Interreg Sudoe

EUROPEAN UNION

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

European Regional Development Fund

D.3.5.1
Report on durability and dimensional stability of IMIP Panels

IMIP-SOE3/P3/E0963

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PROJECT CONTEXT

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CONTENT

INTRODUCTION

Four types of building elements have been developed and assessed in the frame of this project (Figure 1):

- Two types of stressed skin panels based on the use of CLT (Cross-Laminated Timber) and structural finger-jointed timber ribs: panels A (for roofs) and C (for floors). Mountain pine (*Pinus uncinata*), a lesser-utilised wood species from the SUDOE region, was used in the production of these elements.
- A specific sandwich panel, panel B, based on the use of a special three-layered face material, manufactured using maritime pine (*Pinus pinaster*) solid wood panels (SWP) and OSB panels, and a core of glued ICB cork insulation elements.
- Finally, CLT elements manufactured using a species belonging to the SUDOE area, maritime pine (*Pinus pinaster*), for wall and roof applications, panel type D.

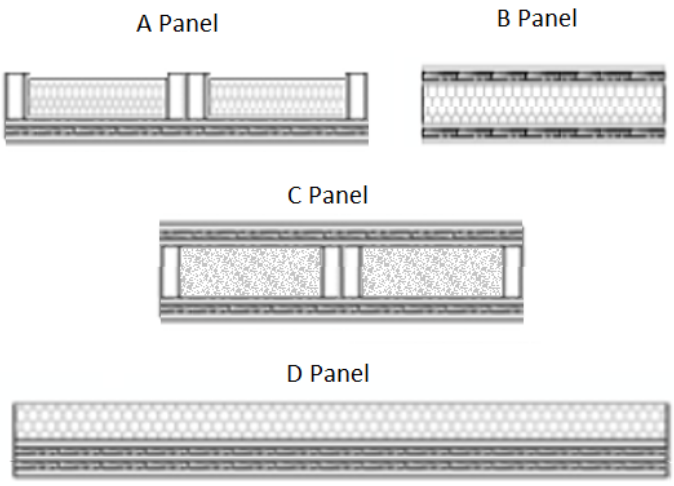

Figure 1. Cross-sections of different IMIP panels including cork insulation.

All the systems described have been designed to be used with cork insulation materials such as expanded black cork (ICB), for A, B and D panels, or granulated cork, for the C panels. After the design phase, prototypes were manufactured for testing (mechanical and other), and for the pilot actions.

In more detail, the A and C panels are large format elements with a width of 1.2 m and a length of 6 m, that were manufactured:

- Using Cross-Laminated Timber faces of 3 layers, with a total thickness of 60 mm,
- Using Finger-jointed solid wood ribs with a cross section of 80 x 200 mm,

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- Gluing and pressing the CLT and the ribs in a second process, using a vacuum press.

The B panel, on the other hand, is a smaller self-supporting roof sandwich, 0.5 m wide and 2 m long, with the following characteristics:

- The faces are a special three-layered thin CLT hybrid element with a thickness of 45 mm, made up of two single layered SWP panels glued with a PUR adhesive to a 9 mm OSB/3 inner layer.
- The cork core is composed of several ICB cork elements glued only on their faces, horizontal surfaces, obtaining two different layouts (Figure 2). The ICB cork elements, measuring 0.5 m x 1 m, were bonded in three layers with thicknesses of 30, 40 or 50 mm depending on the final size of the sandwich. For example, the panels with a core thickness of 100 mm were made with a 40 mm inner layer and two 30 mm outer layers (30+40+30).
- The faces of the sandwich panel were bonded to the core using a PUR single component adhesive and pressed using an hydraulic press with reduced pressure.

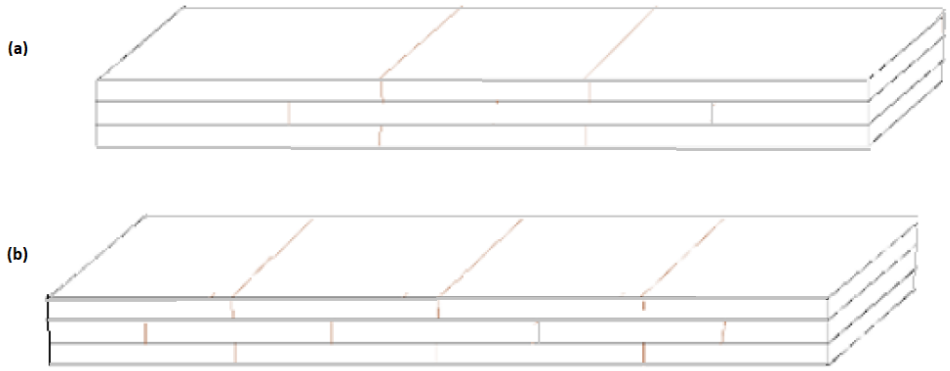

Figure 2. ICB core bonding layout for the IMIP sandwich panels (B panels). (a) subtype B1; (b) sutype B2.

Panel D is generally a 5 layer CLT element in different sizes and shapes depending on its use. It is combined with ICB cork insulation, mechanically fixed, and other necessary elements depending on its use as a roof or wall.

All the elements are designed to be used under a waterproof and breathable membrane as part of the wall or roof system, as they must remain dry even in the event of water leakage in other waterproofing systems. No direct or indirect exposure to the rain or water splash, condensation moistening or dripping is accepted for the product.

