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The INCSEB European research project (1 August 2021- 31 July 2025), aims at developing five innovative ultra-low carbon building steel envelope systems thanks to the innovative use of wood fiber, a renewable and bio-sourced insulation material, while achieving a high level of thermal performance and ensuring compliance with other requirements such as mechanical, fire and acoustic performances. These systems could have many applications, particularly for non-residential buildings (industrial and logistics buildings, offices, shopping centers, etc.).

Six partners are involved in the project: L'ENVELOPPE METALLIQUE DU BATIMENT (FRANCE) as a project's coordinator, JORIS IDE NV (BELGIQUE), MONOPANEL SAS (FRANCE), TECNALIA RESEARCH AND INNOVATION (SPAIN) TU DARMSTADT (GERMANY) and UNIVERSITY OF COIMBRA (PORTUGAL)

The purpose of this article is to give an overview of some of the first results of the project.

INCSEB PROJECT OBJECTIVES.

The core objective of the project is to develop an innovative family of steel envelope systems, roofing (flat roof and pitch roof sandwich panels) and cladding (double skin system & façade cladding with cassettes), with biobased insulation (wood fiber) that meet the new low carbon construction requirements.

The main challenge for this innovative family is to meet the new carbon requirements but also, at the same time, all the other performance requirements (thermal, mechanical, reaction and resistance to fire, acoustic, durability…).

The carbon performance of the new systems is studied from two angles:

1. For each of the system, all the indicators of life cycle assessment (LCA) are determined.
2. An evaluation of the benefits obtained in terms of carbon footprint (GWP) is also assessed by comparing the GWP of an existing office building equipped with a traditional steel envelope system (sandwich panels with PU core) with the same building equipped (by calculation) with the new systems.

To study all the other performances for each of the new systems, an extensive series of tests and calculations according to relevant EN standards is carried out in order to evaluate their mechanical, thermal, fire and acoustic performances together with their air, vapour and water permeability.
In addition, the behavior and durability of the five innovative systems in real life conditions is studied. Indeed, two full scale building prototypes fitted with the new systems are built in Germany and exposed for two years to the rigors of the outside environment.

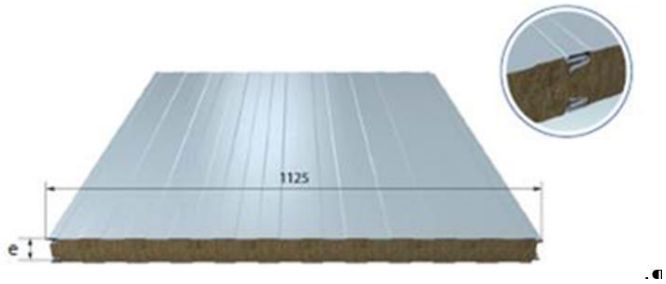
To facilitate the industrial application of the new systems, a series of tools are also developed. For example, a number of pedagogical guides for designing and installing the news systems, including recommendations for their dismantling in view to recycling or reusing them will be prepared. Generic BIM objects, for each of the system, will be also produced.

PRESENTATION OF THE FIVE INNOVATIVE STEEL ENVELOPE SYSTEMS DEVELOPED.

Three cladding systems are being developed (one sandwich panels with fasteners, one double skin with spacers and one facade cladding with insulated cassettes) together with two roofing systems (one pitch roofing sandwich panel and one flat roofing sandwich panel).

The systems are described below.

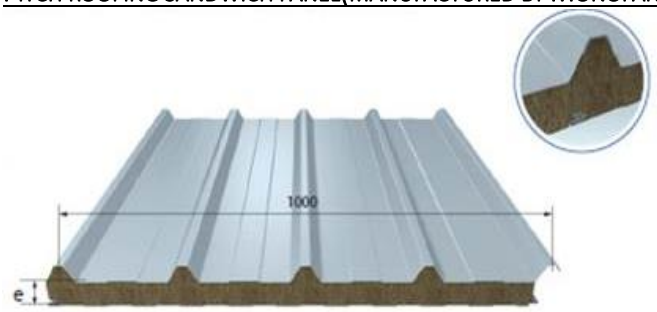
CLADDING SANDWICH PANEL (MANUFACTURED BY MONOPANEL)



