CLIMA CONTROL

EXPERIMENTAL TESTING

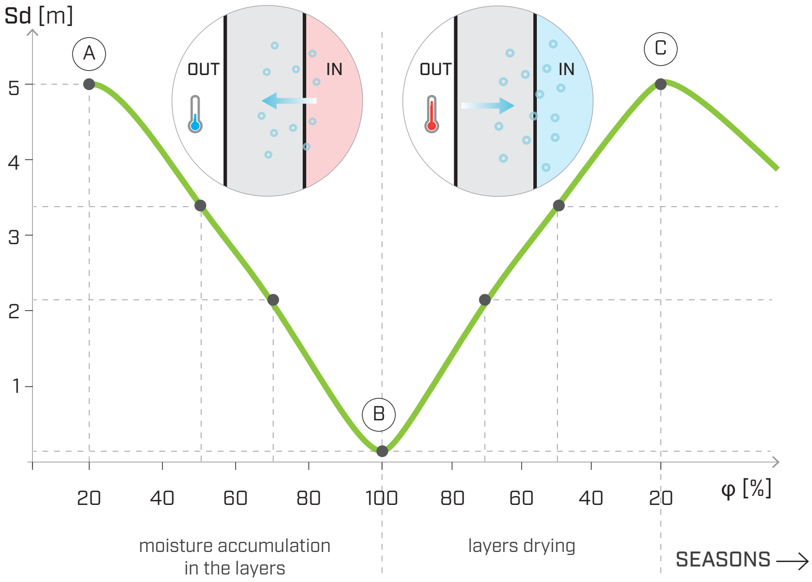
rothoblaas

Solutions for Building Technology

INTRODUCTION AND OPERATING PRINCIPLES OF THE CLIMA CONTROL MEMBRANE

CLIMA CONTROL membranes are manufactured using a new technology and feature variable vapour diffusion resistance. These membranes are capable of adapting to the hygrometric content of the structure depending on the interstitial relative humidity: in the case of high amounts of moisture, these behave like a more breathable membrane, facilitating the structure drying.

In order to avoid damage to the structure due to high vapour content, the accumulation of moisture within the building component is prevented by its ability to dry.



Ⓐ **DRY LAYERS : Sd 5 m**
maximum protection - vapour barrier to limit the passage of vapour in view of the season when moisture accumulates within the layers

Ⓑ **HUMID LAYERS : Sd 0,15 m**
maximum breathability - breathable membrane to allow drying during the reverse vapour diffusion phenomenon

Ⓒ **DRY LAYERS : Sd 5 m**
maximum protection for the start of a new year and a new cycle

A construction building undergoes an annual cycle with two phases: an unfavourable one in which moisture accumulates and a more favourable one in which drying is possible.

Diagram 1 shows the behaviour of CLIMA CONTROL during this cycle.

Initially, the construction building is dry and the CLIMA CONTROL membrane acts as a vapour barrier (A) that restricts the passage of vapour through the layers.
During the most unfavourable season, the interstitial moisture increases (A-B section) and by the end of this period, a small amount of moisture has accumulated inside the component (B).
Then the most favourable season begins in which vapour flow reversal occurs, and the layers may also dry in the CLIMA CONTROL direction because the membrane has become breathable (B).
After the drying phase is complete, CLIMA CONTROL returns to being a vapour barrier (C) and the layers are ready for a new annual cycle.

The drying phase is essential to prevent excessive moisture accumulation and avoid condensation phenomena: however, it is only possible if the membrane is able to change its vapour permeability according to the boundary conditions.

The vapour transmission property change range of the CLIMA CONTROL membrane is optimized to allow it to change its behaviour from vapour barrier to breathable membrane and is in line with the recommendations to date for this particular type of product.

- DIN 68800-2 — UR 45%: Sd>3m; UR 70%: 1,5m <Sd< 2,5m
- DIN 4108-3: — UR 25%: 2,0m <Sd< 10,0m; UR 90%: Sd≤ 0,5m

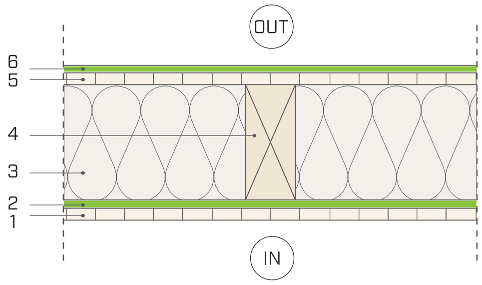
The purpose of these instructions is to ensure the proper functioning of the membrane: changes in the moisture content within the layers are necessary to produce the change in the vapour transmission property of the membrane and ensure the drying of the construction building.

Because of the innovative behaviour of CLIMA CONTROL membrane, Rothoblaas, in collaboration with external research institutions, funded laboratory tests and dynamic simulations for the purpose of verifying the actual behaviour of CLIMA CONTROL within different construction buildings (roof and wall) and under different climatic conditions.

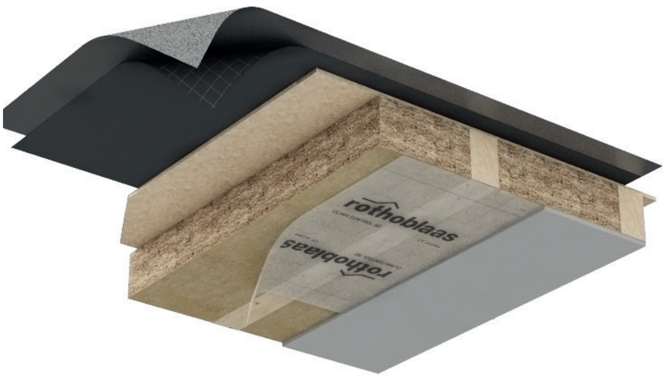
THERMO-HYGROMETRIC ANALYSIS OF A FLAT ROOF WITH CLIMA CONTROL

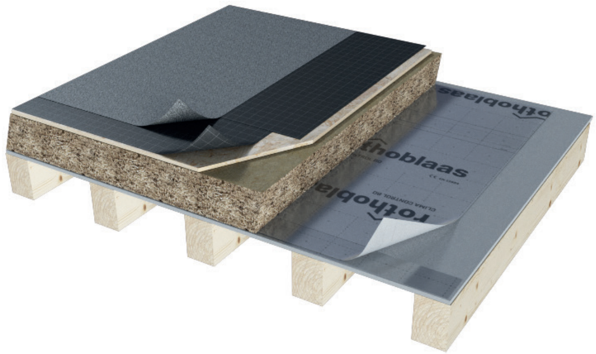
The purpose of the study was the verification of the thermo-hygrometric performance of a flat roof layer incorporating a variable vapour diffusion membrane (CLIMA CONTROL).

