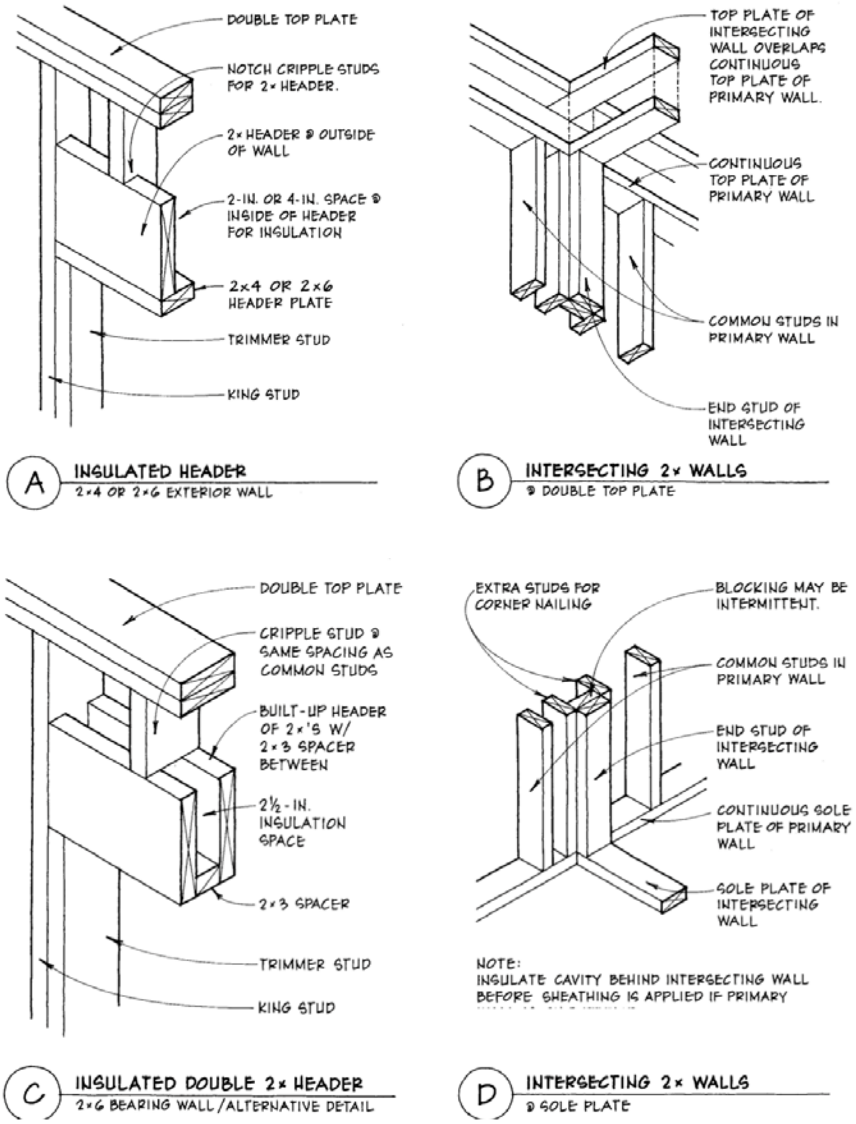


Figure 3. Insulated headers and intersecting walls

Construction terms vary regionally, and the names for the components that frame wall openings are the least cast in stone. Studs called “trimmer studs” in one locality are called “jack studs” in another, and the bottom plate may go by either “bottom plate” or “soleplate.” For clarity, insulation is not generally shown in the exterior walls except in the insulation section.

Platform framing is commonly the selected method when a horizontal structural element such as a floor or ceiling attach the structure together at the level of the top plate or when the top plate itself is short enough to provide the necessary lateral strength.

Balloon framing allows an easy construction and economy of material and stabilizes a tall wall where there is no horizontal structure at the level of the top plate or where lateral forces are extreme, such as in high-wind areas.

The goal when designing an energy-efficient header is to allow for the most insulation while providing for nailing at both the exterior and interior of the opening.

When a structural header is required over an opening in an exterior wall, the header itself occupies space that could otherwise be filled with insulation. Because a deep (tall) header is structurally more effective than a wide one, the header does not usually have to fill the entire width of the wall. In fact, the taller and thinner the header, the more space there will be for insulation. The headers illustrated provide both structure and space for insulation. The box header also provides space for insulation because it uses sheathing as structure.

Conclusion

This systems exposed reduce the volume of wood needed, but slows down its construction process as the assembly is totally manual, so more systematized or prefabricated wood-based systems would save time and labour, which would reduce overall costs.

The frame wall system is very widespread in certain regions of Europe and there is a large number of buildings built with this system, so it is a system to take into account to design a compatible systems within IMIP project.

Based on what can be inferred from the advances of the IMIP project, different parts can be compatible with the wall frame system, both in rehabilitation and expansion or a combination of both systems for a new project.

4.2 SOLID TIMBER WALL

The solid timber wall is a traditional construction system in northern countries where climate is cold and humid and productive forests occupy large areas, an important characteristic because it requires a large volume of wood. The wood aesthetically conditions the final look of the building normally remaining as the last exterior and interior layer. The structural method consist of resistant solid wood walls that transmit the loads of the roof and floors to the foundation. The resistance of the wood is not used on its optimum since vertical loads are transmitted in the perpendicular direction to the woodgrain. In fact, the wood resistance is optimized when loads are transmitted in parallel to its grain. This construction system is executed by stacking logs one on top of the other achieving structural resistant walls characterized by different thickness depending on the section of the trunk, and with different shapes depending on how the wood is worked (figure 4).

As a great advance, buildings built using laminated wood plank are being introduced, giving greater strength and physical stability to the construction.

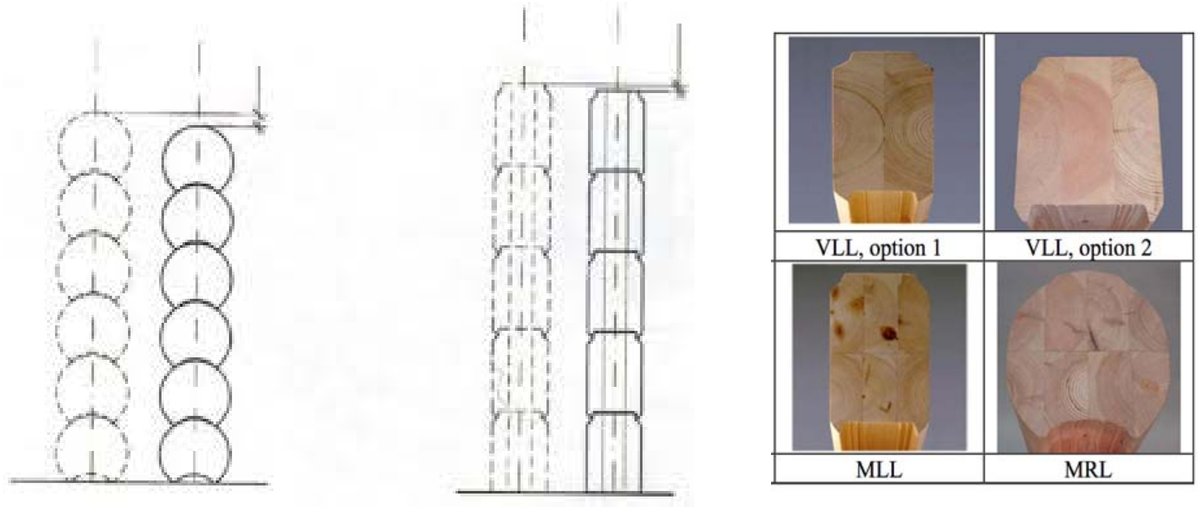


Figure 4. Insulated headers and intersecting walls

4.2.1 Glued timber

Another possibility in solid timber walls is the glued timber construction system made from 100% massive wood (figure 5, 6). Walls breathe naturally allowing water vapour to move freely between the wall and the air. When additional insulation is needed, wood fibber insulation is used in the walls to enhance the natural qualities of the wood.

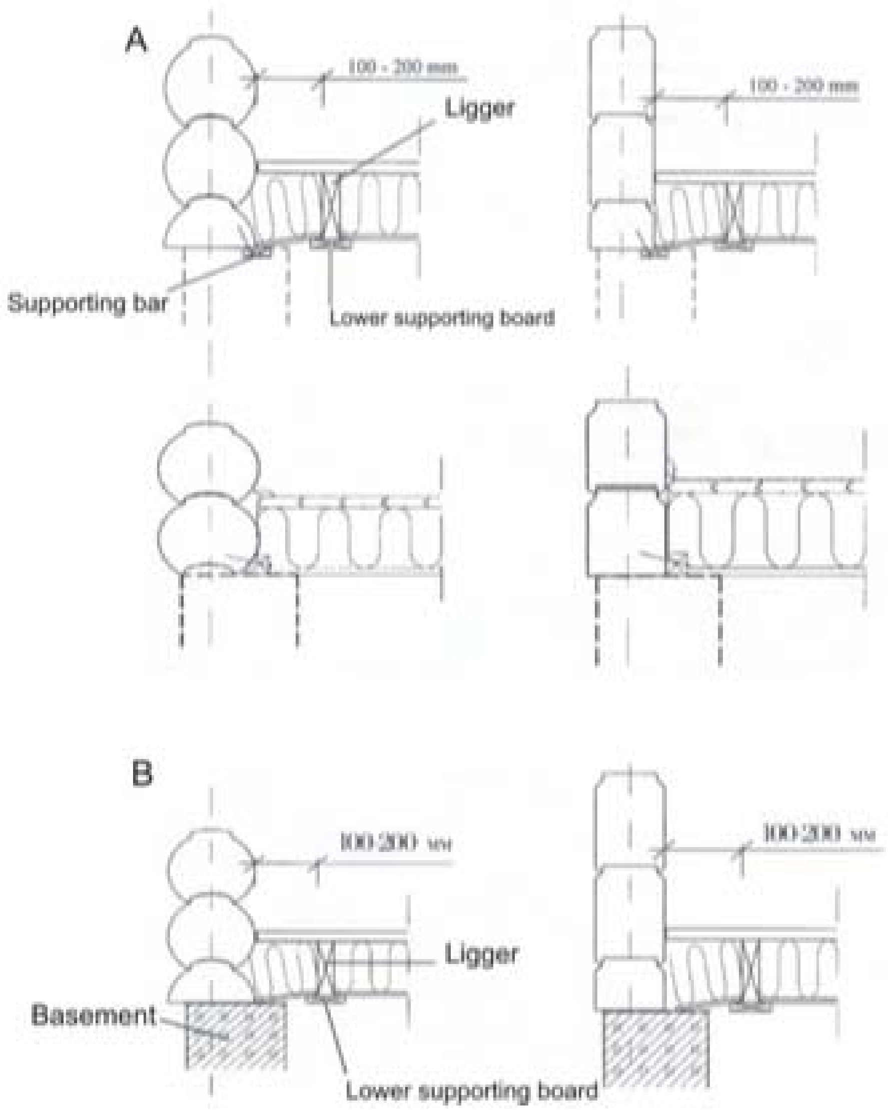


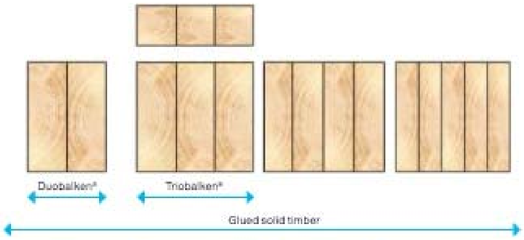
Figure 5. Glued solid timber

Figure 5. Construction of glued solid timber

More usual in buildings around the world is the use of **glued laminated timber** which according to EN 14080 is defined by two to maximum five equally large and homogeneously sorted and assembled individual cross sections with lamella thicknesses between 45 and 85 mm. The maximum possible cross section is 280 x 280 mm. Glue laminated timber according to EN 14080 is defined by at least 2 lamellas with thicknesses equal to or greater than 6 mm to max. 45mm. Duo, Trio or glued solid timber, other than regulated according to EN 14080, can be manufactured according to the general building inspectorate approval Z-9.1-440, considering defined lamella and cross-sectional dimensions.

A standard maximum length of 13 m ensures logistical handling and enables tailored cutting on site. System lengths cover a large part of the intermediate lengths and are manufactured individually. Technical Standard For laminated timber, the minimum requirements according to EN 14080 apply to the production. The general building inspectorate approval Z-9.1-440 with corresponding standards references applies to beams not regulated in EN 14080. This is also used for all laminated timber cross sections. Dimensional Stability due to technical drying-process in order to minimize deformation of the wood and the associated adverse consequences for a construction due to shrinkage or swelling, average wood moisture of 12 % ± 2 % (max. 15 %) is specified. Adhesive Gluing with a melamine adhesive leads to a bond quality that meets the requirements of usage classes 1 and 2 according to EN 301.

The surface is planned and chamfered on 4 sides as standard. For visible use, the bars are subjected to an additional optical selection during raw material assessment and in production. If necessary, minor defects are reworked.



No. of lamellaes	2	3	4	5
acc. EN 14080*	Glued Solid Timber (max. cross section)			
Beam	170 x 280 mm	255 x 280 mm	280 x 280 mm	280 x 280 mm
Lamellaes	85 x 280 mm	85 x 280 mm	70 x 280 mm	56 x 280 mm

*Thickness of Lamellaes ≤ 45 mm or a higher number of lamellaes corresponds to glue laminated timber acc. EN 14080 upon request.

acc. Z.9.1-440	Duobalken®	Triobalken®	Comments
Beam	160 x 280 mm	240 x 280 or 100 x 360 mm	Deviations from EN 14080 such as: max. lamellae cross sections, separating cuts, strength composition, etc. are regulated in Z-9.1-440
Lamellaes	80 x 280 mm	80 x 280 or 100 x 120 mm	

Figure 6. Standard sections for glued solid timber

Conclusions

This system uses big volumes of wood, but slows down its construction process as the assembly is totally manual with large pieces of elongated format, so more systematized or prefabricated wood-based systems would save time and labour, which would reduce costs.

The system is used in certain regions of Europe and there are some number of buildings built with this system, so it is a system to take into account when making the systems of the IMIP project compatible.

The part that has less developed this system is the thermal insulation and the thermal bridges that, since it is based only on wood, the performance is directly proportional to the volume of wood used, which means that its use is not optimized.

Based on what can be inferred from the advances of the IMIP project, different parts can be compatible with the wall frame system, both in rehabilitation and expansion or a combination of both systems for a new project.

4.3 PANELS OR PLATED SYSTEMS

This structural system is based on the transmission of the longitudinal and transverse loads through the panel or plate. It consists of plates or panels formed by a perimeter frame with intermediate studs. The outer and inner surface plates for the enclosure of the perimeter frame help to stiffen the panels. This system has led to what is known as a sandwich panel, which gives resistance to load-bearing walls. Usually, it arrives with the insulation and pre-installations already placed inside the panel. It is a highly industrialized system, so it facilitates a rapid assembly when the prefabricated panels arrives on the construction site reducing execution times.

Figure 7. Example of plated wall system

4.3.1 Structural Insulates Panels (SIP)

Structural Insulated Panels, or SIP, are pieces of insulation bonded on each side to (typically) two skins of oriented strand board (OSB). These blank panels start their life in a 1.2m-wide format and come in various standardised heights from 2.4m to 7.45m.

The panels are then cut to size, timber edge pieces added and any openings formed. The same panel is used for the external wall, any internal load bearing walls and the roof panels (figure 8).

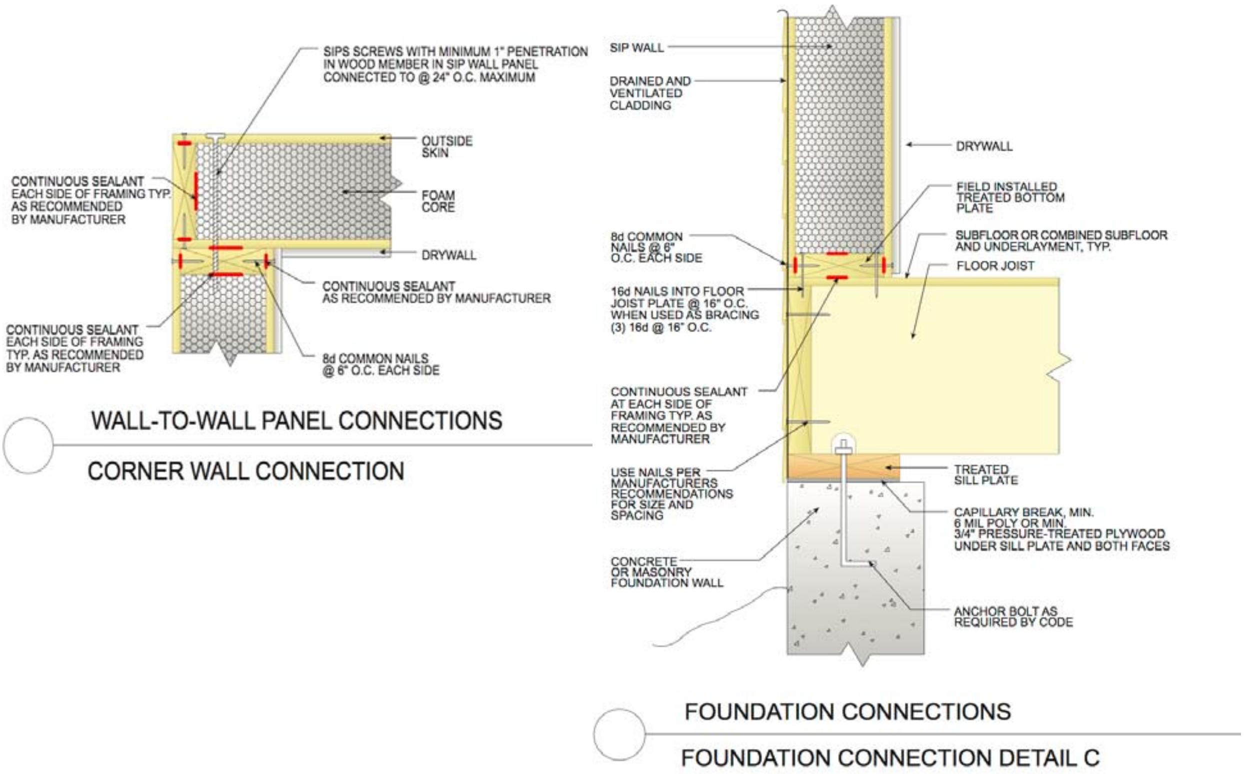


Figure 8. Example of installation of plated wall systems

The foam core of the panel is typically composed of expanded poly- styrene (EPS), polyurethane, extruded polystyrene (XPS) or polyisocyanurate. Where required by the manufacturing process, structural adhesive is used to adhere the foam cores to the skins of the panel in the lamination process. Once laminated, panels can be fabricated either onsite or in the manufacturing plant to meet the design specifications of a home and shipped to the site for a quick and easy installation.