Components:

- 2 steel facings (MONOLAINE B (0.5mm; 0.63mm; 9.6kg/m²))
- wood fiber core (150mm, 115kg/m^3)

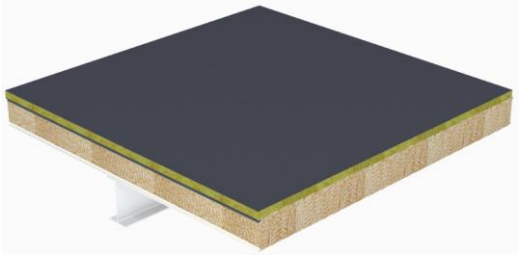
PITCH ROOFING SANDWICH PANEL(MANUFACTURED BY MONOPANEL)



Components:

- 2 steel facings (MONOLAINE T (0.5mm; 0.63mm; 10.3kg/m²))
- wood fiber core (150mm; 115kg/m^3)
- mineral wool in the trapezoidal part in the ribs

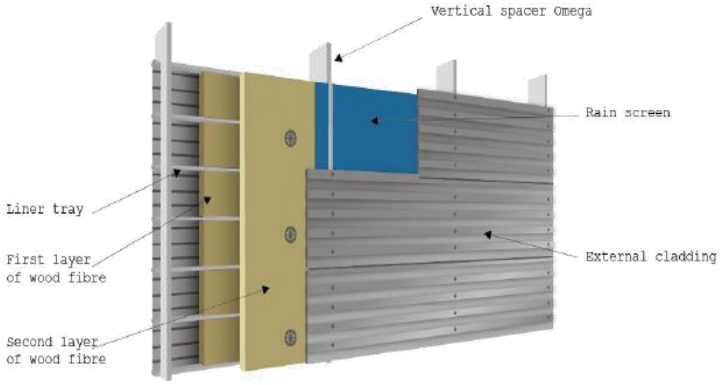
FLAT ROOFING SANDWICH PANEL(MANUFACTURED BY JORIS IDE NV)



Components :

- 2 steel facings, Vulcasteel roof (0.5mm ;0.6mm; 9.3kg/m²)
- wood fiber core (200mm; 115kg/m^3)
- mineral wool (thickness 50mm)
- PVC water proof

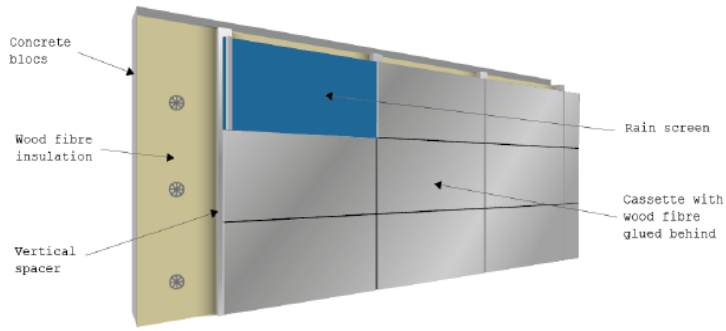
DOUBLE SKIN CLADDING SYSTEM(MANUFACTURED BY JORIS IDE NV)



Components:

- steel liner tray (0.75mm; 90x500mm; 8.8kg/m²)
- wood fiber in the liner tray (90 mm; 115kg/m^3)
- wood fiber in front of the liner tray (120 mm)
- steel spacer (40-120-120-120-40x1.5)
- polypropylene rain screen
- Omega spacer (30-20-60-20-30x1.5)
- steel cladding (0.75mm; 6.62kg/m²)

FAÇADE CLADDING SYSTEM WITH CASSETTES (MANUFACTURED BY JORIS IDE NV)



Components:

- concrete wall 20cm
- wood fiber glued to the siding (30 mm; 115kg/m^3)
- wood fiber in front of the wall (200 mm; 115kg/m^3)
- steel spacer (40-200-120-200-40x1.5)
- polypropylene rain screen
- Omega spacer (30-20-60-20-30x1.5)
- steel siding (1mm; 11.1kg/m²)

FIRST RESEARCH RESULTS OBTAINED.