The choice of the layer was made by taking the example proposed by the German DIN 68800-2:2012 standard, in which a variable diffusion membrane is to be used:



1. Inner coating Sd < 0.5m
2. Membrane with variable vapour diffusion
   (Sd ≥ 3 m for UR ≤ 45% and 1,5 m ≤ Sd ≤ 2,5 m with 70% UR)
3. Mineral fibre insulation according to EN 13162, timber fibre insulation according to EN 13171 or other insulation approved for this application.
4. Timber element
5. Upper wooden plank
6. Waterproofing sheath or metal roof



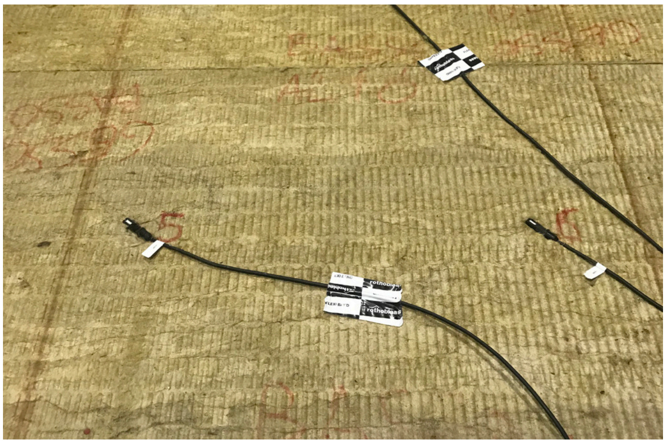


LABORATORY TEST

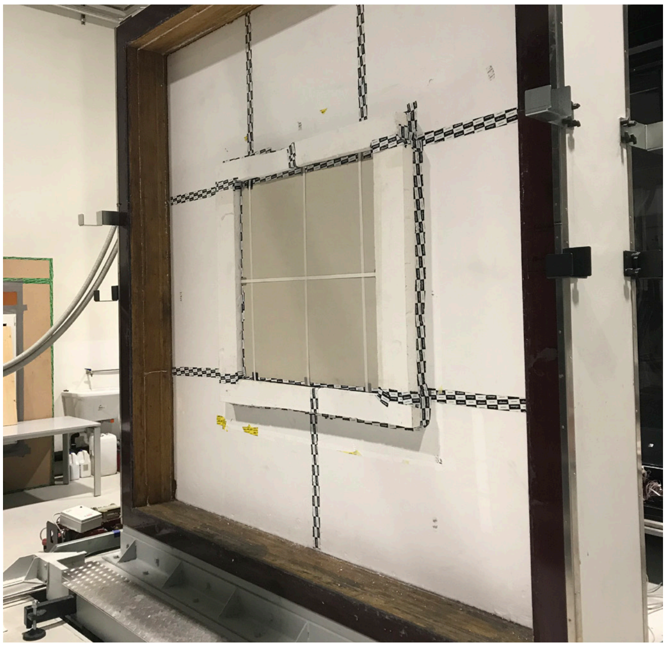
Given the innovative behaviour of the CLIMA CONTROL membrane, a preliminary laboratory measurement phase was set up to evaluate the actual behaviour of the layers and to be able to use the results to calibrate the theoretical model.

The properties of the materials used in the construction package are shown in the following table:

Layer	thickness [mm]	density [kg/m^3]	thermal conductivity [W/mK]	water vapour permeability Sd: [m^2] μ: [ ]
BYTUM SLATE 3500 Self-adhesive slated bituminous membrane	2.8	1250	0.17	Sd = 280
BYTUM BASE 2500 Self-adhesive bituminous membrane	2	1250	0.17	Sd = 200
OSB panel	20	530	0.1	Sd = 1.8 - 3 μ = 90 - 150
Mineral wool insulation	120 + 120	110	0.036	Sd = 0.24 μ = 1
CLIMA CONTROL Membrane with variable vapour diffusion	0.2	400	n.a.	Sd = 0.15 - 5
Fibre-gypsum board	12.5	744	0.21	Sd = 0.05 μ = 4



In order to monitor the thermo-hygrometric behaviour during the tests, the specimen was equipped with 8 temperature and relative humidity sensors.



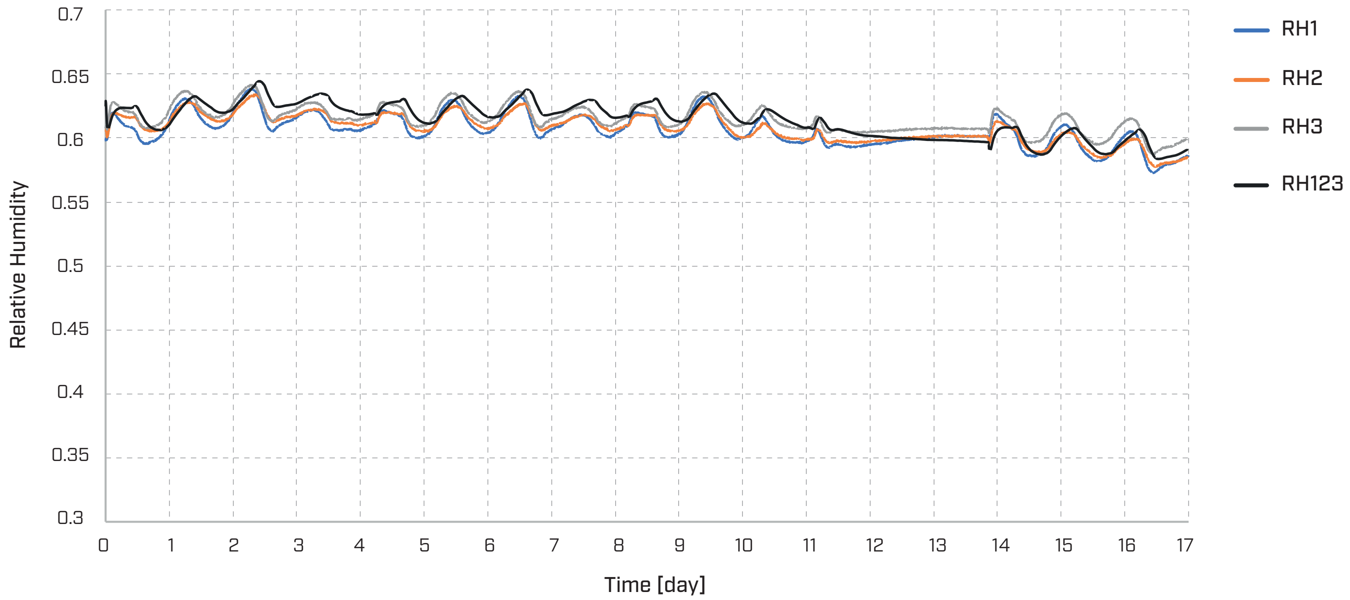
Specimen installed in the stand in the middle of the (open) climate chambers in the Multifunctional Facade Lab.

The various layers underwent a pre-conditioning phase and were kept at high humidity (~80%) and constant temperatures for about three days to ensure that the initial moisture content of the materials was around that threshold in the subsequent test phase.
Once the pre-conditioning phase of the various layers of the specimen was completed, it was subjected to the dynamic test phase for approximately 17 days. During this phase, operational environmental boundary conditions (Central European summer climate-Munich, Germany) were reproduced in the laboratory.

