Nataliia Vinogradova

Passive control of indoor humidity with wooden materials

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Abstract

This thesis investigates if the moisture buffering effect of wooden materials can stabilize indoor humidity by using a case study of an administrative building. This work was done for the PUUSTA project (Welfare Innovations from Wood).

The simulations have been carried out in IDA ICE. The HMWall model developed by EQUA was used to simulate the moisture buffering effect in structures. During the research, guidelines and advice from HMWall developer were used to run the simulation correctly.

The entire simulation environment has been established and described. Three simulation cases were performed. These cases were chosen to find out if replacing walls with the new model (thereby adding the moisture buffering effect) has an impact on the results.

It was concluded that the humidity flux through the structure during the summer is 4 times higher than the values in winter. It shows that the work of HMwall is correct and does not conflict with the theory. It was also noticed that the largest amplitude of humidity flux for January is observed at the internal wall with the largest area and is 5.4·10(-7) kg/s. In July, the greatest amplitude is observed at the external wall with the largest area and is 22.6·10(-7) kg/s.

Occupants, lighting, or equipment activity had almost no impact on the increase or decrease in the humidity in the room at the scale of the simulation. This was observed both at the level of the working week and at the level of the working day.

After a comparison of simulation cases, it can be concluded that according to the results, there is an impact of moisture buffering on humidity, but it is extremely small. Humidity peaks decreased by approximately 1% or less, which is almost imperceptible to humans.

Keywords

Moisture buffering, humidity stabilization, indoor humidity, IDA ICE humidity simulation, HMwall IDA ICE, wooden material

CONTENTS

1 INTRODUCTION

Presently, everyone is concerned about the efficiency of buildings, reasonable energy consumption, and the application of such technologies and materials that would reduce energy consumption and the cost of building and operating objects. People also strive to make construction and housing the most environmentally friendly. One of the leading materials in many respects is wood. Undoubtedly, this is one of the most environmentally friendly materials, with the lowest emissions and valuable technical characteristics. The researchers also strive to reveal the potential of the wood, even more, to try to use all the abilities of wood to improve the technical characteristics of the building and the climate of its premises.

Hygroscopic materials exhibit the property of moisture buffering, which enables them to mitigate the peaks of relative humidity in indoor air. By absorbing and desorbing moisture from the surrounding environment, these materials attain a state of equilibrium moisture. This favorable effect results in an improved perception of indoor air quality and thermal comfort. Wood, owing to its inherent ability to buffer moisture, can actively stabilize indoor air humidity. However, the full potential of this moisture-buffering capacity has yet to be harnessed on a large scale. /1/.

Can we use the moisture buffering ability of wood to improve the indoor humidity climate? In this thesis, a review of previous studies on this topic will be done and there will be an effort to get my results using simulation software from EQUA, after that it will be possible to conclude: is there a significant effect on the indoor humidity climate, and is it advisable to use it?

The main aim of the study is to evaluate the potential of using wooden materials to stabilize the humidity in a room. To achieve this aim the simulation of a room in an administrative building will be created in IDA ICE software. To make moisture buffering simulation possible, the HMWall extension will be explored and the correct environment for the simulation will be set. After the simulation, the results will be analyzed and values with and without extension software will be compared. Upon completion of all of the above, it will be possible to evaluate the potential of using the phenomenon of moisture buffering to stabilize indoor air humidity.

This thesis will be done for the project PUUSTA (Welfare Innovations from Wood). In particular for Work Package 2 (WP2). This work package deals with the moisture buffering of wood materials used indoors and how this moisture buffering phenomenon could be utilized for improving indoor air quality and reducing energy used for regulating the indoor climate.

2 THEORETICAL BACKGROUND

Before doing the research, it is essential to understand the idea of the moisture buffering effect and the history of its study. According to the test protocol developed in the Nordtest project on moisture buffering of building materials “The moisture buffering effect of a room is the ability of the materials within the room to moderate variations in the relative humidity”. /2, p. 15/

Since the 1980s, there has been a significant interest in utilizing building materials to control indoor thermal environments, and research on hygrothermal conditions has focused more on the use of building materials for this purpose. The findings have been implemented in building design and analysis ever since. However, there has been a growing interest in examining the moisture buffering properties of absorbent, porous building materials in recent years. In 1999, Arfvidsson described a method for calculating the depth of moisture penetration /3/. In 2001, Mitamura et al. conducted assessments of moisture buffering in building materials. /4/.

In 1998 Time /5/ and Padfield /6/ suggested methods for characterising the buffering effect of moisture. In 2000 Hansen et al. proposed a method for assessing the moisture buffer effect through basic measurements such as continuous weighing of the specimen, density, permeability, and sorption /7/.

Simonson et al. have been given an example of how the transfer of moisture between wooden structures and indoor air significantly reduces the maximum humidity in the room (up to 35% relative humidity) and increases the minimum humidity in the room (up to 15% relative humidity). Additionally, Simonson, Salonvaara, and Ojanen found that the use of hygroscopic materials for internal surfaces in a building could decrease the maximum RH in the room compared to "non-breathable" surfaces, reducing overall RH by 20%. /8/.

In their study, Salonvaara et al. /9/ found that wood and other materials have the capability to maintain the average relative humidity at approximately 40% over a 24-hour testing period. This relative humidity level falls within the recommended range for ensuring the health and comfort of building occupants.

One of the most famous events related to the topic of moisture buffering is the NORDTEST project. The NORDTEST project on moisture buffer capacity (MBC) constituted a collaborative endeavor among Nordic research institutions and industry organizations with the goal of developing a standardized method for quantifying the capacity of building materials to regulate indoor humidity levels via the absorption and release of moisture. MBC pertains to the ability of materials to absorb and desorb moisture in response to variations in the indoor environment, such as temperature and relative humidity. Materials with high MBC can help to maintain a stable and comfortable indoor environment by attenuating fluctuations in humidity levels. /10/

The NORDTEST project involved laboratory testing of various building materials to establish their respective MBC values, as well as the formulation of a calculation method for estimating MBC based on material properties such as porosity and sorption isotherms. The primary objective of the project was to develop a standardized MBC test method that would be applicable to a broad range of building materials, including wood, concrete, gypsum, and insulation materials.

The standardized MBC test method derived from the NORDTEST project has since been adopted as a national standard in several Nordic countries and has also served as a foundation for international standards. The project has contributed to increased comprehension and recognition of the significance of moisture buffering in building design, and has facilitated the promotion of materials with high MBC for enhancing indoor comfort and reducing energy consumption in buildings.

It was discovered after the project's initiation that a Japanese standard (JIS A 1470-1) /11/ had recently been published on a related topic, albeit with some differences in methods. While the Japanese standard only applied to building materials, the Nordtest project included other materials and systems exposed to indoor air.

Wood2New project was a European research project completed in 2017 that aimed to promote the use of wood in construction and increase the efficiency of wood-based building products. One aspect of the Wood2New project was investigating the moisture buffering potential of wood-based materials. The project involved testing various wood-based materials for their moisture buffering properties, such as cross-laminated timber (CLT) and wood fiber insulation. Preliminary results showed that these materials had a positive impact on indoor air quality by regulating humidity levels and reducing the risk of mold and other moisture-related problems. /10/

Additionally, the results of the project showed that the use of wood as a building material brings significant benefits to both the environment and our health. The scientists involved in the project mentioned such vital properties of wood as exceptional strength, ease of processing, renewability and wide availability of the material. In addition, wood absorbs carbon dioxide, equalizes the humidity in the room and is suitable for recycling. When people, for example, take a shower or prepare food, this contributes to an increase in humidity in the room. Wood absorbs moisture and then gives it back to the atmosphere when the air of the room becomes dry - this process has been studied using a thermal camera. /10/

3 RESEARCH METHODS AND MATERIALS

To fulfill the tasks set, it was decided to make a simulation in IDA Indoor Climate and Energy (IDA ICE) software using the HMwall extension from EQUA /12/. Part of an office building will be modeled. There will be three office spaces connected with each other. Each of the room will have different purpose to have opportunity to simulate different types of activity at different times of the day. It will allow to have different moisture content during the day. HMWall will be used to simulate adsorption and desorption of wooden interior material.

3.1 Building model preparation

Before the HMwall implementation, an initial project must be created with the building model and the main parameters set. The key aspects of building model preparation are listed below.

3.1.1 The reason for choosing an office building type

The floor plan of office building that was selected for modeling in IDA ICE is illustrated in Figure 1.

Figure 1. Office building ground floor plan, print screen from IDA ICE

As a model, it was decided to take three spaces of an office administrative building. The rooms are located in the corner of the building. The type of building is chosen because it is possible to clearly represent the different levels of activity of people and equipment during the day. To see the effect of moisture buffering, humidity changes inside the room are required so that the wooden material has something to stabilize.

Different activities sufficiently affect the microclimate of the room, including temperature and humidity. In a residential building activity of people and appliances is considered not so diverse during the day. In office buildings, people spend a lot of time during the day doing both active actions (going from office to office, holding meetings, opening and closing doors and windows, working with equipment, and passive actions (working at a computer, sitting at a meeting).

Also, in office buildings, there is equipment that consumes energy and releases a lot of heat during work, which also affects the microclimate of the room. It is also convenient to program a schedule of activities in an office building since people come and leave the office according to a work schedule. On weekends, there is minimal activity, which also enhances the variety of activity schedules.

3.1.2 Zones

Figure 2 illustrates three rooms of different purposes that were selected in the office building:

- Conference (50.44 m2)
- Hall (55.88 m2)
- Staircase(21.05 m2)

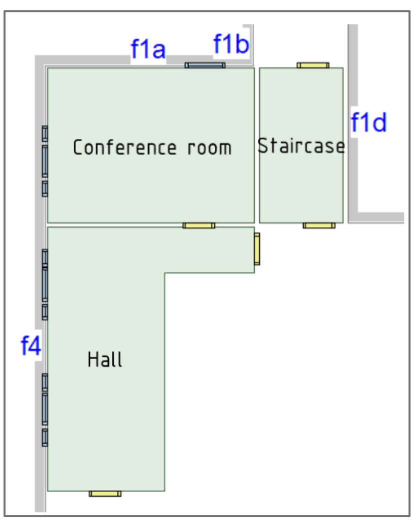


Figure 2. The office building zones under consideration, print screen from IDA ICE

The choice of the rooms that can be seen in Figure 2 was due to the difference in activities because of the different purposes of the spaces. The room space under consideration is the Conference room. The other two rooms are necessary to create realistic conditions because the room is not in a vacuum but is connected to surrounding rooms. The wall does not just enclose the studied room but also divides existing spaces. Nearby rooms can also affect the buffering of moisture in the wall structure. That is why it is essential to consider the influence of surrounding rooms and their microclimate.

There are two internal and two external walls in the room under study (conference room). The internal walls are connected to the other rooms (one with a hall and another with a staircase). This choice of wall type is also due to the wide variety of influencing factors on humidity.

3.1.3 Activity schedule

As mentioned earlier, a lot of attention is paid to a variety of the activity during the day for continuous changes in indoor humidity. It was decided to use the schedule for people, equipment, and lighting to do this. In Table 1 there is input data for schedules.

Table 1. Input data for schedules

	Conference room	Staircase	Hall
Number of people in a group	6	1	2
Activity level	1.1 MET	1.7 MET	1.7 MET
Number of units (equipment)	2	0	1
Number of units (light)	2	1	2

The number of people in a group means how many people there are in the room when the chart of the schedule reaches one. The exact number of people in the room at a particular time can be traced on the graph by multiplying the value on the graph by the number of people in the group. The same is true with number of units. Below are the daily schedules of each room for each of the types. The graphs and schedules can be seen in Figures 3,4,6.

The Conference room

The schedule that applies to occupant, equipment and lighting for the conference room is illustrated in Figure 3.

