Interreg Sudoe

EUROPEAN UNION

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

European Regional Development Fund

WP2 Activity 2.1.1. Descriptive report on interconnected modules.

IMIP-SOE3/P3/E0963
Project funded by the Interreg Sudoe programme through the European Regional Development Funds (ERDF)

IMIP_
Interlocking Modular Insulation Panels

Interreg Sudoe
European Regional Development Fund

PROJECT CONTEXT

Project acronym	IMIP
Project title	Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels
Project code	SOE3/P3/E0963
Coordinator	Universitat Politècnica de València (UPV), Instituto ITACA
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Technical Report	GT.2 D 2.1.1.
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WP Leader	UPV
Activity coordinator	UPV
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IMIP_
Interlocking Modular Insulation Panels

Interreg Sudoe

PARTNERS

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IMIP
Interlocking Modular Insulation Panels

Interreg Sudoe

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IMIP-SOE3/P3/E0963

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INTRODUCTION

The work is contemplated in the IMIP project of the INTERREG SUDOE Program, within Working Group 2: GT2 Design and manufacture of interconnected modules.

This report focuses on the design and manufacture of interconnected modules. It studies the IMIP integral construction systems as well as the single construction elements that use cork and wood as renewable and autochthonous raw materials in the SUDOE region.

Thus, the purpose of this report is to describe the designed and manufactured interlocking panels for private and public buildings, and its technical description.

The study is carried out within the scope of the Interreg SUDOE territories: Portugal, France and Spain.

Table 1: Programme and Project objectives and results.

Programme specific objective	To improve energy efficiency policies in public buildings and homes through the implementation of networks and joint experimentation.
Project main objective	To support the change towards a low carbon economy using bioproducts (wood and cork) for smart, sustainable, and inclusive growth with a special focus on the public construction sector.
Project specific objectives	To design, validate and implement a new ecological construction system to improve energy efficiency in public buildings. Related activities are: - To design an ecological construction system based on innovative wood and cork products supporting a low carbon economy, - To test prototypes, - To develop an Information and Communication Technology for design, modelling, and evaluation of potential construction solutions, - To compare the modular and interconnected insulating panels designed with currently used insulating panels, - To disseminate results and to train prescribers.
Programme result indicator	Percentage of actors in the energy efficiency sector participating in transnational cooperation projects.
Project results	An interconnected modular system of insulating panels made of wood and cork to improve energy efficiency of buildings, including their entire life cycle. A BIM plug-in to analyse the environmental benefits of bioproducts used in construction (carbon storage and substitute effect).

OBJECTIVES

The main objective of this report consists of describing and analysing the prefabricated and interconnected modules developed in the IMIP project.

To achieve this objective, the technical and specific characteristics of each panel and the construction systems are detailed, as well as the potential uses of each of them.

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PRINCIPLES

The main goal of the IMIP project is to design an innovative eco-construction system based on interlocking modular insulation wood & cork-based panels, and verify the feasibility of the designed materials, element and const5uction solutions both in interventions on public and private buildings as well as in new constructions like rehabilitation or expansion of buildings.

This project focuses on advancing in solutions that help make a transition towards sustainability in a sector with as much environmental impact as the construction one, generating technical, environmental and socio-economic benefits for smart, sustainable and inclusive growth, through the implementation of networks and experimentation joint.

PARTNERS

ASSOCIATED PARTNERS

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IMIP Panels & Systems

The IMIP panels designed and manufactured are:

IMIP CLT

IMIP CLT composite

The IMIP systems designed, manufactured and put in the constructive pilot actions are:

Type A

Type B

Type C

Type D

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IMIP Panels

IMIP CLT

IMIP CLT (Cross Laminate Timber) boards are based on the use of low-resistance, fast-growing wood from Spain, Portugal and southern France. After carrying out an exhaustive study of the forest resources available in this region, it was concluded that the best option was to use Maritime Pine (*Pinus pinaster*) wood. This type of wood has been used for the manufacture of transport pallets due to its characteristic of fast growth and what was supposed to be a low structural resistance.

Due to technological advances and the possibility of improve it with greater technical and resistant capacity through the industrial manufacturing process of CLT, it was decided to make the IMIP products and systems through a value-added process through industrial transformation.

The designed IMIP CLT, has different configurations and thicknesses, all of them start from the base of 20mm thick wooden planks, the standard type being that of 5 layers and a total thickness of 100mm. The most novel contribution in this CLT is the use of the Maritime Pine, being a fast-growing pine widespread in the south of France and in the Iberian Peninsula.

The type of wood used in the project for the defined structural elements will be coniferous wood C18, following EN 338.

Type D		
Height [m]	P [kN]	
Material	C16	C18
2.5	45.3	49.0
3.0	29.2	32.1
3.5	17.1	20.8
4.0	8.8	10.7
-Material: C16/C18 -Panel orientation in the perpendicular direction of the load -Loads considered: Wind 1kN/m² and eccentricity of 2cm -In graphs live load per meter of width [kN/m] -Vibrations not considered		

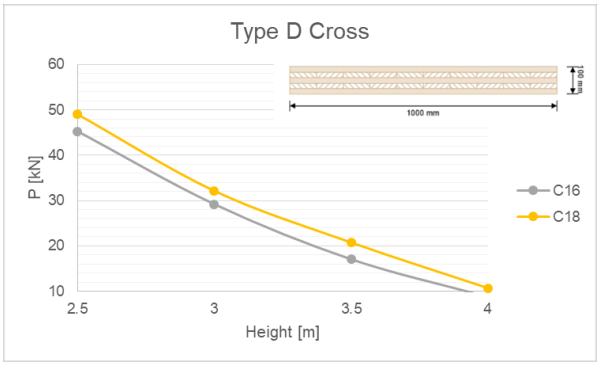

Fig.1 Type D for Deck and Walls.