From the manufacturing plant, panels are shipped to the construction site. Panels are available with different insulation characteristics to adapt to all climate zones.

Structural insulated panels are used in single and multifamily residential buildings as well as light commercial structures. SIPs are most commonly used in walls and roofs, but they can also be used in floors and foundations.

One of the key benefits over traditional timber frame or modern closed timber frame systems is the spacing of the vertical timber studs within the walls. In a timber frame building these are at 600mm centres, while in a SIPs wall they are at 1,200mm centres. Therefore, the amount of poorly performing timber in the wall is halved. This dramatically reduces repeated cold-bridging in the building.

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This construction system saves energy. Energy use and thermal efficiency are two of the anchor points of a green building. Buildings that use less energy and generate less carbon dioxide emissions have a smaller impact on the environment.

Conclusion

This system reduces volume of wood used, and its construction process drastically decreases assembly times since it is a prefabricated system made up of large-format parts, so assembly is quick.

It is also a thermally efficient system since one of its fundamental components is the insulation layer. On the other hand, the insulations are usually made of XPS expanded polystyrene, which is a not very eco-friendly derivative.

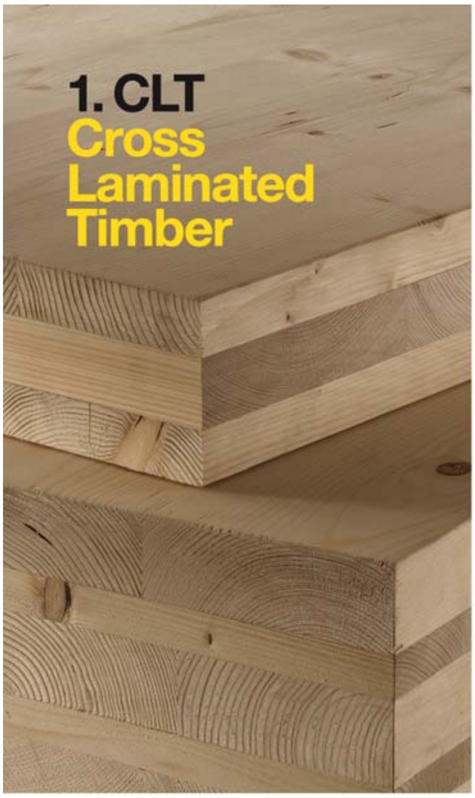
Based on what can be inferred from the advances of the IMIP project, different panels can be compatible with the SIP wall frame system, both in rehabilitation and expansion or for new buildings.

4.4 CROSS LAMINATED TIMBER FOR WALLS

4.4.1 Cross Laminated Timber (CLT)

Cross Laminated Timber (CLT) is a massive wood construction product consisting of at least three single-layer panels that are bonded together crosswise. Structural CLT panels use environmentally friendly adhesives to press the panel layers and acquire the necessary dimensional stability and rigidity.

CLT is available in different panel thicknesses depending on structural requirements (figure 9).



Key data

Application	Structural elements for walls, floors and roofs
Maximum element dimensions	Length: 16 m / Width: 3.45 m / Thickness: 0.35 m
Invoiced widths	2.25 m / 2.45 m / 2.75 m / 2.95 m / 3.25 m / 3.45 m (on request up to 3.90 m)
Panel lay-up	3, 5, 7 or more layers depending on structural design requirements
Wood species	Spruce (pine, fir, stone pine/larch and other wood types on request)
Strength class	C24 according to EN 338, maximum 10% C16 permitted (other strength class compare with ETA 14/0349)
Moisture content	12% +/-2% on delivery
Adhesive	Formaldehyde-free PUR adhesive for finger jointing and surface bonding, approved for load-bearing and non-load-bearing components indoors and outdoors according to EN 15425; Formaldehyde-free EPI adhesive for narrow side bonding
Surface quality	Non-visual quality (NVI), Industrial visual quality (IVI) and Visual quality (VI); the surfaces are always sanded on both faces
Weight	5.0 kN/m³ according to DIN 1055-2002 for structural analysis 470 kg/m³ for determination of transport weight
Fire rating	In accordance with Commission Decision 2003/43/EC: • Timber components (apart from floors) ● Euroclass D-s2, d0 • Floors ● Euroclass Dfl-s1
Thermal conductivity	0.12 W/(mK)
Air tightness	CLT panels are made up of at least three layers of single-layer panels and are therefore extremely air-tight. The air-tightness of a 3-layer CLT panel was tested according to EN 12 114
Service class	Service class 1 and 2 according to EN 1995-1-1

CLT by Stora Enso 4

Figure 9. CLT specifications (Stora Enso)

CLT with superior acoustic, fire, seismic, and thermal performance, cross-laminated timber is currently being used in place of concrete, masonry and steel in the construction of commercial, industrial and residential buildings.

Thanks to its inherent structural qualities, CLT presents good oportunities to architecture. The strength-to-weight ratio of CLT makes it especially interesting and cost-effective for multi-storey and long-span applications. Because of its dimensional stability and structural properties, this massive wooden product is well suited for floors, walls and roofs (figure 10).

Figure 10. CLT walls

CLT is a highly flexible wood product that is easily tailored for further processing and can be used together with any building material. Compared with heavy mineral-based materials, CLT is easily moved by light cranes at the construction site.

CLT panels are pre-cut to size using Computer Numerical Control cutting machines in the factory which are able to make complex cuts with high precision. The CLT panels are generally prefabricated and transported to the building site.

Prefabrication allows to produce high-precision panels and, in turn, a fast construction process, a lower demand of workers on site and less disruption to the surrounding community. Prefabrication also helps increase construction site safety and reduces waste (figure 11).

Figure 11. Example of wall CLT construction process

With CLT, rapid assembly, construction and dismantling is possible due to its prefabricate characteristics (figure 12). Also is an energy-efficient product.

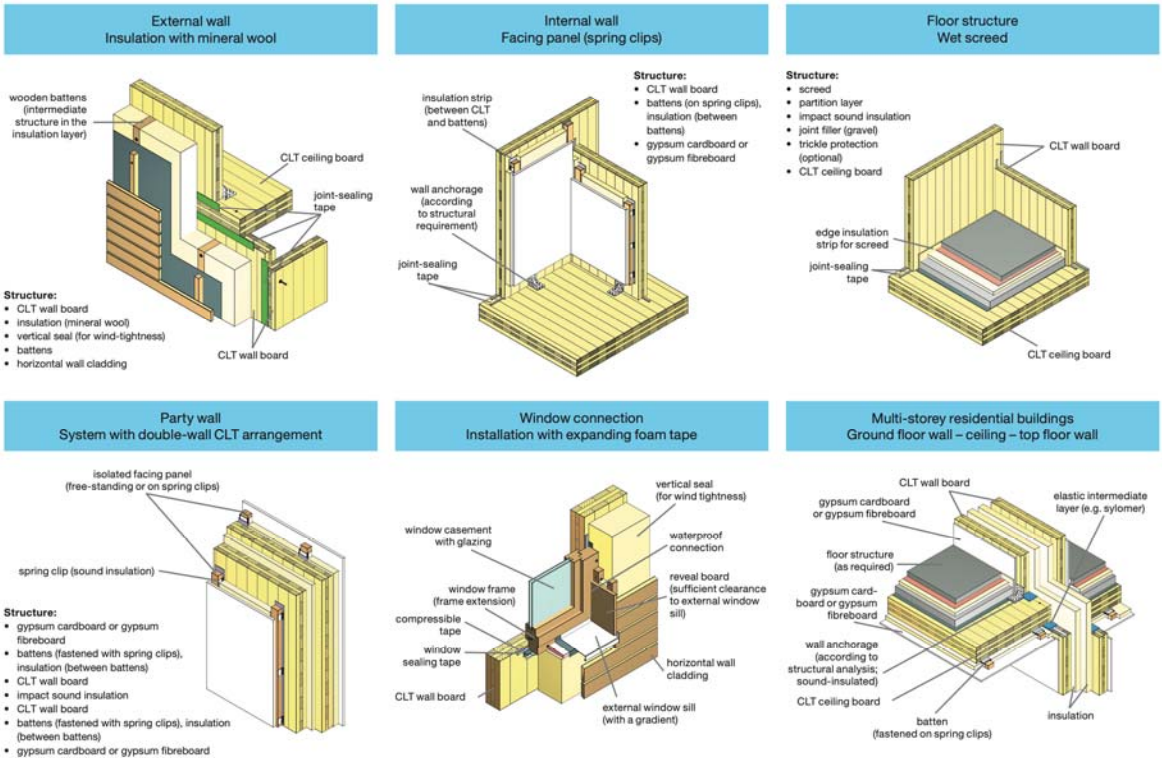


Figure 12. Uses of CLT

Conclusions

CLT is becoming the engineered wood product of the future. It has been successfully used in solutions for residential, commercial and industrial buildings. CLT offers strength and stability on high demanding structures, rapid assembly, cost effectiveness and excellent sustainability credentials.

It could be criticized because consumes a big volume of wood for the current wood production in the countries of the IMIP project. Hence, the use of this system, being highly recommended, could be improved by the combination of systems able to reduce the amount of wood.

4.4.2 Cross Laminated Timber with insulation (CLTi)

A new generation of structural lattice made up of crossed and offset wood strips is called CLTi (Cross Laminated Timber with Insulation). This is a hybrid panel that takes the best of existing timber framed and CLT construction systems (figure 13).

Figure 13. Example of CLTi

Moreover, this product is complementary and can be combined with other building materials (e.g., concrete, metal, or steel) for the construction of new and rehabilitated buildings.

CLTi is a cross fold panel composed of several layers of timber crossed at 90° and shifted, filled in with insulated materials totally configurable (gaps between the wooden lattices, width of insulating strips...) under an industrial process according to the required technical performances (thermal, fire and structural resistance, acoustics etc.) (figure 14).

CLTi can combine a wide range of insulation materials (e.g., wood, glass or rock wool) within the same panel. The customer usually has the possibility to select dimensions from 6 to 60 cm thick and up to 30 m2 (8,5m*3,5m in length and width).

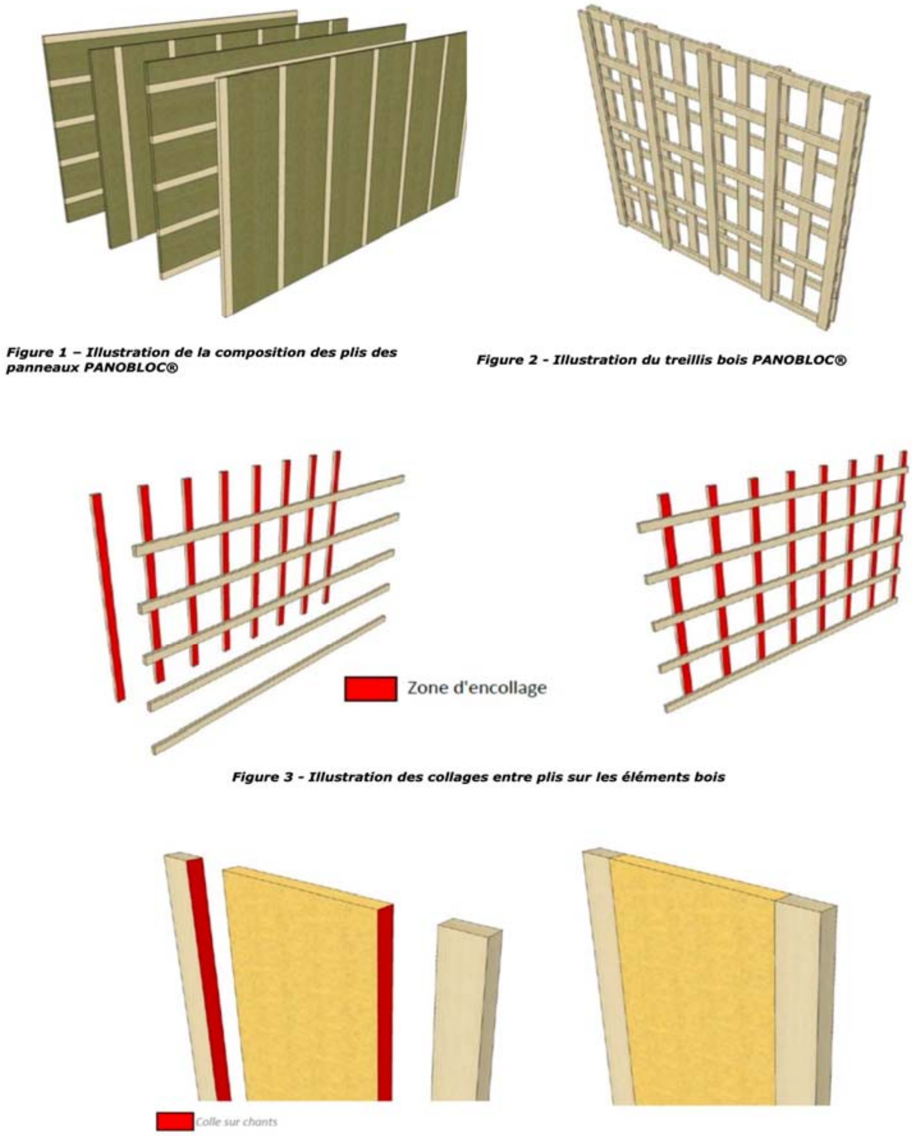


Figure 14. Example of CLTi composition

CLTi is used in structural walls, curtain walls, floor-ceiling and roof panels. It can be mixed with concrete or metal structures.

This industrial bio-sourced solution is ideal for sustainable construction and renovation of high-performance buildings and fulfils the needs of all types of buildings: collective housing, tertiary or industrial building.

Parallel planed wooden strips with a rectangular cross-section are joined and arranged vertically and horizontally alternating from one ply to the next. The crossed plies are glued together by the wooden strips, which are offset from the strips of the neighbouring ply (figure 15). This offset arrangement reduces or even eliminates any thermal bridges.

Insulating sheets (thermal insulation, acoustic insulation and thermal mass) fill the free space between the wooden strips.

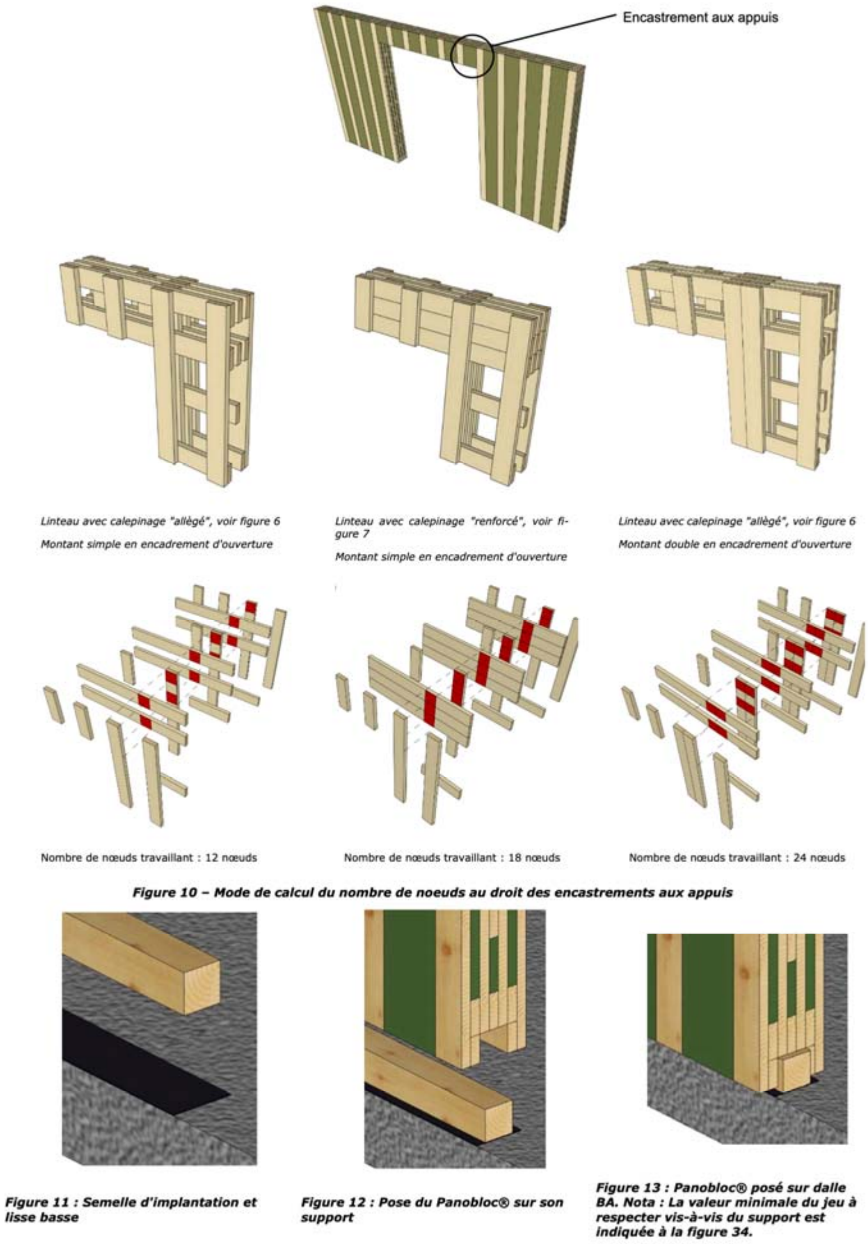


Figure 15. CLTi composition

The overall strength of the panel is obtained by the structural bonding of the wooden strips where intersect. These wooden strips are bonded over their entire surface in order to ensure the best possible bond at the point where they meet. The spacing between the wooden strips depends on the width and number of filling sheets laid out between the wooden strips, given that the width of the filler sheets ranges from 150 to 600mm.

The proportion and the layout pattern of the wooden strips and insulating material are defined according to the required performance objectives and structural forces that the product will sustain when used in the building (curtain walls, external walls, external load-bearing walls and cross walls, slabs and floors, inclined roofs, flat roofs). Consequently, the insulation sheets may be different from one ply to another in order to optimise the thermal, fire and acoustic properties in one panel, e.g. the CLTi which is made up of 2 internal plies insulated with wood wool and 3 external plies insulated with rockwool.