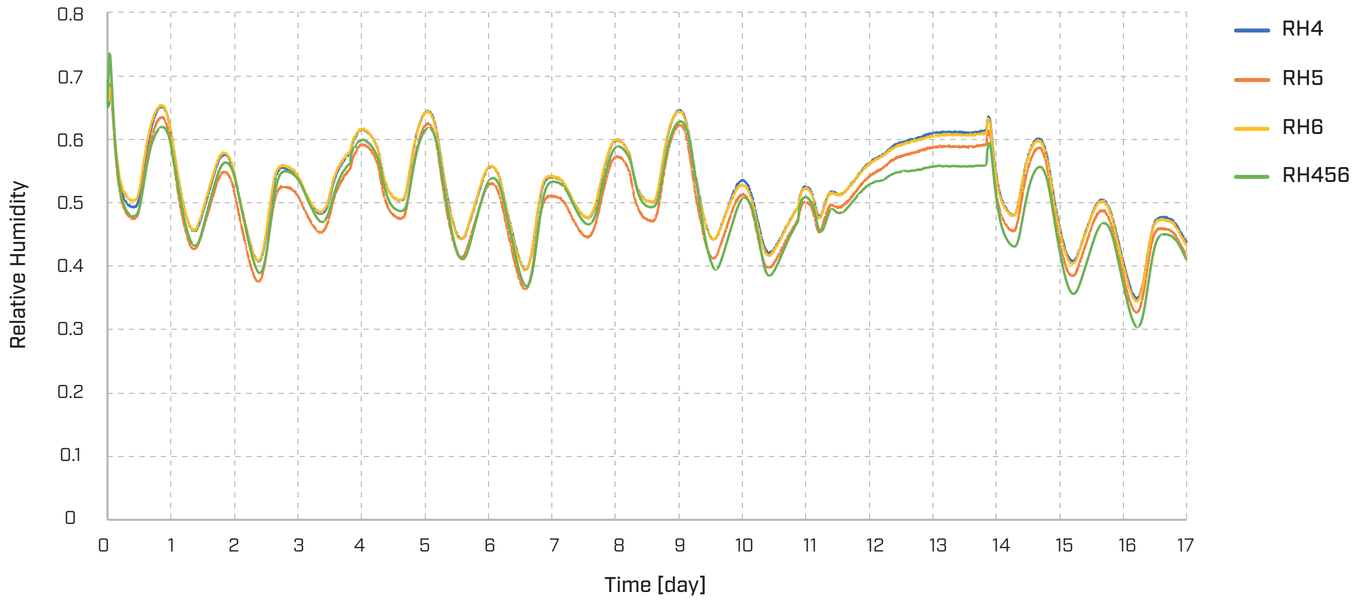
SIMULATION WITH SOFTWARE

The data collected from the various sensors inside the specimen during the laboratory test were used to calibrate a two-dimensional thermo-hygrometric model developed with DELPHIN 6 software.

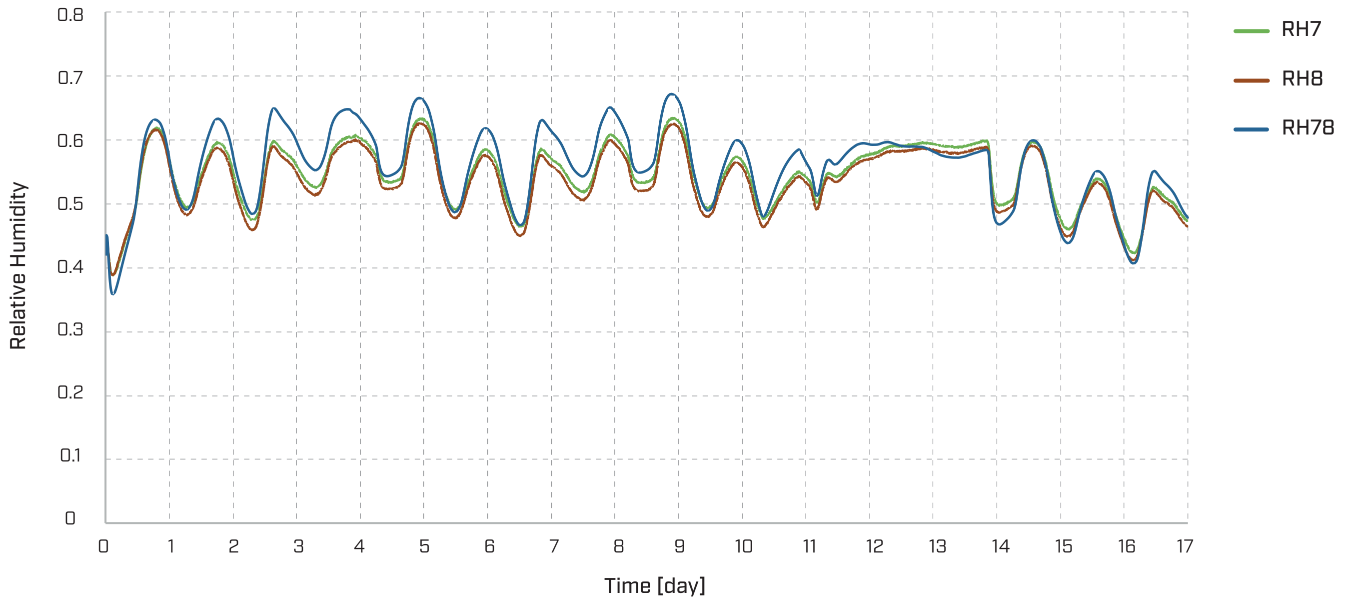
Temperature (T) and relative humidity (RH) of sensors 1, 2 and 3 were compared with outputs of the T123 and RH123 model respectively; values of T/RH sensors 4, 5 and 6 with outputs T456 and RH456; values of T/RH sensors 7 and 8 with outputs T78 and RH78.



Comparison of RH 1, 2 and 3 from tests with model values (RH123)



Comparison of RH 4, 5 and 6 from tests with model values (RH456)



Comparison of RH 7 and 8 from tests with model values (RH78)

Once the model was calibrated, it was used to extend the thermo-hygrometric study in various climates and for a long-term analysis (10 years).

As the layers are related to a roof, the multi-year simulations were carried out by setting the model horizontally, considering the effect of gravity on moisture transport, in order to verify the real behaviour of the roof construction.
The simulation was then run on the same configuration calibrated with the test data but changing the external T/RH conditions (Brisbane Annual Climate File and Abu Dhabi Annual Climate File), adding a layer of insulation and a plasterboard panel to the inside. This was carried out in order to understand the behaviour of the membrane, should it be located further inland and thus in more unfavourable conditions, while maintaining the climatic conditions of the laboratory test (Annual Climate File Central Europe, München).

The last simulation is the same configuration calibrated with test data and the same climatic conditions (Annual Climate File Central Europe, München) in the absence of the CLIMA CONTROL membrane.