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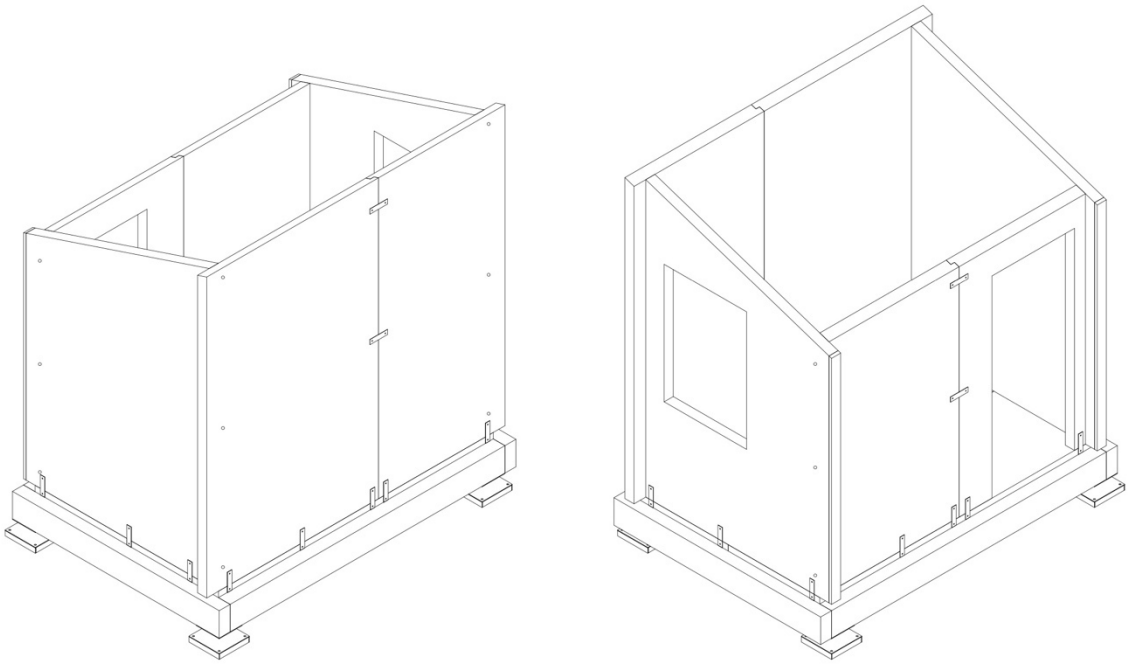


Fig.3 and 4. Walls panels from Portugal pilot action in new construction (Interconnected system panels).

Fig.5 and 6. IMIP Deck panels for rehabilitation, Espadilla pilot action.

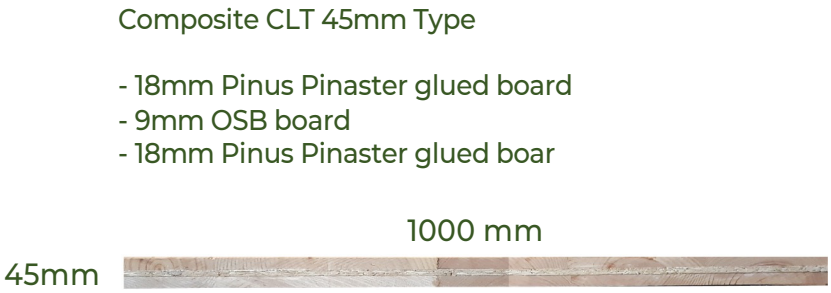
IMIP CLT composite

IMIP CLT of 45mm composite is formed by 2 layers of 15mm Pinus pinaster glued board + OBS layer of 9mm with a total thickness of 45mm.
Given that the use of the construction is a building structure and as a part of a (SIP) systems for partitions and small covering, it is considered a design working life of 50 years.

The type of wood used in the project for the defined structural elements will be Coniferous wood (Pinus Pinaster) C16 and C18, following EN 338.

The OSB panel is type 3 comply with standard NF EN 15804:2012

Type		
Span [m]	qv [kN/m2]	
Material	C16	C18
1	9,05	10,2
1.5	2,45	2,75
2	0,8	0,95
2.5	0,25	0,3
-Material: C16/C18 -Deformation L/300 -Loads considered: PP -In graphs live load per meter of width [kN/m] -Vibrations not considered		



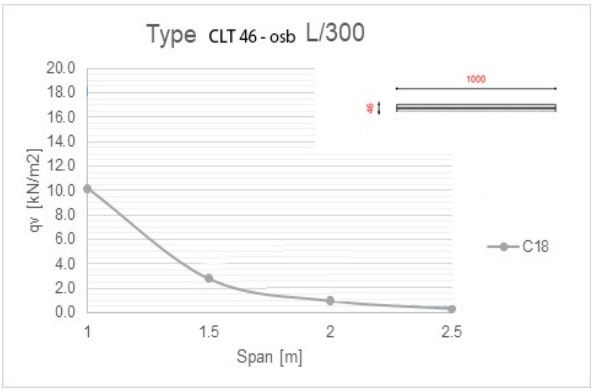


Fig.7 CLT composite 45mm technical specifications.

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Fig. 8 and 9. Composite 45mm fabrication system.

Configuration Table

This table shows all different types of IMIP panels, and the configuration of all the IMIP details based on the initial panels and the possible combination among them.
The base of most of them is is timber of *Pinus Pinaster* and natural cork for type A and type B details, in different thickness and combinations. For detail type A and type C the material employed is *Pinus Uncinata* and natural cork.