In addition, all the elements must be installed at a minimum distance from the ground or damp surfaces, including, where necessary, a moisture barrier to prevent high levels of moisture in the panels, as the wood must always remain below a 20% of moisture content.

Where necessary, anti-termite barriers shall also be used to prevent the access to the structural elements of this xylophagous social insect from the ground, neighbouring buildings, or adjoining building elements such as walls, roofs, etc.

Periodic inspections are necessary to detect actual or potential problems such as possible termite access or other xylophagous damage, condensation problems, roof leaks, etc. This will require the inspection tasks to be considered and facilitated in the design of the building. Preventive and curative treatments to protect the wood shall be used whenever is necessary.

In the case of cold roofs adequate ventilation must be provided, including the use metal or other materials mesh protection in the vents or eaves to prevent insects from gaining access to the structure or other woodwork. The advice of experts, roof and wall element manufacturers and installers, shall be always requested, using roofing systems compatible with the elements (double batten system, etc.) and proper wall sheathing.

OBJECTIVES AND SCOPE

This report summarises the results of the analyses and considerations regarding aspects of durability and dimensional stability of the panels developed in the IMIP project.

The results are focused on the service situation of the elements, which is considered to be in general Service Class 1 and exceptionally Service Class 2[1] according to EN 1995-1-1 (2004+AC 2006+A1 2008+A2 2014) definitions.

This analysis does not deal with medium, high or extreme hazard situations such as the local presence of dry wood termites, direct or indirect wetting due to the lack of use of protective measures such as waterproofing membranes, roof leaks, pipe leaks, termite access to infrequently inspected structural elements, lack of distance of wooden elements to the ground, etc.

The IMIP project aims to research and develop panels to be used as prototypes in order to learn about their mechanical, physical and other building performance characteristic, but is not intended to certify or fully assess compliance with the CE Marking requirements, such as those necessary to obtain a voluntary European Technical Assessment or an Initial Type Testing for CE Marking, as this effort exceeds the available time resources of the project.

[1] Service Class 2 use in IMIP panels will require additional assessment for the behaviour of the cork insulation of the panels, not included in this analysis, regarding its long-term behaviour (e.g., possibiity of mould development, cohesivity variation, creep), currently is only considered as a temporary situation for the product.

DURABILITY ASSESSMENT

The durability of a glued wood-based structural panel depends on two different aspects that need to be assessed:

1. The **natural durability of the wood species** used and of the type of the wood used in the pieces (sapwood, heartwood or both) **in relation to the Use Class** (defined in EN 335, 2013) in which the element will be in service, which will indicate the need for protective treatments (defined by its penetration and retention levels).
2. **The durability of the bond based on** the type of the adhesive used and its certification, which ensures **the glue durability, and the assessment of the bonding strength and quality** through periodic testing and process inspection.

These aspects are discussed in the following sections, both for the general application of the panels and for the manufactured prototypes evaluated.

1. Natural durability and treatability of the wood species used

The natural durability and treatability (impregnability) of the wood species is a complex study that is beyond the scope of this project, as it requires long term and wide analysis, and is normally available in standards or scientific references.

For the wood species used in the IMIP panels, based on the references available, the following applies:

- *Pinus pinaster*: according to EN 350 (2016) its heartwood is not durable for termites and fungi, is durable for wood boring beetles of the families Cerambicidae (*Hylotrupes bajulus:* house longhorn beetle*)* and Ptinidae-Anobiinae (*Anobium punctatum:* common furniture beetle or common house borer*)* , and is little or not treatable; the sapwood is not durable but is treatable.
- *Pinus uncinata*: heartwood not durable for fungi and little or non-treatable (Correal Modol et al. 2016), without documented information available for durability to wood boring beetles, but with similar behaviour as maritime pine; the sapwood is not durable but is treatable (Correal Modol et al. 2016).

The fact that the sapwood is impregnable or treatable is a positive feature if curative treatment based on deep insecticide injection is required to deal with a specific xylophagous insect attack.

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2. Service & Use Classes for the IMIP panels

As a general analysis, the service class (SC) for the use of the IMIP panels is considered to be SC 1 or in a temporary situation, a SC2 (see note 1). This shall be particularised with a more detailed evaluation for each construction project, in any case.

SC1 and SC2 are the Service Class allowed for the use of CLT according to EN 16351 (2022) and EAD 130005-00-0304 (2015). They are used as a reference as the IMIP panels are CLT derived products.

These conditions correspond to wood moisture contents between 12% and a maximum of 20% for a few weeks a year. In this case, if they are maintained, the risk of decay (wood-destroying fungi, rot) due to fungal attack is low, although possible in Service Class 2. On the other hand, the risk for dry wood boring insects attack is present.

The above-mentioned Service Classes are considered generally to correspond[2] to a maximum Use Class 1 according to EN 335 (2013) standard, "the wood-based product is inside a construction, not exposed to the weather and wetting" or more exceptionally, to Use Class 2 "product under cover and not exposed to the weather (particularly rain and driven rain), but where occasional but not persistent wetting can occur".

According to the Spanish Technical Building Code (CTE) document DB-SEM (2019) the wood structural elements must be protected according to the Use Class to which they are exposed (section 3.2.1.1-1).

For Use Classes 1 and 2 a surface treatment with a penetration level of NP1 is required, equivalent to a surface treatment with an adequate insecticide product, recommended for Use Class 1 and mandatory for Use Class 2 (section 3.2.1.3-1, Table 3.1). Such treatment may be considered necessary for any of the two Use Classes mentioned if there is risk of attack for *Hylotrupes bajulus*. as is common in Spain, for example.