Configuration	layers used in the model	INDOOR T/RH conditions (1)	OUTDOOR T/RH conditions (2)
CONDITION 1	calibrated layers with test data (Table 5)	from WTA adaptive indoor climate model implemented in the Delphin6.0 software	annual climate file Central Europe **München**
CONDITION 2	calibrated layers with test data (Table 5)	from WTA adaptive indoor climate model implemented in the Delphin6.0 software	annual climate file hot-humid condition **Brisbane**
CONDITION 3	calibrated layers with test data (Table 5)	from WTA adaptive indoor climate model implemented in the Delphin6.0 software	annual climate file hot-humid condition **Abu Dhabi**
CONDITION 4	calibrated layers with test data (Table 5) + 5 cm insulation layer + plasterboard sheet	from WTA adaptive indoor climate model implemented in the Delphin6.0 software	annual climate file Central Europe **München**
CONDITION 5	calibrated layers with test data (Table 5) without CLIMA CONTROL	from WTA adaptive indoor climate model implemented in the Delphin6.0 software	annual climate file Central Europe **München**

(1) WTA Adaptive Indoor Climate Model is taken from DIN EN 15026 and allows the relative temperature and humidity conditions of an indoor environment to be determined from outdoor conditions

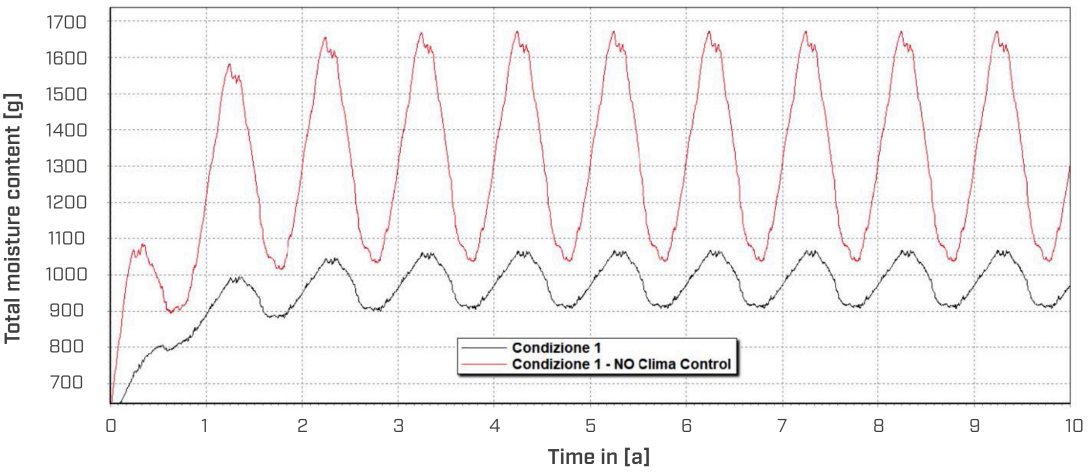
(2) The climate data used to carry out the multi-year simulations are made available by the World Meteorological Organisation and provided by the EnergyPlus website (https://energyplus.net/weather)

RESULTS

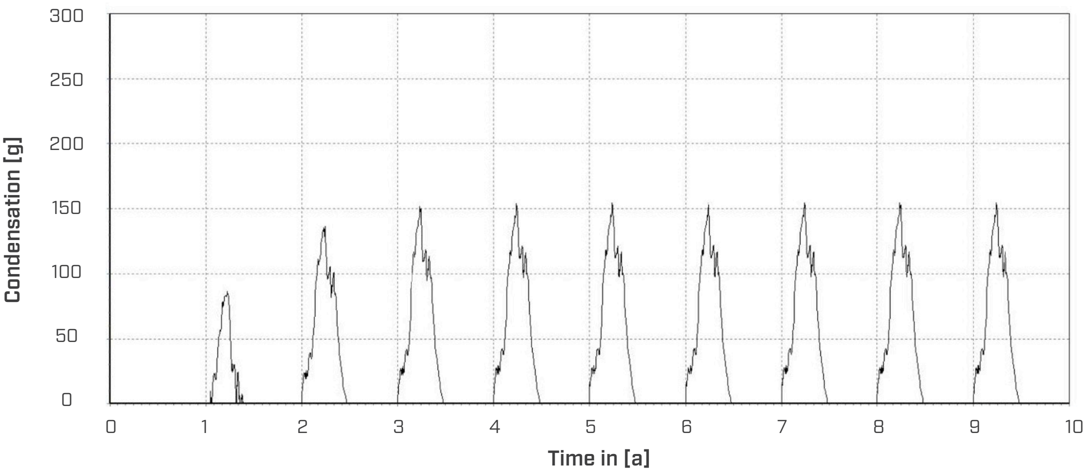
In all layers with CLIMA CONTROL (condition 1, 2, 3, 4), the internal moisture content in the layers, over the simulated 10 years, increases during the winter season and then discharges and repeats the cycle. It is also important to note that the moisture content stabilises over the course of the first few years and reaches a maximum level that, in the peaks, does not exceed relative humidity levels within the layer of more than 95%, a level considered to be the maximum permissible threshold before condensation occurs.

CASES				
1	2	3	4	5
MUNICH	BRISBANE (AUSTRALIA)	ABU DHABI	MUNICH + suspended ceiling	without CLIMA CONTROL
NO CONDENSATION	NO CONDENSATION	NO CONDENSATION	NO CONDENSATION	CONDENSATION

In the simulation without CLIMA CONTROL (condition 5), moisture content levels are significantly higher and several grams of condensation periodically form.



Comparison of moisture content trends in CONDITION 1 with and without CLIMA CONTROL membrane



Condensation formation in the absence of CLIMA CONTROL (condition 5)

CONCLUSIONS

The analysis methodology successfully verified the behaviour of a typical flat roof layers with variable vapour diffusion CLIMA CONTROL membrane.
After testing with dynamic boundary conditions on a test specimen for the duration of approximately 17 consecutive days, the monitored temperature and relative humidity values were used to calibrate a thermo-hygrometric model developed with the DELPHIN 6 software.
Once an adequate level of model accuracy had been reached, the model was used to extend the analysis to 10 years, evaluating the behaviour of the layers under different climatic conditions.
In all the cases simulated, the layers did not present any problems relating to the formation of condensation, suggesting that the application of the CLIMA CONTROL membrane with variable vapour diffusion is valid for preventing the excessive accumulation of humidity, also allowing the layers to dry in summer.
As shown in simulation 5 (Central European climate in the absence of CLIMA CONTROL), the presence of CLIMA CONTROL plays a decisive role in periodically avoiding winter condensation phenomena towards the outer strata of the layers.
It should be noted that the analysis of layers for a flat roof requires in-depth knowledge of technical physics and the ability to use specific software. A correct design and analysis of the layers is not easy and each situation requires a precise definition of the boundary conditions and the materials used.

THERMO-HYGROMETRIC ANALYSIS OF WALLS WITH CLIMA CONTROL

The purpose of the study is to verify the thermo-hygrometric performance of certain walls under varying external conditions.

COLD AND HUMID OUTDOOR CLIMATE		
WINTER CON-DITIONS	INTERNAL	OUTDOOR
	T = 20°C U.R.= 40%	T = 0°C U.R.= 80%

Usually, in cold climates and during the winter months there are problems with excessive humidity inside buildings due to poor ventilation. The vapour produced in closed rooms penetrates the walls and condenses in contact with cold interstitial layers, beams or cladding.