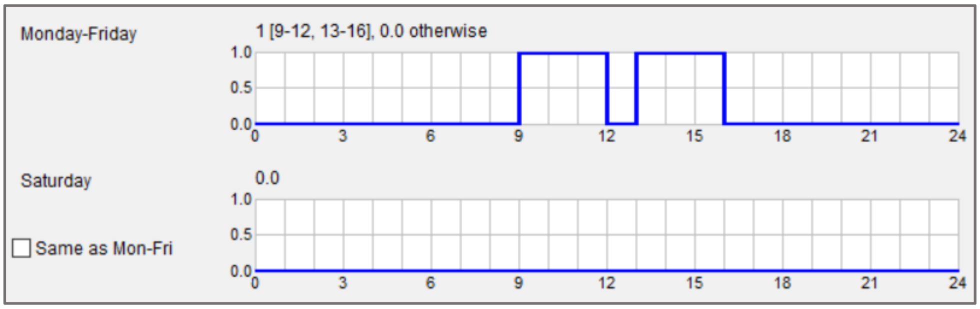


Figure 3. The occupant, equipment and lighting schedule for the conference room, print screen from IDA ICE

It was decided to choose such kind of schedule that the meeting room is occupied from 9:00 to 16:00, but during lunchtime, it is empty (12:00 to 13:00)

The Staircase

The schedule of occupants in the staircase is shown in Figure 4 and Figure 5.

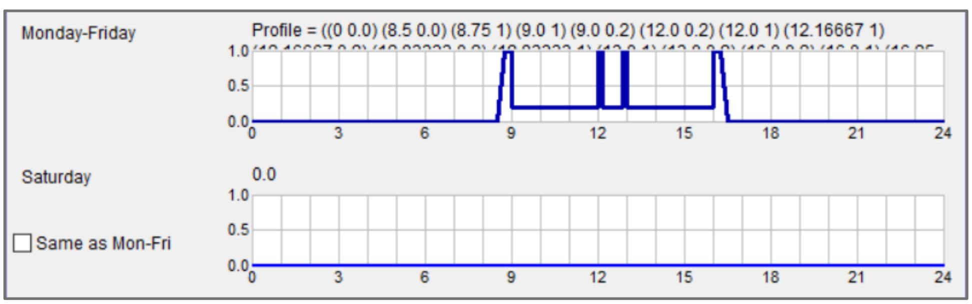
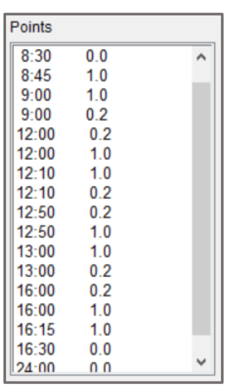


Figure 4. The occupant schedule for the the staircase, print screen from IDA ICE



Points

8:30	0.0
8:45	1.0
9:00	1.0
9:00	0.2
12:00	0.2
12:00	1.0
12:10	1.0
12:10	0.2
12:50	0.2
12:50	1.0
13:00	1.0
13:00	0.2
16:00	0.2
16:00	1.0
16:15	1.0
16:30	0.0
24:00	0.0

Figure 5. The occupant schedule points for the the staircase

The idea of the occupant schedule is that people start coming to the office from 8:30, and from 8:45 until 9:00, there is the maximum activity at the staircase and hall. From 9:00 to 12:00, there is little activity because most people are at their workplaces, but some still go from office to office using the hall and staircase. There are two activity peaks at the beginning and the end of lunchtime when workers go out of their offices. The rest of the day is the same until the end of work. The end of work was set at 16:00 due to the symmetry of the schedule before and after lunch.

The lighting schedule for the the staircase is shown in Figure 6.

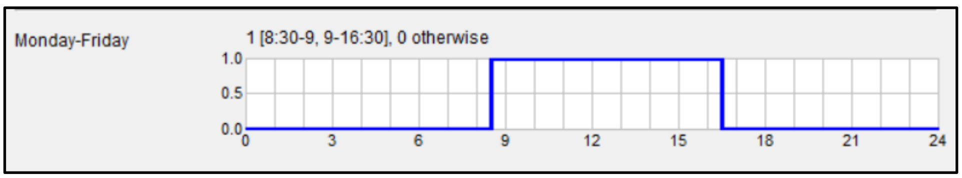


Figure 6. The lighting schedule for the the staircase, print screen from IDA ICE

As can be seen in Figure 6, light is on from the first occupant is arrival until the last occupant is departure. There is no equipment in the staircase, so the schedule is always off.

The Hall

The occupant schedule is the same as the staircase occupant schedule.

The equipment schedule is always on because, in the hall, there might be some vending machines or other equipment that requires electricity without interruption.

The lighting schedule is also the same as staircase lighting.

3.1.4 Wall Structure Materials

Figure 7 illustrates the structures of the exterior and interior walls of the buildings that were selected for the model.

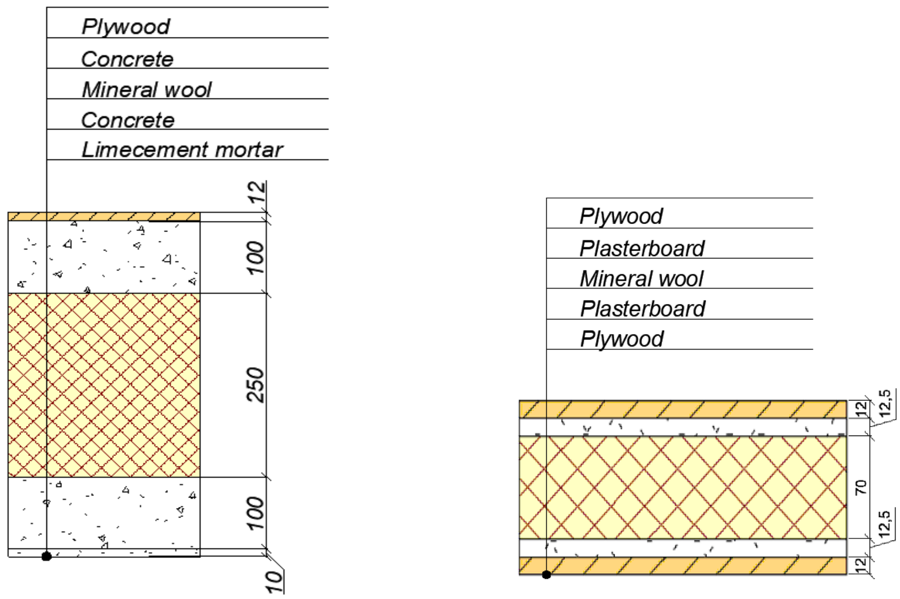


Figure 7. The layers of wall construction materials: external wall (left) and internal wall (right)

As we can see from Figure 7, the material of the interior walls is plywood. In essence, this layer of material will be tested for the ability to stabilize the humidity in the room during simulation. Knowing the full structure of the walls is important for understanding the conductivity of moisture through the structure.

3.1.5 Air flow for spaces

The purpose of the room affects the required amount of supply and return air. Different type of room requires different air flow. Selected air flow for each room is illustrated in Figure 8.

Name	Supply air, L/(s.m2)	Return air, L/(s.m2)
Zone 1 (Conference room)	3.0	3.0
Zone 2 (Staircase)	0.5	0.5
Zone 3 (Hall)	0.5	0.5

Figure 8. Air flow for zones, print screen from IDA ICE

Supply air and return air flow were found in the normative document /13, table 3.2.1/. As it can be seen in Figure 8 it is important to pay attention that IDA ICE requires an air flow in l/(s*m2).

3.2 Reasons for using the HMwall model

The IDA ICE itself does not handle moisture buffering in the building materials. The HMwall model was used to make the moisture buffering simulation possible. HMwall is the additional extension from EQUA. The following cases can be studied by using this model of moisture transfer /14/:

• how building construction materials affect indoor air quality and thermal comfort;

• how can moistening of building materials and furniture reduce fluctuations in air humidity;

• how does the induction of over and under pressure by the ventilation system affect the hydrothermal conditions in the building envelope;

• how does humidity affect the room climate and the load on heating and cooling systems.

Moisture transfer is modeled using a single moisture transfer potential, humidity by volume, v [kg/m3]. Liquid water transfer is not simulated.

This model takes into account the outdoor conditions (e.g. temperature, relative humidity) and the indoor conditions (e.g. temperature, moisture production, ventilation and infiltration). The HMwall model can calculate the heat and moisture transfer through the wall.

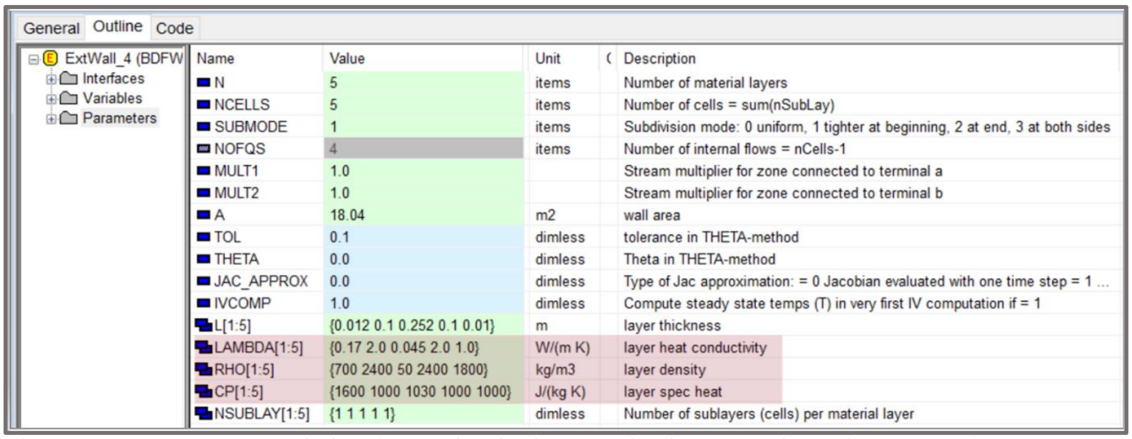
3.3 Implementation of the HMwall model in IDA ICE

After installing the extension, the moisture buffering wall model icon appears in the tab. After copying the HMwall from the tab, the standard wall model is replaced with moisture buffering wall model**.** New wall model is without suitable properties of the selected default materials because the default wall does not exist anymore.

As all mathematical models are based on simplified parameterizations, the performance of the HMwall model requires to be refined at different levels, from the building materials to the whole-building response. The detailed process of correct replacing the standard wall with an HMwall is listed below.

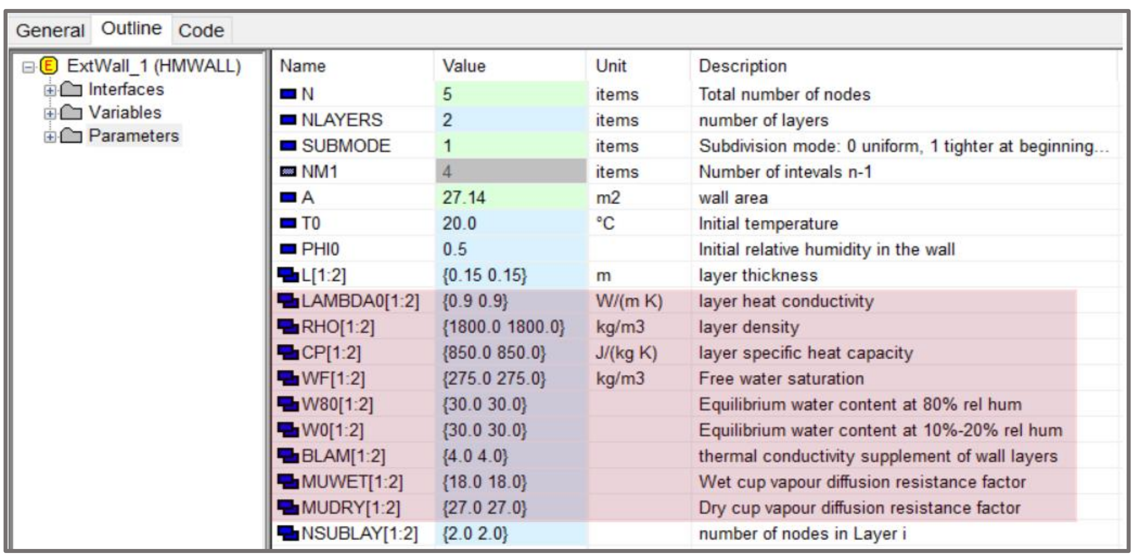
3.3.1 Entering correct data about materials and layers

As mentioned earlier, the new wall model does not have the appropriate parameters of the selected wall material (Figures 9 and 10).