If other specific xylophagous organisms are present locally, such as dry wood or subterranean termites (*Reticulitermes* sp.), or if information is available on previous attacks of termites or other insects, higher levels of treatment or the use of special barriers must be necessary, and it is always advisable to consult an expert. Special care must be taken in areas with risk of *Cryptotermes* (dry wood termites) present in mild climate areas such as in locations of the Canary Islands.

[2] An informative recognition to this equivalence is available in EN 335 (2013), Annex 3.

3. Durability of the adhesives – A, C and D panels

The faces of the A and C panels and the D panels are CLT elements, i.e. structural glued laminated elements composed by several layers of wood lamellas oriented at 90º and glued by its wide faces. When used as a component of the panels of this project, they must be manufactured according to the requirements of EN 16351 or EAD 130005-00-0304.

On the other hand, the A and C full panels are Prefabricated Wood-based Loadbearing Stressed-Skin Panels as defined in EAD 140022-00-0304 (2018).

As A, C and D panels are considered loadbearing elements the adhesives used in its manufacture must be certified for structural purposes by an external recognized laboratory according to EN 301 (2017) for MUF/PRF, EN 15425 for PUR glues, or EN 16254 (2013 + A1 2016) for EPI adhesives, as specified in EN 16351 and EAD 130005-00-0304.

Type I PUR 1C certified adhesives were used in the finger-joints and laminations bonding of the CLT components of the IMIP panels, fulfilling the requirements above mentioned. The same type of adhesive was used to bond the ribs to the faces of the A and C panels.

4. Durability of the adhesives – B panels

IMIP B panels are self-supporting sandwich panel type, which according to ETAG 16-1 (2003) definition is “a prefabricated non-loadbearing panel, that by virtue of its material and shape, will support all applied loadings and transmit these to structural supports”.

This reference (used as a guide for voluntary CE Marking) does not provide specific details on the adhesives to be used in the manufacture of such elements. Therefore, as these panels were prototypes for preliminary analysis, a PUR adhesive type C4-D4 was used (non structural moisture resistant). However, for products manufactured for commercial production a Type I according to EN 15425 (2017) adhesive shall be used in order to obtain a higher reliability.

5. Prototype bonding strength assessment – A, C and D panels

The manufacturing of the prototypes of the A and C panels was performed by a company while the fabrication of the D panels was performed by a different company.

Both manufacturers had or were in the process of obtaining a voluntary ETA (European Technical Assessment) for CLT production, which includes the implementation of factory production control with periodic bonding strength testing.

To confirm the bonding quality of the CLT elements delamination tests according to EN 16351 (2021) Annex A were carried out on specimens obtained from the prototypes:

- Test group 1 consisted of 3 specimens[3] obtained from a D panel, CLT of 100 mm thick and 5 layers.
- Test group 2 consisted of 18 specimens taken from the flanges of various A and C panels, which were 60 mm thick CLT elements with 3 layers. 3 specimens per panel were tested.

The test results were assessed using the requirements stated in section 4.2.2 of the mentioned European Standard, see summary in Annex 2.

The results of test group 1 showed that all the specimens tested obtained good results in delamination, whereas the results of test group 2 were mixed, with a 44% of the specimens not fulfilling the requirements of EN 16351.

As the CLT elements with mixed results in the delamination tests correspond to A and C panel flanges, and these were only used for the production of prototypes for testing and for a small pilot action located in the facilities of the UPV, Polytechnic University of Valencia, the material was accepted. However, in panels A and C manufactured for commercial purposes and installed in the market the CLT elements must meet the requirements of the delamination test according to EN 16351 or EAD 130005-00-0304.

Regarding the bonding of the flanges to the ribs in the A and C panels, EN 16351 does not provide a specific normative test method for SSP, whereas EAD 140022-00-0304 for loadbearing SSP indicates the use of shear tests according to EN 14080 in the glue-line. Therefore, shear tests were performed to assess this bonding:

- test group 3, that consisted of 18 shear tests for the A panels (3 panels, 6 specimens per panel, one glue line per specimen), and 36 shear tests for the C panels (3 panels, 6 specimens per panel, two glue lines per specimen).

[3] The number of specimens in this test group was reduced as this manufacturer had a valid ETA and previous testing was done in the product.

The results are summarized in Annex 2 and also show mixed results, with a higher number of tests meeting the requirements for the C panels (86%) and a lower number of tests passing for the A specimens (50%), based on the specification of individual glue-lines of EN 14080 (2022).

As a conclusion on the bonding quality of the rib to the flange the material can be accepted as it is used only in prototypes, but the results of the shear test assessing the bonding between the skins and the ribs of the A and C panels must be fulfilled in commercial product for future use.

According to these tests, the results of the bonding of the A panel need to be improved. A possible explanation for the results could be that the pressing process is difficult for this type of element, as it has only one skin, and needs to be improved for commercial applications.

6. Prototype bonding strength assessment – B panels

No failure associated to the bonding was detected in the bending tests of the sandwich panels (B panels), and as these panels were not going to be used beyond the prototype testing and in a a small pilot action located in Portugal focused on assembly and disassembly verification, no further bonding quality control tests were carried out.

However, for commercial product B, quality control of the bond will always be required, at least by means of small size tensile tests with load perpendicular to the skins. Also the necessary tests to obtain an ETA or equivalent evaluation document for voluntary CE Marking should be performed, being this, as mentioned, beyond the scope of the IMIP project.