The different plies used to make up a CLTi panel are glued and pressed together on a fully automated production line. As a result, thousands of combinations are possible and each manufactured CLTi panel is designed according to the needs. See figureS 16 and 17 for examples of use of CLTi.

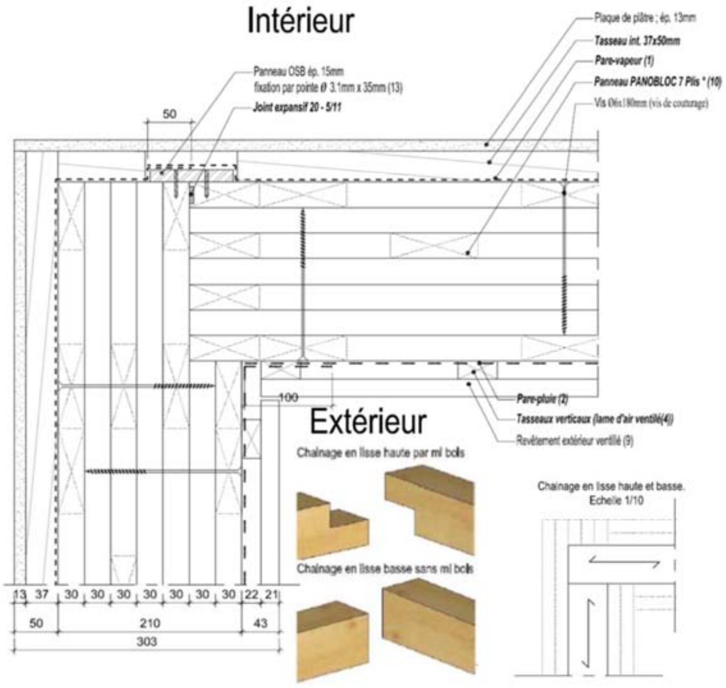


Figure 16. Building position consideration in design with CLTi

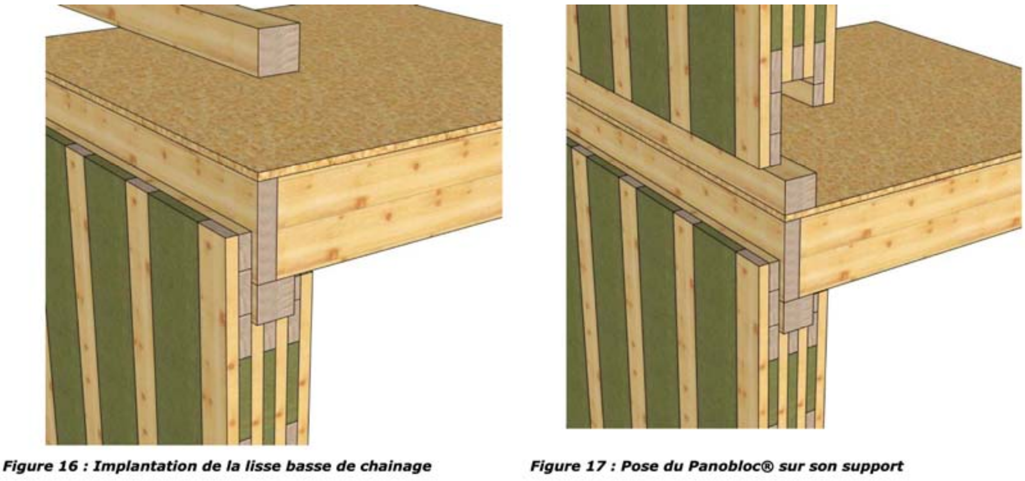


Figure 17. Example of implementation between CLTi panels

Conclusions

CLTi is making its mark as the innovative engineered wood product of the future. It has been successfully used in solutions for residential, commercial and industrial buildings. Whether in stunning structures like wooden high-rises and floating staircases or more everyday applications, CLT offers strength and stability, rapid assembly, cost effectiveness and excellent sustainability credentials.

It could be commented that it contains a high amount of wood for the production of the countries of the IMIP project, so the use of these systems, being highly recommended, can be improved from the combination of systems capable of reducing the amount of wood. Possibly with the most profitable type of wood for the area of France, Portugal and Spain, the quantity of wood could be reduced and economized in the final system.

4.5 TIMBER BLOCK WALLS

Timber blocks combine renewable resources with the most modern technologies and again reconciles economy and ecology. The wood modules could be used for temporary buildings, trade fair and stage buildings, renovations, extension buildings, room dividers or as infill for skeleton structures. The modular building system allows sustainable construction meeting stability, earthquake safety, durability, comfort and design flexibility requirements.

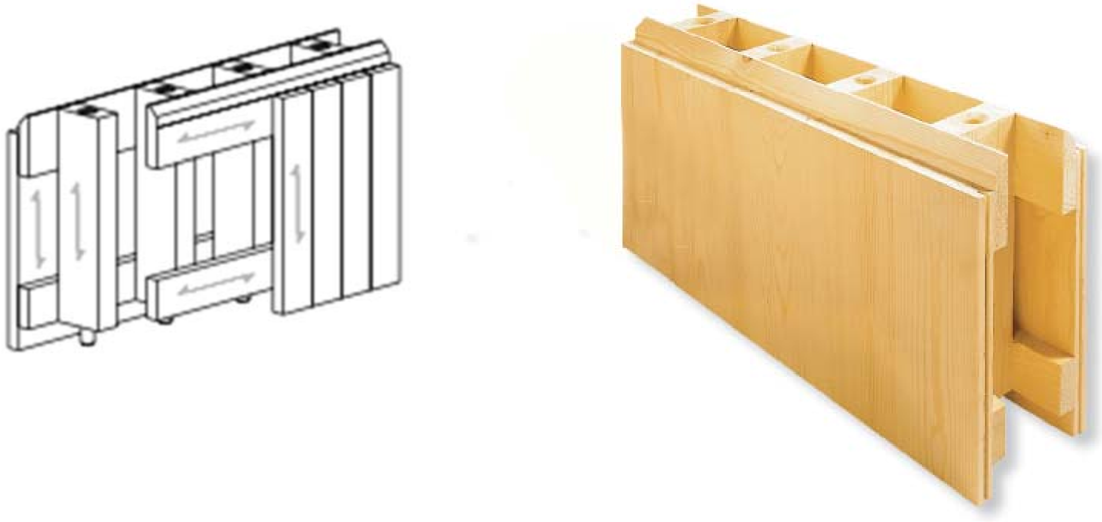


Figure 18. Timber block system. Source:Steko

This construction system allows for a high degree of facing flexibility. In the interior, walls may be kept visible or may be clad using the traditional interior materials such as plaster or gypsum. The exterior facade may be created using back-ventilated materials or compact plastering systems.

Modules and additional parts may be provided by manufacturers on pallets as construction kits. Once the thresholds are mounted on the foundation, the modules are quickly and simply stuck onto one another piece by piece without using expensive lifting tools (figure 19). Without mortar, cement or glue can set up a solid house in few days. The roof elements are integrated into the building using the blocks.

The installation of the electricals may be carried out already during – or after – the building of the walls. At the same time, the insertion of the doors and windows may be commenced. These are fitted tightly into the walls using prefabricated system parts.

Figure 19. Construction using timber blocks. Source: Steko

It is still claimed that individual building and industrial manufacture do not go together. The tests show the cost and logistic advantages of industrial production may also be used in the process of individual and creative construction. The modules are prefabricated serially, are available ex-warehouse and may easily be transported and mounted (figure 20).

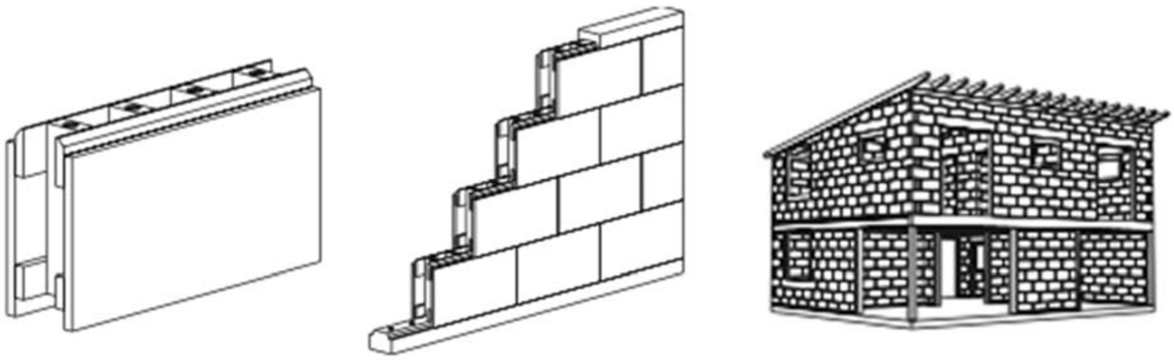


Figure 20. Timber blocks set up.

This is an energy efficient system consisting on solid wood modules. This is an energy efficient system of modules that may be recycled without problems.

This construction system provides good technical qualities. The insulation of the exterior walls suppose the thermal efficiency improving the energy efficiency of the whole building (figure 21).

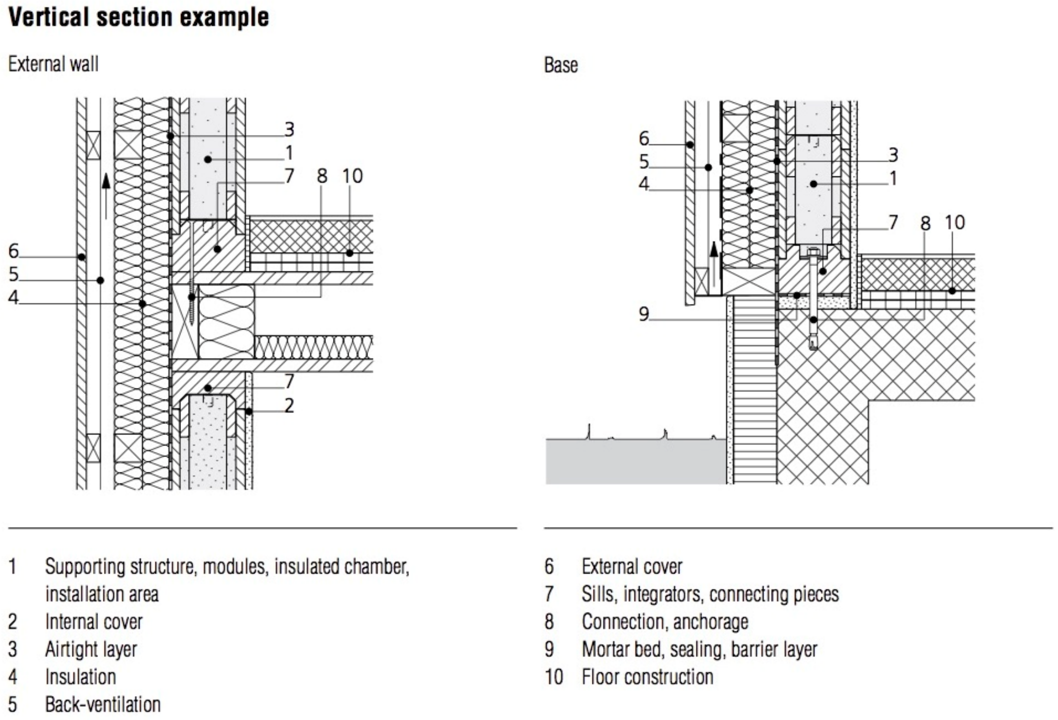


Figure 21. Insulation of timber blocks construction

Conclusions

The timber block system is a modular, versatile and lightweight system that does not need heavy machinery to be installed and be compatible with slab structure systems from the IMIP project. It could be criticized because it contains a low amount of wood in comparison with other systems, on the contrary, the heights that can be reached with these systems are limited, which can restrict the proposals.

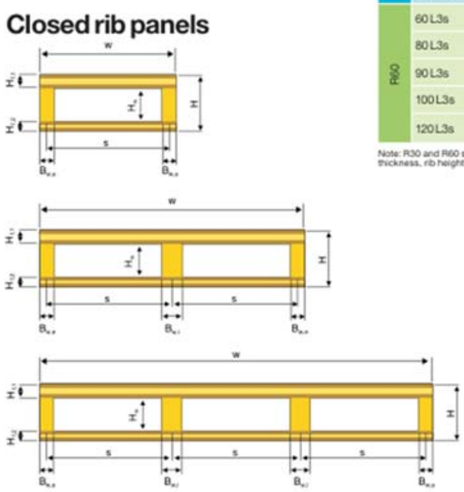
5. HORIZONTAL STRUCTURE

5.1 PLATFORM FRAME (Rib systems)

The rib system is a cage construction system which can be prefabricated being ecological and flexible, highly adaptable to all architectural projects including or refurbished buildings. Its high mechanical resistance allows its use for large spans (figure 22).

Figure 22. Platform frame

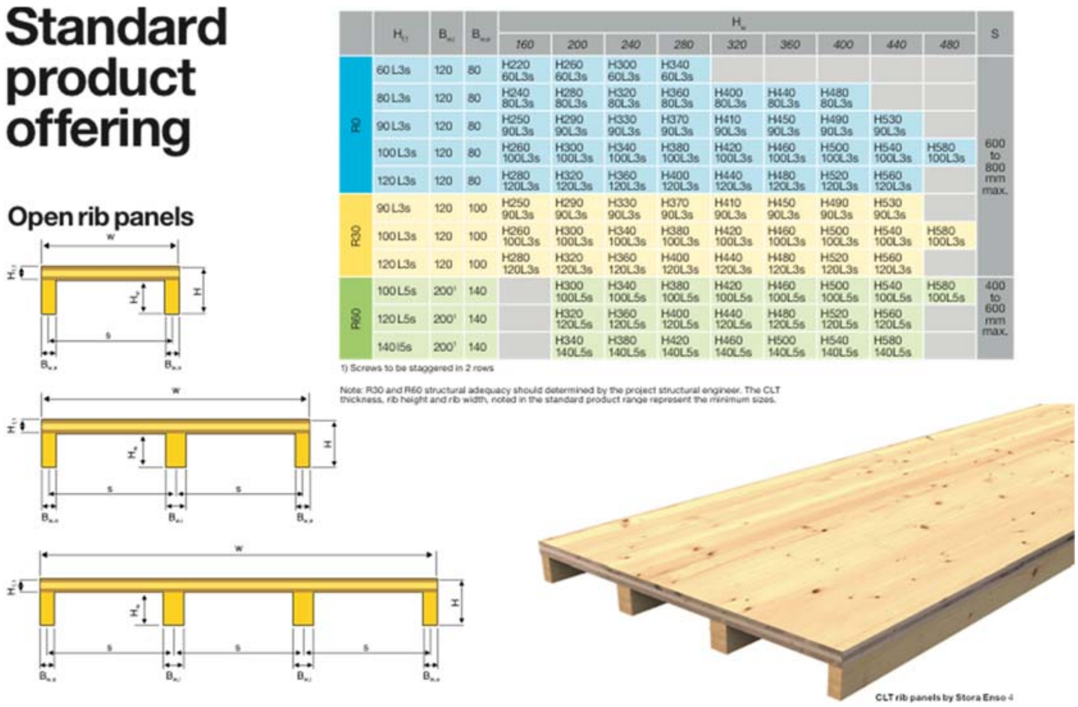
This product can be found as closed ribbed panels or open ribbed panel (figures 23 and 24).



	$H_{t,1}$	$H_{t,2}$	$B_{w,i}$	$B_{w,e}$	H_w 160	200	240	280	320	360	400	S
R0	60 L3s	60 L3s	120	80	H280 60L3s	H320 60L3s	H360 60L3s	H400 60L3s				600 to 800 mm max.
	80 L3s	60 L3s	120	80	H300 80L3s	H340 80L3s	H380 80L3s	H420 80L3s	H460 80L3s	H500 80L3s	H540 80L3s	
	90 L3s	60 L3s	120	80	H310 90L3s	H350 90L3s	H390 90L3s	H430 90L3s	H470 90L3s	H510 90L3s	H550 90L3s	
	100 L3s	60 L3s	120	80	H320 100L3s	H360 100L3s	H400 100L3s	H440 100L3s	H480 100L3s	H520 100L3s	H560 100L3s	
	120 L3s	60 L3s	120	80	H340 120L3s	H380 120L3s	H420 120L3s	H460 120L3s	H500 120L3s	H540 120L3s	H580 120L3s	
R60	60 L3s	80 L3s	120	80	H300 60L3s	H340 60L3s	H380 60L3s	H420 60L3s				400 to 600 mm max.
	80 L3s	80 L3s	120	80	H320 80L3s	H360 80L3s	H400 80L3s	H440 80L3s	H480 80L3s	H520 80L3s	H560 80L3s	
	90 L3s	80 L3s	120	80	H330 90L3s	H370 90L3s	H410 90L3s	H450 90L3s	H490 90L3s	H530 90L3s	H570 90L3s	
	100 L3s	80 L3s	120	80	H340 100L3s	H380 100L3s	H420 100L3s	H460 100L3s	H500 100L3s	H540 100L3s	H580 100L3s	
	120 L3s	80 L3s	120	80	H360 120L3s	H400 120L3s	H440 120L3s	H480 120L3s	H520 120L3s	H560 120L3s		

Note: R30 and R60 structural adequacy should determined by the project structural engineer. The CLT thickness, rib height and rib width, noted in the standard product range represent the minimum sizes.