The tests on durability in real-life conditions are still ongoing.

The study of the carbon performance of the systems, and in particular the determination of LCA indicators (in accordance with the new standard EN 15804 + A2) is also still in progress. However, the very first estimates show, for an equivalent thermal performance, a carbon reduction of 34% for the flat roof sandwich panel with a wood fiber core in comparison with a conventional panel with a mineral wool core.

The results detailed below concern mechanical, thermal and air permeability, fire, acoustic performances and water and vapour permeability.

i. MECHANICAL PERFORMANCES

a. FOR THE SANDWICH PANELS

A series of tests to determine the diaphragm structural behaviour in static on 2 supports (wind behaviour) –imposed displacements in the plane were performed with the results given below.

- for the cladding sandwich panels thickness 150mm²: 4.8kN /150 mm
- for the Pitch roofing sandwich panel thickness 150mm: 8.2 kN/150mm
- for the flat roofing sandwich panel thickness 200mm: 10 KN/150 mm

A dynamic seismic test was also carried out (maximum loads applied: 7611 N and 12747 N, maximum displacements measured/ 138.7 mm for wall) and 150.7 mm for roof in horizontal and estimated absolute maximum accelerations of 2.25 m/s² and 1.85 m/s²). In all cases, (wall and roofing systems) there was no collapse of the panels

Figure 1 Cladding panel and its fixing under diaphragm testing

So far, the main findings are:

- For the mechanical tests in bending, the pitch roofing test results (relation span 6m load applied) and the flat roofing test results (relation span 3m load applied) are of the same order of magnitude as those for sandwich panels with mineral wool core.
- For the diaphragm tests, which have been repeated three times, good consistency and repeatability of performances were recorded. All results were also compatible with the

state of the art for sandwich panels with mineral wool core. In addition, a high rigidity in plane of the panels was noted.

- For the seismic tests, the observed behaviour of the wood core panels is identical (no collapse) to that seen for conventional sandwich panels (with mineral wool core or with polyurethane core). In addition, the acceleration that the innovative panels can windstand was established with a safety coefficient of 2.

b. FOR THE PROFILES: DOUBLE SKIN CLADDING AND FAÇADE CLADDING WITH CASSETTES.

Because of the height density of the wood fibre insulation and of the increased rigidity due to the added wood insulation core, it was necessary to verify the performance of the systems in both dynamic (mass acceleration) and static (diaphragm effect).

In the case of the cassette, in order to determine in bending (wind pression/suction) how to optimize the span, several vacuum chamber tests and linear loading tests have been carried out.

Figure 2 Double skin cladding system during the seismic tests

So far, the main findings are:

- The mechanical tests results for the façade cladding with cassettes with or without insulation are equivalent. Furthermore, no dislocations were observed for the cassettes with insulation by comparison with cassettes without insulation.
- For the diaphragm tests, which were repeated three times, they showed both consistency and repeatability of performance. A high rigidity of profiles with wood fibre insulation was observed.
- For the seismic test, a high rigidity of the system was again observed. No system tested has fallen to the ground during and after the seismic displacements imposed.

II) THERMAL AND AIR PERMEABILITY

a) FOR THE SANDWICH PANELS

The study of the thermal resistance and thermal conductivity of cladding sandwich panels and pitch roofing sandwich panels is still ongoing.

For the flat roof sandwich panels, the calculations were made considering the optimum thermal conductivity values of the wood fire insulation according to the DoP performance

declaration (λ = 0.038 W/m.K) and the most unfavorable values detected by the customer (λ = 0.044 W/mK)-Table XXX gives the thermal transmittance values obtained. They are compatible with the market request.