Product	type	IVE code	Composition mm				Width mm	Length mm	Pilot Action
Slab	C	EEFM.4$	CLT 60	Cork + ribs 200	CLT 60	tot 320	1200	6000	Valencia, Portugal
Cover Salb	A	EEFM.5$	CLT 60	Cork 100 + ribs 200	OSB 18	278	1200	6000	Valencia
Enclosure Wall	D	EEMM.8$	CLT 100	Cork 100		200	2400	5500	Valencia, Portugal Espadilla
Structural Insulated Panels SIP	B	EFPM.4a	CLT-OSB 45	Cork 100	CLT-OSB 45	190	1000	2000	Portugal

	mm	Number of layers	Layer Thickness Mm
CLT	45	3	18+9+18
	60	3	20
	100	5	20
	120	6	20
	140	7	20
Cork	60		
	80		
	100		
	110		
	120		
	140		

Table 1. Table of panel specifications, details and configurations.

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IMIP Systems and Details

Type A

Type A panel is a combination of CLT) using *Pinus uncinata* timber starting from the base of 20mm thick wooden planks, the standard type being that of 3 layers and a total thickness of CLT 60mm, and 80x200mm ribs. The boxes are filled by natural cork as insulation material.
The regular dimensions of the panel are 1,200mm x 6,000mm by 260mm edge, but the final length can be adjustable according to needs or requirements.

Definition and characteristics of coniferous sawn wood defined in the UNE-EN 338:

Properties	C16	C18
Charasteristic strenght N/mm^2		
Bending strength f_{mk}	16	18
Tensile strength along the grain $f_{t,0,k}$	10	11
Tensile strength perpendicular to the grain $f_{t,90,k}$	0.4	0.4
Compressive strength along the grain $f_{c,0,k}$	17	18
Compressive strength perpendicular to grain $f_{c,90,k}$	2.2	2.2
Shear strength $f_{v,k}$	3.2	3.4
Stiffness kN/mm^2		
Mean value of modulus of elasticity $E_{0,mean}$	8	9
Fifth percentile value of modulus of elasticity $E_{0.05,k}$	5.4	6.0
Mean value of modulus of elasticity perpendicular $E_{90,mean}$	0.27	0.30
Shear modulus G_{mean}	0.50	0.56
Density Kg/m^3		
Characteristic density ρ_k	310	320
Mean density ρ_{mean}	370	380

L/300

Type A		
Span [m]	qv [kN/m2]	
Material	C16	C18
2	24.2	25.8
3	15.3	16.4
4	9.0	10.4
5	3.9	4.6
6	1.5	2.0
7	0.3	0.6
-Material: C16/C18 -Deformation L/300 -Loads considered: PP+1kN/m^2 -In graphs live load per meter of width [kN/m] -Vibrations not considered		

Type A (Slab):

- CLT **60 mm**
- 200mm ribs & granulated cork

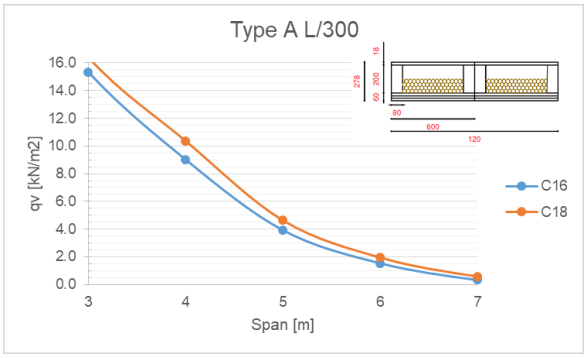

Fig. 11 Type A Deck, technical specifications.

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Fig. 11 . Type A manufacturing and installation

Fig. 12. Type A (Valencia pilot action)

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Type B

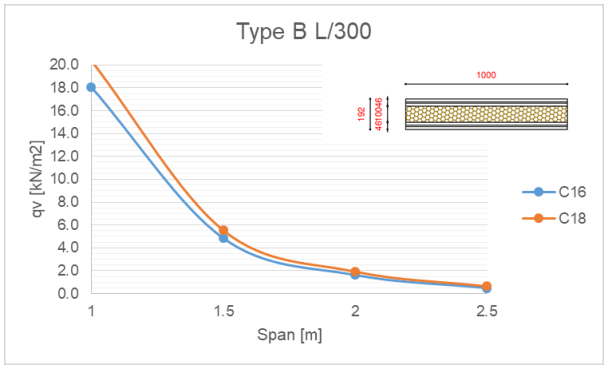
The IMIP type B is a special SIP (Structural Insulated Panel) formed by an IMIP CLT composite of 45mm (2 layers of 18mm + oriented strand board layer of 9mm) + insulation (100 - 150mm natural cork) + CLT composite 45mm. The total thickness is 190 to 240mm.
The regular dimensions of the panel are 1,000mm x 2,500mm, but the final length can be adjustable according to needs or requirements.

The material used is the *Pinus pinaster* C16 - C18, natural Cork (E=5MPa) and OSB 3.

This system is used as a partitions or small deck and covering.
It is the principal IMIP tested type on Portugal pilot action.

L/300

Type B		
Span [m]	qv [kN/m2]	
Material	C16	C18
1	18.1	20.4
1.5	4.9	5.5
2	1.6	1.9
2.5	0.5	0.6
-Material: C16/C18 -Deformation L/300 -Loads considered: PP -In graphs live load per meter of width [kN/m] -Vibrations not considered		



Type B (Roof):

- Composite CLT **45 mm**
- 100mm Black cork board
- Composite CLT **45 mm**

Fig. 13. Type B, SIP; deck and partitions. Technical specifications.