Figure 23. Example of closed rib panels



	H_{CLT}	$B_{w,i}$	$B_{w,e}$	H_w 160	200	240	280	320	360	400	440	480	S
R0	60 L3s	120	80	H220 60L3s	H260 60L3s	H300 60L3s	H340 60L3s						600 to 800 mm max.
	80 L3s	120	80	H240 80L3s	H280 80L3s	H320 80L3s	H360 80L3s	H400 80L3s	H440 80L3s	H480 80L3s			
	90 L3s	120	80	H250 90L3s	H290 90L3s	H330 90L3s	H370 90L3s	H410 90L3s	H450 90L3s	H490 90L3s	H530 90L3s		
	100 L3s	120	80	H260 100L3s	H300 100L3s	H340 100L3s	H380 100L3s	H420 100L3s	H460 100L3s	H500 100L3s	H540 100L3s	H580 100L3s	
	120 L3s	120	80	H280 120L3s	H320 120L3s	H360 120L3s	H400 120L3s	H440 120L3s	H480 120L3s	H520 120L3s	H560 120L3s		
R30	90 L3s	120	100	H250 90L3s	H290 90L3s	H330 90L3s	H370 90L3s	H410 90L3s	H450 90L3s	H490 90L3s	H530 90L3s		
	100 L3s	120	100	H260 100L3s	H300 100L3s	H340 100L3s	H380 100L3s	H420 100L3s	H460 100L3s	H500 100L3s	H540 100L3s	H580 100L3s	
	120 L3s	120	100	H280 120L3s	H320 120L3s	H360 120L3s	H400 120L3s	H440 120L3s	H480 120L3s	H520 120L3s	H560 120L3s		
R60	100 L5s	200[1]	140		H300 100L5s	H340 100L5s	H380 100L5s	H420 100L5s	H460 100L5s	H500 100L5s	H540 100L5s	H580 100L5s	400 to 600 mm max.
	120 L5s	200[1]	140		H320 120L5s	H360 120L5s	H400 120L5s	H440 120L5s	H480 120L5s	H520 120L5s	H560 120L5s		
	140 l5s	200[1]	140		H340 140L5s	H380 140L5s	H420 140L5s	H460 140L5s	H500 140L5s	H540 140L5s	H580 140L5s		

1) Screws to be staggered in 2 rows

Note: R30 and R60 structural adequacy should determined by the project structural engineer. The CLT thickness, rib height and rib width, noted in the standard product range represent the minimum sizes.

Figure 22. Example of open rib panel

The wood panels may be created to the exact measures of each project, facing subsequent machining of stairwells in floors, carpentry holes in walls and even conduits passage of facilities.

The central plank is replaced by a stringer structure, generating a hole or box. This box is used to place thermo-acoustic insulation: rock, sheep or wood wool. Glue is applied on the stringers - as if it were the sheet ironing - and two layers are placed on each side, making a total of five. These panels provide better mechanical, thermal and acoustic performance for the same volume of wood per unit area. Its main use is floor and roof slabs. They provide great stability allowing buildings with relatively large spans, up to 10-12 m, for the usual loads of residential and administrative buildings.

Figures 25 a) and b) show details of construction design using this system.

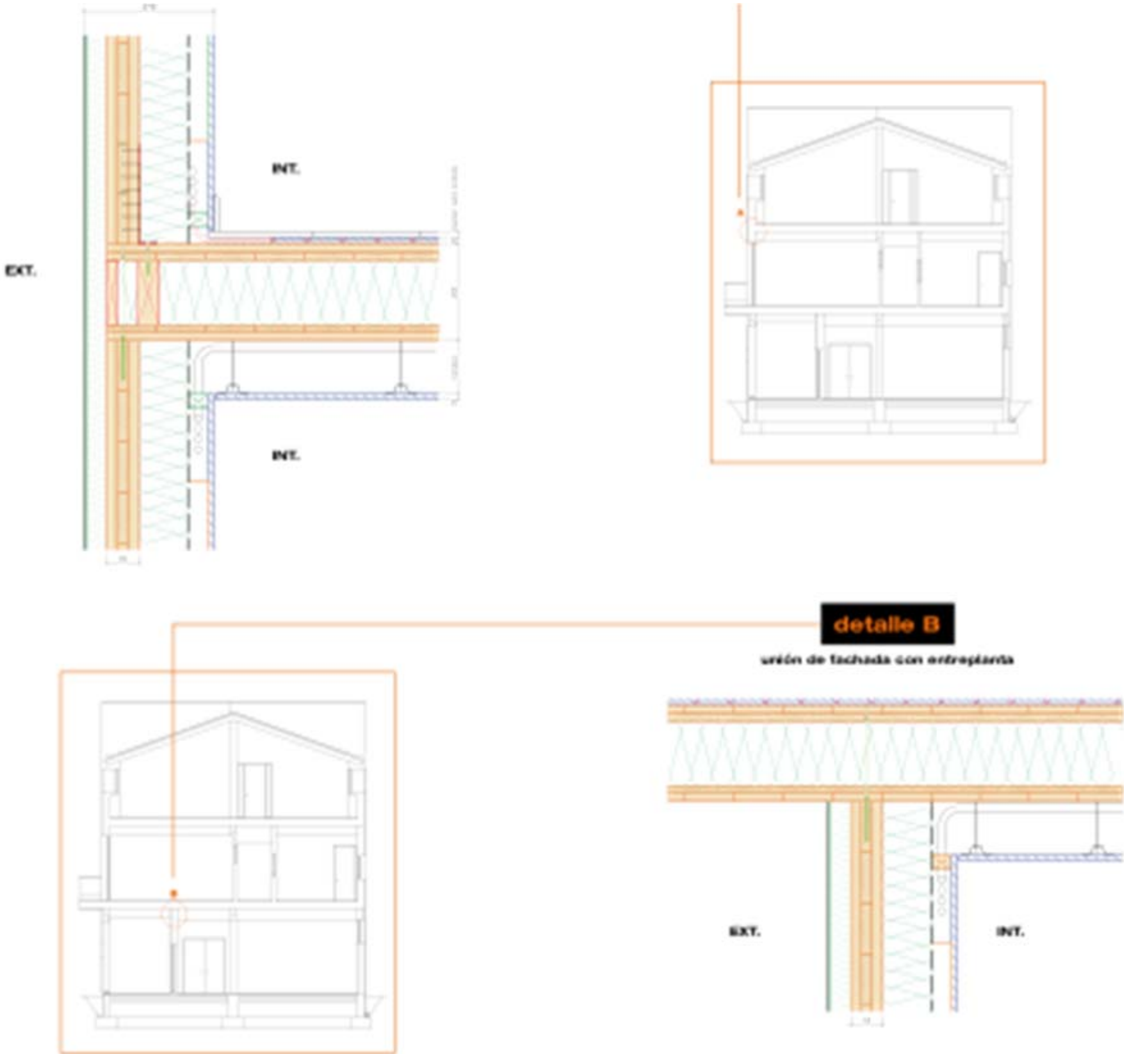


Figure 25 a). Design details

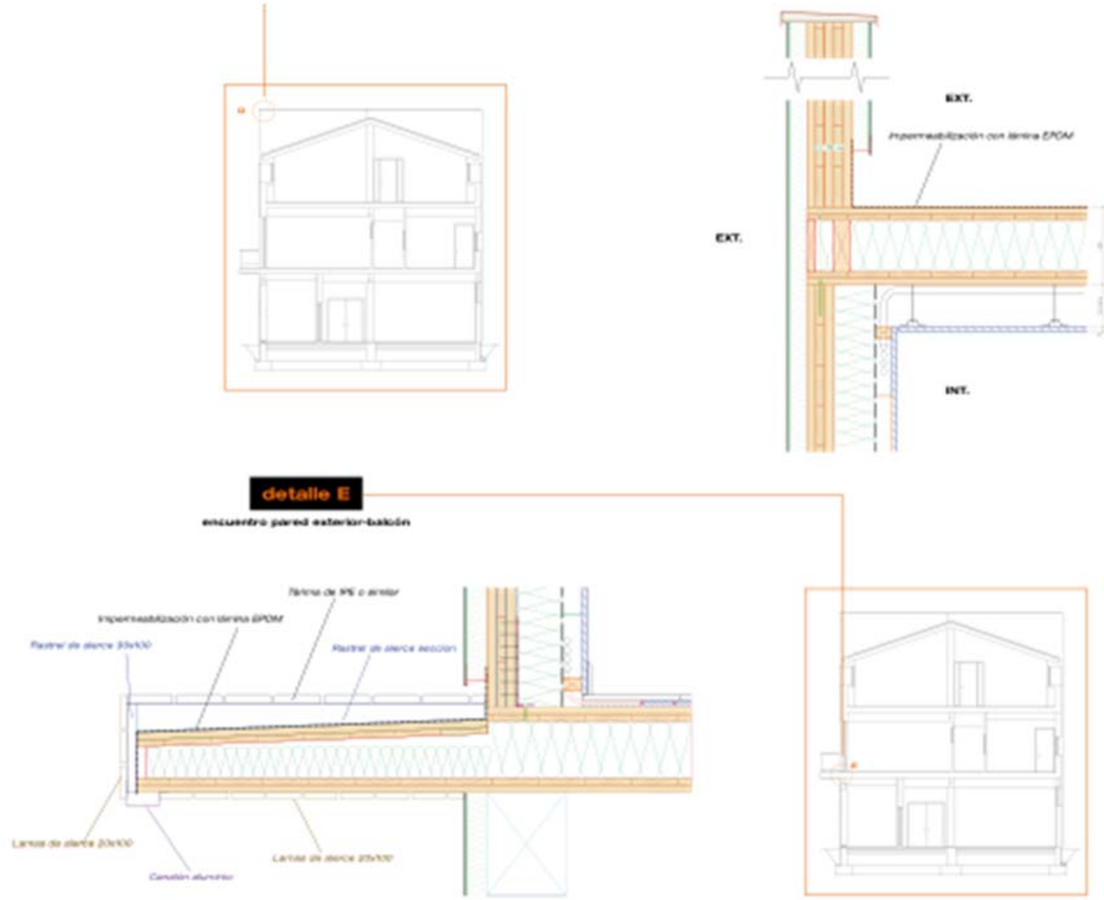


Figure 25 b). Design details

Conclusions

The platform frame with ribs is a modular, versatile construction system that need heavy machinery to be installed and can be compatible with systems from the IMIP project. It could be highlighted that it contains a low amount of wood in comparison with other systems with big spans. This condition can be critical to select the most efficient system for horizontal structures with the better ratio of wood quantity and structural resistance.

It could be concluded that the combinations of this system with other systems such as CLT seems to be a good combination to balance the qualities of the systems that are being studied in the IMIP project.

5.2 CROSS LAMINATED TIMBER, FLOORING AND SLABS

CLT structural timber is a technically-dried, strength-graded and generally finger-jointed solid wood product made from softwood and designed for a wide variety of applications in modern timber construction, including slabs or horizontal structural flooring.

Precisely defined product characteristics, requests for resource efficient supporting frameworks and attractive surfaces coupled with fast delivery times to the site of use are further good reasons to use CLT structural timber.

Some specifications of CLT used for floors, is in figure 26.

L panels
The grain direction of the cover layers is always at right angles to the production widths.

Thickness [mm]	Panel type [–]	Layers [–]	Panel design [mm]						
			L	C	L	C	L	C	L
60	L3s	3	20	20	20				
80	L3s	3	20	40	20				
90	L3s	3	30	30	30				
100	L3s	3	30	40	30				
120	L3s	3	40	40	40				
100	L5s	5	20	20	20	20	20		
120	L5s	5	30	20	20	20	30		
140	L5s	5	40	20	20	20	40		
160	L5s	5	40	20	40	20	40		
180	L5s	5	40	30	40	30	40		
200	L5s	5	40	40	40	40	40		
160	L5s-2*	5	60	40	60				
180	L7s	7	30	20	30	20	30	20	30
200	L7s	7	20	40	20	40	20	40	20
240	L7s	7	30	40	30	40	30	40	30
220	L7s-2*	7	60	30	40	30	60		
240	L7s-2*	7	80	20	40	20	80		
260	L7s-2*	7	80	30	40	30	80		
280	L7s-2*	7	80	40	40	40	80		
300	L8s-2**	8	80	30	80	30	80		
320	L8s-2**	8	80	40	80	40	80		

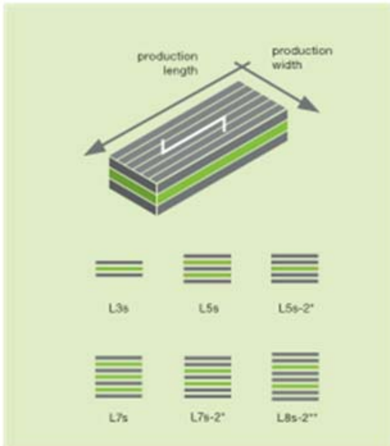
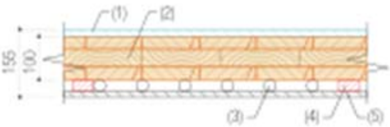


Figure 26. CLT used as floor

As in almost any industrially manufactured product, the price is known and guaranteed: it is not possible to increase the price during construction since, once the design is accepted, the production process begins and the costs are fixed. Likewise, both the manufacturing time and the assembly period are guaranteed, with possible fluctuations of days. The price of the work in CLT can have important variations depending on the formal complexity, qualities, volume of wood and spans. Regarding the specific cost of the CLT item, we can say that, if the design is not artificial, it is competitive. But it is important to raise the cost of the building completely since with this system the indirect costs are substantially reduced.

Figure 27 shows examples of CLT floor calculations.

Forjado planta de madera no vista



1.- Fermacell 150 mm.
2.- EGO_CLT no visto 100 mm.
3.- Paso de instalaciones.
4.- Rastrel 28x48 mm.
5.- Placa de yeso 12 mm.

sección 1	d [mm]	ρ [kg/m³]	λ [W/mK]	μ [-]	R
EXTERIOR					0,040
FERMACELL	15	1000	0,320	13	0,047
EGO-CLT	100	450	0,130	50	0,769
PICEA	28	350	0,130	50	0,215
PLACA DE YESO	12	900	0,250	280	0,048
INTERIOR	-	-	-	-	0,170
Σ	155			$R_{T,1}$	1,289 K/W

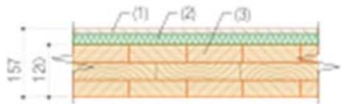
sección 2	d [mm]	ρ [kg/m³]	λ [W/mK]	μ [-]	R
EXTERIOR					0,040
FERMACELL	15	1000	0,320	13	0,047
EGO-CLT	100	450	0,130	50	0,769
CÁMARA DE AIRE 28mm	28	1,1	0,220	0,028	0,127
PLACA DE YESO	12	900	0,250	280	0,048
INTERIOR	-	-	-	-	0,170
Σ	155			$R_{T,2}$	1,201 K/W

R'_T 1,20 K/W

peso por m² 70,8 kg — R''_T 1,21 K/W

transmitancia térmica U = **0,83** W/(m²K)

Forjado planta con madera vista



1.- OSB 12 mm.
2.- Lana de roca 25 mm.
3.- EGO_CLT visto 120 mm.

sección 1	d [mm]	ρ [kg/m³]	λ [W/mK]	μ [-]	R
EXTERIOR					0,040
OSB	12	650	0,130	50	0,092
LANA DE ROCA, ρ=140kg/m³	25	140	0,038	1	0,651
EGO-CLT	120	450	0,130	50	0,923
INTERIOR	-	-	-	-	0,170
Σ	157			$R_{T,1}$	1,876 K/W

sección 2	d [mm]	ρ [kg/m³]	λ [W/mK]	μ [-]	R
EXTERIOR					0,040
OSB	12	650	0,130	50	0,092
LANA DE ROCA, ρ=140kg/m³	25	140	0,038	1	0,651
EGO-CLT	120	450	0,130	50	0,923
INTERIOR	-	-	-	-	0,170
Σ	157			$R_{T,2}$	1,876 K/W

R'_T 1,88 K/W

peso por m² 65,3 kg — R''_T 1,88 K/W

transmitancia térmica U = **0,53** W/(m²K)

Figure 27. CLT calculations used for floor

Conclusions

The CLT system is versatile but need heavy machinery to be installed. It can be compatible slab structure systems from the IMIP project. It could be highlighted that it requires a big amount of wood in comparison with other systems. On the contrary, the span that can be reached with this system is longer than other systems.

CLT is becoming popular as a construction system for small structures and wood composite ceilings. It is also being widely used for internal partitions, facades systems, vertical and horizontal structural systems and others.

It is possible to combine it with other systems, but seems it takes more quantity of timber than other systems like platform frame. This system seems to be better option for vertical systems than horizontal ones.

6. ROOF FORMING SYSTEMS

6.1 CROSS LAMINATED TIMBER FOR ROOF

The high level of prefabrication and related short assembly times are a major advantage, especially when CLT panels are used as roof elements, as buildings can be rendered rain-proof in short time scales. Thanks to CLT, roofs and ceilings can be economically designed with standard span lengths and building requirements can be fully satisfied (figure 28). With the right choice of structural components, requirements can be easily achieved and, at the same time, CLT can be combined with any type of construction material.

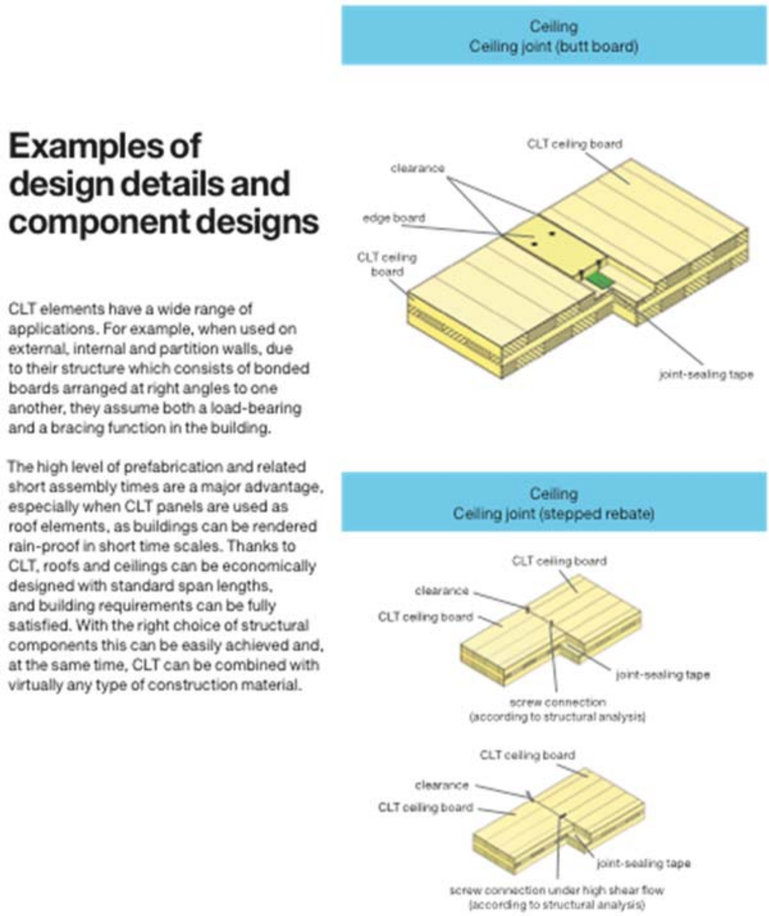


Figure 28. CLT design considerations

Due to their enormous structural load-bearing capacity, CLT panels now also enable new architectural and design dimensions to be created in timber construction. As the board layers are bonded at right angles to each other, the load is transferred along two axes. Projecting or point-supported structures can be realised in outstanding quality with CLT (figure 28). The high inherent stiffness of CLT also has a positive impact on bracing a building.