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Thermal transmittance		**λ = 0.038 W/mK**	**λ = 0.044 W/mK**
Sandwich panel for roofing	Case 15	U = 0.149 W/m²K	U = 0.167 W/m²K
	Case 16	U = 0.145 W/m²K	U = 0.162 W/m²K
	Case 17	U = 0.156 W/m²K	U = 0.173 W/m²K

Table 1. Thermal transmittance values of the flat roof sandwich panel

Regarding air permeability, two wall systems (two type of junctions associated with two types of joints), one pitch roof system and two flat roof system were tested according to EN 12114. Maximum pressures of 200 Pa and-200 Pa were applied. Permeability values obtained have been considered appropriate for the corresponding systems and compatible with the values of sandwich panels with mineral wool core. Only the conception of the joint and type of sealants used are fundamental for this performance.

b) FOR THE PROFILES: DOUBLE SKIN CLADDING AND FAÇADE CLADDING WITH CASSETTES.

The results obtained for the thermal calculations are compatible with the values of systems with mineral wool insulation. Table 2 gives the thermal transmittance values obtained. They are compatible with the market requirements.

Thermal transmittance		**λ = 0.038 W/mK**	**λ = 0.044 W/mK**
Usual double skin cladding	Case 1	U = 0,27 W/m²K	U = 0,31 W/m²K
	Case 2	U = 0,23 W/m²K	U = 0,26 W/m²K
	Case 3	U = 0,23 W/m²K	U = 0,26 W/m²K
Cladding with façade product	Case 4	U = 0,56 W/m²K	U = 0,59 W/m²K
	Case 5	U = 0,39 W/m²K	U = 0,41 W/m²K
	Case 6	U = 0,30 W/m²K	U = 0,33 W/m²K

Table 2 Thermal transmittance values obtained for the two cladding systems.

Regarding air permeability, two wall systems (double skin system and façade cladding with cassette product) were tested according to EN 12114. Maximum pressures of 200 Pa and-200 Pa were applied. The permeability values obtained have been considered appropriated for the corresponding systems and compatible with the values of systems with mineral wool insulation.

Figure 3. The double skin system and façade cladding with cassettes before and during the air permeability test.

III) FIRE PERFORMANCES

a) FOR THE SANDWICH PANELS

a1 Reaction to fire

SBI tests (EN 13823) and flammability test (EN ISO 11925-2) were made for cladding, pitch roofing and flat roofing sandwich panels. Three repetitions of SBI tests per type of system were performed and B-s1,d0 classification was obtained according to EN 13501-1.
The flammability test results confirmed the class B-s1,d0 according to EN 13501-1 for cladding and pitch roofing sandwich panels. For flat roofing sandwich panels, the flammability tests are still ongoing.

Figure 4. SBI tests of roof sandwich panel systems during and after the tests

a2) Smoldering effect

A smouldering phenomenon was observed and studied in detail (fire performance on façade). Two cladding systems, one composed of three horizontal wood fibre sandwich panels and the other cladding composed with a mineral wool sandwich panel in the intermediate position, were tested. The mineral wool insulation panel was able to stop the propagation of smouldering effect.

a3) External fire roof performance

For the external fire roof performance of the pitch roofing sandwich panel, further research is necessary to determinate the classification as too many parameters influence the Brooft1 performancy.
For the flat roofing sandwich panels, two systems were considered to study the external fire roof performance: one composed of only sandwich panels and a second one considering mineral wool insulation and waterproof membrane on the top of the sandwich panels. The sample with insulation and membrane comply with all criteria so this system obtained a B_{ROOF}(t1) classification.

a4) Resistance to fire

The resistance to fire results obtained for the cladding and pitch roofing systems were better than that for sandwich panels with polyurethane core. Indeed, the results for the cladding systems refer to EI 45 classification for partitions and EI 30(i->o) classification for external walls according to EN 13501-2. For the pitch roofing system, the results refer to REI 30 classification. For the flat roofing sandwich panel, the system cannot be classified for resistance to fire (REI). Further research is needed. A sandwich panel with a thickness of 200mm used as a cladding was also tested and the performance obtained was EI60.