Name	Value	Unit	Description
N	5	items	Number of material layers
NCELLS	5	items	Number of cells = sum(nSubLay)
SUBMODE	1	items	Subdivision mode: 0 uniform, 1 tighter at beginning, 2 at end, 3 at both sides
NOFQS	4	items	Number of internal flows = nCells-1
MULT1	1.0		Stream multiplier for zone connected to terminal a
MULT2	1.0		Stream multiplier for zone connected to terminal b
A	18.04	m2	wall area
TOL	0.1	dimless	tolerance in THETA-method
THETA	0.0	dimless	Theta in THETA-method
JAC_APPROX	0.0	dimless	Type of Jac approximation: = 0 Jacobian evaluated with one time step = 1 ...
IVCOMP	1.0	dimless	Compute steady state temps (T) in very first IV computation if = 1
L[1:5]	{0.012 0.1 0.252 0.1 0.01}	m	layer thickness
LAMBDA[1:5]	{0.17 2.0 0.045 2.0 1.0}	W/(m K)	layer heat conductivity
RHO[1:5]	{700 2400 50 2400 1800}	kg/m3	layer density
CP[1:5]	{1600 1000 1030 1000 1000}	J/(kg K)	layer spec heat
NSUBLAY[1:5]	{1 1 1 1 1}	dimless	Number of sublayers (cells) per material layer

Figure 9. Parameters available for setting in the standard wall model, print screen from IDA ICE



Name	Value	Unit	Description
N	5	items	Total number of nodes
NLAYERS	2	items	number of layers
SUBMODE	1	items	Subdivision mode: 0 uniform, 1 tighter at beginning...
NM1	4	items	Number of intevals n-1
A	27.14	m2	wall area
T0	20.0	°C	Initial temperature
PHI0	0.5		Initial relative humidity in the wall
L[1:2]	{0.15 0.15}	m	layer thickness
LAMBDA0[1:2]	{0.9 0.9}	W/(m K)	layer heat conductivity
RHO[1:2]	{1800.0 1800.0}	kg/m3	layer density
CP[1:2]	{850.0 850.0}	J/(kg K)	layer specific heat capacity
WF[1:2]	{275.0 275.0}	kg/m3	Free water saturation
W80[1:2]	{30.0 30.0}		Equilibrium water content at 80% rel hum
W0[1:2]	{30.0 30.0}		Equilibrium water content at 10%-20% rel hum
BLAM[1:2]	{4.0 4.0}		thermal conductivity supplement of wall layers
MUWET[1:2]	{18.0 18.0}		Wet cup vapour diffusion resistance factor
MUDRY[1:2]	{27.0 27.0}		Dry cup vapour diffusion resistance factor
NSUBLAY[1:2]	{2.0 2.0}		number of nodes in Layer i

Figure 10. Parameters available for setting in the HMwall wall model, print screen from IDA ICE

Besides, HMwall got additional material properties than the standard wall. That is why it is not sufficient to copy parameters from the standard wall. Table 2 shows that the implementation of the HMwall model requires several extra parameters for the materials.

Table 2. Comparison of parameters required from the standard wall model and the HM wall model

Parameters	Standard wall	HMWall
Thermal conductivity	+	+
Specific heat capacity	+	+
Density	+	+
Free water saturation	-	+
Equilibrium water content at 80% RH	-	+
Equilibrium water content at 10%-20% RH	-	+
Wet cup vapour diffusion resistance factor	-	+
Dry cup vapour diffusion resistance factor	-	+

MASEA Database was used to find the correct values of these parameters for each layer /15/. Some missing parameters were obtained by request from EQUA /12/. The final summary table with all the parameters required for the simulation is given below.

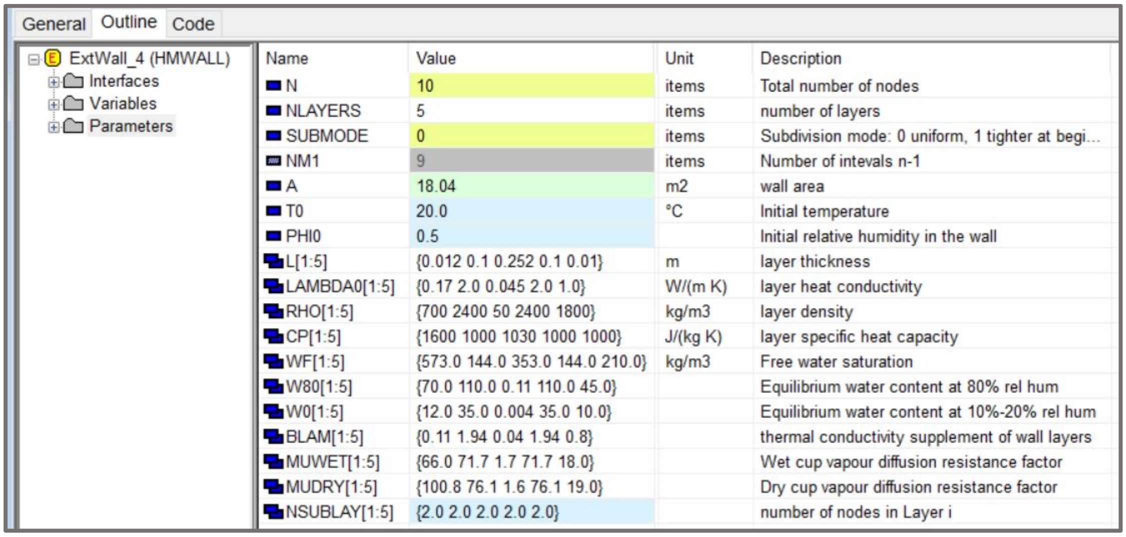
Table 3. The moisture parameters of each layer of the HMwall

	Units	Concrete (Betony)	Plywood (Vaneri)	Mineral wool (mineraalivilla)	Limecement mortar	Plasterboard (Kipsilevy)
Density	[kg/m³]	2104	400-600	85	1900	732
Specific heat capacity	[J/kgK]	776	1600	850	850	1384
Free water saturation	[kg/m3]	144	573	-	210	353
Equilibrium water content at 80% RH	[kg/m³]	110	70	0.11	45	8.3
Equilibrium water content at 10%-20% RH	[kg/m³]	35	12	0.004	10	(0.1) assumption
Thermal conductivity	[W/mK]	1.94	0.11	0.04	0.8	0.21
Wet cup vapour diffusion resistance factor	-	71.7	66	1.7	18	6.35
Dry cup vapour diffusion resistance factor	-	76.1	100.8	1.6	19	6.85

Black – from MASEA Database /13/

Green –from EQUA measurements on request

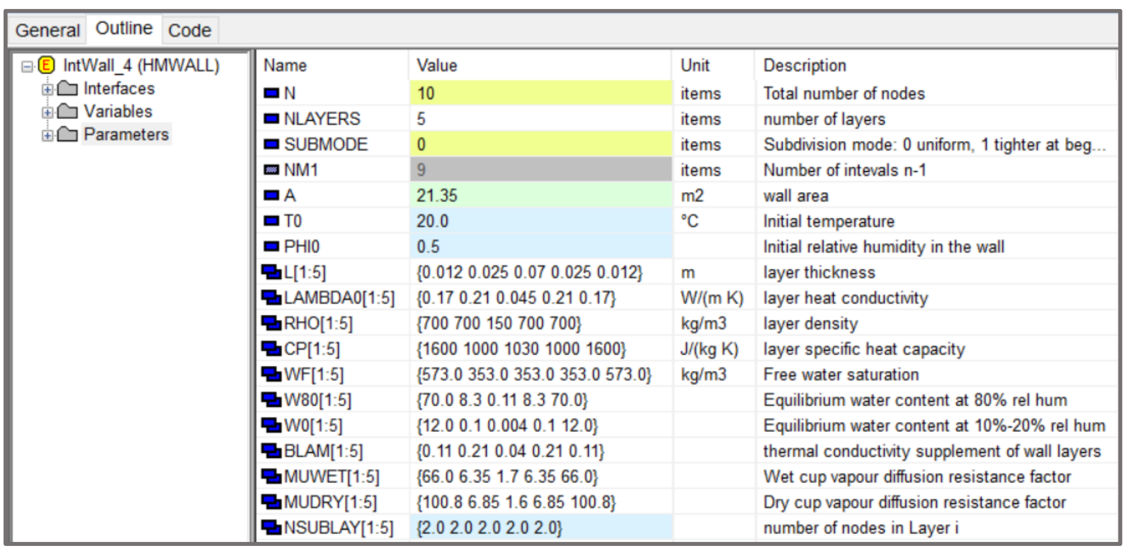
Figure 11 illustrates the external HMwall model with the correct parameters of each layer. Setting the correct number of layers and the correct subdivision mode is also essential to make the simulation run without errors.



Name	Value	Unit	Description
N	10	items	Total number of nodes
NLAYERS	5	items	number of layers
SUBMODE	0	items	Subdivision mode: 0 uniform, 1 tighter at begi...
NM1	9	items	Number of intevals n-1
A	18.04	m2	wall area
T0	20.0	°C	Initial temperature
PHI0	0.5		Initial relative humidity in the wall
L[1:5]	{0.012 0.1 0.252 0.1 0.01}	m	layer thickness
LAMBDA0[1:5]	{0.17 2.0 0.045 2.0 1.0}	W/(m K)	layer heat conductivity
RHO[1:5]	{700 2400 50 2400 1800}	kg/m3	layer density
CP[1:5]	{1600 1000 1030 1000 1000}	J/(kg K)	layer specific heat capacity
WF[1:5]	{573.0 144.0 353.0 144.0 210.0}	kg/m3	Free water saturation
W80[1:5]	{70.0 110.0 0.11 110.0 45.0}		Equilibrium water content at 80% rel hum
W0[1:5]	{12.0 35.0 0.004 35.0 10.0}		Equilibrium water content at 10%-20% rel hum
BLAM[1:5]	{0.11 1.94 0.04 1.94 0.8}		thermal conductivity supplement of wall layers
MUWET[1:5]	{66.0 71.7 1.7 71.7 18.0}		Wet cup vapour diffusion resistance factor
MUDRY[1:5]	{100.8 76.1 1.6 76.1 19.0}		Dry cup vapour diffusion resistance factor
NSUBLAY[1:5]	{2.0 2.0 2.0 2.0 2.0}		number of nodes in Layer i

Figure 11. The external wall with the correct humidity parameters and number of layers set, print screen from IDA ICE

The internal HMwall model with the correct parameters of each layer is given in Figure 12.



Name	Value	Unit	Description
N	10	items	Total number of nodes
NLAYERS	5	items	number of layers
SUBMODE	0	items	Subdivision mode: 0 uniform, 1 tighter at beg...
NM1	9	items	Number of intevals n-1
A	21.35	m2	wall area
T0	20.0	°C	Initial temperature
PHI0	0.5		Initial relative humidity in the wall
L[1:5]	{0.012 0.025 0.07 0.025 0.012}	m	layer thickness
LAMBDA0[1:5]	{0.17 0.21 0.045 0.21 0.17}	W/(m K)	layer heat conductivity
RHO[1:5]	{700 700 150 700 700}	kg/m3	layer density
CP[1:5]	{1600 1000 1030 1000 1600}	J/(kg K)	layer specific heat capacity
WF[1:5]	{573.0 353.0 353.0 353.0 573.0}	kg/m3	Free water saturation
W80[1:5]	{70.0 8.3 0.11 8.3 70.0}		Equilibrium water content at 80% rel hum
W0[1:5]	{12.0 0.1 0.004 0.1 12.0}		Equilibrium water content at 10%-20% rel hum
BLAM[1:5]	{0.11 0.21 0.04 0.21 0.11}		thermal conductivity supplement of wall layers
MUWET[1:5]	{66.0 6.35 1.7 6.35 66.0}		Wet cup vapour diffusion resistance factor
MUDRY[1:5]	{100.8 6.85 1.6 6.85 100.8}		Dry cup vapour diffusion resistance factor
NSUBLAY[1:5]	{2.0 2.0 2.0 2.0 2.0}		number of nodes in Layer i

Figure 12. The internal wall with the correct humidity parameters and number of layers set, print screen from IDA ICE

3.3.2 Connecting HMwall to indoor and outdoor RH using moisture transfer links

The wall model still does not recognize that it is connected to the surrounding space, so connections between the interior wall surface and room space must be created. There are two sides of the HMwall model: A-side and B-side.

a) A-side of internal HMwall

A-side is usually internal that is required to be connected with current open room space as can be seen in Figure 13.