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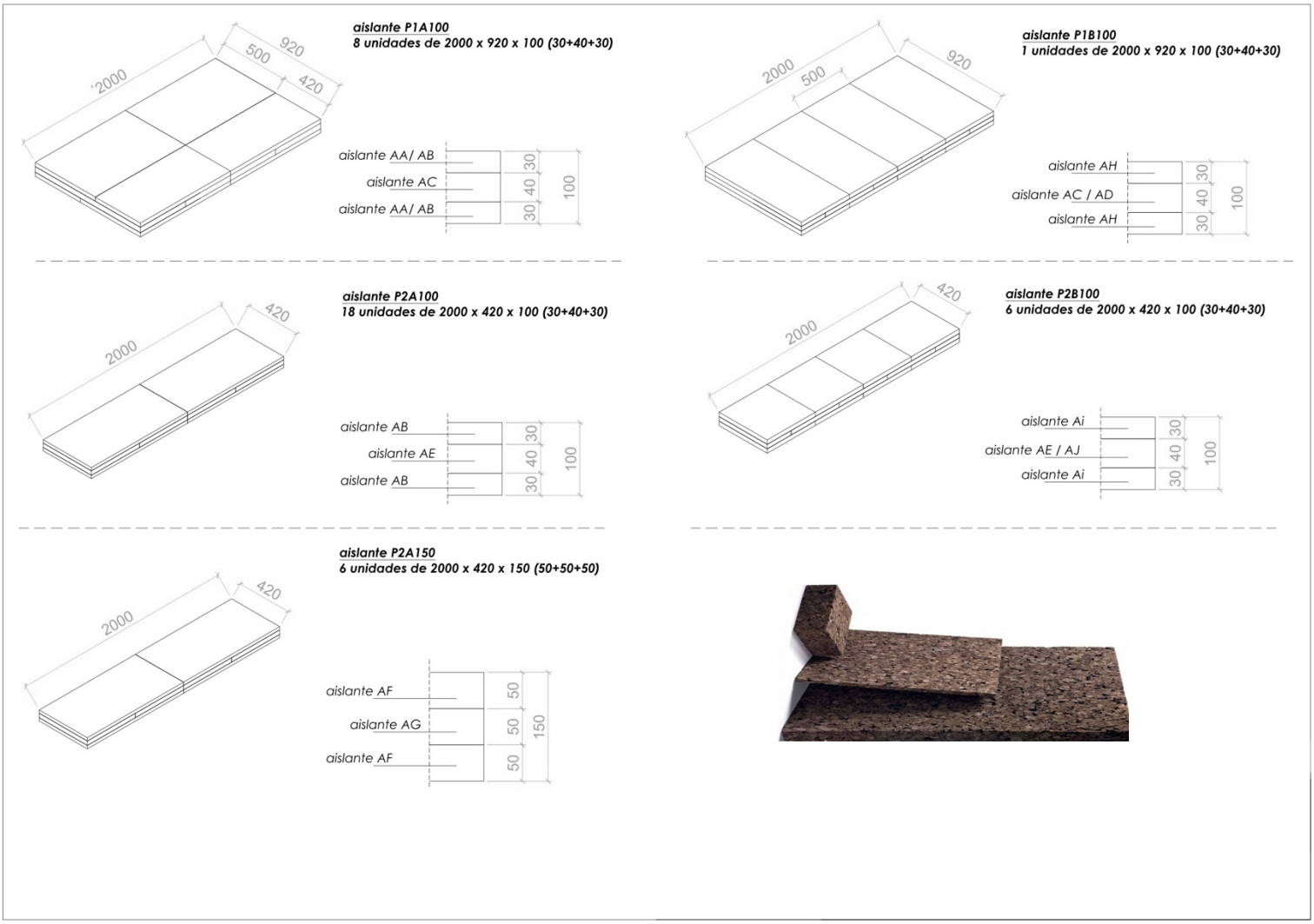
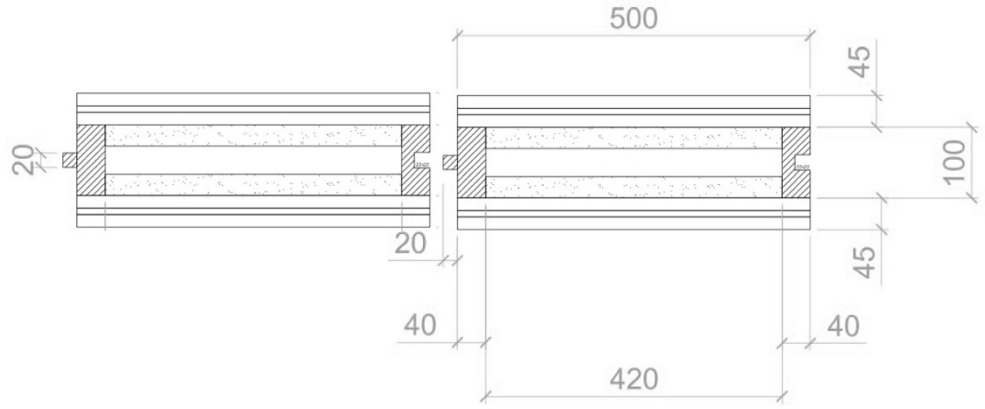


Fig.14. Natural Cork Insulation layers composition forming the insulation of the SIP, IMIP Type B.