DIMENSIONAL STABILITY PRELIMINARY ANALYSIS

1. Dimensional stability of CLT elements and components - A, C and D panels.

The dimensional stability of the A and C panels has not been assessed as the size of the elements does not allow a full-size testing in a climatic chamber.

The main product used in the manufacture of the IMIP panels is CLT, that form part of the A, C and correspond to D panels basic element.

CLT dimensional stability is described in EN 16351 (2021), section 4.5 that indicate that the changes in sizes with the moisture content will be those contained in Annex F, section 9 of the standard, that states that:

- The actual sizes of cross laminated timber are influenced by swelling and shrinkage due to changes of moisture content.
- The swelling and shrinkage ratios of a certain species may be regarded as constant values in the perpendicular to grain and parallel to grain directions of the timber.
- If the actual moisture content differs from the reference moisture content, a corrected size shall be calculated from the actual size using the following formula:

$$a_{cor} = a_a \left(1 + k_{cor,\alpha} \left(u_{ref} - u_a\right)\right)$$

Being,

a_{cor}	is the corrected size, in mm;
a_a	is the actual size, in mm;
$k_{cor,\alpha}$	is the moisture deformation factor perpendicular to the grain for a change in moisture content of 1 % for moisture contents from 6 % up to 25 % (inclusive);
u_{ref}	with u_{ref} = 12 % is the reference moisture content, in %;
u_a	is the actual moisture content, in %.

And considering that,

Moisture deformation factor for unhindered moisture induced deformations and for species listed in 4.1.3.1 may be taken as:

$k_{cor,90}$	= 0,002 4	for deformations perpendicular to the plane;
$k_{cor,0}$	= 0,000 2	for deformations in plane.

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Maritime pine (*Pinus pinaster*) used in D panels is one of the species considered in section 4.1.3.1 of the EN 16351 standard, and therefore the moisture deformation factors for this species can be used as indicated in the standard.

On the other hand, mountain pine (*Pinus uncinata*) used in the flanges of the A and C panels is not included in the EN 16351. For this reason, a preliminary experimental analysis has been carried out on a reduced number of specimens, to verify if the swelling and shrinkage of this type of elements is compatible with those declared in the standard. This study is included in Annex 3 showing values for the swelling of these elements that is similar to the stated in the standard, although the results are only indicative as the number of tests was small and the analysis for the commercial use of the product will require more in-depth research in the future.

2. Dimensional stability of the CLT-OSB components - B panels

The main product used as skin material for the B panels is an hybrid thin CLT element consisting of two 16 mm SWP skins of maritime pine glued with PUR adhesive to a core of 9 mm OSB/3 panels.

As this is a different product not contained in the wood-based panels covered by EN 13986 (2004+A1 2015), a preliminary exploratory analysis was carried out to study dimensional variations from Service Class 1 to Service Class 2 maximum moisture content. This study is included in Annex 3, and its main results are:

- The swelling in the thickness of the panel is greater than that expected for solid wood and less than that of OSB/3, which is reasonable since the panel is composed of these two materials.
- The swelling in perpendicular direction to the grain of the exterior layer is slightly smaller than the one expected for solid wood but not as small as the expected for the OSB. This seems to indicate that the OSB central element is not able to fully restrain the swelling of the upper and lower SWP layers.

The values and results obtained are only indicative, since the number of samples is reduced and the procedure is simplified, based on EN 318 (2002), but does not fulfil all the requirements of this standard. Specific additional tests must be carried out to obtain accurate values before the product is used commercially.

3. Dimensional stability between different face climatic conditions – Panel B

Due to its novelty a specific experimental study was performed on panel B using as a reference the EN 1121 (2000) standard assessing the deflection observed in panels with the two different core layouts explored (variants B1 and B2) under two sets of climatic conditions in each face:

- Climatic conditions C, with 23º C/35% of RH in one face and 3º C / 85% RH in the opposite face (10 days).
- Climatic conditions E, with 20ºC in one face and 75ºC in the opposite face without RH requirement (24 h).

The test included one sample of core variant B1 and one of Variant B2 with a core thickness of 100 mm. The report is included in Annex 4, and a summary of the results in shown in table 1.

Table 1: EN 1121 test results on B panels

	Specimen dimensions (thickness x width x length)	**Maximum deflection under climatic conditions C (measured in the inside face)**	**Maximun deflection under climatic conditions E (measured in the inside face)**
Core layout B1	190 x 495 x 2000 mm	Total displacement central point: -3.94 mm Relative deflection central point vs. edge points: -2.79 mm	Total displacement central point: -4.26 mm Relative deflection central point vs. edge points: -2.17 mm
Core layout B2	190 x 495 x 2000 mm	Total displacement central point: -4.36 mm Relative deflection central point vs. edge points: -3.16 mm	Total displacement central point: -4.59 mm Relative deflection central point vs. edge points: -2.27 mm

The results show that, as expected, differences in the climatic conditions affecting the faces of an unrestrained panel will cause changes in the element including deflection in the centre. This needs to be taken into account and, if necessary, reduced using alternative support design and fixings, for example using a central support and proper screwing to the structure.

As the number of tests is reduced the results are only indicative and further analysis and testing will be required, including the use of a larger number of samples, assessing the effect of screwing and other support configurations in different core panel thicknesses.

SUMMARY AND CONCLUSIONS

Four types of building elements have been designed, manufactured and evaluated in the frame of the IMIP project.

The durability assessment of these panels has focused in defining proper moisture maximum conditions, assessing the natural durability of the timber species used and testing the bonding strength of the elements glued in the prototypes of panels manufactured.