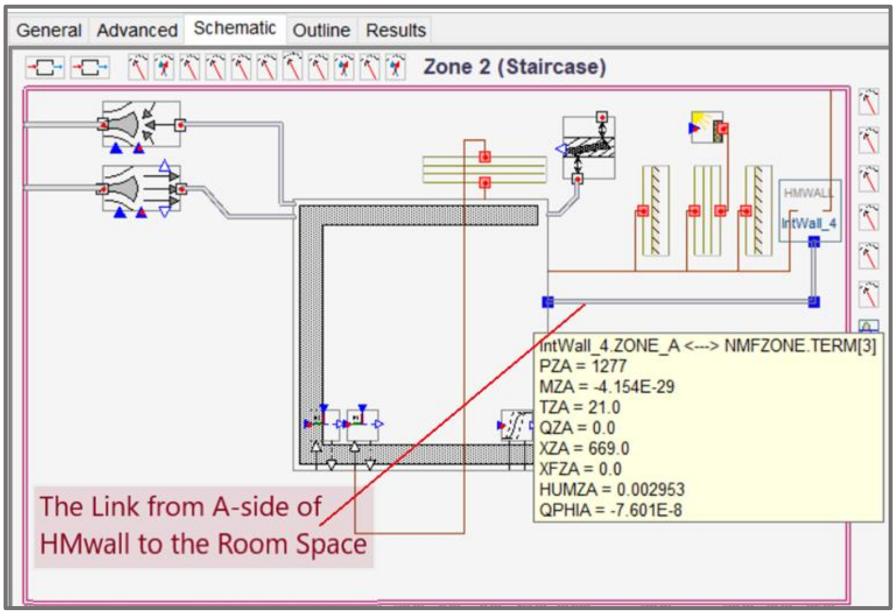


Figure 13. Schematic view in IDA ICE with the moisture transfer link from the internal HMwall to the considered room space, print screen from IDA ICE

b) B-side of internal HMwall

B-side is external (not outside the building, but outside of current open space in schematic view). B-side also requires to be connected with the space of another room. The link from the B-side of the HMwall to the borderline must be created (Figure 14). Then, in the schematic view, the link from this room to another room must be done (Figure 15). And then, in another room view, the link from the borderline to the room space must be done (Figure 16). These three links are eventually the one long link from B-side to the space of another room.

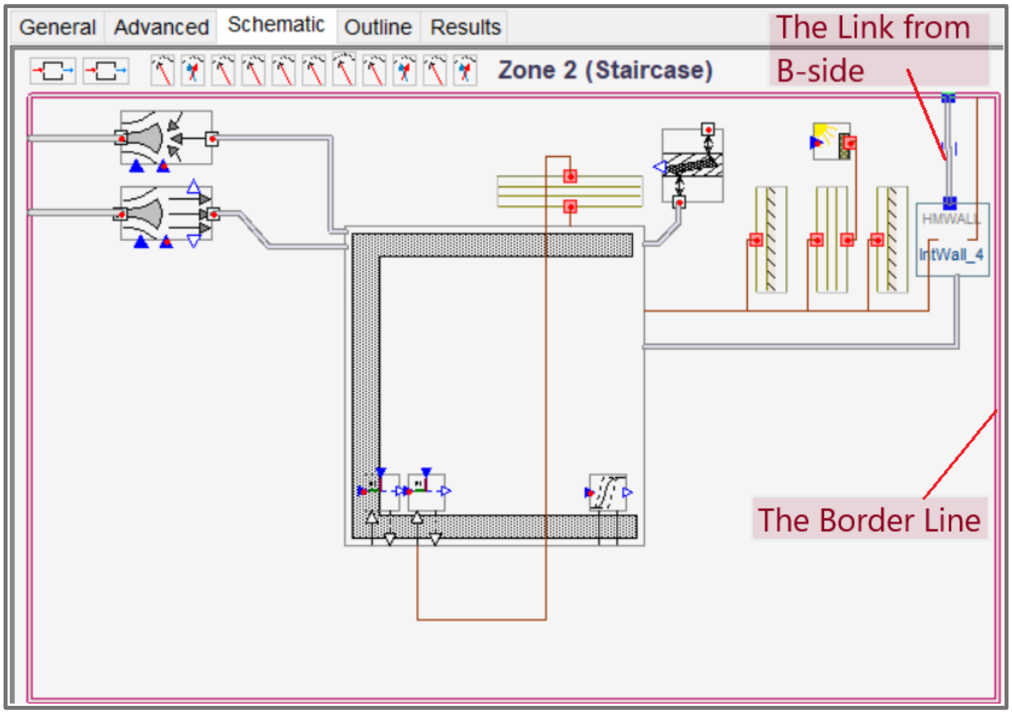


Figure 14. Schematic view in IDA ICE with the moisture transfer link from the internal HMwall to the border line, print screen from IDA ICE

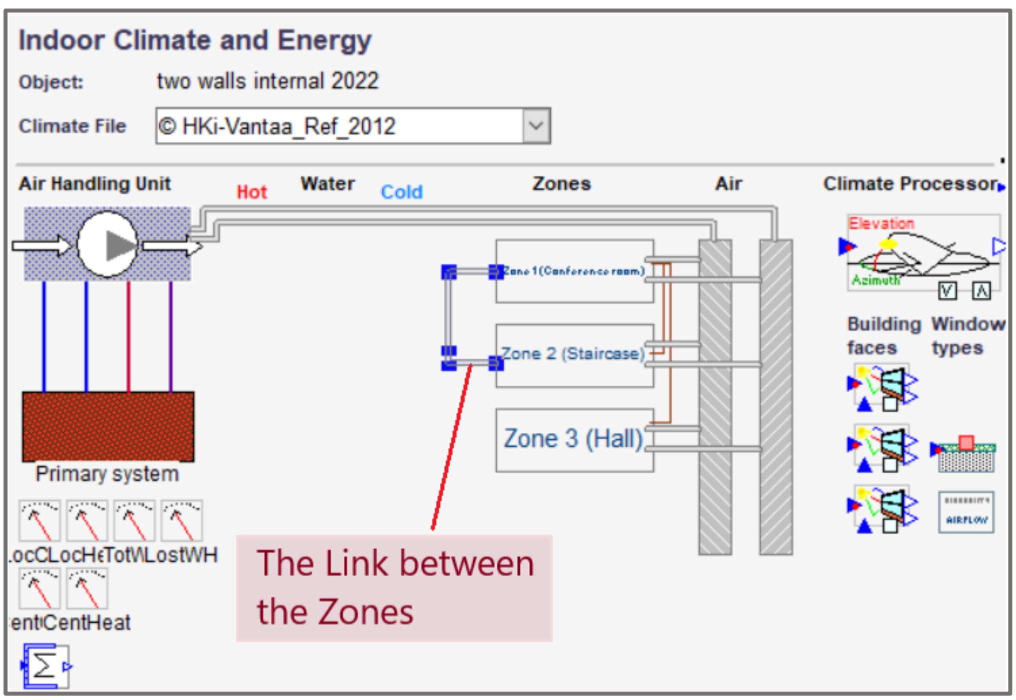


Figure 15. The moisture transfer link between the room zones, print screen from IDA ICE

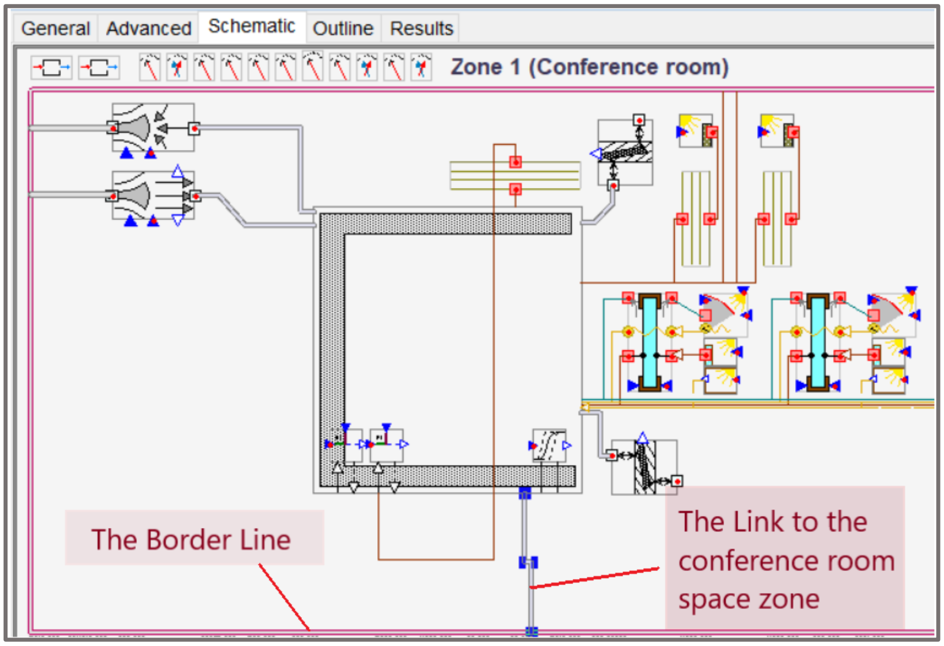


Figure 16. Schematic view in IDA ICE with the moisture transfer link from the border line to Conference room space, print screen from IDA ICE

c) A-side of external HMwall

Link from the external wall A-side is the same, as the link from the internal wall A-side as can be seen in Figure 17.

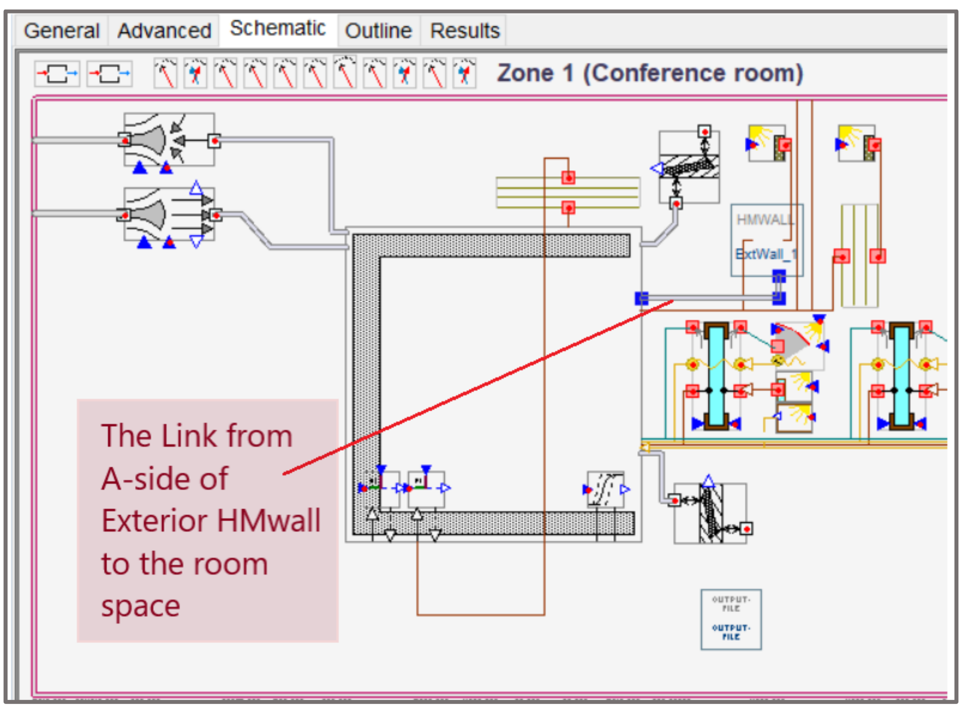


Figure 17. Schematic view in IDA ICE with the moisture transfer link from the external HMwall to the considered room space, print screen from IDA ICE

d) B-side of external HMwall

Link from external wall B-side is different from internal wall. There is no actual outside space to connect with B-side. To make the correct simulation with external walls it is necessary to open an external HMWall and make connection with outside leak as shown in Figure 18.