HOT AND HUMID OUTDOOR CLIMATE		
SUMMER CON-DITIONS	INTERNAL	OUTDOOR
	T = 26°C U.R.= 80%	T = 40°C U.R.= 70%

In hot and humid climates, on the other hand, the source of vapour that leads to mould growth is the outside air: the moisture, brought inside with the outside air, condenses near the interior surfaces, which are colder due to air conditioning.

LABORATORY TEST

Given the innovative behaviour of the CLIMA CONTROL membrane and the special outdoor climatic conditions, a laboratory measurement phase was set up to evaluate the actual behaviour of the layers and to be able to use the results to calibrate the theoretical model.

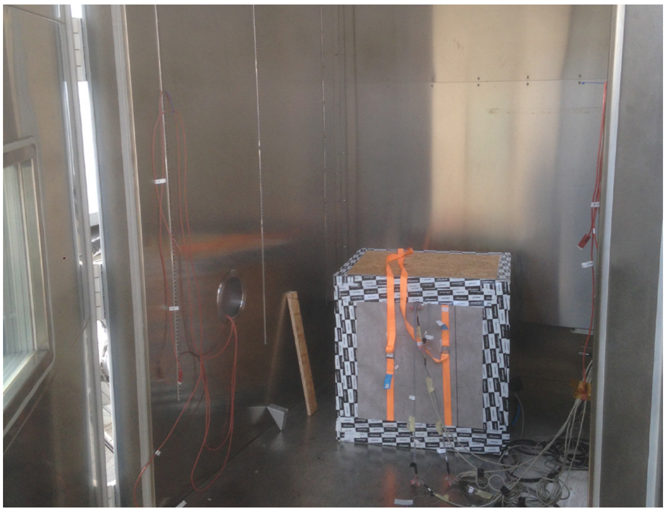
The properties of the materials used in the construction package are shown in the following table:

INSIDE	material name	thickness [mm]	surface [m x m]	density ρ [kg x m3]	specific heat [J/kgK]	thermal conductivity λ [W/mK]	vapour diffusion resistance μ
Layer 1	fibre-gypsum board	12.5	0.5 x 0.5	1133.35	1228.37	0.34	16.83
Layer 2	mineral wool insulation	60	0.5 x 0.5	150.00	2000.00	0.04	3.00
Layer 3	CLIMA CONTROL 80 (1)	0.2	0.5 x 0.5	400.00	1700.00	0.20	1000 - 25000
Layer 4	mineral wool insulation	100	0.5 x 0.5	150.00	2000.00	0.04	3.00
Layer 5	OSB panel	18	0.5 x 0.5	630.00	1880.00	0.13	280.00
Layer 6	TRASPIR 75 (2)	0.3	0.5 x 0.5	250.00	1880.00	0.30	67.00

(1) CLIMA CONTROL (membrane with variable vapour diffusion)

(2) TRASPIR (breathable membrane)

In order to monitor the thermo-hygrometric behaviour during the tests, the specimen was equipped with temperature and relative humidity sensors.

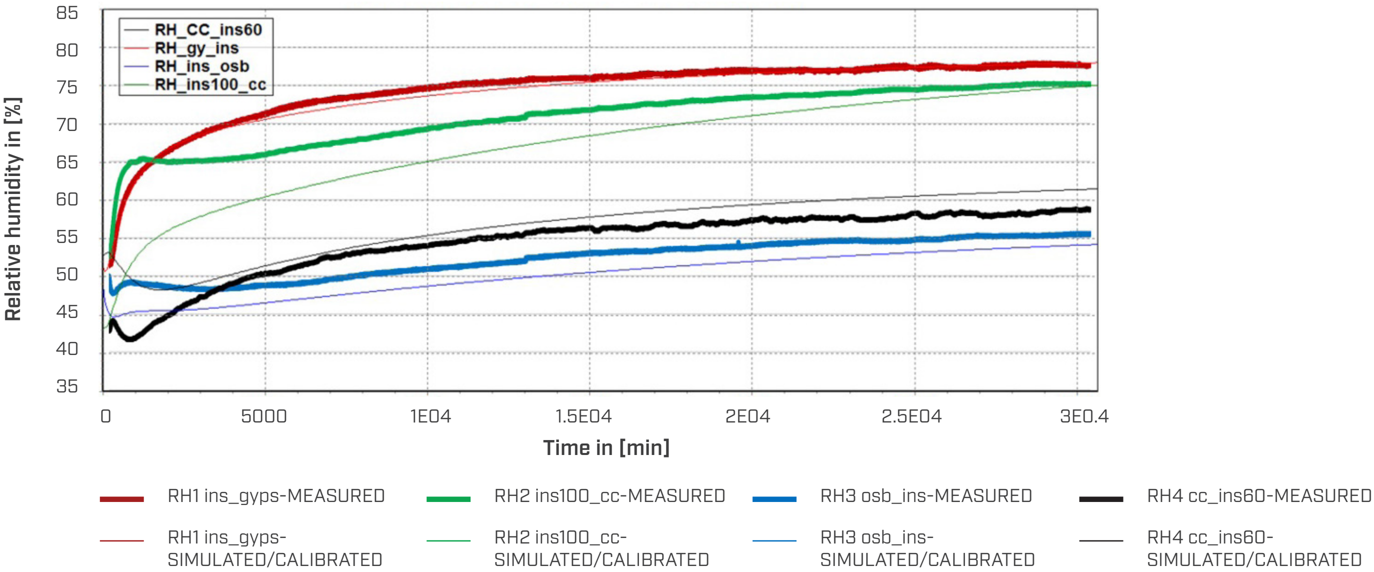


In order to recreate the desired boundary conditions, it was decided to use a fictitious climatic chamber built in the laboratory, which is very well insulated both thermally and in terms of vapour diffusion. The specimen formed one side of the craft chamber, which was placed inside a single-zone climatic chamber capable of generating the desired temperature and humidity conditions. Within the fictitious climatic chamber, the desired temperature and humidity conditions were created by means of a thermostat heater and the use of a specially mixed salt solution.

Two tests were carried out: the first in a warm and humid outdoor climate, the second in a cold and humid outdoor climate. Each test lasted approximately 15 days.
During the first test (hot and humid outdoor climate), it was possible to maintain a variability of the boundary conditions, compared to the desired conditions, of less than 10% for RH and about 2°C for temperature. In the second test (cold and humid outdoor climate), the actual relative humidity differed from the expected humidity by up to 15%; while the temperature fluctuated by approximately 2°C. This slightly varying trend in the conditions imposed on the two sides of the test specimen, however, was not a problem: the conditions inside the two climate chambers were constantly monitored and the recorded humidity and temperature data were subsequently assigned to the software model during calibration.