The natural durability of the wood species is low although the expected moisture content of the wood according to the intended use, when properly used and installed, corresponds to a Use Class 1 or 2. These use classes require a surface insect and fungal protection, except when local risk of termites or dry-wood xylofagous insects is present, in which additional protective treatments or barriers will be necessary following expert advice.

The bonding strength test results show differences depending on the product manufacturer and the test, with the best results being obtained for the CLT manufactured with maritime pine (*Pinus pinaster*) of the D panels, and the worst results being obtained for the CLT manufactured with mountain pine (*Pinus uncinata*) used in the flanges of the A and C prototypes, and for the bonding of the rib to the flange of the A panels.

Although the latter results were accepted for test prototypes, since the production of prototypes is a first step towards the final product, they would not be acceptable for panels intended for commercial or real use and the manufacturing process for these elements needs to be improved.

Finally, some exploratory tests were carried out to evaluate the dimensional stability of new components or unusual species used in the manufacture of parts of the IMIP panels, and also to assess the behaviour on two climates of the B panels. The results are merely informative, as the number of tests performed was small.

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ANNEX 1 - REFERENCES

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ANNEX 2 – PROTOTYPE BONDING STRENGTH RESULTS

Test group 1 – CLT of *Pinus pinaster* with 100 mm total thickness and 5 layers (D panels)

Test description: delamination assessment according to EN 16351:2021 – Annex A

Requirements: according to EN 16351:2021 – Chapter 4.2.2

No. of samples: 3

No. of panels sampled: 1

Test dates: 03.04.23-10.04.23

Results:

Panel	Specimen	No. of layers	PHASE 1 Delamination assessment				PHASE 2 Wood failure percentage (WFP)				Requirement fulfilment
			Maximum Delamination		Total Delamination		Single surface worst WFP		WFP of all surfaces		
			Result	C/I	Result	C/I	Result	C/I	Result	C/I	
1	1	3	0	C	0	C	-	-	-	-	C
	2	3	2.7	C	10.7	C	-	-	-	-	C
	3	3	0	C	0	C	-	-	-	-	C

Note 1: C (correct); I (incorrect)
Note 2: Phase 1 Requirements: Máximum Delamination ≤ 40% and Total Delamination ≤ 10%.
Note 3: Phase 2 Requirements: worst WFP for a single glued surface ≥ 50% and WFP for all glued surfaces ≥ 70%

Test group 2 – CLT of Pinus uncinata with 60 mm total thickness and 3 layers (flanges of A and C panels)

Test description: delamination assessment according to EN 16351:2021 – Annex A

Requirements: according to EN 16351:2021 – Chapter 4.2.2

No. of samples: 18

No. of panels sampled: 6

Test dates: 17.03.23 - 05.04.2023

Results:

Panel	Specimen	No. of layers	PHASE 1 Delamination assessment (%)				PHASE 2 Wood failure percentage (WFP)				Requirement fulfilment
			Maximum Delamination		Total Delamination		Single surface worst WFP		WFP of all surfaces		
			Result	C/I	Result	C/I	Result	C/I	Result	C/I	
1	1	**3**	16.7	C	8.3	C	60	C	80	C	**C**
	2	**3**	32.0	C	20.9	I	50	C	65	I	**I**
	3	**3**	35.2	C	27.2	I	40	I	60	I	**I**
2	1	**3**	47.2	I	23.6	I	50	C	75	C	**C**
	2	**3**	72.3	I	44.5	I	20	I	60	I	**I**
	3	**3**	28.0	C	16.0	I	60	C	80	C	**C**
3	1	**3**	23.5	C	14.7	I	40	I	70	C	**I**
	2	**3**	7.8	C	6.8	C	90	C	95	C	**C**
	3	**3**	**0.0**	**C**	**0**	**C**	-	-	-	-	**C**
4	1	**3**	29.4	C	16.4	I	70	C	85	C	**C**
	2	**3**	39.9	C	25.1	I	40	I	70	C	**I**
	3	**3**	72.2	I	23.6	I	20	I	60	I	**I**
5	1	**3**	19.0	C	17.8	I	40	I	70	C	**I**
	2	**3**	1.2	C	0.6	C	-	-	-	-	**C**
	3	**3**	83.1	I	41.6	I	20	I	60	I	**I**
6	1	**3**	10.8	C	7.5	C	-	-	-	-	**C**
	2	**3**	14.2	C	9.3	C	-	-	-	-	C
	3	3	23.4	C	13.0	I	80	C	90	C	C

Note 1: C (correct); I (incorrect)
Note 2: Phase 1 Requirements: Máximum Delamination ≤ 40% and Total Delamination ≤ 10%.
Note 3: Phase 2 Requirements: worst WFP for a single glued surface ≥ 50% and WFP for all glued surfaces ≥ 70%

Test group 3 – Glue-line between flanges and ribs of A and C panels

Test description: Parallel to the grain shear test on glue-line according to EN 14080 Annex D using prismatic specimens of 45 x 45 mm to test the bonding strength of the rib to the flange.