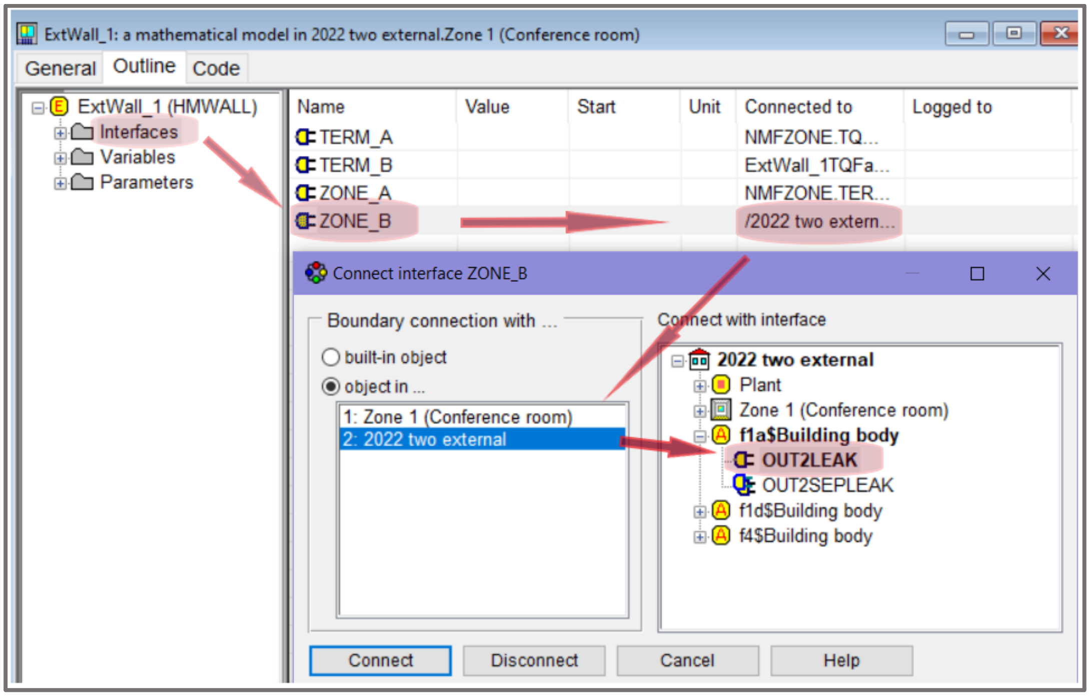


Figure 18. Connection path of the external HMwall to the outside space, print screen from IDA ICE

3.3.3 Connecting the output file

The output file can be found in Utility models as can be seen in Figure 19.

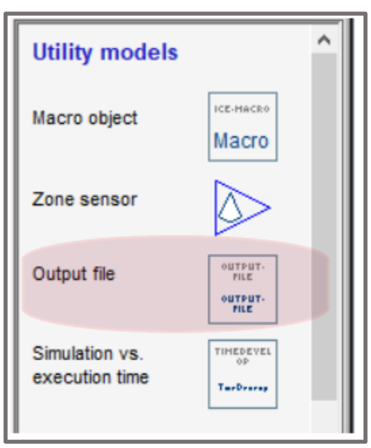


Figure 19. Output file location, print screen from IDA ICE

As can be seen in Figure 20 and Figure 21 the connection path of the output file to the external wall is different from the connection path of output file to the internal wall.

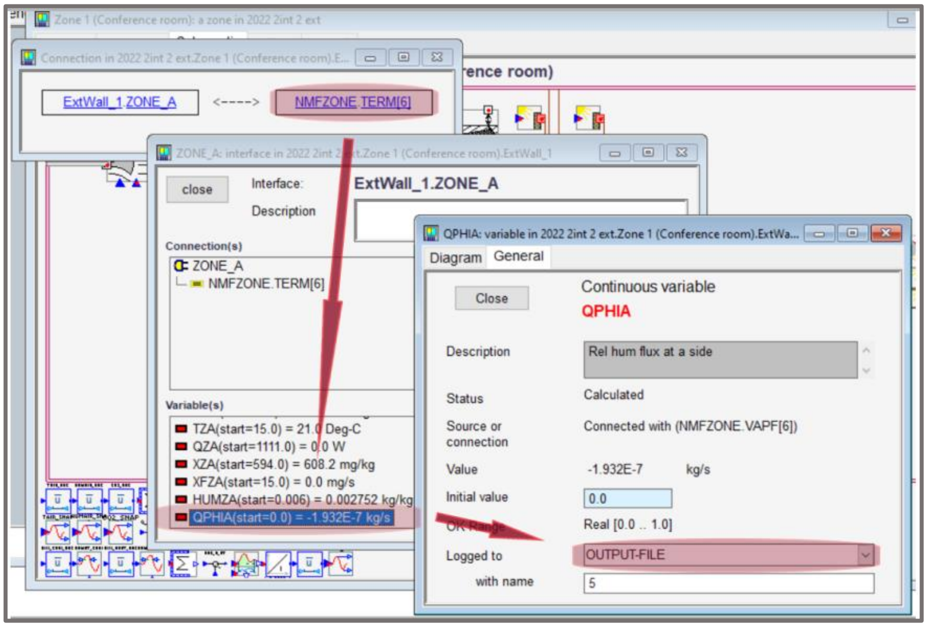


Figure 20. The connection path of the output file to the external wall, print screen from IDA ICE

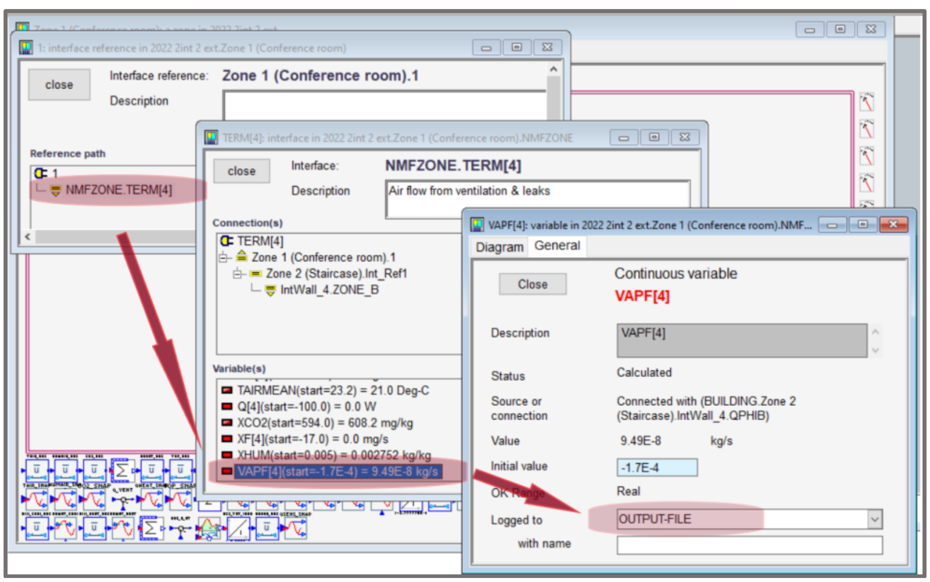


Figure 21. The connection path of the output file to the internal wall, print screen from IDA ICE

3.4 Simulation time

There are different types of indoor humidity fluctuations at different time periods. Seasonal fluctuations are a long-term period, usually annual. Short-term periods have a daily or hourly duration. They arise mainly due to indoor activity, as well as due to daily fluctuations in the outdoor climate.

The simulation time that was selected is one year. This time will allow one to observe both the annual effect and the short-term effect. It will be possible to observe the difference at different times of the year, at different times of the week and at different times of the day.

This will help to find out what influences the moisture buffering the most and if there is a long-term or short-term effect.

3.5 Three cases of simulation

It was decided to make three cases of simulation:

Case №1 – two internal and two external standard walls
Case №2 – two internal and two external HMwalls
Case №3 – four HMwalls with only interior connection

These cases were chosen to find out if replacing walls with the new model (thereby adding the moisture buffering effect) has an impact on the results.

4 RESULTS AND ANALYSIS OF RESULTS

This chapter presents the results of three simulation cases for 2021. First, the second case with HMwall is considered and its results are analyzed. The results of the second case and the first case are then compared to see if there are any differences in the effect of the standard wall and HMwall on humidity. At the end, the results of the third case are analyzed, where only the inner surface of the wall is connected with the room zone.

4.1 Case №2

Figures 22-23 represent the relative humidity flux in internal and external walls during the entire time simulation (1 year). Throughout this chapter, the results of the internal and external walls of the same simulation will be placed in different schemes in order to avoid incorrect display of graphs from IDA ICE and for its readability.

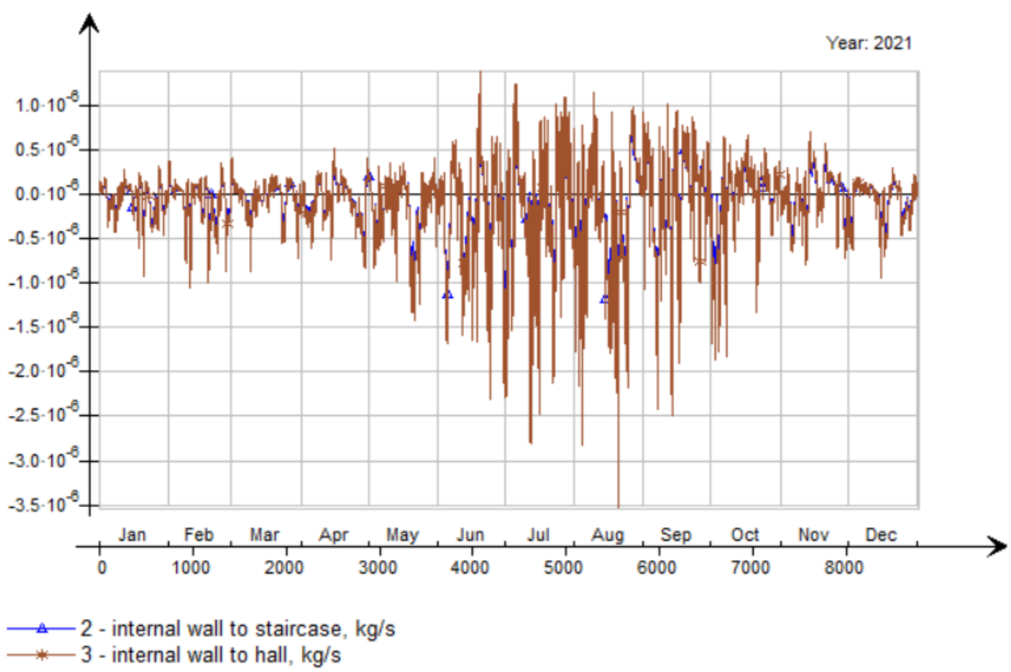


Figure 22. Moisture transport in internal walls with HMWall model, one year simulation, second case.

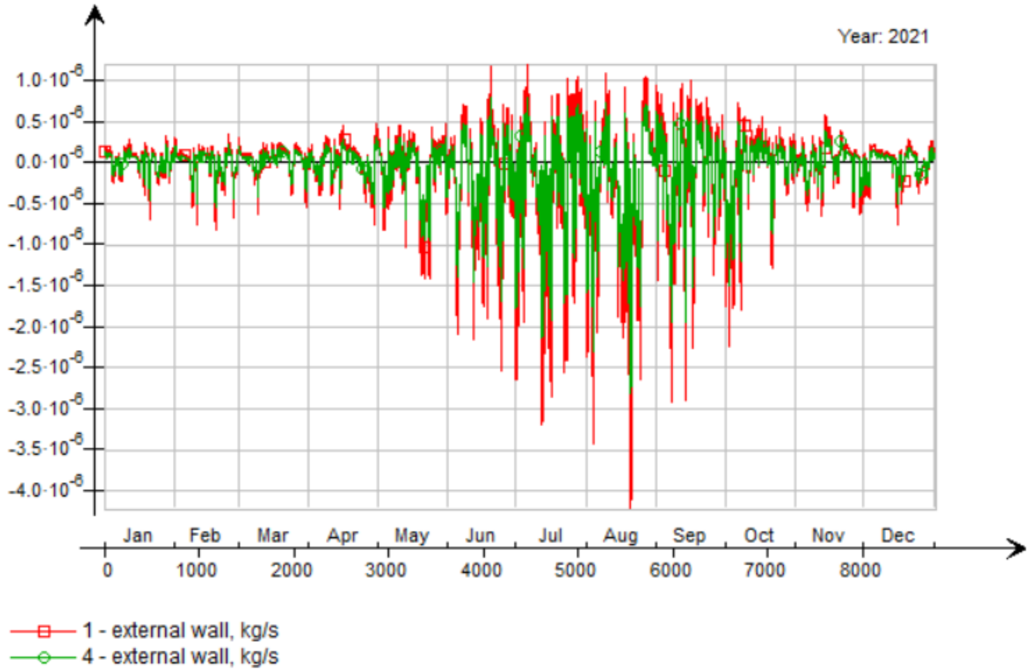


Figure 23. Moisture transport in external walls with HMWall model, one year simulation, second case.