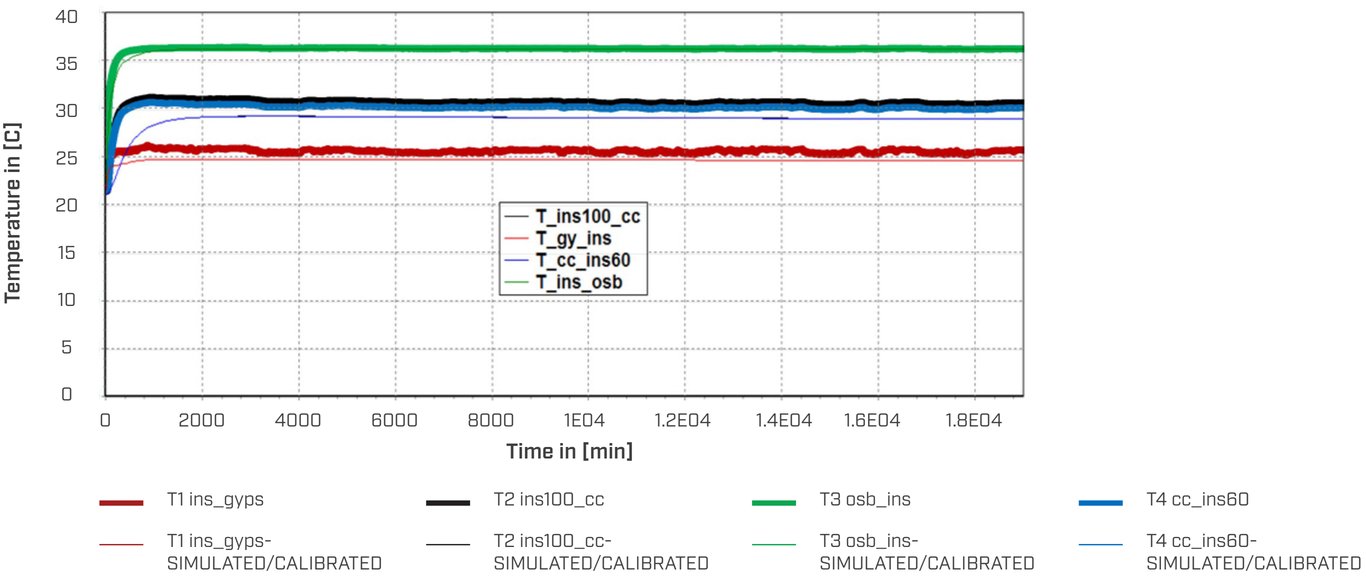
RH LAYERS TEST 1 CC DYNAMICS

Relative humidity (RH) trend in the first test - measured data (thick line) and calculated data (thin line) compared



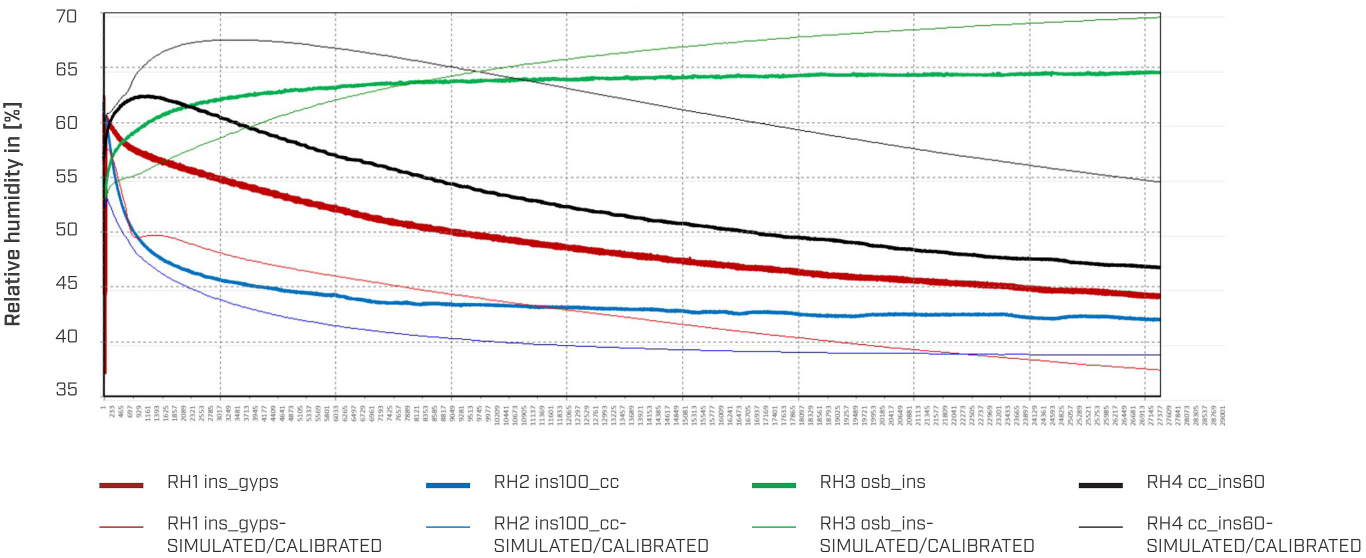
T LAYERS

Temperature trend in the second test - measured data (thick line) and calculated data (thin line) compared



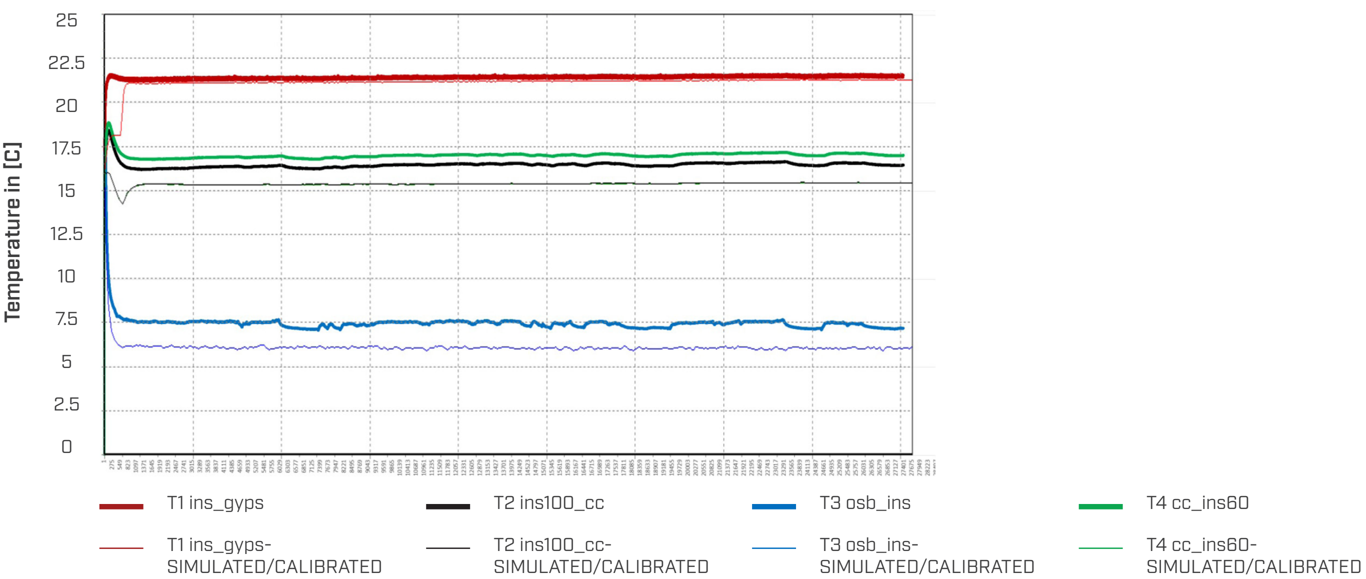
RH LAYERS TEST 2

Relative humidity (RH) trend in the second test - measured data (thick line) and calculated data (thin line) compared