Figure 28. CLT building

For projects with many identical units, such as halls of residence or hotels, it has been developed a modular system whereby most of the work—tiles, paint, technical installations, etc. CLT can efficiently store heat in the winter, and protect buildings from overheating in the summer. This means that passive house standards are easy to implement and less additional insulation material is required.

Solid wood is more fire-resistant than it is generally assumed. CLT has a moisture content of approximately 12%. Before wood can catch fire, the water it contains must evaporate. In addition, the carbonised surface protects the internal CLT layers so that the solid wood construction does not collapse in a fire. To support this statement, the results demonstrating CLT’s high level of resistance.

Conclusions

The CLT system is versatile but need heavy machinery to be installed. It can be compatible with slab structure systems from the IMIP project. It could be highlighted that it contains a big amount of wood in comparison with other systems, on the contrary, the span that can be reached with these systems are higher than other systems, which can enrich the proposals and makes the global system more rigid.

It is possible to affirm that can be combined with other systems, but seems it takes more quantity of timber than other system like platform frame. This system can be good for trapezoidal shapes.

6.2 STRUCTUAL INSULATING PANELS FOR ROOFS

Roof wooden sandwich panels are similar to SIP panels, but technically much more complex. Some panels consist of strong Laminated Veneer Lumber (LVL) board, PUR insulation and OSB board. The closed-cell insulation foam is inserted into panels in liquid mode with a special technology leaving no air gaps (figure 29). Structural roof and floor panels are enforced with inner panel LVL beams.

Panels can be produced according to project's requirements – measures, U values (thermal transmittance) and loads (figure 30).

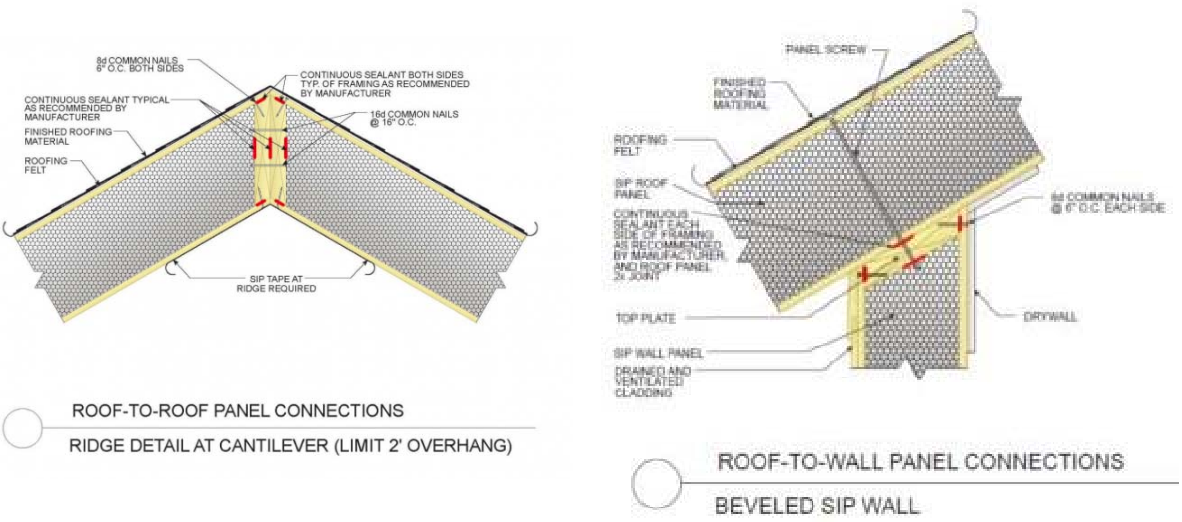


Figure 29. Examples of insulating panels connections

SAMPLE PANELS

TYPE	LENGTH	WIDTH	HEIGTH	U-VALUE
LVL(mm)-PUR(mm)-OSB(mm)	m	m	mm	W/(m²K)
R 27-195-15	max 12	max 3	237	0,153
PASSIVE R 27-290-15	max 12	max 3	332	0,106

Figure 30. Project requirements

SIP are tested for critical values as heat conductivity, load bearing capabilities and many other values to offer quality and durability for different climate conditions (figure 31), like others structural wood products.

Some load bearing tests for wall and roof panels have been carried out by partial contribution of European Regional Development Fund programs. Result of this testing is the lab confirmed test results for load bearing of the panels.

Figure 31. Tests and uses of SIP

Conclusions

The SIP is a modular, versatile and lightweight system but need heavy machinery to be installed and can be compatible with slab structure systems from the IMIP project. It could be commented that it contains a low amount of wood in comparison with other systems. The main structure is needed to support these systems. On the contrary, the insulation used is not of low environmental impact.

6.3 SANDWICH PANELS

The sandwich panels for sloped roofs are composed in their decorative layer by a wide range of finishes in contact with the support structure, a continuous insulating core of tongue and groove extruded polystyrene, and a board on the upper face (figure 32). Insulated sandwich panels decks are installed from wood quickly and economically.

Figure 32. SIP examples

The characteristics of employed materials are lightness, resistance and environmental sustainability. To provide a quick and effective solution for a mezzanine or floor, the sandwich panel with an insulating core is a good option for roofs and cladding. There exist panels with a big range of decorative finishes (figure 33).

Figure 33. Decorative finishes of SIP

Project funded by the Interreg Sudoe programme through the European Regional Development Funds (ERDF)

The most important requirement is the need of a principal and secondary structure in times to receive the sandwich panels.

Conclusions

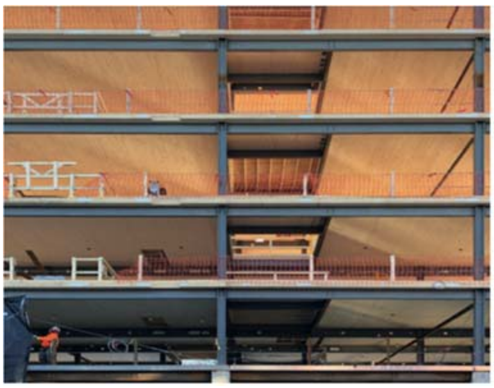
The sandwich system is a modular, versatile and lightweight system and need heavy machinery only to download the panels from the transport system. This can be compatible with slab structure systems from the IMIP project. It could be highlighted that it contains a low amount of wood in comparison with other systems. A main structure is needed to support this system. On the contrary, the insulation can be environmental friendly. The combination of this system in a proper proportion can be really effective as a secondary system, not as the primary one.

7 COMPATIBLE MIXED SYSTEMS FOR IMIP PANELS REUSED

Thanks to its inherent structural properties, cross-laminated timber (CLT) presents no limitations to architecture. CLT resists high racking and compressive forces, so it can be especially cost-effective for multi-storey and long-span applications. Because of its dimensional stability and structural properties, this massive wooden product is well suited for floors, walls and roofs.

CLT is a highly flexible wood product that is easily tailored for further processing and can be used together with all building materials. Compared with heavy mineral-based materials, CLT is easily moved by light cranes at the construction site.

7.1 STEEL STRUCTURE + IMIP PANELS



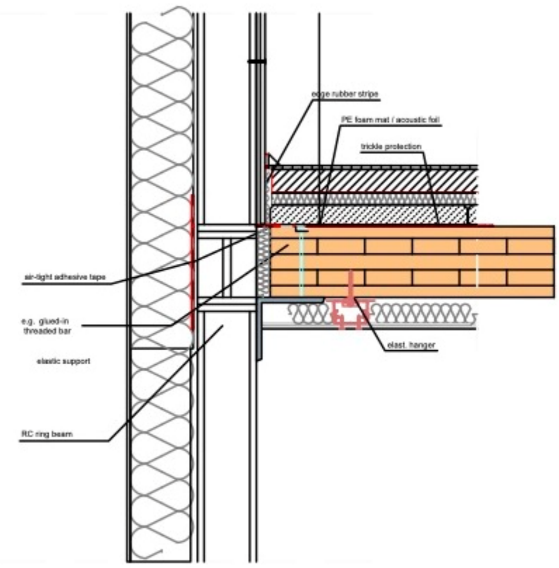


Figure 34. Wood-steel systems

For structural systems made up of different resistant materials, it is important to take into account that the expansions and contractions, as well as the movements of the structures derived from the stresses of tensions and moments, are very different depending on the material.

The metallic structure does not have the same movements as those of the wood, so it is crucial, first to thermally isolate the entire system from the outside and secondly, to separate enough the joints between different systems so that twists in the semi-joints are not affected.

In the case between wood and metal, it must be said that they are two systems with considerable movement, which is why it is necessary to have transverse bracing (figure 34).

A separation between the two systems is required to prevent the movement of one of them negatively affects the other.

7.2 REINFORCE CONCRETE + IMIP PANELS

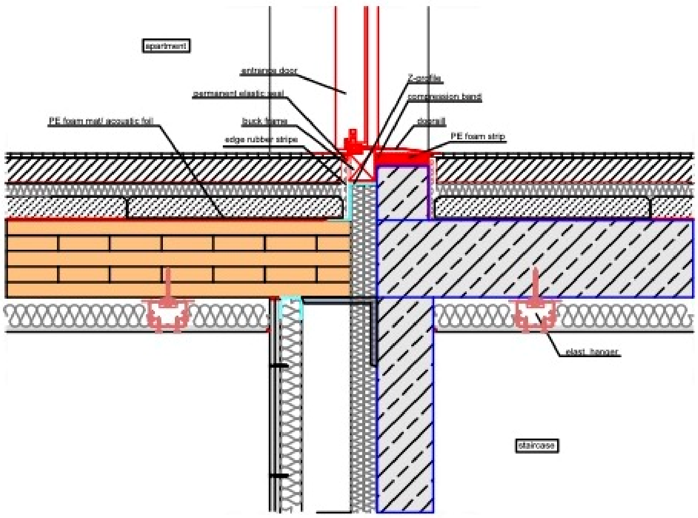


Figure 35. Concrete-wood systems.

In a different way that in the steel case, the reinforce concrete is working in a very rigid way and the join is able to be rigid. But even in this case, it is necessary a union between the systems that allow possible differential movements between wood and concrete (figure 35).

The union between both systems is usually made by means of an intermediate piece such as a metallic L-shaped profile, separating enough the CLT so that the semi-joint does not produce interference between systems.

7.3 LOAD-BEARING WALLS + IMIP PANELS

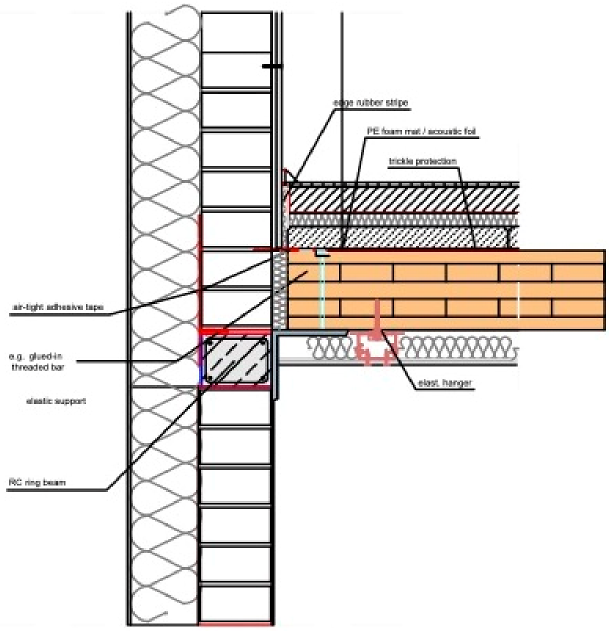


Figure 36. Wood-walls systems.

The structural systems of load-bearing walls have not rigid joint systems either. They tend to be semi-articulated joints due to behaviour differences between the joint mortars and the resistant pieces (figure 36).

Floors supported by these load-bearing walls generally need a more rigid base on which to make the support or semi-articulated joint.

In order to maintain the independence between the wall systems and the CLT floors, an anchor is necessary to allow sufficient separation to absorb the differential movements. This element is usually a standard steel profile.

8. Building characteristics in SUDOE

This section includes an analysis of the building stock in SUDOE territory. The objective is to provide inputs that will allow identifying which buildings are target buildings for the implementation of IMIP panels for the case of retrofitting works.

8.1. BUILDING CHARACTERISTICS IN FRANCE

8.1.1. Building typologies in France

Five time periods were found from 1850 to 1974 in French architectural classification.

Period 1: 1850 to 1914

This period is characterized by increase of rural migration for working in town. This situation leads to a lack of housing in urban neighborhoods. Awareness about the unhealthy living conditions of the workers (industrial revolution period) lead State to make laws for healthy housing. In addition, they allow building or expanding taller buildings up to 20m.

In 1894 appear the first private organizations that manage low-cost and social housing. Most of walls are made by local stones masonry. Since 1895, manufactured materials made buildings: concrete, cement, steel, brick and tiles (figure 37).

Figure 37. Left:Haussmannien: ca 1860. Middle: Faubourien: ca 1888. Right: Post-Haussmannien: ca 1901

Period 2: 1918 to 1939

During this period (between 2 wars), facades are linear and buildings constitute block of houses detached from the existing city. The most used design system is concrete columns and beams, filled by masonry walls (figure 38).

Figure 38. Low cost housing 1925, 1934 and 1934

Period 3: 1944 to 1953

This period is characterized by generalization of concrete structure (column and beam) and filled by masonry and improvement of manufacturing phase: prefabricated elements: bays, slabs, timber floor board, metal formwork (figure 39).

Figure 19. Rationalism: ca 1953 and Modern Classicism: ca 1953

Period 4: 1954 to 1966

During this period, industrialisation of construction runs with high speed in order to solve housing lack crisis. Large constructions are built in suburban areas. Most of buildings are made of concrete: slab and wall system overtakes column and beam system. Slab and wall system allows using sliding formwork and tunnel (figure 40).

Figure 40. Social housing: 1959-1960

Period 5: 1967 to 1974

Consequences of the last urban planning (with large buildings and social housings) were disapproved because of social relations, lack of equipment and uniformity of design. Then, innovative construction came out with diversification of design and function. Concrete is still the major of material used for building and building was industrialized. Large and tall buildings are forbidden in little and medium city areas. Buildings design presents new elements: cavity, loggias and balconies (figure 41).

Figure 41. Tower: 1971 and Tall building 1969

8.1.2. Constructive characteristics in France

8.1.2.1. Building envelop

Façade types

Six façade types are defined from RECOLCI French national project and TABULA European project.

- Façades F0 are flat and do not include any balcony. Possible variants are presence of horizontal bands marking the boundary between stages, or presence of small flaps or chassis (figure 42).
- Façades F1 are flat, have windows with flowing supports, and have no balcony. Possible variants are presence of guardrails for windows/doors, presence of horizontal bands marking boundary between stages, presence of bands framing the bays (figure 42).

Figure 42. Type F0 and F1 facades.

- Façade F2 types are flat and have windows, doors and balconies. Possible variants are extension of balconies for two or three doors or, F1 with balconies (figure 43).

Figure 43. Type F2 facades.

- Façade F3 are similar to F2. Number of doors is more important than with F2 type (figure 44).

Figure 44. Type F3 facades.

- Façade F4 types are characterised by horizontal projection of intermediate floors and grooving (vertical projection). Possible variants are: horizontal projection only or vertical projection only, or thickness of projections (figure 45).

Project funded by the Interreg Sudoe programme through the European Regional Development Funds (ERDF)

Figure 45. Type F4 facades.

- The façade F5 types balconies are of loggias characteristics. Possible variants are presence of guardrails (figure 46).

Figure 46. Type F5 facades.

Facades may also be represented by combination of two or three different types.

8.1.2.2. Roofing types:

Sloping roof or flat roofs cover French building. There are three main types of pitched roofs:

- One slope
- Two symmetrical or asymmetrical slopes
- More slopes

And three types of flat roof:

- With balustrade (acroterium)
- With balustrade and no overhang
- No balustrade and no overhang

8.1.2.3. Building energy efficiency systems

Among the various types of heating the French park, the collective central heating is largely predominant, with over 70% of homes affected (more than 3.1 million), individual central heating represents 1 / 5 th house (900 000 residences). As for electric heating, it represents only 7% of homes (about 300 000 homes). The distribution of types of heating is given in following table 1.

Table 1. Main residences in apartment buildings 1949-1974 by type of heating and number of floors.

		Number of floors				
Heating	Fuel	<4	4 to 8	≤8	>8	Total
Individual central	Oil	18	3	20	3	23
	Gas	367	420	786	53	839
	LPG	18	2	20	0	20
	other	12	4	17	1	18
	Total	415	429	834	56	900
Collective central	Oil	215	528	743	180	923
	Gas	309	977	1286	409	1695
	LPG	8	7	15	1	16
	heating	25	206	231	175	406
	Other	23	52	74	43	117
	Total	579	1771	2350	808	3157
Electrical		176	117	293	6	298
Another type		59	44	102	5	107
No heating		0	2	2	0	3
Total		1228	2362	3590	875	4465

Units: thousands of homes (source: project RECOLCI).

Energy efficiency standards

The actual thermal regulation RT2012 sets rigorous performance expectations, requiring that residential and non-residential buildings use a maximum of 40-65kWh/m2/pa depending on locality and altitude of the building.

France is divided into eight climate zones: H1a, H1b, H1c, H2a, H2b, H2c, H3 and H2d (figure 47).

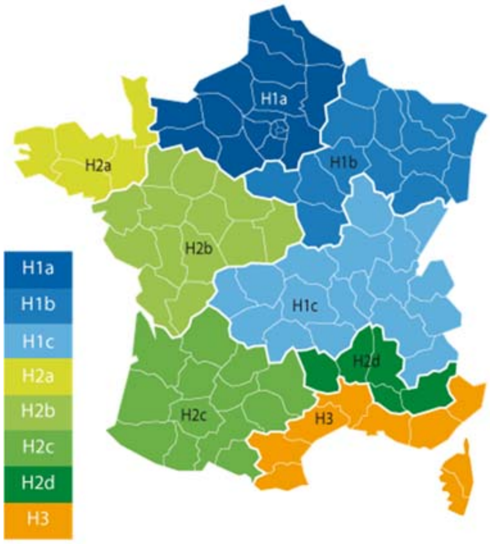


Figure 47. Metropolitan France climate zone

Envelop thermal performance (U) is showed in table 2:

Table 2. Thermal performance according to façade typologies.