As can be seen from Figures 22-23, the highest relative humidity flux occurs in summer, and the lowest in winter, which agrees with the theory. Next, we will consider separately the results in the middle of winter and in the middle of summer for more accurate results.

4.1.1 Month level

Figures 24-27 show the comparison of relative humidity flux separately in the middle of winter (January) and the middle of summer (July).

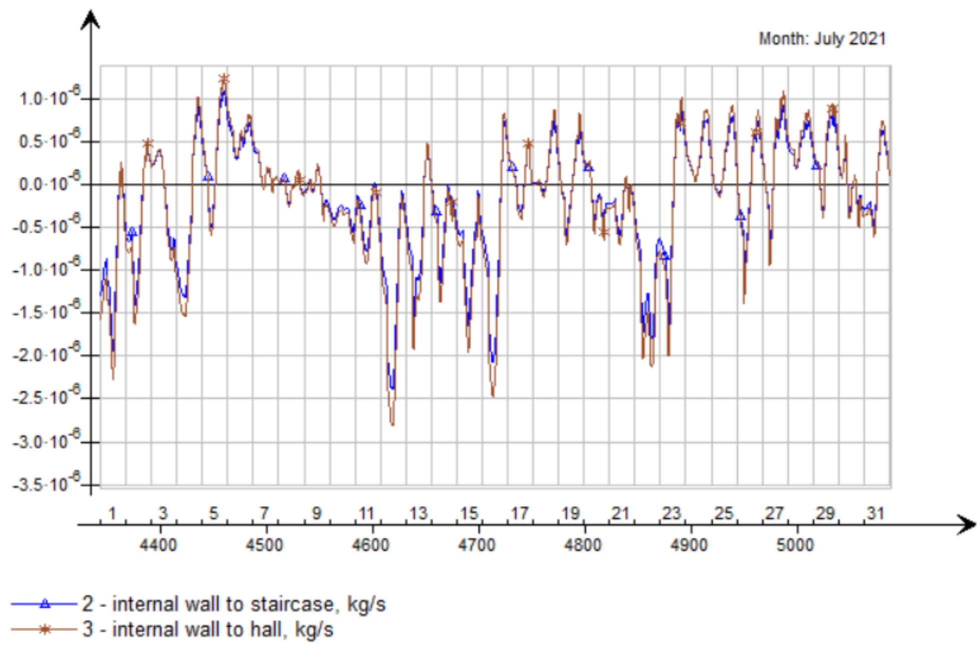


Figure 24 Moisture transfer in internal walls with the HMWall model in July

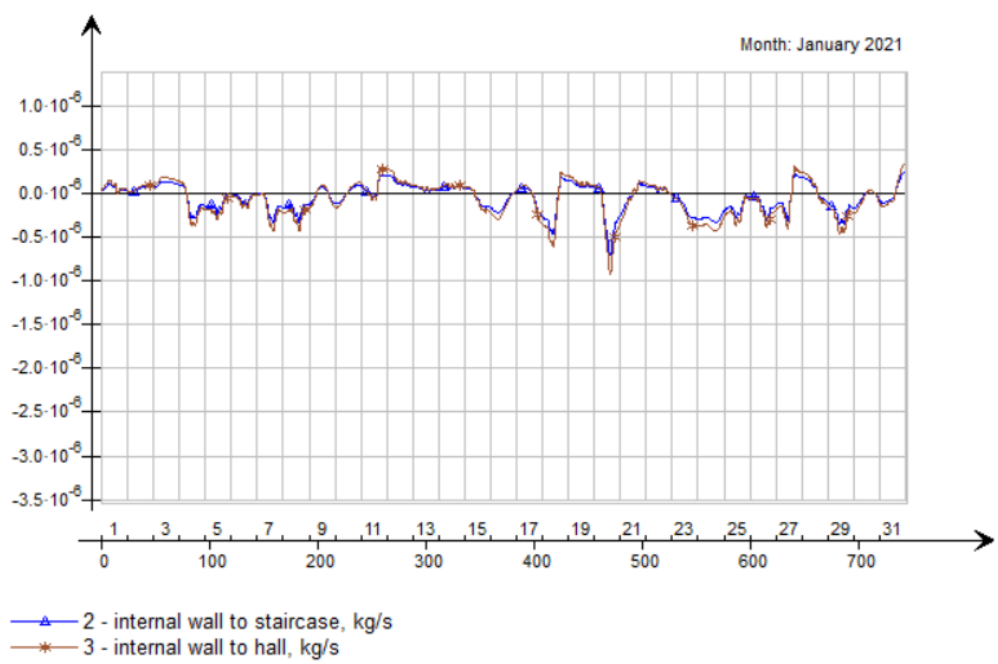


Figure 25 Moisture transfer in internal walls with the HMWall model in January

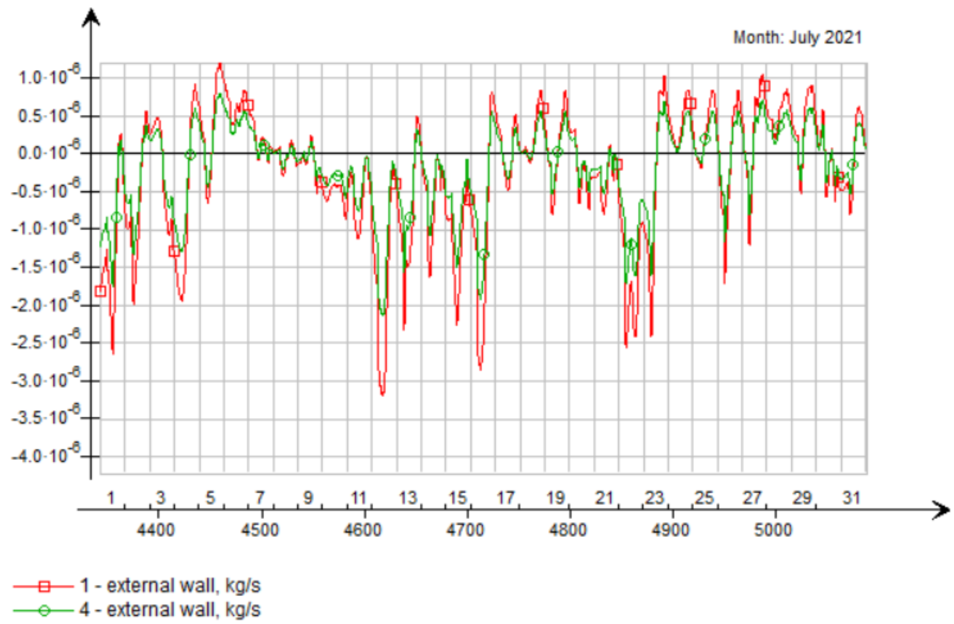


Figure 26. Moisture transfer in external walls with the HMWall model in July.

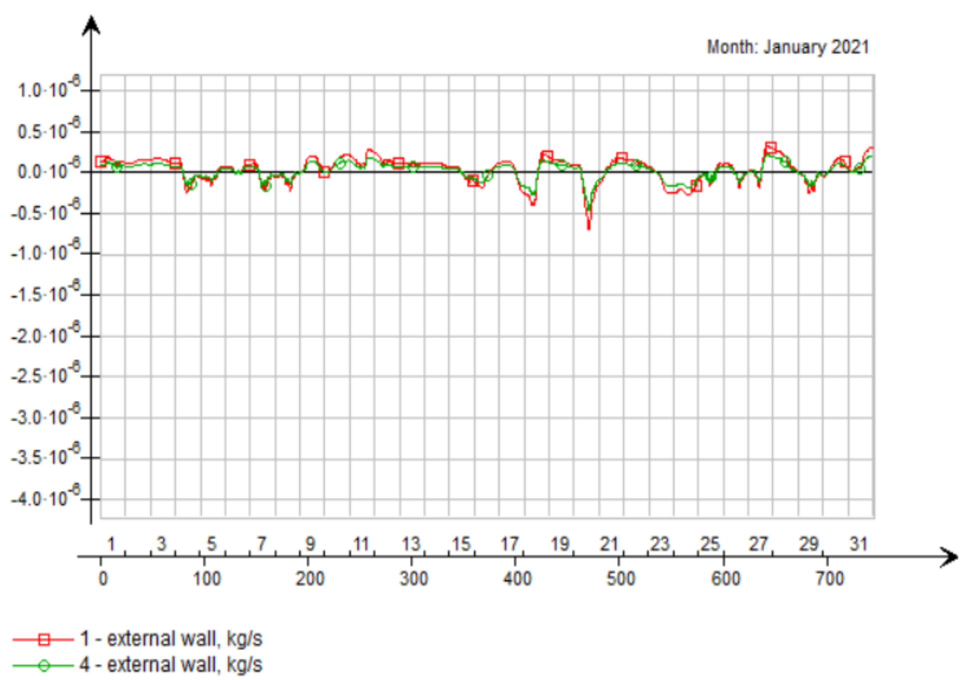


Figure 27. Moisture transfer in external walls with the HMWall model in January

As can be seen from figures 24-27 the moisture transport is highest during the summer when the external air is warm and humid. This is 4 times higher than the values in winter. It was also noticed that the largest amplitude of humidity flux for January is observed at the internal wall with the largest area (wall to the hall) and it is $5.4 \cdot 10^{(-7)}$ kg/s. In July , the greatest amplitude is observed at the external wall with the largest area and is $22.6 \cdot 10^{(-7)}$ kg/s.

4.1.2 Week level

In the figures 28-31 we can see comparison of relative humidity flux separately in one week in January (18/01/2021-24/01/2021) and in one week in July (12/07/2021-18/07/2021).

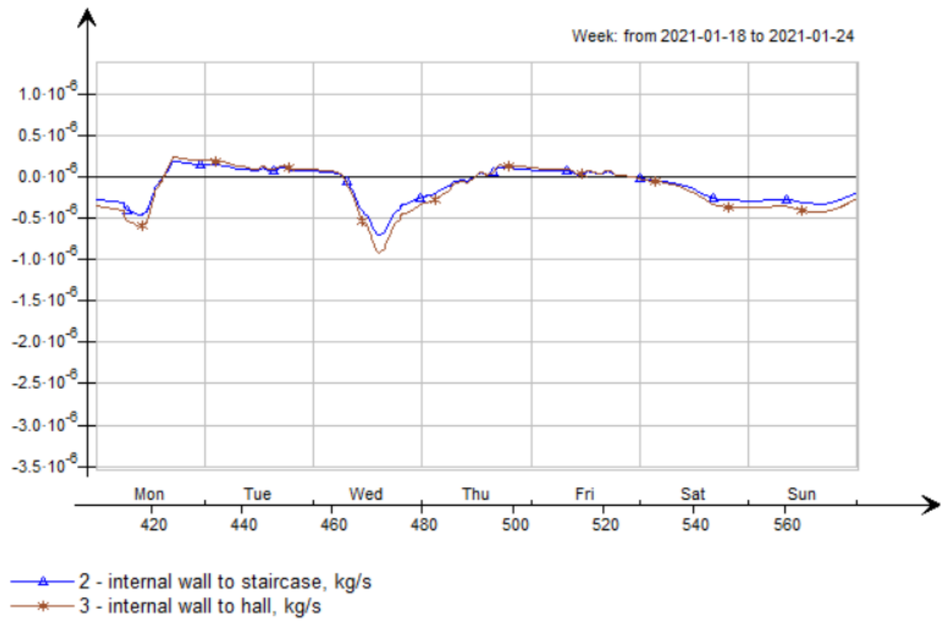


Figure 28. Moisture transfer in internal walls with the HMWall model in 4th week of January