LAYERS TEMPERATURE TEST 2

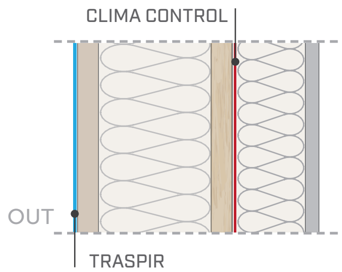
Temperature trend in the second test - measured data (thick line) and calculated data (thin line) compared

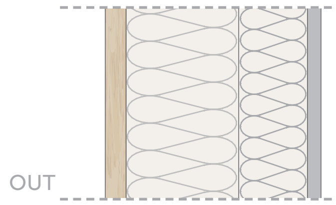


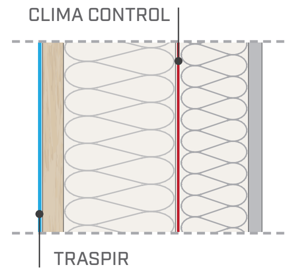
The data measured in the second test show a greater deviation from those calculated by software modelling. This result may have been influenced by the unstable boundary conditions of the humidity level, both inside the box and in the climate chamber. The main problem could be attributable to the need to operate the machine at temperatures very close to 0°C. In addition, a non-optimal dosage of the salt solution was found to regulate the amount of vapour in the air. Added to this, there is the incomplete drying of the specimen at the end of the first test, due to the short period of time between the two tests.

SIMULATION WITH SOFTWARE

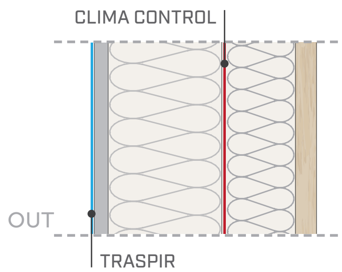
The data collected from the various sensors inside the specimen during the laboratory test were used to calibrate a two-dimensional thermo-hygrometric model developed with DELPHIN 6 software.

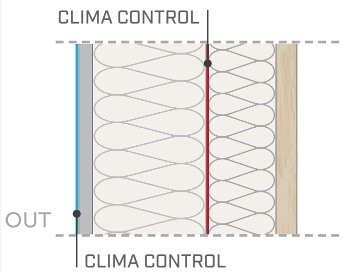


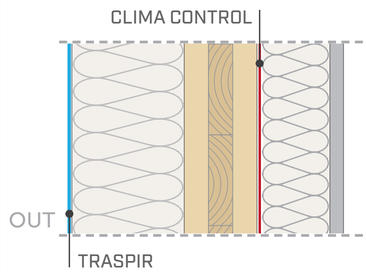




	CASE 0	OUTDOOR OSB CASE	OUTDOOR OSB CASE
HOT AND HUMID OUTDOOR CLIMATE	NO CONDENSATION	NO CONDENSATION	NO CONDENSATION
COLD AND HUMID OUTDOOR CLIMATE	NO CONDENSATION	CONDENSATION	NO CONDENSATION







	INDOOR OSB CASE	INDOOR OSB CASE	CLT CASE
HOT AND HUMID OUTDOOR CLIMATE	CONDENSATION	NO CONDENSATION	NO CONDENSATION
COLD AND HUMID OUTDOOR CLIMATE	NO CONDENSATION	NO CONDENSATION	NO CONDENSATION

Below are the graphs chosen to evaluate the conditions of the construction packages relating to temperature, internal relative humidity, moisture mass density and possible condensation content.

As an example, for the purpose of brevity, only the results of configurations with OSB are shown where the importance of putting attention to the choice and placement of membranes within the layer structure is pointed out. The incorrect use of vapour barriers and breathable membranes can lead to condensation and consequently to damage to the structure.

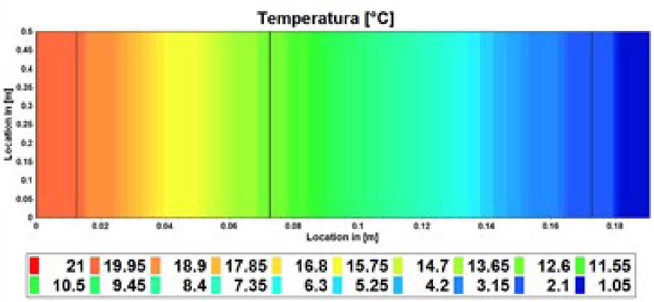
OUTDOOR OSB CASE:

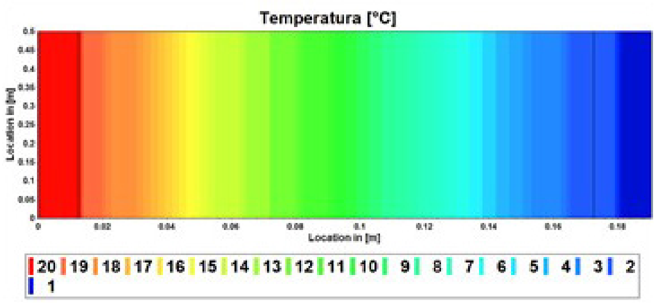
The case with OSB placed towards the outside in a warm humid climate did not develop any problems, both with the use of membranes and without, presenting low levels of relative humidity within the material.

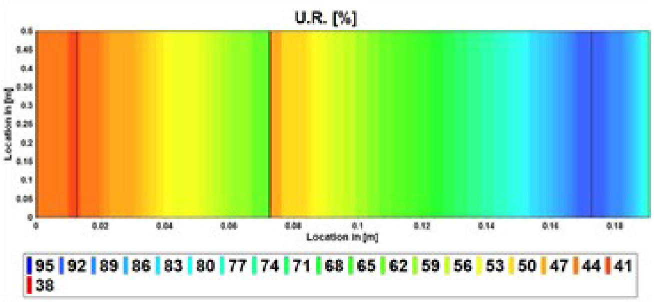
In cold humid climate, however, it is interesting to note the formation of condensation when membranes are not used (approx. 23 g/dm3 of condensation). In this particular situation, as there is no CLIMACONTROL80 vapour barrier, the humidity level becomes too high at the cold surface close to the outdoor environment, leading to condensation (internal relative humidity above 95%).