b) FOR THE PROFILES: DOUBLE SKIN CLADDING AND FAÇADE CLADDING WITH CASSETTES.

b1) Reaction to fire

For the reaction to fire, SBI test results point to B-s2,d0 and B-s1,d0 classifications. Two repetitions of SBI test for the configuration selected and flammability tests are being carried

out to obtain a classification according to EN 13501-1. So far, B-s2,d0 /Bs1d0 is conform to the performance obtained in similar R&D projects (see for example www.programmeprofeel.fr)

b2) Smoldering effect

As had been the case previously, smoldering was again observed and was corrected by the addition of mineral wool.

Figure 5. Cassette cladding system before, during and after the fire propagation test.

b3) Resistance to fire

For the resistance to fire, the facade systems (double skin cladding & cassette cladding system were tested in a vertical furnace and were classified as E60 EI45 as a partition and as E60 EI30 as an external wall

IV) Acoustic performances

a) For the sandwich panels

For the cladding sandwich panel, the pitch roofing sandwich panel and the sandwich panels for flat roof covering (200 mm thickness), the global weighted sound reduction index obtained were respectively Rw(C;Ctr)=29dB(-1;-3), Rw(C;Ctr)=30dB(-1;-3) and Rw(C;Ctr)=33dB(-1;-4). The performances are similar to that of sandwich panels with mineral wool insulation.

b) For the profiles: double skin cladding and façade cladding with cassettes.

For the double skin cladding system, the global weighted sound reduction index obtained was Rw = 49dB (with the adaptation coefficient Ctr equal to-9 dB and the adaptation coefficient C equal to-2 dB, for 25mm cladding profile configuration, and-3 dB, for 40mm cladding profile configuration).

Freq. [Hz]	R (dB)
50	23,0
63	13,8
80	20,7
100	23,8
125	28,8
160	30,7
200	32,2
250	37,0
315	42,4
400	49,0
500	51,1
630	52,5
800	54,6
1000	55,6
1250	56,3
1600	59,3
2000	62,5
2500	61,5
3150	59,6
4000	57,7
5000	62,2

Rw(C;Ctr)=49(-3;-9)

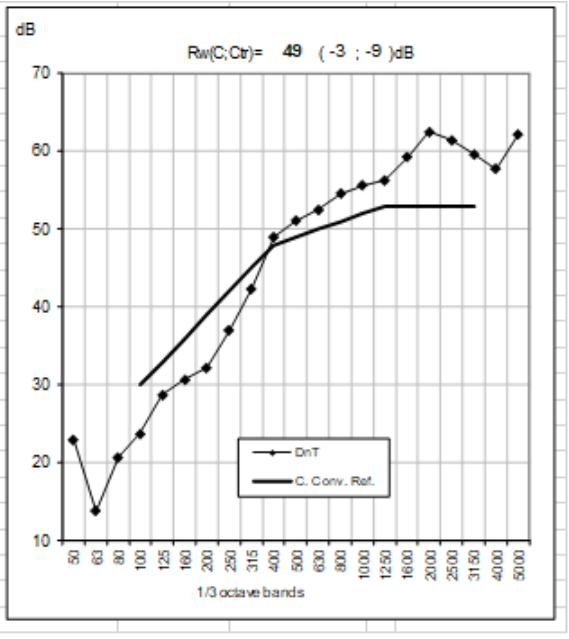

Figure 6. Test results for double skin cladding profile configuration

V) WATER AND VAPOUR PERMEABILITY

a) FOR THE SANDWICH PANELS

For water permeability, at a maximum pressure of 1200 Pa, classification A (highest classification) was obtained for the three systems of sandwich panels (cladding, pitch roofing, flat roofing).