Typology	Uvalue (W/m²K)	Glazing	Ventilation
F0-F1-F2	1,8 to 3,5	Simple	By sealing default or by air inlet/openning on envelop
F3-F4	2.1 to 2.9	Simple	
F5	2 to 2.9	SImple	

8.1.3. Type of ownership/residents in France

There are three types of ownership:

- individuals, including family members,
- public housing agencies, which include the offices, companies and the OPAC (public organism of construction)
- administrations, comprising state and local governments,

The following table 3 shows the distribution of types of ownership. Individuals and organizations HLM (Low-rent housing) share most of the park: more than half of the homes for the former and over 40% for the latter. In addition, all owners own 80% of homes in building exceeding 8 floors.

Table 3. Main residences in apartment buildings 1949-1974 depending on the owner and the number of floors. Units: thousands of homes.

Owers	<4	4 to 8	≤8	>8	Total
Private	755	1192	1947	358	2305
Low rent house compagnies	384	1045	1429	435	1864
Other compagnies	49	93	143	62	205
Administrations	39	30	69	15	84
Associations	2	1	3	5	8
Total	1228	2362	3590	875	4465

Of the 2.3 million primary residences owned by individuals, 84% are in group of buildings (32% in buildings with less than 3floors and 52% in building with 4 to 8floors).

Of the 1.8 million primary residences owned by HLM, 77% are in group of buildings (21% in buildings with less than 3floors and 56% in building with 4 to 8floors).

8.1.4. Refurbishment market in France

After the end of Second World War, nearly 9 million homes that were built in France between 1949 and 1974, with production growing almost steady over this period. The year 1973 was a greatest year, with 556 000 housing units.

Since the first regulation on 1974, building envelop are insulated and energy consumptions of new residential buildings are more and more optimized. That is the reason why IMIP should choose to focus on the period between 1949 and 1974 for IMIP solutions in France.

8.1.5 Conclusion of building characteristics in France

The focus of IMIP panels should be buildings built between 1949 and 1974. Figure 48 summarized façade types of these buildings.

Figure 48. Facade types of 1949-1974 buildings

The most representative wall of these typologies of building is in following table 4.

Table 4. Wall typologies and thermal conductivity for façade

Façade type	U[W/m²K]
Brick masonry	1,80 to 3,5
Cinderblock wall (20mm) + air (50mm) + internal brick masonry (50mm)	1,45
Concrete wall (200mm)	1, 24
Concrete blocks	1,52

Concerning roofing, representative performances are in table 5:

Table 5. Thermal conductivity for roof types

	U[W/m²K]
Heavy roofs	
No isolated	0,68
Isolated	0,34
Light roofs	
Ventilated	1,94
Isolated	0,49
Pitched roof and not isolated	1,7

8.2. BUILDING TYPOLOGIES IN SPAIN

Three time period have been stablished for building analysis:

- Until 1945 (old buildings)
- Between 1946 until 1990 (post war buildings)
- After 1991 (current and new buildings).

In the case of Spain, the project has to be focused on the building period 1946-1990 due to several reasons. Buildings previous to 1945 are considered old buildings and they could require deeper interventions than energy rehabilitation. Moreover, a significant quantity of buildings has high probability of demolition in a near future. Another fact is that they are usually involved in strategic city action plans or they constitute the cultural heritage of the city, unlike the rest of the building stock.

Buildings constructed after 1991 have minimum comfort conditions because of the existing standards in that period. Thus, energy efficient rehabilitation would not achieve so high impact in terms of energy performance improvement. Furthermore, it might become complicate to convince dwellers for an energy efficient rehabilitation when no noticeable upgrade can be obtained.

In contrast, during 1945-1991, the industrial revolution lead to a huge immigration into the cities because of the need for laborers, and added to the high fertility rates of the period, there was a massive construction. The need for a dwelling resulted in a rapid buildings construction which was not demanding and, therefore, with low quality. Nowadays, buildings constructed between 1945-1991 are obsolete in terms of energy efficiency and living conditions. Additionally, according to Boverket (2005), the majority of the buildings in Spain, Italy, Greece and France are constructed between 1945 and 1980 (see Figure49).

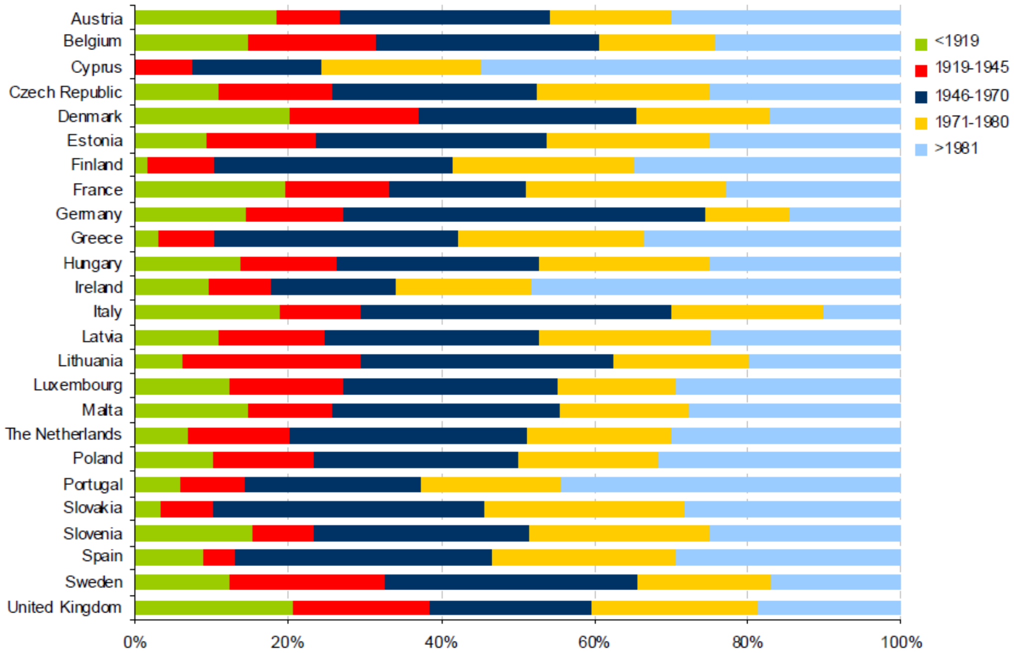


Figure 49. Age distribution of the housing stock (Boverket, 2005)

Spain had a massive construction activity between the 50s and the 80s, time of boom due to industrial development period, as said before they are all pre-normative constructions. Therefore, all the Spanish building stock erected during this period is of poor quality and highly inefficient in terms of energy performance.

According to SECH-SPAHOUSEC (2011), 60% of the buildings were erected between 1941-1980 and 49% of the buildings erected before 1979 are multifamily blocks of houses. With regard to unifamiliar houses, a vast majority was erected in the last 30 years. The existence of standards in this period led to more strict building requirements with better-determined constructive solutions and installations than multifamily buildings. Consequently, the most representative building typology in South Europe will be characterized by the multifamily blocks constructed between 1945-1980.

8.2.1. Building size typologies

TABULA project provide the definition of the main building typologies in Spain depending on the year of construction.

In general, according to the results of the SECH SPAHOUSEC (IDEA, 2011) project, the Spanish building stock is mainly composed of block of flats (70%) which are usually located in high-density urban areas (figure 50).

The height of this flat blocks is very variable, but the geometry hasn't change along the years.

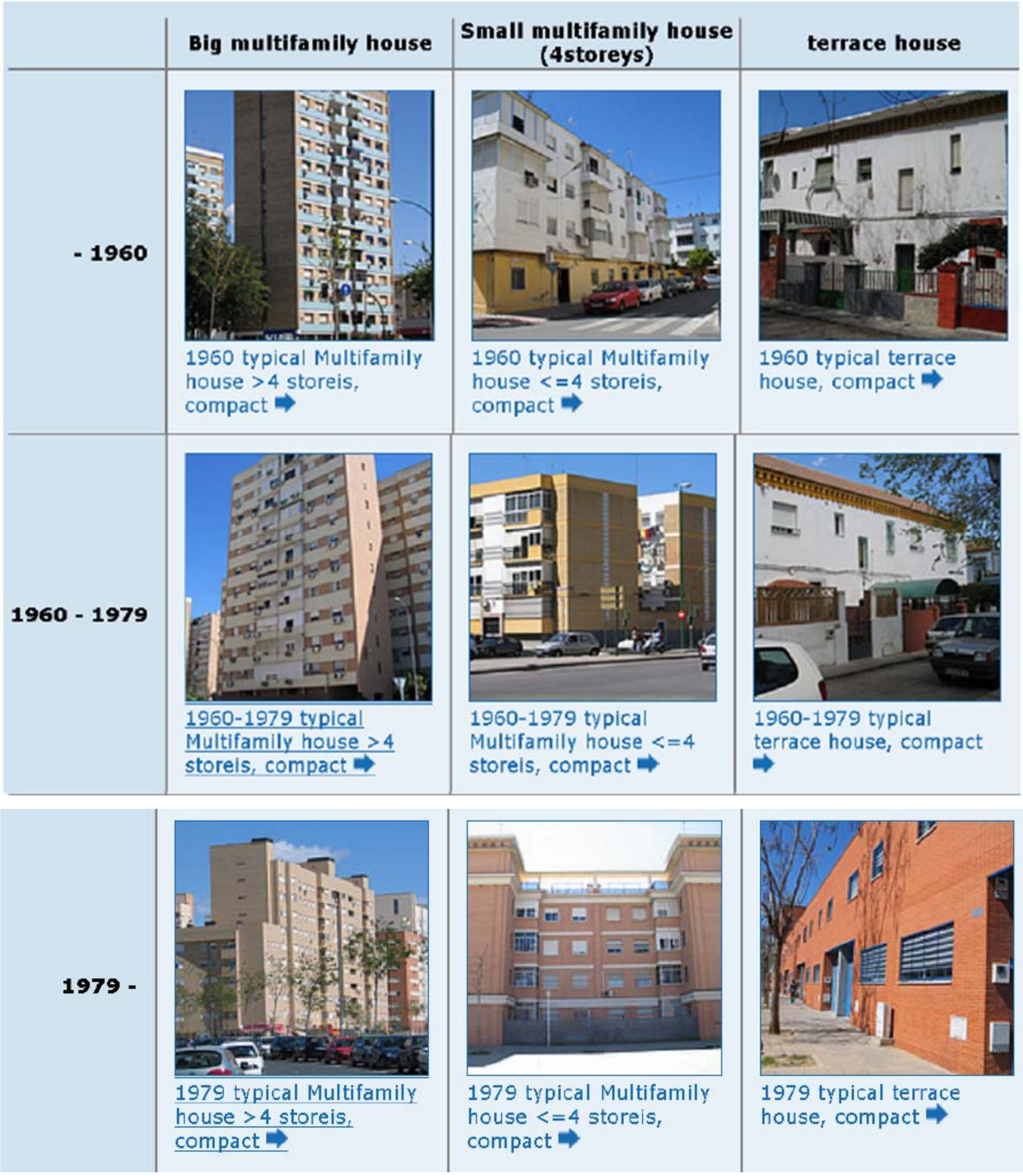


Figure 50. Age distribution of the housing stock (Boverket, 2005).

8.2.2. Constructive characteristics in Spain

The constructive characteristics vary depending on the region and period of construction.

Considering building structure, there are two options of structure typology for buildings built before 1965: Timber and masonry structures or reinforced concrete structures with non-load bearing facades of several types (brick, cavity, concrete block). In the case of the vast majority of residential buildings built after 1965, the structure typology is reinforced concrete. Stone or brick load bearing facades are more common in older buildings, built before 1945. Unfortunately, there is no available source of information regarding use percentages for each of these facade solutions.

For building envelop, the most representative façades (table 6) have been stablished as:

Table 6. Thermal information for facade types

Façade type	U[W/m^{2}K]
Stone masonry	2,22
Brick factory	1,98
Cavity wall made of perforated or hollow bricks	1,75
Cavity wall made of perforated or hollow brick with thermal insulation in the cavity	1, 58
Concrete blocks	1,52
Precast concrete panels	0,43

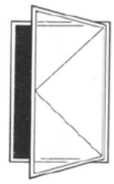
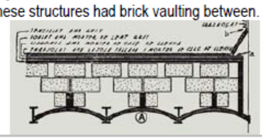
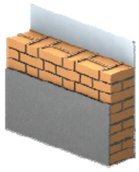
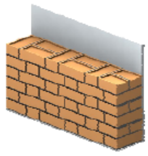
As in façades, different types of roofing are present in the Spanish buildings (table 7):

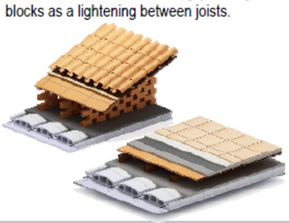
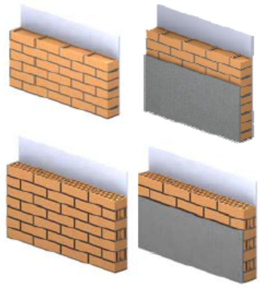
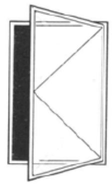
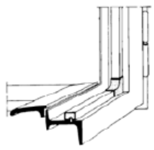
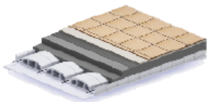
Table 7. Thermal information for roofing types

	U[W/m^{2}K]
Heavy roofs	
No isolated	0,68
Isolated	0,34
Ventilated with partition walls (only in the case of flat roof)	1,74
Light roofs	
Ventilated	1,94
Isolated	0,49
Pitched roof and not isolated	1,7

Between 1945 and 1980, the most common façade typology is brick factory or cavity wall made of perforated hollow bricks without insulation. The typical roof typology is pitched roof without insulation. And finally, windows are built of aluminium or timber frame, both with single glass.

The TABULA project provides some example of the most typical building constructive characteristics depending on the year of construction (figure 51).

YEAR	ROOFING Type	U W/m²K	EXTERIOR WALLS Type	U W/m²K	WINDOWS Type	U glass W/m²K	U Frame W/m²K	g⊥
1900	In the early twentieth century the most common pitched roofs were a set of wooden trusses which supported one or more ceramic pieces layers, as support for the tiles. Often the attic space was closed with a straw ceiling covered with plaster to create a ventilated chamber. 	4,17	In the early twentieth century, especially in buildings of short height and in small towns, the load-bearing walls of stone are still been used, either limestone or granite. 	2,63	Wooden swing windows with monolithic glass.   When the metalwork window appeared, they came to be used in the main facade, placing the wooden windows in the courtyards facades.	5,7	2,2	0,80 - 0,85
	In the early twentieth century, the most common solution of flat roofs were the ventilated flat roofs generated by brick partitions. This brick partitions had hollows to permit ventilation and they were leaned on metal or wood structures. These structures had brick vaulting between. 	3,08	Although in Europe framed structures have been introduced, in Spain, the load-bearing walls are still in use until the 1940s. The facade usually consisted in a single wall of brick of a foot or a foot and a half, either coated or uncoated. The slab was supported by the entire sheet thickness. Sometimes a thin brick wall was built as an interior skin.  	2,63				

YEAR	ROOFING Type	U W/m²K	EXTERIOR WALLS Type	U W/m²K	WINDOWS Type	U glass W/m²K	U Frame W/m²K	g⊥
1940	After the reinforced concrete framed structures proliferation, the brick partitions of the ventilated flat or pitched roofs now lean on unidirectional slabs. These slabs had mostly plaster joist infill blocks as a lightening between joists. 	1,67	From 1940 framed structures are begun to be used, usually of reinforced concrete, with lights of 3-4 meters. From the sixties these structures were the most common. The facade is released from its structural function, so in most cases the thickness of the facade was reduced to half a foot of solid or perforated bricks. The slabs were supported by big beams in which the factory fully rested. There was no movement joints between structural components and facades which has caused numerous cracks and fissures in the brick walls. 	3,03	Folding steel window with monolithic glass.  	5,7	5,7	0,80 - 0,85
	In the forties, the advent of lightweight concrete, allowed the introduction of an insulating body which replaced in many cases the air chambers in flat roofs. The roof becomes a single sheet multi-layer: slab, concrete slope, waterproofing and protection. 	1,37						

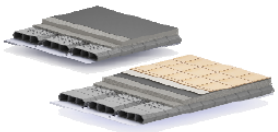
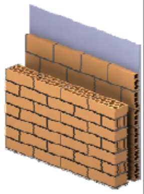
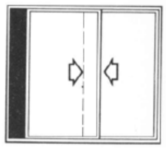
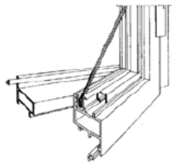
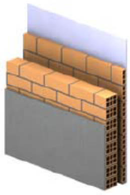
YEAR	ROOFING		EXTERIOR WALLS		WINDOWS			
	Type	U W/m²K	Type	U W/m²K	Type	U glass W/m²K	U Frame W/m²K	g⊥
1960	In the sixties, coinciding with the development of waterproofing, flat roof extends to populations with a tradition of pitched roof. The ceramic joist infill blocks take greater prominence to the time the concrete ones start to enter in the market. 	1,92	In the sixties the framed structures grow in height and raise the lights to 4-5 m. A hollow brick inner sheet is added to the existing brick wall, leaving a cavity in the middle. With the entry into force of the Standard NBE-CT-79 thermal insulating are into the air chambers. 	1,43	Aluminum sliding window with monolith glass.  	5,7	5,7	0,80 - 0,85
1980	Ventilated roofs are still used frequently. NBE-CT-79 Standard entry into force in 1979 and insulation begins to be putted in the air chambers of the ventilated roofs and under the pavement of non-ventilated roofs. 	2,33	The cheapest alternative to perforated brick was used in the outer sheet: a half foot hole brick wall covered and painted. In many buildings, combining both options. 	1,33				

Figure 51. Typical construction systems

8.2.3. Building energy systems in Spain

Multifamily blocks constructed between 1940 and 1965 do not have gas heating system. Sometimes, we can find electric radiators, installed recently. In the case of buildings constructed between 1965 and 1980, **electric radiators or gas heating system** are installed recently. The gas heating systems are usually common heating systems for each building block. The most recent buildings have gas systems with individual boilers in each dwelling.

Buildings located in the Center and South of Spain have individual cooling systems.

Many houses located in the Mediterranean area don't have any kind of heating systems.

There isn't any mechanical ventilation systems installed in any building typology.