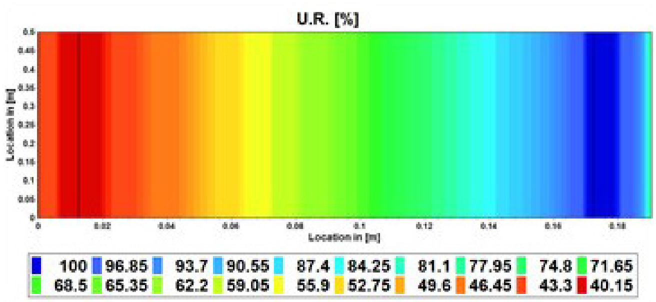
WINTER WITH MEMBRANES

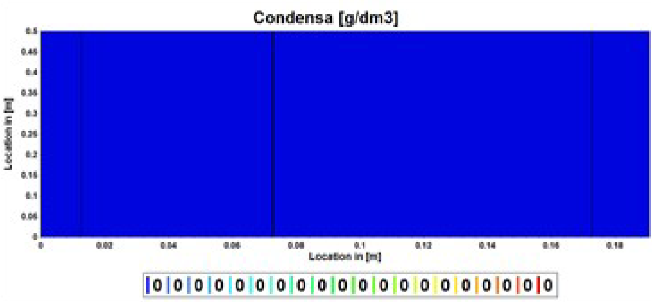
WINTER WITHOUT MEMBRANES

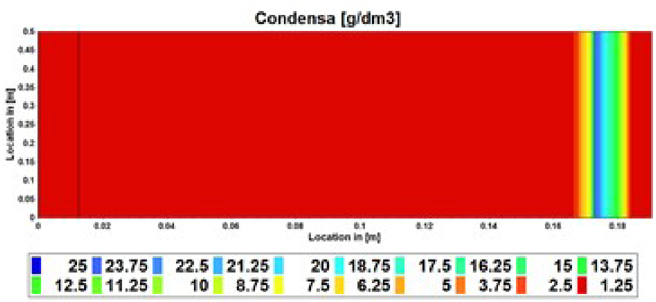










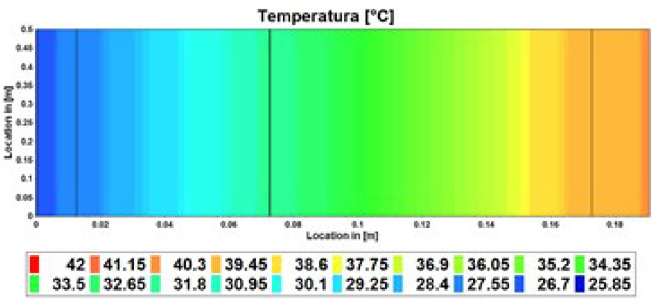


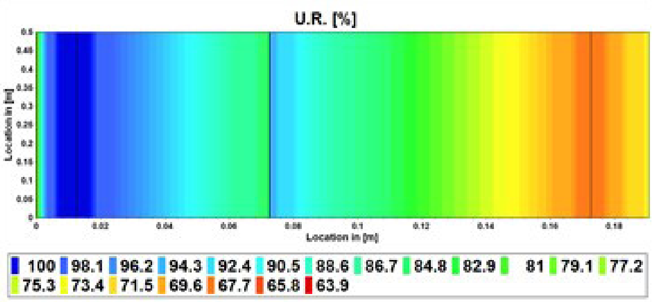
INDOOR OSB CASE:

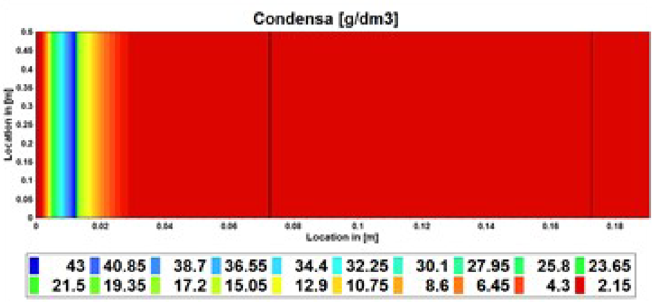
The layers with OSB facing the air-conditioned indoor environment, in hot and humid outdoor conditions, caused condensation problems when using CLIMA CONTROL on the inner side and TRASPIR on the outer side. As vapour rises up the construction package from the outside to the inside, it accumulates near the OSB at relatively low temperatures and reaches the relative humidity limit for condensation (approx. 43 g/dm3).

To overcome this problem, an attempt was made to replace the external TRASPIR breathable membrane with an additional CLIMA CONTROL: this solution proved effective in reducing the flow of vapour from outside and preventing condensation inside the package.

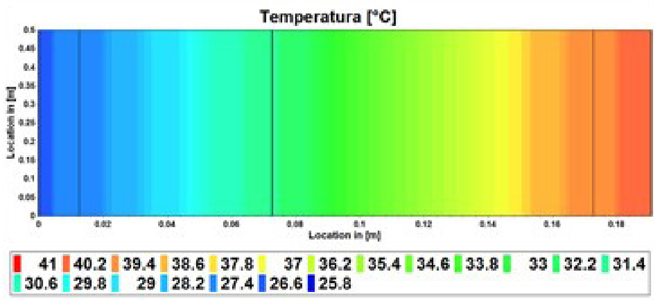
SUMMER CLIMA CONTROL 80 + TRASPIR 75

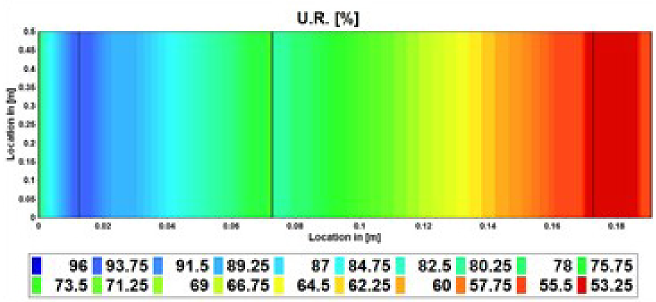


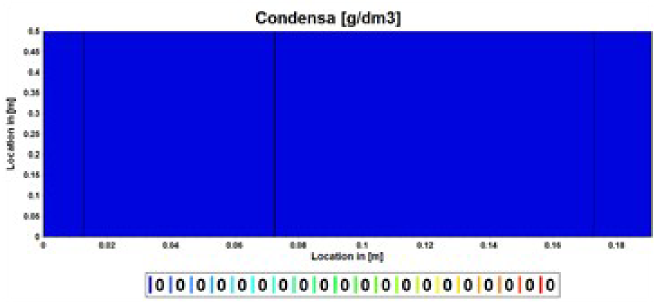




SUMMER 2 CLIMA CONTROL 80







It should be noted that in cold and humid climates, this construction package did not present problems of excessive relative humidity within the materials.

CONCLUSIONS

In this work, a number of typical construction packages of timber structures were analysed from a thermo-hygrometric point of view. One of the aims of the project was also to verify the correct functioning and positioning of the vapour barrier and breathable membranes.

Given the increasing demand for solutions in non-European markets, it was interesting to see whether the characteristics of the packages currently used could also be valid in particularly hot and humid or cold and humid climates.

Comparing the various outputs, it is clear that the use of breathable and vapour barrier membranes is crucial in order to adequately regulate vapour flows through construction packages, but that the position within the layers of certain materials is also particularly important in order to avoid condensation phenomena.

In order to ensure optimal performance of the building casing, the processes of heat, vapour, air and wind transport that occur within the different components must be studied and controlled to avoid interstitial and surface condensation.

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Rotho Blaas Srl

Via dell'Adige N.2/1 | 39040, Cortaccia (BZ) | Italia
Tel: +39 0471 81 84 00 | Fax: +39 0471 81 84 84
info@rothoblaas.com | www.rothoblaas.it