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Type B interconnection detail

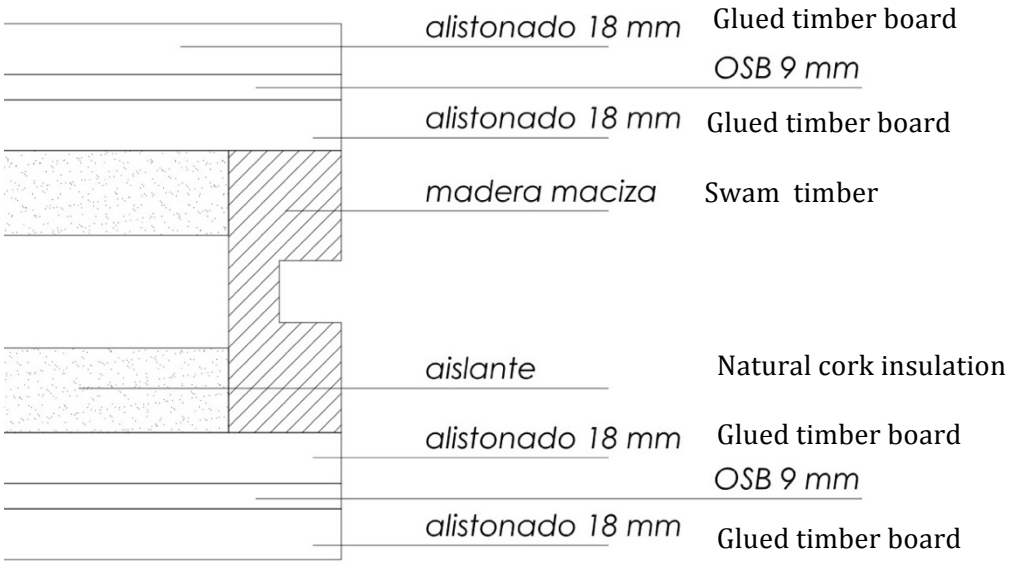

Fig.15. Connection system of the interlocking panel SIP, IMIP Type B.

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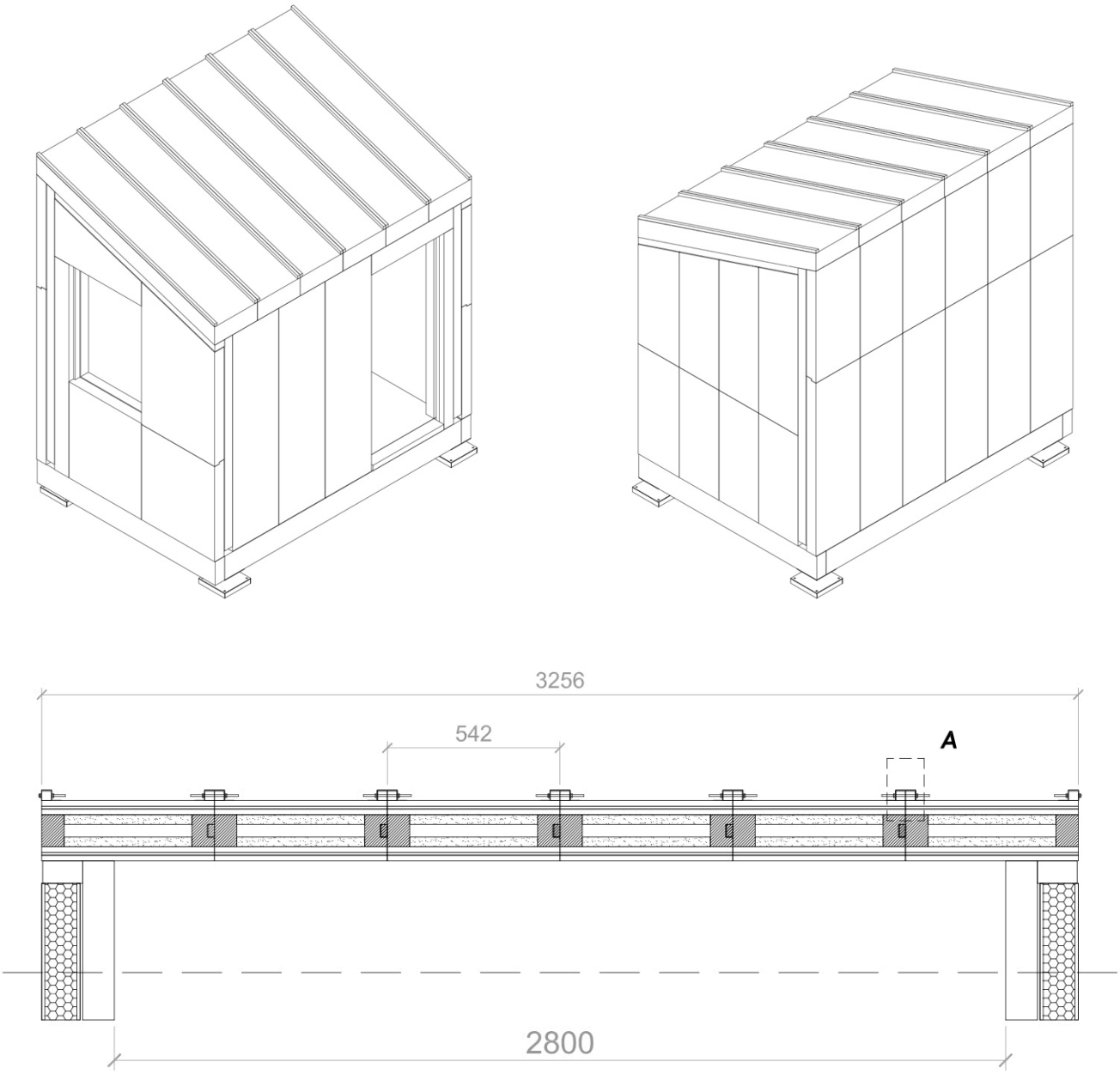

Fig.16. Connection system of the interlocking panel SIP, IMIP Type B in “Portugal pilot action”.

The "Portugal" Pilot Action is an example of a building assembled by the IMIP construction systems that are assembled in a very simple way by the interlocking panels, which also can be quickly dismantled.
This construction system is an example that can show a new regular construction way, but with a great improvement in energy efficiency, low environmental impact and quick installation.

Type C

This system is formed by: CLT of 60mm (3 layers of 20mm) + ribs of 80x200mm + CLT of 60mm. Total thickness of 320mm.

The interiors of the boxes are full of granulated natural cork as an insulation material.
The sawn wood finally used in the detail type C is *Pinus uncinata* C16-C18, following EN 338.