8.2.3.1. Energy efficiency standards in Spain

The EPBD was transposed in Spain by means of three royal decrees:

One of it was the "Technical Code of Buildigns (CTE). It was approved in May of 2006 and it is divided in six "basic documents": Structural security (DB-SE); Security in case of fire (DB-SI); Security of use and accessibility (DB-SUI); Salubriousness (DB-HS); Protection against noise (DB-HR); and Energy saving (DB-HE) (CTE, 2006). Two of these documents were used as important data sources in this master thesis:

The Energy savings DB-HE document establishes the required procedures and regulations for energy savings in the building sector. It sets, for instance, the required U-values and the hot water demand for the design of the installation for the different climatic zones in the Country.

8.2.4. Type of ownership/residents

According to the Central European Bank the 83% of the Spanish residents live in a house of their own ownership. This number is much higher than the average of the 60% for the whole Europe. Moreover the 33% of the population has a mortage to pay their houses, also far beyond from the European average.

This ratio is similar for social houses, where the most of them re also built to be sell, not for renting purposes.

8.2.5. Refurbishment market in Spain

In order to fulfill the European requirements for the reduction of the greenhouse gases emissions, all the European countries should promote the energy efficient retrofitting in their building park.

In Spain, a study carried out by CONAMA (tabla 8) establishes that the total number of buildings to be renovated for the years 2020, 2030 and 2050 starting from the year 2012 should be:

Table 8. Building numbers to be renovated in Spain

2020	2030	2050
2.200.000	5.700.000	10.000.000

The target buildings for retrofitting are usually located in the city centre or in the surrounding areas of the cities. It is not usual to find it in the rural areas.

8.2.6. Conclusions for building characteristics in Spain

Main characteristics of most representative building typology in Spain for the IMIP project are multifamily blocks/Apartment blocks constructed during 1941-1980.

The insulation levels are very low and the energy performance of the building envelop is very poor in this kind of buildings.

The heating systems are electric radiators or could be central or individual gas heating systems.

8.3. Building characteristics in Portugal

In Portugal from 18th to early 20th century buildings adopted timber for roof and floor structures, and also, as reinforce of masonry walls (Branco J.M., 2009, Portuguese traditional timber structures: Survey, analysis and strengthening) or using slab mixed with concrete. These buildings are still in use although they have suffered some modifications. Great number of this traditional structures, require intervention nowadays due to deterioration. These are also the objective of the project, where IMIP panels could help to buildings rehabilitation with same material that originally were built.

8.3.1. Constructive characteristics

In Portugal, the most commonly used building solutions, especially in residential buildings, have remained practically unchanged for several years. The construction system is well-rooted and is used throughout the country, usually consisting of a porticoed structure with pillars and beams in reinforced concrete and slabs lightened. For the execution of the outer walls, a simple wall solution, also in ceramic brick, is currently used. In the Census in 2011, the Portuguese housing stock was constituted by more than 85% of buildings with only one housing unit and 84.9% of the buildings in the Portuguese housing stock were between one and two floors. These are the main aim for the IMIP panels use. With more recent construction, the proportion of buildings with one or two floors declined steadily in buildings, but remained above 75%. Although the proportion of isolated and banded buildings varied substantially in the different regions of the country, 60.5% were isolated and only had one or two housing units.

Regarding construction methods, buildings built after the 1970s constituted 63.1% of the traditional construction buildings in Portugal's existing housing stock in 2011 (Mendes, 2013, Public policies on urban rehabilitation and their effects on gentrification in Lisbon, AGIR. Revista Interdisciplinar de Ciências Sociais e Humanas, vol. 1, n.º 5, pp.200-218). Table 2 shows the typology of the houses in Portugal by the number of bedrooms, according to the Decree-Law no. 650/15, of 18 November. This decree stablishes that the dwellings are distinguished by the number of rooms they have, starting from T0 upwards. The “T” means “typology” and the number after is referring to the number of rooms of the dwelling.

In 2011, almost half of the residential buildings had reinforced concrete structures (48.6%) and roughly one-third of the buildings had masonry walls with reinforced concrete slabs (31.7%). The remaining buildings had less representative structure types such as masonry walls without reinforced concrete slabs, loose stone or adobe masonry walls and other types of structure, respectively 13.6%, 5.3%, 0.8% (Public policies on urban rehabilitation and their effects on gentrification in Lisbon, Mendes, 2013. AGIR. Revista Interdisciplinar de Ciências Sociais e Humanas, vol. 1, n.º 5, pp.200-218). The main types of construction of residential buildings in Portugal used in the structure are reinforced concrete, masonry walls with reinforced concrete deck, masonry walls without reinforced concrete deck, loose stone masonry walls, agglomerate; in exterior wall cladding are traditional coats and granolithic concrete, stone, ceramic tile or mosaic, other coatings; finally covering materials are exterior wallcovering, inclined roof covered with ceramic or concrete tiles, inclined roof covered with other materials, mixed (inclined and terrace), roof terrace. This point out that wood panels are very welcome in the Portuguese construction due to the necessity to fulfill environmental issues in buildings.

On the other hand, for insulation purposes, there is a wider number of materials used. The most used materials for insulation are Expanded Polystyrene (EPS), Extruded Polystyrene (XPS), Polyurethane foam (PUR), Polyisocyanurate foam (PIR), Mineral Wool (MW) and Expanded Insulation Corkboard (ICB) (Study of most used materials in construction sector in Portugal, OERCO2, cofounded Erasmus+ program). Due to the extended use of cork in Portugal, it appears in insulation applications also.

8.3.2. Building constructive regulations

In Portugal there is no Building Act that forms the legal basis for the building regulations and procedures, and defines of obligations and responsibilities of parties involved. The General Building Regulations1 is the main national building regulation, setting general provisions for building, regarding construction, health, safety and aesthetics. It is in force since 1951 and, although several small amendments, no fundamental revision has been approved. In addition, there are more than 45 national building regulations and other regulatory documents that focus on specific requirements. Most of these were approved in the last two decades and some of them resulted from the transposition of European Directives. In addition, there are other national regulations with construction and/or operational provisions for different types of buildings, which have to be observed to ensure that the building can be used for the intended purpose. For example, social housing, nurseries, elderly homes and stadiums have to comply with specific regulations. (The Portuguese building regulation system: A critical review, João Branco, Pedro Frits Meijer, Henk Visscher July 2009, International Journal of Law in the Built Environment 1(2):156-171. DOI: 10.1108/17561450910974759)

8.3.3. Building energy systems in Portugal

The Directive 2002/91/CE (EPBD - Energy Performance of Buildings Directive) (EPBD 2002) was the first European regulation on the energy performance of buildings. The EPBD defined the procedures in order to establish the requirements for energy performance in buildings to be followed by the member states.

To accomplish the EPBD recommendations, the Portuguese government defined as targets to increase in 40% the energy efficiency of buildings through the National Action Plan for Energy Efficiency (Resolution of the Ministers Council of n.º 80/2006), the review of the Thermal Regulations, for residential (RCCTE, Decree-Law n.º 80/2006, 4 th April) and office buildings

(RSECE, Decree-Law nº 79/2006, 4 th April), and through the introduction of the National System for Energy and Indoor Air Quality Certification of Buildings (SCE, Decree-Law nº 78/2006, 4th April) (PORTUGAL & RCCTE & RSECE & SCE, 2006).

Buildings Energy Certification System (SCE) is mandatory, as of January 1, 2009, in all, new or existing, residential and service buildings. After 10 years and around 1.250.000 certificates issued, as demonstrated by the application of the three calculation methodologies that SCE had adopted over the years, the main energy efficiency indicators have changed without coherence, although energy consumption should remain unchanged. Results showed that a certificate issued in 2009 had a final energy consumption 37% higher than the same building certified in 2013 which, in turn, are 52% lower than those resulting from the methodology to be applied since 2016. A similar situation occurred for primary energy, but CO2 emissions quadrupled, clearly offsetting the reduction of primary energy. Finally, with the accounting for the share of renewable energy from heat pump equipment, the renewable energy contribution has gone, from Roadmap 2013 to 2016, from 36% to 74%. (6th International Conference on Energy and Environment Research, ICEER 2019, 22–25 July, University of Aveiro, Portugal Buildings Energy Certification System in Portugal: Ten years later Petra Vaquero).

The energy rehabilitation appears as an opportunity to upgrade the existing building stock increasing their energy efficiency, comfort conditions and market value. The energy rehabilitation of the Portuguese residential buildings would allow addressing residential buildings and social problems and also the energy dependency of the country. The rehabilitation would bring back to the market, unoccupied or energy inefficient buildings, increasing also its real-estate value.

In response to social needs, the investment on rehabilitation would contribute to increase the quality of life of the residents. The reduction of the energy consumptions, that might be achieved if it incorporates wood and cork insulation products as IMIP panels, would be economically advantageous and would contribute to create new job opportunities in wood industry. Furthermore, wood energy rehabilitation would also ensure the sustainability of the building stock. It is necessary to make a good use of the existing energy resources, taking into account the life cycle of each building in the decision making process and wood products have a relevant position there.

Notwithstanding the positive effects for the society, the rehabilitation in general and the energy rehabilitation of buildings in particular, had not yet a significant role in the Portuguese construction market. The absence of a widespread awareness about the subject is perhaps one of the most important difficulties to its promotion.

Other of the reason for the lack of investment in the wood rehabilitation is the lack of specialized workmanship in the sector. Frequently, technicians are not aware of the technical solutions available on the market and of the benefits of undertaking energy rehabilitation using wood panels. About 40% of the anomalies in building are due to design defects and to wrong selection of technical solutions (Hausmannian Buildings Rehabilitation and Strengthening, Silva R, Paiva A, Goncalver JC, Pinto J, 2020, International Congress on Engineering).

8.3.4. Rehabilitation market

For decades, there was an almost absence of interventions and investments in the rehabilitation of the Portuguese building stock, particularly when compared with similar European countries (IHRU, Urban Rehabilitation Institute, 2004). This is the main reason for the current poor state of repair of a significant part of the Portuguese buildings. In average the most recent buildings in Portugal were located in Autonomous Region of Madeira with an average of 32.33 years old, while the Autonomous Region of Azores had in average the older buildings with 34.26 years old. The buildings in Continental Portuguese territory had an average of 33.95 years old (Statistics Portugal, INE 2010).

There were multiple factors that led to such situation. It is recognized by many actors in the construction sector that the rehabilitation of the residential building stock is needed but require of public policies support it.

In 2001, 38% of the building stock needed some kind of repair, and 3% of the buildings were extremely degraded (INE 2010). The majority of the rehabilitation interventions needed refers to the exterior envelope of the buildings, specially the window frames. About 47% of the residential buildings needed rehabilitation works in its facade. The second major retrofit interventions were needed in building roofs (representing in 2001 about 40%). In 2010, 79% of the classic familiar residential buildings did not have any kind of thermal insulation in the exterior walls and about 89% did not had any kind of insulation in the roof. (INE & DGGE 2011 and Energy rehabilitation of Portuguese residential building stock through its transformation into NZEB, Joana Sousa, Sandra Silva, Manuela Almeida, 2012). Therefore, this can be a unique opportunity to correct past mistakes and to incorporate wood products eco-friendly and energy efficiency as IMIP panels.

8.3.5. Conclusions for building characteristics in Portugal

Most of buildings in Portugal are old and suffer lack of maintenance. These characteristics open great opportunities to the introduction of wood products in rehabilitation, as IMIP panels in several uses: roofs, walls, facades.

It is necessary the support of public policies oriented to extend timber. As cork is a product very well extended in Portugal, its supply to IMIP panels is more feasible than in Spain or France market.

9. FINAL CONCLUSION

Most of the usual construction systems are compatibles with the IMIP purpose, since wood panels have several applications: walls, floor, roof and mixed systems. They are summarized in this report.

It is also important to keep in mind that in a sustainable and energy-efficient construction system for the public and private sectors, wood is one of the most important raw material, has many advantages over the materials made from non-renewable resources. Wood is renewable, recyclable and it can be used as bioenergy at the end of its life cycle. With carbon captured in the wood, the products offer a truly sustainable means of combating climate change.

The main users of wood engineering products are mainly construction and joinery companies, merchandisers and retailers. Wood Products operates globally in Europe and the IMIP product will be incorporated to that market.

They must always comply with local laws and regulations and at the same time should help us have a positive impact on people and the communities they live in beyond the local level.

CLT, one component of IMIP product, is extremely versatile and can be fully combined with other building materials. Thanks to its load distribution properties in two directions, CLT presents no limitations to architectural, residential or utility building projects. For this reason, it is becoming increasingly used for the construction of houses and apartment buildings, as well as for industrial and commercial buildings. As a high-quality structural material with an enormous load-bearing capacity, CLT is becoming popular for the construction, and it is optimums for facades systems, vertical structural systems.

On the other hand, a combination of frame cage and ribs seems to better optimize the use of wood than the CLT system alone, so that is the base of IMIP product development.

As a final conclusion it is possible to affirm that a proper combination between CLT-PLATFORM FRAMES – SIP SYSTEMS, obtained for be used in described systems, will contribute to the better benefits for a different construction option. So, a system that can be compatible with these systems can be successful.

ANNEX I

WATCHING EXISTING PATENTS

This technological watch consisted in identifying patents relating to wood-based insulating sandwich panels, in particular maritime pine or cork.

This information search was carried out internationally and on the following sources:

- ✓ **Derwent Innovation** (international patent database)
- ✓ **Lens** (more than 208 million scientific articles and nearly 118 million patents)

The queries were conducted with the following key expressions:

- insulated sandwich panel, structural insulated panel
- cork
- maritime pine, Pinus pinaster

The research was carried out over the **2000-2020** time-period and at the world global level.

This produced the following results:

- for the expression "insulated sandwich panel":
  - single expression => 928
  - expression coupled with the term “wood” => 69
  - expression coupled with the terms “cork” or “pine” => 5
- for the expression "structural insulated panel":
  - single expression => 1726
  - expression coupled with the term “wood” => 97
  - expression coupled with the terms “cork” or “pine” => 16

We note that as soon as we look for patents that involve wood for this type of technology, there are few results (a little more than 150 families over a period of 20 years), the few most interesting examples of which are listed in the following section 2.1.

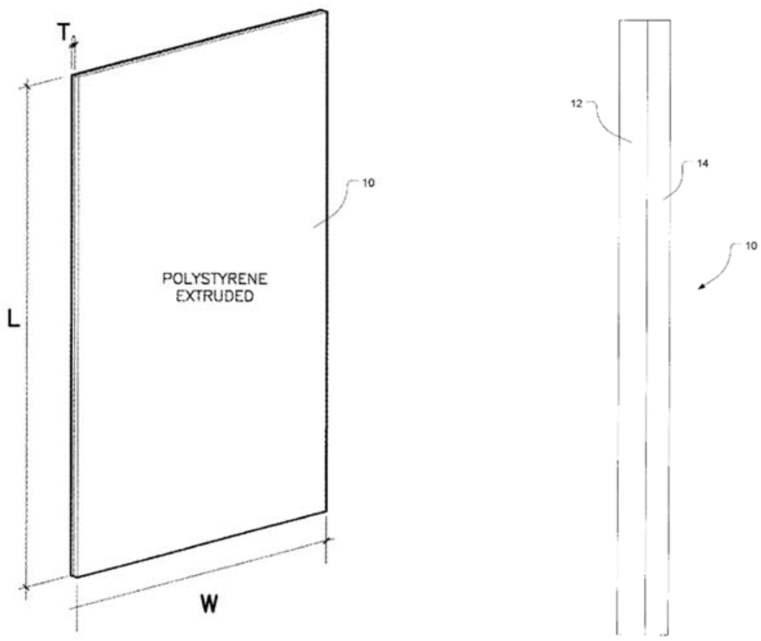
Regarding patents involving cork or maritime pine, the number of results is even lower, since we obtain about 20 patent families over 20 years, of which only 2 families were retained in section 2.2. next.

A.1. Patents for insulating sandwich panels comprising wood

A.1.1. Insulated panel

Inventor: BOSSE, FRANCIS **Assignee**: BUILDING PRODUCTS OF CANADA CORP./LA CIE MATERIAUX DE CONSTRUCTION BP CANADA,LASALLE,Q1,CA	**Priority**: CA2972755A - 10/07/2017 **Application**: CA2972755A - 10/07/2017 **Publication date**: 10/01/2019
Fampat family CA2972755A1	

A structural insulated panel (figure 52) includes an extruded polystyrene layer that is impermeable to both water and air and a wood-based panel to which the extruded polystyrene is attached. The insulated panel may be made of extruded polystyrene layer that is 11/16 inch thick and fibreboard of a thickness of 1/2 inch. The panel is reversible so as to be installable either with the extruded polystyrene panel facing outward or inward.



Pertinence : neutre
Constituants :

12 = EPS
14 = fiberboard or plywood or OSB

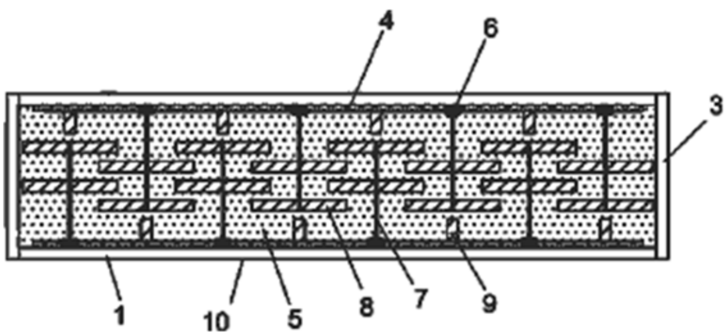
Figure 52. Structural insulated panel

A.1.2. Light wood structure without heat bridge sandwich panel

Inventor: 张延年 | 杨森 | ZHANG, Yan-nian | YANG, Sen **Assignee**: 沈阳建筑大学,沈阳市,辽宁省,110168,CN | Shenyang Jianzhu University,Shenyang,Liaoning,110168,CN	**Priority**: CN201810123085A - 07/02/2018 **Application**: CN201810123085A - 07/02/2018 **Publication date**: 19/06/2018

Reference : CN108179838A

This invention claims a light wood structure without heat bridge sandwich board, belonging to the technical field of building (figure 53). Light wood structure without heat bridge sandwich board is provided with a light metal plate, the light metal plate is uniformly distributed with anchoring frame, two inner longitudinal wood wall bone column on the same anchoring with it form a soil shape; of the adjacent anchoring on the two ends of the light metal plate on the longitudinal wood wall bone column are arranged in interlaced structure design, not only can effectively cut off the bridge and the wall heat preservation performance, and can obviously improve the integrity and strength of the wallboard, anchoring the light metal plate, inner longitudinal wood wall bone column is fixed. it can effectively prevent wall integrally sliding or deformation occurs easily when the bearer. The invention has small weight and obviously simplify installation and operation, fast assembling speed, can use the product assembly, reduces a lot of field work, high industrialization degree and avoids the environment pollution.