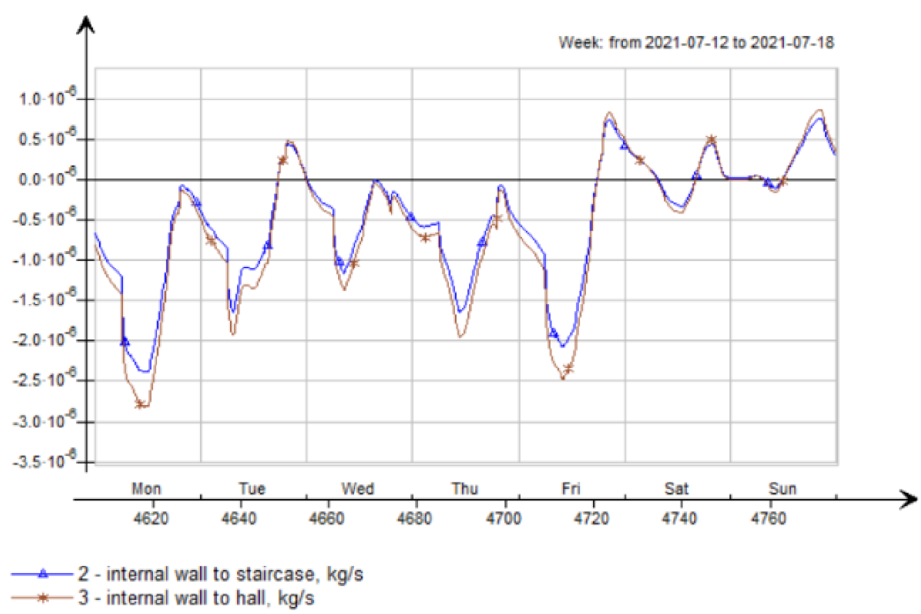


Figure 29. Moisture transfer in internal walls with the HMWall model in 3rd week of July

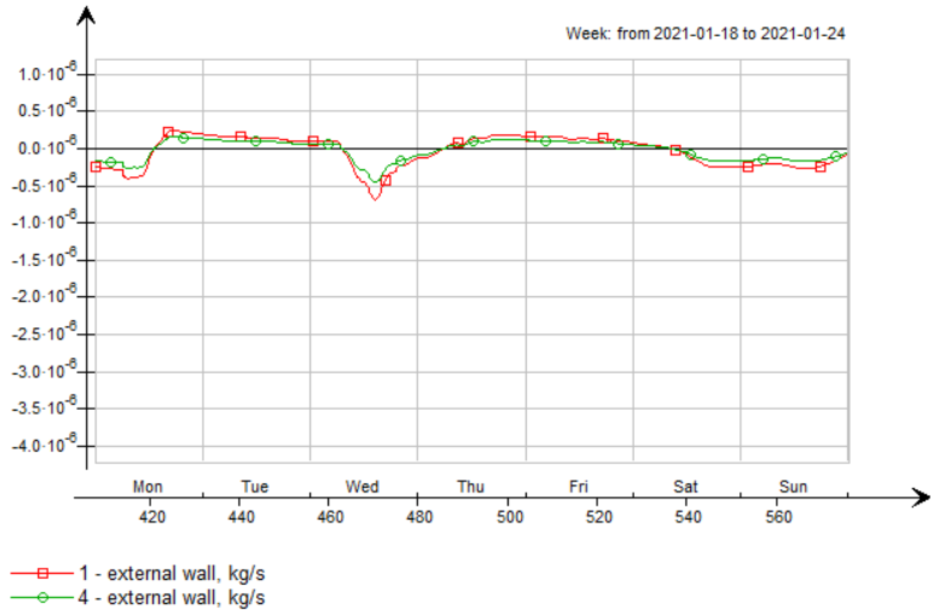


Figure 30. Moisture transfer in external walls with the HMWall model in 4th week of January

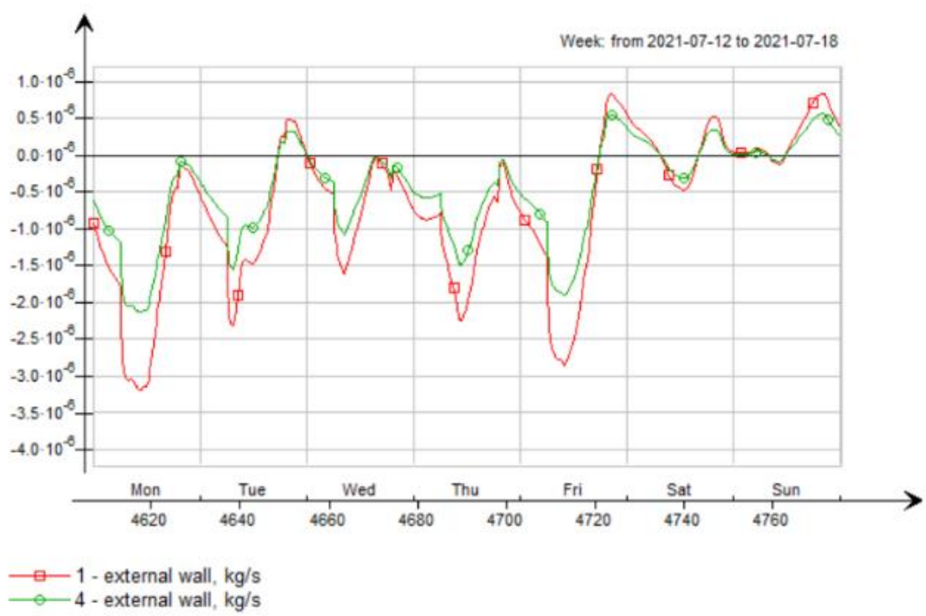


Figure 31. Moisture transfer in external walls with the HMWall model in 3rd week of July

Figures 28-31 show that there is almost no impact of light activity in the office. If you compare the humidity flux on weekdays and weekends, in some weeks of the year you can actually notice a difference, such as in Figure 29 (week 12/07 – 18/07), where on weekends, when there is no activity in the office, the humidity flux really decreases. However, if we compare the relative humidity readings that week (Figures 32-33), we can see that on weekends the air humidity drops were not as abrupt as on weekdays, so the humidity flux calmed down.

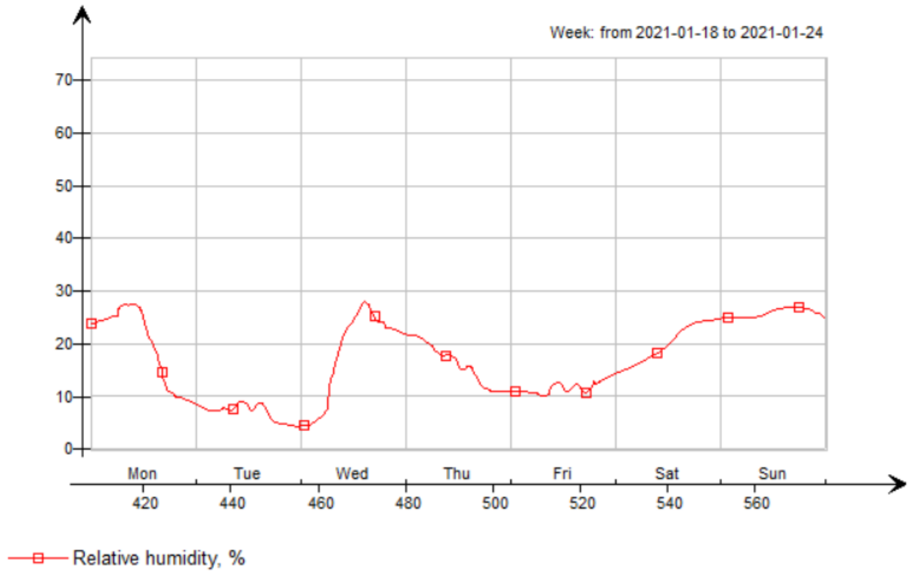


Figure 32. Relative humidity in 4th week of January

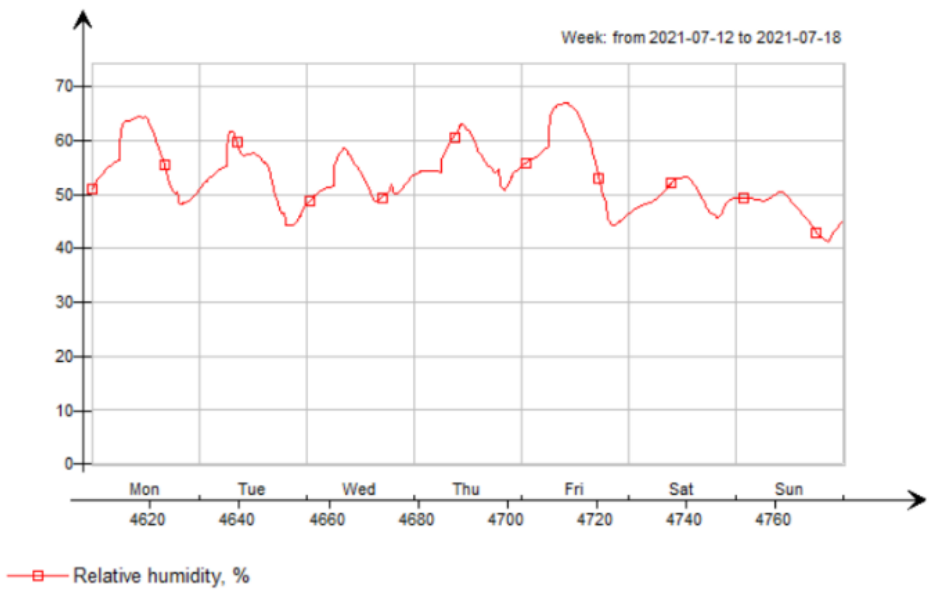


Figure 33. Relative humidity in 3rd week of July

4.1.3 Day level

Figures 34-37 show results of relative humidity flux separately on one day in January (21/01/2021) and on one day in July (13/07/2021).

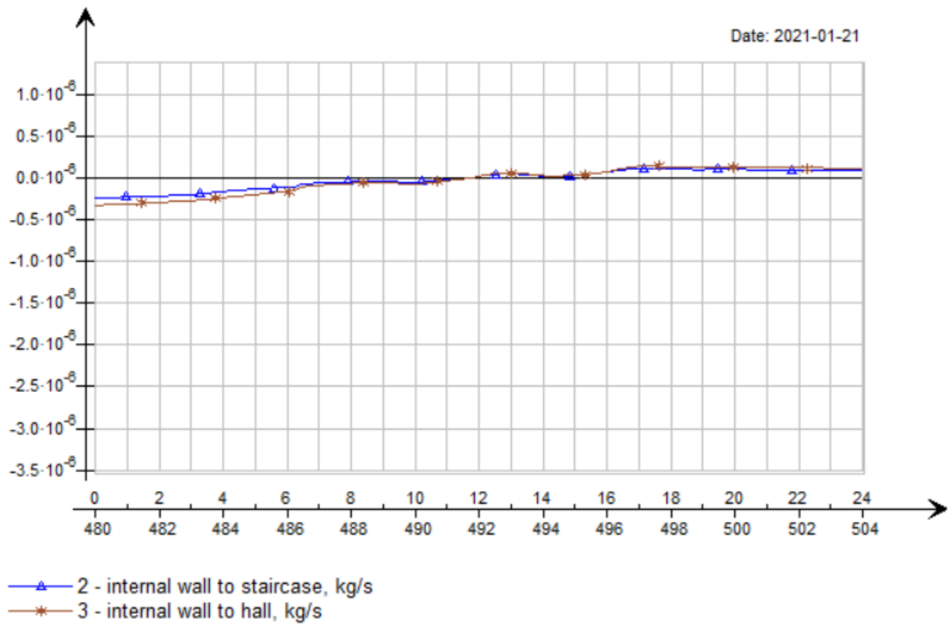


Figure 34. Moisture transfer in internal walls with the HMWall model on January 21st

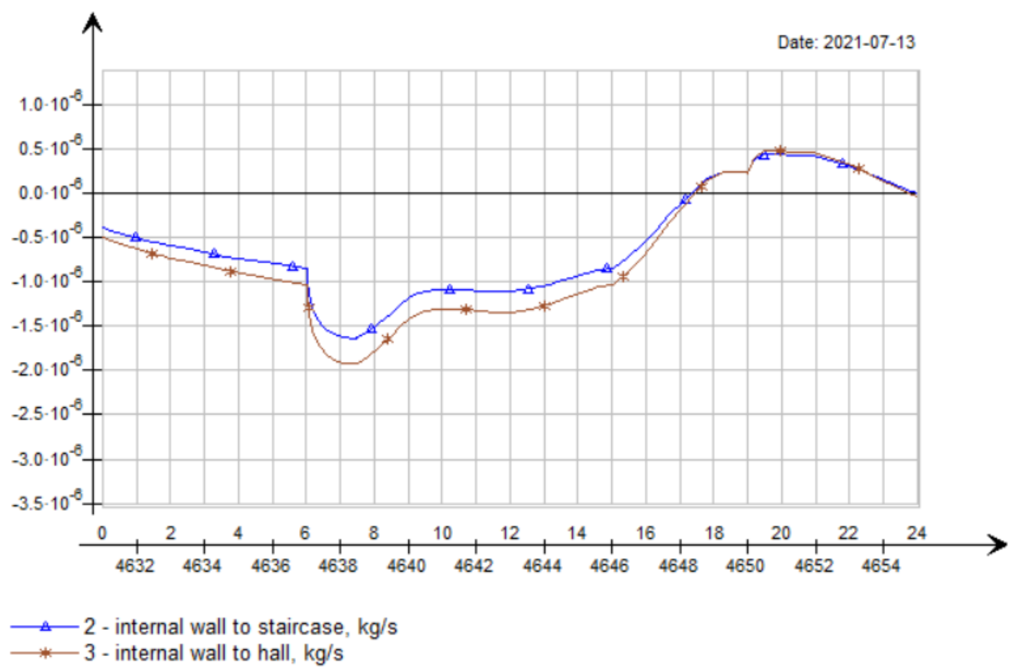


Figure 35. Moisture transfer in internal walls with the HMWall model on July 13th