Requirements: Chapter 5.5.5.2.3 of EN 14080 standard

No. of samples: 6 specimens per panel (2 glue-lines per specimen in C panels and 1 in A panels)

No. of panels sampled: 3

Test dates: 17.03.23 - 05.04.2023

Results for A panels:

Panel	Specimen	Glue-line	Shear strength (N/mm2)	Wood failure percentage	Fulfilment (indvidual line)
1	1	L	3.18	85	I
	2	L	6.82	30	I
	3	L	10.34	90	C
	4	L	7.70	30	I
	5	L	10.21	90	C
	6	L	3.30	20	I
2	1	L	8.83	45	C
	2	L	4.27	55	I
	3	L	8.67	80	C
	4	L	8.72	95	C
	5	L	3.31	95	I
	6	L	7.90	70	C
3	1	L	10.10	100	C
	2	L	10.01	100	C
	3	L	10.02	100	C
	4	L	5.92	35	I
	5	L	-	-	-
	6	L	1.06	20	I

Note: L, lower; C, correct; I, incorrect.

50% of the test fulfilling the requirement for individual lines.

44% of the test not fulfilling the requirement for individual lines.

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Results for C panels:

Panel	Specimen	Glue-line	Shear strength (N/mm2)	Wood failure percentage	Fulfilment (indvidual line)
1	1	U	-	-	-
	1	L	7.58	75	C
	2	U	9.94	100	C
	2	L	9.90	35	I
	3	U	8.34	60	C
	3	L	8.35	65	C
	4	U	9.92	50	C
	4	L	8.49	45	C
	5	U	6.82	70	C
	5	L	5.65	50	I
	6	U	9.78	90	C
	6	L	9.86	85	C
2	1	U	10.41	85	C
	1	L	8.71	55	C
	2	U	8.92	55	C
	2	L	7.90	55	C
	3	U	9.73	85	C
	3	L	8.55	55	C
	4	U	6.70	100	C
	4	L	9.87	85	C
	5	U	7.31	75	C
	5	L	10.20	60	C
	6	U	10.18	90	C
	6	L	10.01	900	C
3	1	U	9.46	30	C
	1	L	-	20	I
	2	U	10.24	95	C
	2	L	8.46	80	C
	3	U	9.42	80	C
	3	L	7.36	70	C
	4	U	10.03	60	C
	4	L	9.86	95	C
	5	U	8.95	100	C
	5	L	9.56	80	C
	6	U	1.29	25	I
	6	L	8.95	85	C

Note: L, lower; C, correct; I, incorrect.

86% of the test fulfilling the requirement for individual lines.

11% of the test not fulfilling the requirement for individual lines.

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ANNEX 3 – PRELIMINARY ANALYSES ON DIMENSIONAL STABILITY OF SOME PROTOTYPE COMPONENTS

CLT of A and C panels (flanges)

Test description: procedure based on climatic conditions changes 20ºC/ 65% HR and 20ºC/85%HR stated in EN 318 using specimens of 50 x 300 mm oriented parallel and perpendicular to the grain of the exterior layer. Measurements of thickness and of width of the specimens to analyse swelling and shrinkage between these two climatic conditions (in sorption and desorption).

Requirements: -

No. of samples: 3 parallel and 3 perpendicular to the exterior layer grain per panel.

No. of panels sampled: 3

Test dates: 03.04.23-27.03.23

Results:

CLT-OSB specimens before starting the test.

Temp. (º C)	Δ RH	Direction with respect to the grai
20	65%→85%	Perpendicular
	85%→65%	
20	65%→85%	Parallel
	85%→65%	

According to well known references for example Argüelles et al (2013) the expected wood moisture content for 20ºC-65% HR would be a 12 % content for 20ºC-85% HR would be a 18%.

Based on this estimation a change of 6 percentual points is expected a

The expected increment in width per 1% variation in wood moisture co

0.85%/6% =0.14 %/%	In perpendicular direction
0.28%/6% =0.047 %/%	In parallel direction
((1.79%+2.03%)/2)/6%=0.32%/%	In thickness

The values obtained are merely orientative since the number of sampl on EN 318 but does not fully comply with this standard.
Specific additional testing must be performed in order to obtain accura

CLT of A and C panels (flanges)

Test description: procedure based on climatic conditions changes 20ºC/ 65% HR and 20ºC/85%HR (Service Class 1 to Service Class 2) using specimens of 140 x 140 mm of CLT containing a board separation in the midle of the layer. Measurements of thickness and of width of the specimens using a calibrated caliper, and analysis of swelling and shrinkage between these two climatic conditions (in sorption).

Requirements: -

No. of samples: 1 sample per panel, 3 in total.

No. of panels sampled: 3

Test dates: 03.04.23-27.04.23

Results (average values):

CLT specimen before starting the test.

		External layer		
Temp. ºC	Δ HR	Δ Width parallel (%)	Δ width perp. (%)	Thickness (%)
20	65%→85%	0.04%	0.17%	1.29%

Based on an estimation of wood moisture content change of 6 percentual points (and thus dividing the previous results by 6):

		External layer		
Temp. ºC	Δ HR	Δ Width parallel (%)	Δ width perp. (%)	Thickness (%)
20	65%→85%	0.01%	0.03%	0.21%
Expected for CLT (EN 16351):		0.02	0.02	0.24

The results are close to those expected in general for CLT although the number of specimens tested is low and the procedure for testing is not standardized so far, so the information must be taken just as orientative or informative and deeper research must be carried out before the commercial use of the product

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ANNEX 4 – TEST REPORT ON BEHAVIOUR BETWEEN TWO DIFFERENT CLIMATES FOR B PANELS