Pertinence : +

Constituants : 10 = OSB

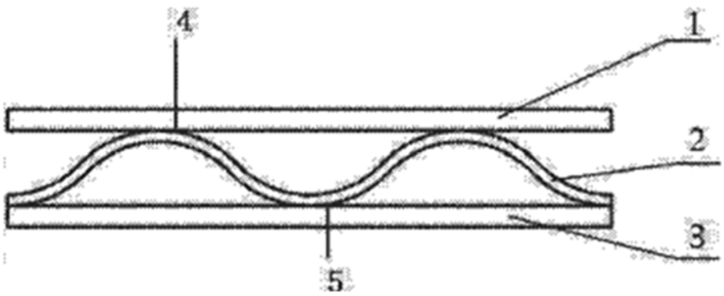
Figure 53. Light wood structure

A.1.3. A sandwich plate based on fast-growing wood veneer and manufacturing method and application thereof

Inventor: 张海洋 | 卢晓宁 | 何倩 | 洪璐 | 韩书广 | 崔举庆 | ZHANG, Hai-yang | LU, Xiao-ning | HE, Qian | HONG, Lu | HAN, Shu-guang | CUI, Ju-qing **Assignee**: 南京林业大学,南京市,江苏省,210037,CN | Nanjing Forestry University,Nanjing,Jiangsu,210037,CN	**Priority**: CN201710846516A - 18/09/2017 **Application**: CN201710846516A - 18/09/2017 **Publication date**: 08/12/2017

Reference : CN107443496A

The invention claims a fast-growing wood veneer-based sandwich plate and manufacturing method and application thereof, belonging to the preparation field of wood structure. the structure comprises a surface layer (1), sandwich layer (2) and back layer (3), the core layer (1) is at least one wavy veneer obtained by curved surface mould, said surface layer (1) and the back layer (3) is veneer. the core layer (2) is located between the surface layer (1) and a back layer (3), the core layer (2) textured surface with the surface layer (1) on the surface of the texture, a back layer (3) is parallel to surface of the texture, the core layer (2) of the convex surface (4) and concave surface (5) are respectively connected with the inner surface; the inner surface of the back layer. sandwich plate has good heat insulation performance, large intensity rigidity, low integral density, exponentially improves the efficiency of fast growing wood, but also guarantees the performance as wood structured roof panel (figure 54).



Pertinence : neutre

Constituants : 2 = corrugated plywood

Figure 54. Sandwich plate

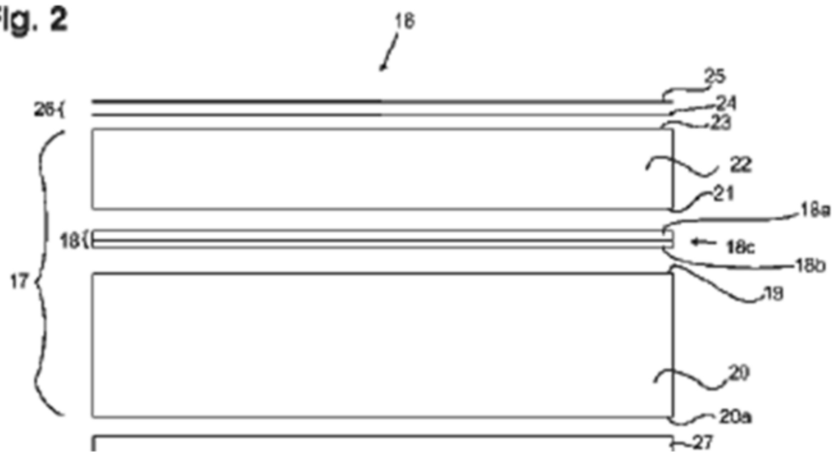
A.1.4. Method for producing a sandwich panel

Inventor: BRAUN, ROGER **Assignee**: FLOORING TECHNOLOGIES LTD.,RICASOLI,MT	**Priority**: EP2011171652A | WO2012EP61845A - 23/11/2020 **Application**: CA2840005A - 20/06/2012 **Publication date**: 26/09/2017

Refercence : CA2840005C

The invention relates to a method for producing a panel sandwich 17 for use as a wall, ceiling or floor panel 16, having at least the following steps: supplying a basic panel 20 made of wood-based material, arranging a sound-insulating layer 18 above the basic panel 20, arranging a cover panel 22 above the basic panel 20 and above the sound-insulating layer 18, and pressing the sandwich, preferably in a press (figure 55). In order to supply a panel sandwich 2 which has a particularly permanently active sound-insulating layer 18, is particularly cost-effective and can be integrated particularly straightforwardly into conventional processes for producing panel sandwiches 2 and panel structures 1. It is provided that use is made of an elastic plastics material for producing the sound-insulating layer 18, wherein, according to a first alternative of the invention. The elastic plastics material provided is a closed-cell foam or, according to a second alternative of the invention. The elastic plastics material applied is a self-adhesive plastics material 18c, which connects the basic panel 20 to the cover panel 22, is elastic when set and has a minimum thickness of 0.3 mm.

Fig. 2



Pertinence : +

Constituants : 20 = MDF; 22 = HDF; 27 = polyurethane or wood fiber board or cork

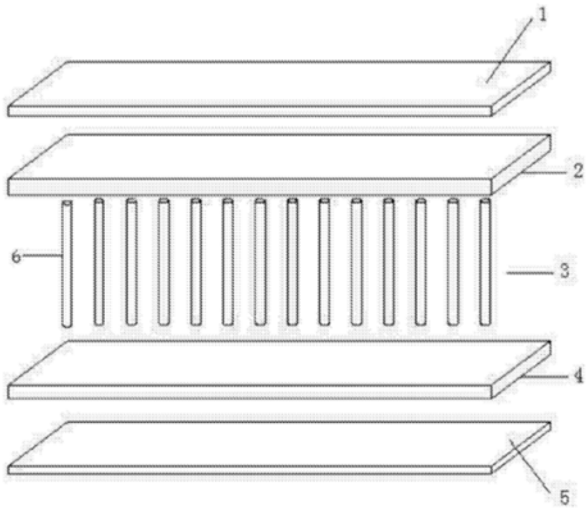
Figure 55. Panel constitution

A.1.5. A wood-based insulation, energy-absorbing multilayer lattice sandwich structure and preparation method thereof

Inventor: 赵鑫 | 胡英成 | 王雪 | 赵依威 | ZHAO, Xin | HU, Ying-cheng | WANG, Xue | ZHAO, Yi-wei **Assignee**: 东北林业大学,哈尔滨市,黑龙江省,150040,CN | Northeast Forestry University,Harbin,Heilongjiang,CN	**Priority**: CN201610512328A - 04/07/2016 **Application**: CN201610512328A - 04/07/2016 **Publication date**: 23/11/2016

Reference: CN106142727A

The invention claims a wood-based insulation, energy-absorbing multilayer lattice sandwich structure and preparation method thereof. the structure is composed of an upper panel (1), resin layer (2), a foam insulating layer (3), a lower resin layer (4) and lower panel (5) and a core rod (6) (figure 56). The preparation method specifically comprises the following steps: a, preparing resin absorbing; secondly, preparing foam insulating plate, three, preparing lattice sandwich structure core layer, four, preparing lattice sandwich structure. The invention solves the problem that artificial plate as wood engineering material strength is not enough, the problem of single performance, improving the capability of the existing wood substrate lattice sandwich structure panels and core cutting performance.



Pertinence : neutre

Constituants :1 = particle board , OSB Or plywood; 5 = MDF; 6 = red pine

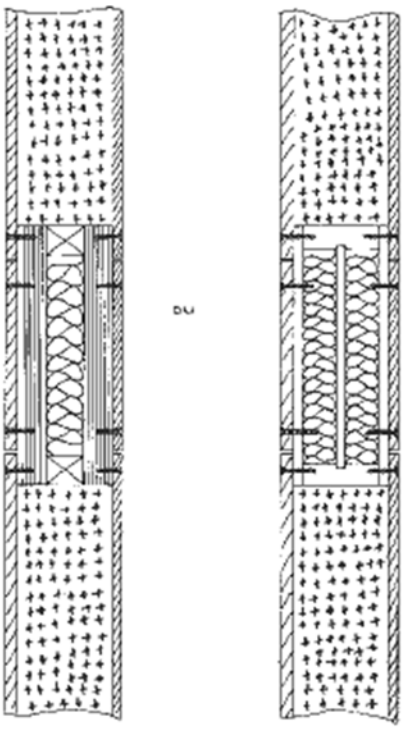
Figure 56. Wood base insulation

A.1.6. Prefactory self-supporting panels pre-drilled for construction, insulated. Self-supporting structural panels.

Inventor: LEGRAND, DAVID **Assignee**: LEGRAND DAVID,HOUDAIN,FR	**Priority**: FR20131948A - 19/08/2013 **Application**: FR20131948A - 19/08/2013 **Publication date**: 20/02/2015

Reference: FR3009730A1

The invention relates to a device for implementing a construction without risk of error (figure 57). The system consists of a pre-factory and pre-drilled sandwich type panel as well as different wood profiles to facilitate installation without worry or risk of installation error. It suffices to place a wood to guide the installation of the panel, the connection between two panels is also made by a profiled wood in order to respect the implementation of the connection in the rules of the art. The angles are made using a specially machined panel. We finish the work with a belt wood.



Pertinence : +

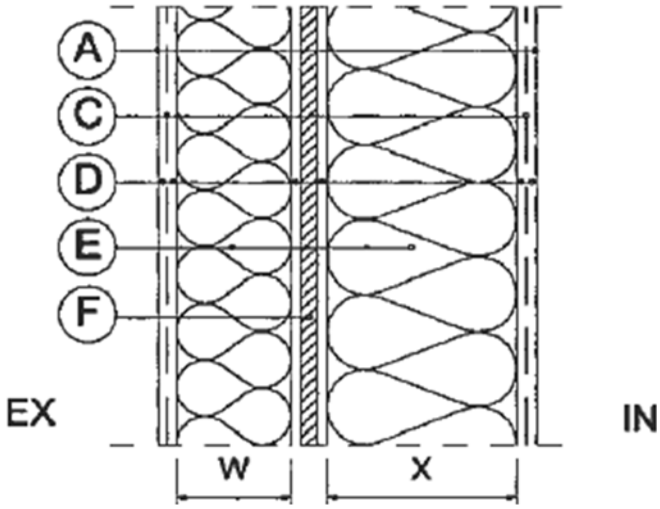
Figure 57. Self supporting panels

A.1.7. Insulated multilayer sandwich panel

Inventor: Silvestri, Massimo **Assignee**: Silvestri & associati-Studio Tecnico,24044 Dalmine (BG),IT,101180573	**Priority**: IT2009BG13U | IT2009BG12U - 23/11/2020 **Application**: EP20105385A - 24/05/2010 **Publication date**: 24/04/2013

Reference: EP2256265B1

A multilayer insulated sandwich panel characterised by comprising: an intermediate bulk layer (F); a first wood fibre insulation (F) associated with at least one of the two sides of said bulk layer (F); a metal sheet (A) associated with said wood fibre insulation (E) on the opposite side to said bulk layer (F) (figure 58).



Pertinence: neutre

Constituants: E = wood fibers with a density of 170-190 kg / m3 and a heat capacity of about 2.1 kJ / kg K

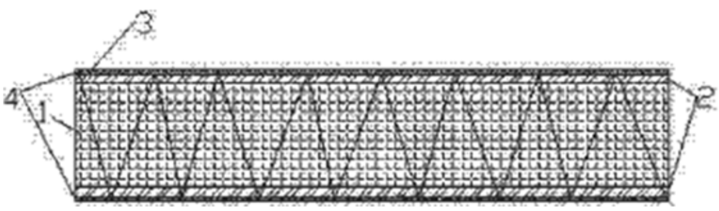
Figure 58. Insulated multilayer sandwich panel

A.1.8. A composite sandwich board

Inventor: 蔣泽锋 | JIANG, Ze-feng **Assignee**: 昆山乔锐金属制品有限公司,苏州市,215313,CN | Kunshan Qiaorui Metal Products Co. Ltd.,Suzhou,Jiangsu,215313,CN	**Priority**: CN201210283010A - 10/08/2012 **Application**: CN201210283010A - 10/08/2012 **Publication date**: 14/11/2012

Reference: CN102777025A

The invention claims a composite sandwich board, comprising a middle soft layer, the upper layer and the lower layer of the hard wood board layer, the soft layer comprises a plastic foam and mineral wool, the hard board layer comprises wood, birch and sandalwood, wherein the hard wood board layer and the soft layer is connected with the hard board layer is coated on the surface with a layer of lubricating resin passes through steel wire. It is made of pure natural wood board of main body board, there is no pollution, and has special smell of tree, and the middle is filled mineral wool has good sound insulation effect, and not easy to corrosion, damage, has long service life, the surface layer is coated with a lubricating resin, comfortable hand feeling, besides, the omni-directional steel wire is inserted to make the composite sandwich board structure (figure 59).



Pertinence : +

Constituants :

1. Soft layer = mousse plastique et laine minérale
2. Hard wood layer = oak, birch and sandalwood
3. Steel wire
4. Lubricating resin.

Figure 59. Composite sandwich board

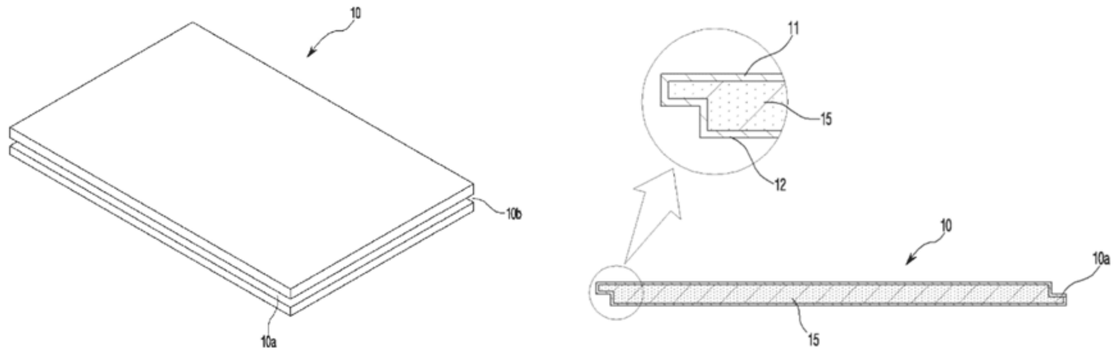
A.2. Patents for insulating sandwich panels comprising cork or maritime pine.

A.2.1. Sandwich panel using carbonized cork

Inventor: 김수봉 | KIM, SOO BONG **Assignee**: 아이에스포르토 주식회사,KR | IS PORTO CO. LTD.,KR	**Priority**: KR201729357A - 03/08/2017 **Application**: KR201729357A - 08/03/2017 **Publication date**: 16/11/2017

Reference: KR1798096B1

The present invention relates to a sandwich panel used mainly for constructing an outer wall of a building, and more specifically, an eco-friendly carbonized cork insulation material is combined instead of a steel foam insulation material which causes various problems in the event of fire between metal panels, so the sandwich panel is lighter than a conventional sandwich panel, is easily handled, has excellent insulation, soundproofing, sound absorbing effects, prevents a building from being collapsed due to melting by heat like a styrofoam insulation material, and can minimize damage due to accidents by preventing various toxic gas, thereby providing improved safety of use. COPYRIGHT KIPO 2017 (figure 60).



Pertinence: ++

Constituants: **15 = blackcork**

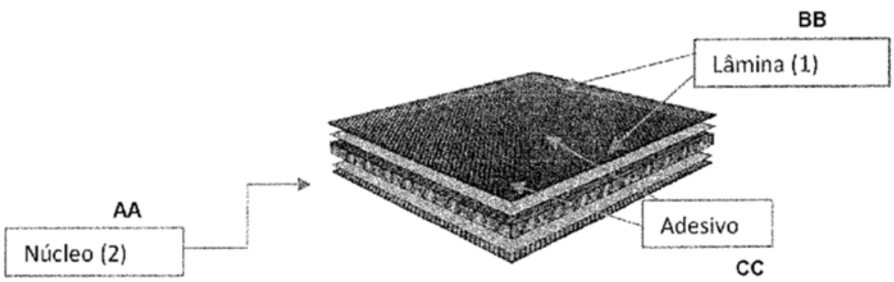
Figure 60. Sandwich panel using carbonized cork

A.2.2. SELF-COATING FIBER PANEL WITH CORK AGGLOMERATED CORE

Inventor: LUIS MIGUEL PLÁ DE MAGALHÃES VILLAR | BRUNO FERREIRA MARTINS | MIGUEL BELTRÃO RIBEIRO FERREIRA | ALEXANDRE BOUDRY DE CARVALHO MAGALHÃES MEXIA **Assignee**: BMM BLOCO MULTIMODULAR SIST DE EDIFICAÇÃO LDA	**Priority**: PT107851A - 21/08/2014 **Application**: PT107851A - 21/08/2014 **Publication date**: 22/07/2016
Fampat family PT107851A | PT107851B | WO2016028179A1	

Reference: PT107851A

The present invention relates to composite panels comprising at least three layers: a thicker layer of a low-density material, the core (2), which is coated with two thin outer layers, the sheets (1), which have a higher density than the core (2). The core (2) is united to the layers (1) by adherence, both by adhesion (of a chemical nature) and by friction (of a physical nature). The sheets (1) are formed by a combination of a thermally hardenable epoxide resin matrix impregnated into one or more fibre glass nettings. The core (2) is formed by a cork agglomerate, which is a product characterised by its low density, considerable stiffness and cut resistance, good thermal insulation and good acoustic insulation. As a result of the combination of the materials used, the present invention provides a light-weight construction panel which makes it possible to build self-bearing walls for building floors having the usual ceiling height, with mechanical characteristics that enable the panel to be used in walls and roofs of buildings, with satisfactory properties when subjected to external influences such as impacts, moisture and fire (figure 61).



Pertinence : +

Constituants :1 = plaques de résine époxy
2 = low density agglomerated cork (thickness 80mm, density: 105-125 kg / m3, thermal conductivity: 0.040 W / mK)

Figure 61. Self- coating fiber with agglomerated cork

PARTNERS

ASSOCIATED PARTNERS