Definition and characteristics of coniferous sawn wood defined in the UNE-EN 338:

Properties	C16	C18
Charasteristic strenght N/mm^2		
Bending strength f_{mk}	16	18
Tensile strength along the grain $f_{t,0,k}$	10	11
Tensile strength perpendicular to the grain $f_{t,90,k}$	0.4	0.4
Compressive strength along the grain $f_{c,0,k}$	17	18
Compressive strength perpendicular to grain $f_{c,90,k}$	2.2	2.2
Shear strength $f_{v,k}$	3.2	3.4
Stiffness kN/mm^2		
Mean value of modulus of elasticity $E_{0,mean}$	8	9
Fifth percentile value of modulus of elasticity $E_{0.05,k}$	5.4	6.0
Mean value of modulus of elasticity perpendicular $E_{90,mean}$	0.27	0.30
Shear modulus G_{mean}	0.50	0.56
Density Kg/m^3		
Characteristic density ρ_k	310	320
Mean density ρ_{mean}	370	380

L/300

Type C		
Span [m]	qv [kN/m2]	
Material	C16	C18
5	11.5	12.3
6	6.9	8.0
7	3.6	4.3
8	1.7	2.2
9	0.6	0.9
-Material: C16/C18 -Deformation L/300 -Loads considered: PP+1kN/m^2 -In graphs live load per meter of width [kN/m] -Vibrations not considered		

Type C (Slab):

- CLT **60 mm**
- 200mm ribs & granulated cork
- CLT **60 mm**

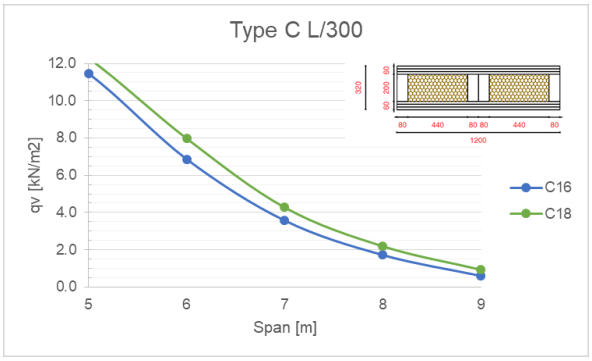

Fig. 17 Type C Slabs technical specifications.

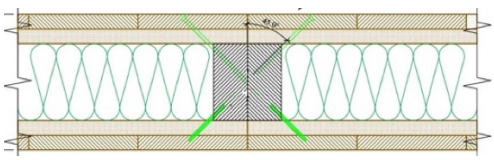

Fig. 18 Type C interconnection.

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Fig. 18. Type C interconnection.

Fig. 19. Type C and D interconnection.

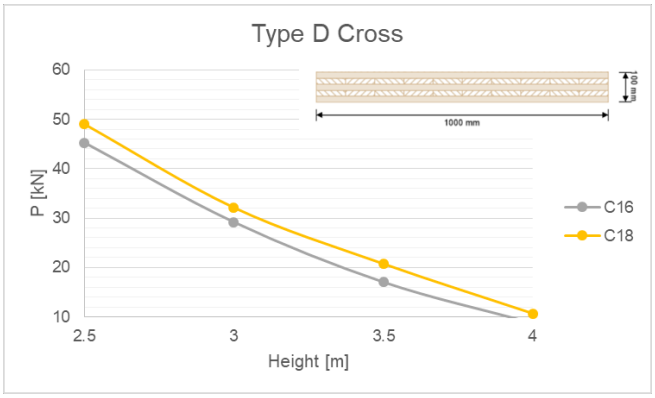
Type D

This system is configurated by IMIP CLT *Pinus pinaster* timber + insulation of natural cork.
The IMIP Type D, has different configurations and thicknesses, all of them start from the CLT based of 20mm thick wooden planks, the standard type being that of 5 layers and a total thickness of 100mm. The most novel contribution in this CLT is the use of the *Pinus pinaster*, being a fast-growing pine widespread in the SUDOE region.
The type of wood used in the project for the defined structural elements will be coniferous timber C16 - C18, following EN 338. As an insulation in the combination of the type D, the natural cork board are used.
The final thickness is determinated by the final requirements, for the Valencia pilot action the final option is CLT 100mm and natural cork panels of 110 mm thickness as insulation.

Cross (perpendicular)

Type D		
Height [m]	P [kN]	
Material	C16	C18
2.5	45.3	49.0
3.0	29.2	32.1
3.5	17.1	20.8
4.0	8.8	10.7

-Material: C16/C18
-Panel orientation in the perpendicular direction of the load
-Loads considered: Wind 1kN/m² and eccentricity of 2cm
-In graphs live load per meter of width [kN/m]
-Vibrations not considered



Type D (Wall):