INFORME DE ENSAYO
COMPORTAMIENTO ENTRE CLIMAS DIFERENTES

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PETICIONARIO *Applicant*	AITIM C/ FLORA 3, 2° DCHA 28013- MADRID
PRODUCTO[1] *Product*	Paneles Sándwich especiales realizados con caras de tablero tricapa CLT-OSB de 45 mm de grosor y alma de 100 mm de grosor compuesta por tres capas de planchas de corcho negro expandido (ICB) encoladas. Alma en dos variantes de disposición de las planchas, denominadas B1 y B2
REFERENCIA[1] *Reference*	PROTOTIPO. TIPO B PROYECTO IMIP
MODELO[1] *Model*	Probeta IMIP / AITIM-ED-B1-100 Probeta IMIP / AITIM-ED-B2-100
DIMENSIONES *Dimensions*	495 mm x 2000 mm x 190 mm (ancho x alto x espesor)
MATERIAL[1] *Material*	Tablero CLT especial de 3 capas, exteriores de tablero alistonado monocapa de pino pinaster y alma de 9 mm de grosor de OSB/3" "Alma compuesta por tres capas de planchas de corcho negro expandido, ICB, de 110 kg/m3 en espesores 30+40+30 mm
FECHAS DE ENSAYO *Date/s of tets*	Del 25.04.2023 al 09.05.2023
FECHA DE EMISIÓN *Date of issue*	23.05.2023

Norma de Ensayo:

UNE-EN 1121:2000 Puertas. Comportamiento entre dos climas diferentes. Método de ensayo.

CARACTERÍSTICAS DE LOS CLIMAS ENSAYADOS
Characteristics of the tested climates

	CARA 1		CARA 2	
Clima	ºC	%HR	ºC	%HR
C	23 ± 2	30 ± 5	3 ± 2	85± 5
E	(20-30)	--	f + (55 ± 5)	--

Luis García Viguera
Director Técnico Departamento
Department Director

GARCIA VIGUERA LUIS - 16537975D
Firmado digitalmente por GARCIA VIGUERA LUIS - 16537975D
Fecha: 2023.05.23 13:46:00 +02'00'

El resultado del presente ensayo/s no concierne más que al objeto/s ensayado/s. Los informes firmados electrónicamente en soporte digital se consideran un documento original, así como las copias electrónicas del mismo. Su impresión en papel no tiene validez legal.
[1] ENSATEC, S.L.U., declina toda la responsabilidad sobre la información aportada por el cliente.

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1 ANTECEDENTES Y OBJETO.

Este informe ha sido realizado a petición de **AITIM**, en las instalaciones de ENSATEC, S.L.U. con objeto de realizar los ensayos de comportamiento en diferentes ambientes, de dos referencias del siguiente elemento constructivo:

- **Panel Sándwich con cara de tablero OSB y alma de corcho negro expandido ICB**
  Referenciado por el peticionario como:
  - **Probeta IMIP / AITIM-ED-B1-100**
  - **Probeta IMIP / AITIM-ED-B2-100**

Los climas a los que se van a realizar los ensayos son: Clima C y Clima E

2 DOCUMENTOS APLICABLES.

- UNE-EN 1121:2000 Puertas. Comportamiento entre dos climas diferentes. Método de ensayo.
- Procedimiento interno de ENSATEC.

3 CARACTERÍSTICAS DE LA MUESTRA

Las especificaciones técnicas de la muestra de ensayo, y de los materiales y elementos que la componen, han sido aportadas por el solicitante [1]

Descripción	Paneles Sándwich especiales realizados con caras de tablero tricapa CLT-OSB de 45 mm de grosor y alma de 100 mm de grosor compuesta por tres capas de planchas de corcho negro expandido (ICB) encoladas. Alma en dos variantes de disposición de las planchas, denominadas B1 y B2
Proveedor	AITIM
Referencias	Probeta IMIP / AITIM-ED-B1-100 Probeta IMIP / AITIM-ED-B2-100
Dimensiones (mm)	495 mm x 2000 mm x 190 mm (ancho x alto x espesor)
Superficie total (m2)	0,99
Material	Paneles Sándwich especiales realizados con caras de tablero tricapa CLT-OSB de 45 mm de grosor y alma de 100 mm de grosor compuesta por tres capas de planchas de corcho negro expandido (ICB) encoladas. Alma en dos variantes de disposición de las planchas, denominadas B1 y B2
Método de unión:	Cola de poliuretano mono componente (PUR-1C).

Probeta IMIP / AITIM-ED-B1-100. Detalle de la disposición de las planchas en el alma

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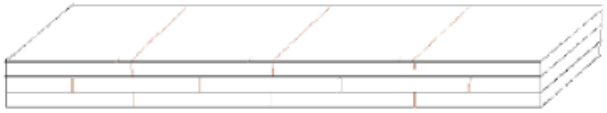
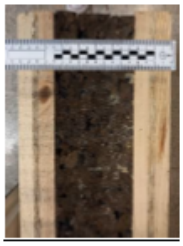


Probeta IMIP / AITIM-ED-B2-100. Detalle de la disposición de las planchas en el alma

Probeta IMIP / AITIM-ED-B1-100.

Probeta IMIP / AITIM-ED-B2-100.

Probeta IMIP / AITIM-ED-B1-100.



Probeta IMIP / AITIM-ED-B2-100.

4 CRITERIOS DEL ENSAYO

Nº muestras: 2

Exposición: Clima C y Clima E

Características: Las características de los climas ensayados son las siguientes:

	CARA 1		CARA 2	
Clima	*ºC*	*%HR*	*ºC*	*%HR*
C	23 ± 2	30 ± 5	3 ± 2	85± 5
E	(20-30)	--	ϕ+ (55 ± 5)	--

Sensores de temperatura: Se colocan los sensores de temperatura, en el eje vertical de cada cara de la muestra, a 100 ± 50 mm de la cara, en el centro y a 100 mm de la parte superior e inferior.