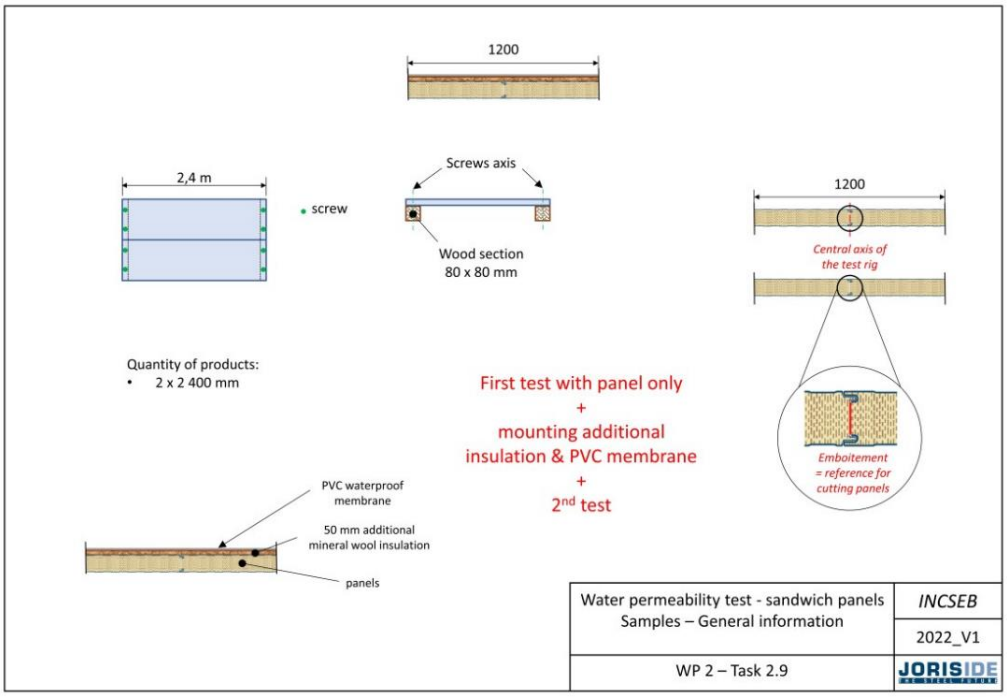

Figure 7. Example of drawings for water permeability tests flat roofing samples and mounting instructions

For vapour permeability, two different insulations (wood fibre insulation and mineral wool insultation) were tested to compare the performance of the new product to that of current products. Wood fibre insulation presents better results than the mineral wool insulation with respectively 2.2 and 1.9 water vapour diffusion resistance factors and 0.319 mg/(mhPa) and 0.369 mg/(mhPa) water vapour permeability values.

Hygrothermal models (EN ISO 13788) were developed for the flat roof sandwich panels (work in progress for the other 2 panels) which showed a risk of condensation for hygrometry class 5 (building with high humidity level).

b) For the profiles: double skin cladding and façade cladding with cassettes.

For water permeability, two double skin cladding systems were tested at a maximum pressure of 1200 Pa. Classification A was obtained (highest classification).

For vapour permeability, the systems with wood fibre insulation presents better results than those with mineral wool insulation: respectively 2.2 and 1.9 water vapour diffusion resistance factors and 0.319 mg/(mhPa) and 0.369 mg/(mhPa) water vapour permeability values.

The risk of condensation of each hygrometry classes was studied through hygrothermal models developed and based on thermal calculations. After considering different layers, it was concluded that there was no risk of condensation in double skin cladding while such a risk could occur in the cladding with the façade product (cassettes). For the system with cassettes, more calculations need to be done to evaluate characteristic and period of condensations.

The following preliminary conclusions can be drawn from the above results:

For the steel envelope systems studied, wood fiber is a viable alternative to polyurethane and mineral wool insulation, even if a few adjustments and/or optimisations are necessary for example to prevent smoldering or to protect the wood fiber against humidity during its installation. Wood fiber is also an efficient alternative for meeting new low-carbon environmental requirements.

At the end of the project, with all the INCSEB data available, manufacturers will be able to immediately start producing and marketing the 5 new systems. They will simply need, in the countries where they plan to market the new systems, to apply for the certifications required for innovative products (e.g "ATEX/avis technique" in France, "zulassung" in Germany, etc)

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