- CLT **100 mm**
- 100 mm Black cork board

Fig. 20 Type D Walls

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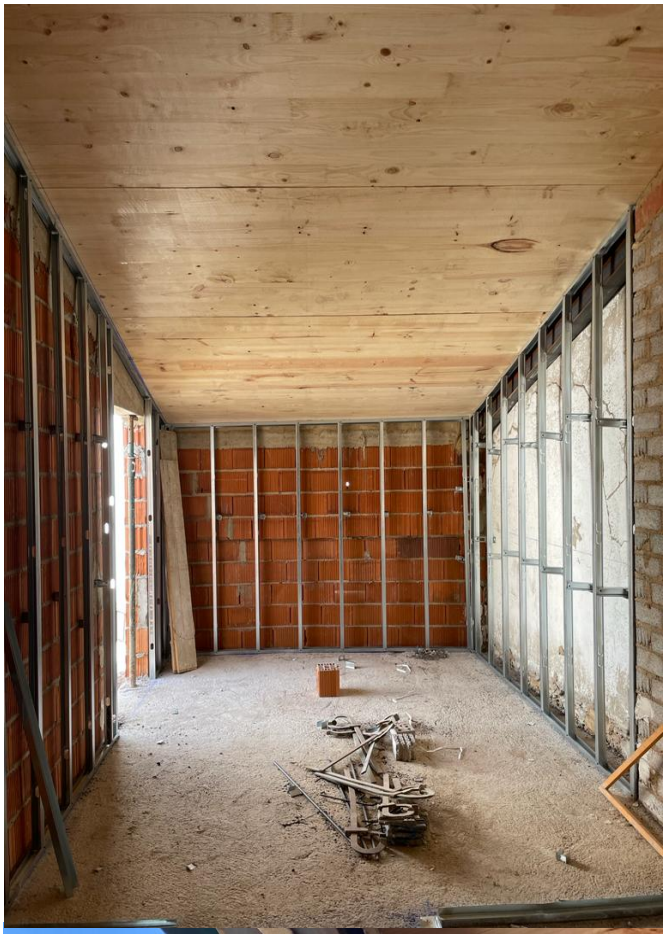

Fig. 21 and 22. Type D, CLT + Cork board for covering. Espadilla Pilot action.

Combination of construction systems

Valencia Pilot Action

This pilot action has been used the combination of the panels type A, C and D

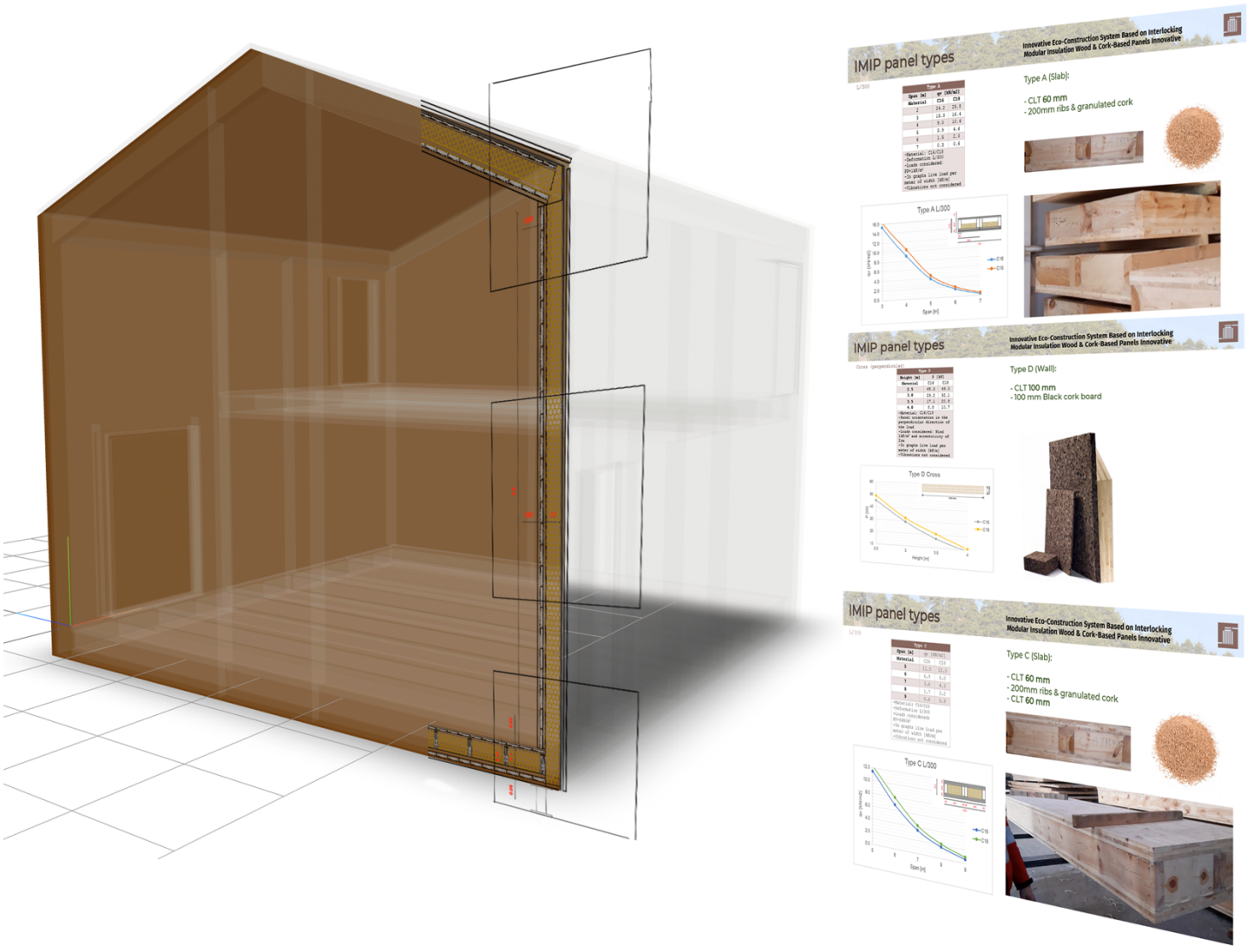

Fig. 23. Valencia pilot action configuration systems.

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Fig. 24. Valencia pilot action combination systems.