Deformaciones: Para el control de las deformaciones producidas durante el ensayo se han considerado los puntos más vulnerables de la muestra realizándose medidas periódicas a lo largo de la duración del ensayo.
Las medidas de desplazamiento se han realizado colocando los sensores en el eje vertical de cada cara de la muestra, a 100 ± 50 mm de la cara, en el centro y a 100 mm de la parte superior e inferior.

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4.1 Clima C

Inicio del ensayo: 25.04.2023
Fin del ensayo: 04.05.2023
Nº de horas totales : 168 h
Valores medios durante el ensayo:

	CARA 1		CARA 2	
clima	*ºC*	*%HR*	*ºC*	*%HR*
C	22,6	28,9	2,7	86,4

Probeta IMIP / AITIM-ED-B1-100

fecha	Cara 1 (interior)					Cara 2 (exterior)				
	punto 1	punto 2	punto 3	Flecha relativa	variación en 24 h	punto 4	punto 5	punto 6	Flecha relativa	variación en 24 h
25/04/2023	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
26/04/2023	-0,34	-1,63	-0,34	-1,29	1,29	0,12	0,76	0,12	0,64	0,64
27/04/2023	-0,59	-2,37	-0,59	-1,78	0,49	0,34	1,40	0,34	1,06	0,42
28/04/2023	-0,74	-2,86	-0,74	-2,12	0,34	0,52	1,89	0,50	1,38	0,32
02/05/2023	-1,05	-3,64	-1,05	-2,59	0,47	0,59	2,51	0,80	1,82	0,44
03/05/2023	-1,13	-3,87	-1,13	-2,74	0,15	0,65	2,73	0,89	1,96	0,15
04/05/2023	-1,15	-3,94	-1,15	-2,79	0,05	0,70	2,81	0,93	2,00	0,04

Probeta IMIP / AITIM-ED-B2-100

fecha	Cara 1 (interior)					Cara 2 (exterior)				
	punto 1	punto 2	punto 3	Flecha relativa	variación en 24 h	punto 4	punto 5	punto 6	Flecha relativa	variación en 24 h
25/04/2023	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
26/04/2023	-0,43	-1,93	-0,42	-1,51	1,51	0,36	0,45	0,01	0,27	0,27
27/04/2023	-0,77	-2,76	-0,71	-2,02	0,51	0,67	1,05	0,13	0,65	0,39
28/04/2023	-0,83	-3,27	-0,81	-2,45	0,43	0,82	1,50	0,22	0,98	0,33
02/05/2023	-1,10	-4,06	-1,11	-2,96	0,50	1,08	2,18	0,39	1,45	0,47
03/05/2023	-1,16	-4,28	-1,17	-3,12	0,16	1,11	2,41	0,39	1,66	0,22
04/05/2023	-1,19	-4,36	-1,21	-3,16	0,04	1,11	2,51	0,43	1,74	0,08

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4.2 Clima E

Inicio del ensayo: 08.05.2023
Fin del ensayo: 09.05.2023
N° de horas totales: 24 h
Valores medios durante el ensayo:

	CARA 1		CARA 2	
clima	*ºC*	*%HR*	*ºC*	*%HR*
E	19,9	--	75,2 2	--

Probeta IMIP / AITIM-ED-B1-100

fecha	Cara 1 (interior)					Cara 2 (exterior)				
	punto 1	punto 2	punto 3	Flecha relativa	variación en 24 h	punto 4	punto 5	punto 6	Flecha relativa	variación en 24 h
04/05/2023	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
05/05/2023	-2,11	-4,26	-2,17	-2,12	2,12	3,52	3,60	2,88	0,40	0,40

Probeta IMIP / AITIM-ED-B2-100

fecha	Cara 1 (interior)					Cara 2 (exterior)				
	punto 1	punto 2	punto 3	Flecha relativa	variación en 24 h	punto 4	punto 5	punto 6	Flecha relativa	variación en 24 h
04/05/2023	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
05/05/2023	-2,28	-4,59	-2,37	-2,27	2,27	4,26	3,48	0,66	1,02	1,02

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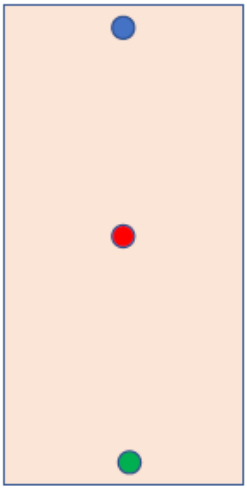
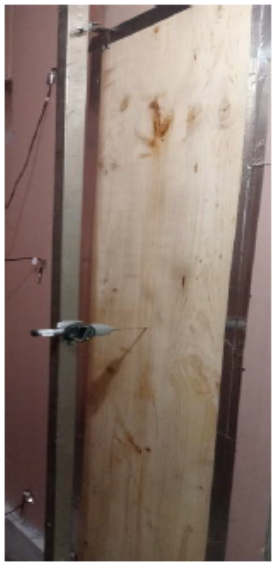
5 CROQUIS- DETALLE SITUACIÓN DE PUNTOS DE MEDIDA DEFORMACIÓN



Punto 1/4. Punto superior de la cara interior y exterior
Punto 2/5.Punto central de la cara interior y exterior
Punto 3/6. Punto inferior de la cara interior y exterior

6 DOCUMENTACÓN FOTOGRÁFICA

Cara exterior



Cara interior

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ASSOCIATED PARTNERS

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