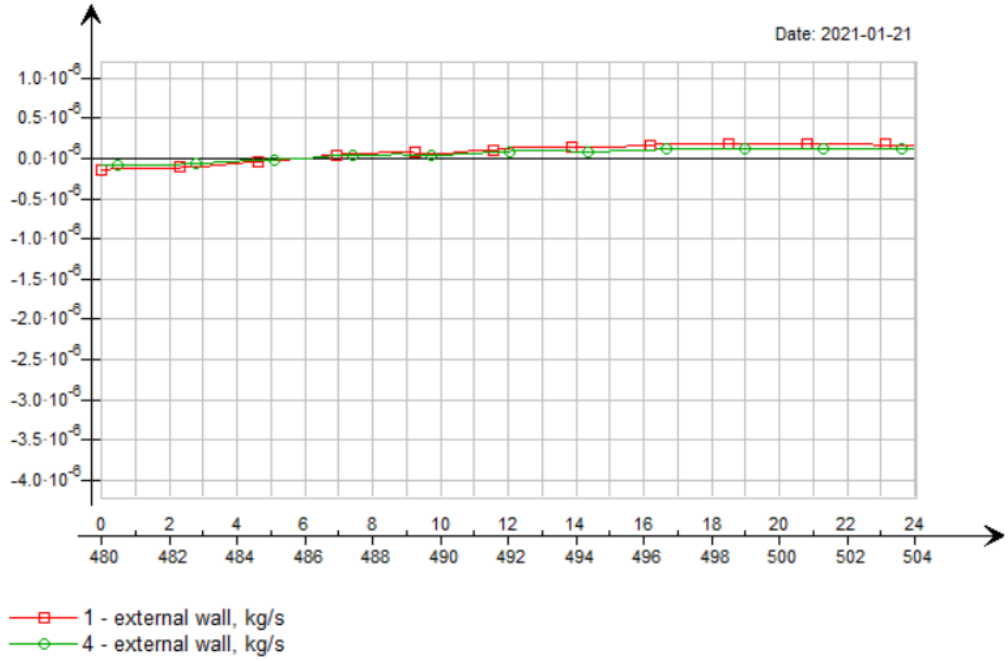


Figure 36. Moisture transfer in external walls with the HMWall model on January 21st

Figure 37. Moisture transfer in external walls with the HMWall model on July 13th

As can be seen in figures 34-37 during the day there is also practically no effect of activity on humidity changes from morning to evening. The arrival of workers at 8 am and the inclusion of equipment does not affect humidity flux, and neither does leaving workplaces during lunch. Air humidity and temperature have the greatest influence (Figures 38-39). Also from Figures 34-37 one can observe more clearly that the value of humidity flux differs from wall to wall.This is because the surface area of each wall is different, which affects the value of moisture transfer through the wall surface.

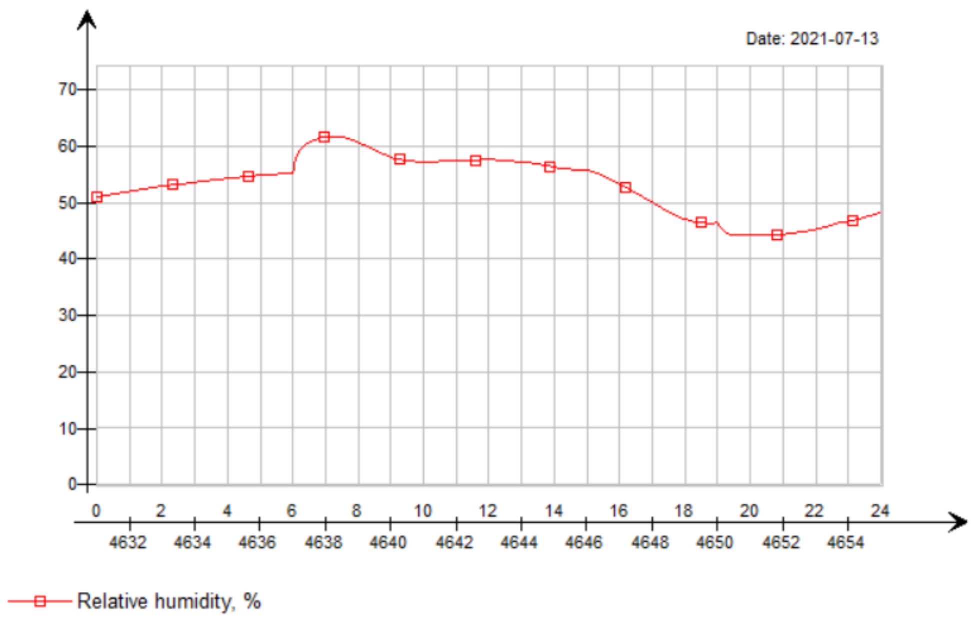


Figure 38. Relative humidity on January 21st

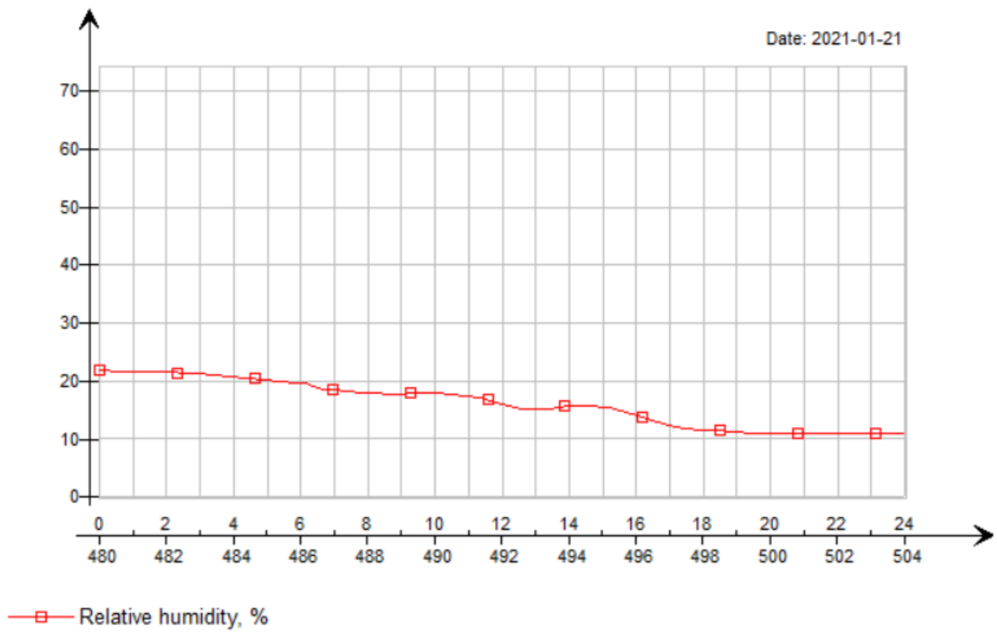


Figure 39. Relative humidity on July 13th

4.1.4 Intermediate conclusions for the case №2

After analyzing the results of the case №2, several conclusions can be drawn. It can be concluded that humidity flux is greater in summer than in winter, which corresponds with the theory. This shows that the work of HMwall is correct and does not conflict with the theory, humidity flows actually pass through the structures.

Occupants, lighting, or equipment activity have almost no impact on the increase or decrease in the humidity in the room on the scale of the simulation. This was observed both at the level of the working week and at the level of the working day. The relative humidity of the outdoor air has the greatest influence.

It was also concluded that small differences in the values of humidity flux of different walls were due to differences in the surface areas of the walls.

4.2 Comparison of case №2 and case №1

In the last section, we reviewed the results of the simulation with the HMwall model and analyzed how humidity flux behaves in this case. As already mentioned above in chapter 3.2 of this work, there is no moisture transfer function in a standard wall in IDA ICE, so it is impossible to compare the results of moisture transfer with a standard wall and with HMwall, but it is possible to compare the state of relative humidity in the zone with a standard wall and with HMwall.

In the Figure 40 we can see results of relative humidity on 13/07/2021 with and without HMwall.

Hour	Variables
	RHUM, dimless
1	52.45
2	53.44
3	54.34
4	55.19
5	55.97
6	56.69
7	61.4
8	62.37
9	60.19
10	58.24
11	58.13
12	58.39
13	58.28
14	57.57
15	56.71
16	55.32
17	52.22
18	48.81
19	46.94
20	45.01
21	44.57
22	44.92
23	46.18
24	47.7
mean	53.79
mean*24.0 h	1291.1
min	44.57
max	62.37

Hour	Variables
	RHUM, dimless
1	51.52
2	52.5
3	53.26
4	53.96
5	54.53
6	55.07
7	60.23
8	61.46
9	59.37
10	57.47
11	57.34
12	57.57
13	57.45
14	56.75
15	55.94
16	54.6
17	51.58
18	48.3
19	46.49
20	44.6
21	44.21
22	44.74
23	45.97
24	47.44
mean	53.01
mean*24.0 h	1272.3
min	44.21
max	61.46

Figure 40. Comparison of relative humidity in zone on July 14th with standard wall (left) and with HMwall (right)

For comparison, a day in July was chosen when there was high air humidity in order to present the results more clearly and so that the difference was more noticeable. Comparing the results presented in Figure 40, it can be seen that, according to IDA ICE simulation, moisture buffering actually reduces humidity peaks, but by approximately 1% or less.

4.3 Case №3

The third case with only interior connections could not be carried out. The program requires additional connections with another zone for proper operation. Otherwise, the simulation fails when only one link of each wall is connected. If the required additional connections are added, we will get the same case as the case №2, which has already been made.

5 DISCUSSION

During this research, an appropriate environment has been set up to simulate the moisture buffering effect of wooden material. A model of the administrative building was developed. Details that could influence the appearance of humidity peaks were thought out and applied, and the parameters of activity in the premises were configured. The HMwall extension for IDA ICE software has been investigated and applied to make the humidity flux simulation possible. All connections between the walls and the zones were properly set up and explained. The search for the required values related to humidity transfer in materials has been performed and all these found specific material parameters have been implemented. All algorithms, steps of operations, and explanations were recorded in this work.

Two of the three cases were completed. From the second case, it was concluded that the humidity flux through the structure is highest during the summer when the external air is warm and humid. This is 4 times higher than the values in winter. It shows that the work of HMwall is correct and does not conflict with the theory, humidity flows actually pass through the structures. It was also noticed that the largest amplitude of humidity flux for January is observed at the internal wall with the largest area (wall to the hall) and is 5.4·10(-7) kg/s. In July, the greatest amplitude is observed at the external wall with the largest area and it is 22.6·10(-7) kg/s. It was also concluded that the values of humidity flux of different walls are not identical due to the differences in the surface areas of the walls.

Occupants, lighting, or equipment activity have almost no impact on the increase or decrease in the humidity in the room on the scale of the simulation. This was observed both at the level of the working week and at the level of the working day. The relative humidity of the outdoor air has the greatest influence.

The case №1 was created to compare it with the case №2 and does not have its own separate results. The case №3 was not successful, presumably due to the inability to link the wall connections on only one side. When leaving only one connection with the internal space, the simulation failed.

Back to the main aim, the goal of this study was to evaluate the potential of using wooden materials to stabilize humidity in the room. After all the work done, it can be concluded that according to the results of my simulation, there is an impact of buffering on humidity, but it is extremely small. Humidity peaks decreased by approximately 1% or less, which is almost imperceptible to humans.

Even though the third case with surface wall connections could not be implemented, it remains a very interesting topic for work. Further research should pay attention to the study of building a correct model and environment for such a simulation. If it runs, it can still give interesting results for analysis and comparisons.

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