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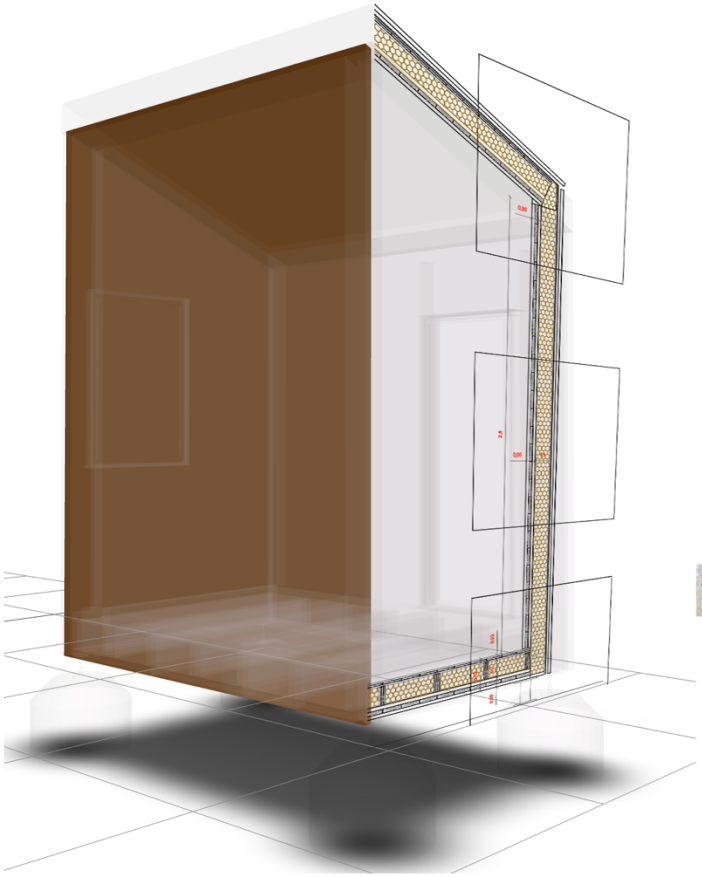
Portugal Pilot Action

This pilot action has been used the combination of the panels type B, C and D.



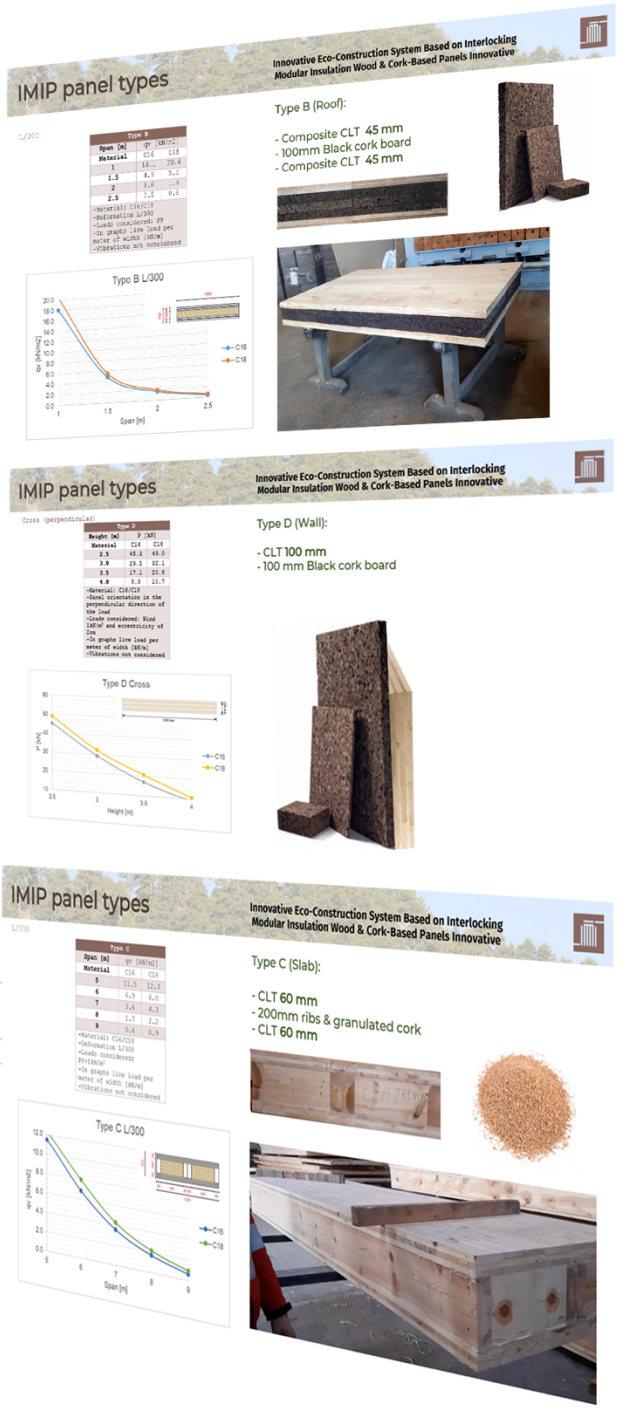


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Fig. 25 and 26. Portugal pilot action combination systems

Fig. 27. Finishes and façade systems in Portugal pilot action.

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FINAL CONCLUSIONS

The IMIP construction systems were proposed to be able to cover a range of options both for rehabilitation and for carrying out new construction, so that any type of project can be undertaken. In this sense, we can conclude that the IMIP details have been a complete success. The construction systems developed are sufficient to undertake both new construction and rehabilitation using the main systems such as roofs, floors, enclosures and interior partitions with the IMIP SIP.

We can also conclude that in 2019, when we were discussing the choice of wood to be used and implemented in the IMIP details in the project, we opted for maritime pine wood (*Pinus pinaster*), which at that time was not being used in the CLT industry.

A year later, early 2021, the Xylonor company, a subsidiary of FINSA (an important multinational for the construction sector of the production of wood-based systems) set up a complete factory in Galicia, Spain to manufacture CLT with maritime pine wood. This vision that were manifested in the first part of the project, were decisive.

The developed systems manage to cover a wide range of construction details that can replace the current building construction standards, meeting all the required needs.

Likewise, we can confirm that through the IMIP systems and details, both energy efficiency and the reduction of the environmental impacts of the buildings in which they are implemented are significantly improved.