Contributions above the dew-point problem in civil building EPS insulated walls modeling with finite element the convective heat transfer

Madalina Xenia Calbureanu, Emil Albota, Dragos Tutunea, Sorin Dumitru, Raluca Malciu, Alexandru Dima

Abstract**—** In this paper we present the analysis of convective heat transfer in the walls of a house insulated with polystyrene. In the first part we make an evaluation of the insulation that is currently used in the houses. We start the simulation using a real model of a house and than we make the model in Solidworks 2009. We run the model in Solidworks Thermal study after we insert the initial conditions. We notice that the obtained results indicate a problem which occurs inside the brick, the dew-point appearance. Further investigations must be made to solve this problem.

Keywords**—** convective heat transfer, dew-point, finite element, polystyrene insulation, thermal bridges.

I. INTRODUCTION

THERMAL insulation in buildings is an important factor to achieving thermal comfort for its occupants. Insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling systems. It does not necessarily deal with issues of adequate ventilation and may or may not affect the level of sound insulation. In a narrow sense insulation can just refer to the insulation materials employed to slow heat loss, such as: cellulose, glass wool, rock wool, polystyrene, urethane foam, vermiculite and earth or soil. But it can also involve a range of designs and techniques addressed to the main modes of heat transfer - conduction, radiation and convection materials.

Construction quality issues include inadequate vapour barriers and problems with draft-proofing. In addition, the properties and density of the insulation material itself is critical. The use of building walls and roof thermal insulation does not only contribute in reducing the required air-conditioning system size, but also in reducing the annual energy cost. Additionally, it helps in extending the periods of thermal comfort without reliance on mechanical air-conditioning especially during inter seasons periods. Therefore, proper use of thermal insulation in buildings enhances thermal comfort at less operating cost. However, the magnitude of energy savings as a result of using thermal insulation vary according to the building type, the climatic conditions at which the building is located as well as the type, thickness and location of the used insulating material. The question now is no longer if insulation should be used but rather which type and how much [9]. The purpose of buildings thermal insulation is to maintain a comfortable and hygienic indoor climate at low ambient temperatures. A minimal amount of thermal insulation is required to protect the constructional elements against thermal impact and moisture related damage. The main aim of thermal insulation in winter is energy conservation leading to a decrease in heating demand and hence the protection of the environment.

This aim has to be considered in new buildings as well as in renovating the building stock. Strategies to reach this aim are the use of building materials with low thermal conductivity values and the installation of windows with low U-values on the one side and the avoidance of thermal bridges and uncontrolled infiltration on the other side. Besides the above mentioned purpose, thermal insulation plays a major role in preventing summertime overheating of buildings through reducing the transmission of solar radiation, absorbed on the buildings exterior surfaces, to the interior. The lowest λ values of non-evacuated elements achievable are the one of motionless air. Hence the basic principle in developing insulation materials is to enclose as much non-moving air into the structure of the material as possible and still satisfy the required structural stability. In cold conditions, the main aim is to reduce heat flow out of the building. The components of the building envelope - windows, doors, roofs, walls and air infiltration barriers are all important sources of heat loss; in an otherwise well insulated home, windows will then become an important source of heat transfer. The resistance to conducted heat loss for standard glazing corresponds to an R-value of about $0.17W/m^2/Ko$ (compared to $2\text{-}4W/m^2/Ko$ for glass wool bats). Losses can be reduced by good weatherization, bulk insulation and minimizing the amount of non-isolative (particularly non-solar facing) glazing. Indoor thermal radiation can also be retarded with spectrally selective (low-emissive) glazing. Some insulated glazing systems can double to triple R values [1].

II. PARAMETERS RELATED TO BUILDING PHYSIC

The thermal properties of structural elements are characterized by the mass densityρ, the λ-values of the building elements layers and the heat transfer coefficients α at the surfaces. The heat transmission through an element is defined by the air to air heat transmission coefficient U. Reducing the λ-value of a material or increasing the thickness of the insulation layer results in an decreasing U-value. The heat transfer coefficients are composed of a convective and a radiative part [2].

III. TYPES OF THERMAL INSULATION

The older building codes used to include cavity walls as the standard way of building the external walls of a house. Cavity walls have an air gap between the inner and outer course of bricks. The air gap stops heat being transferred via conduction through the two brick courses. The air gap acts as a partial insulator because heat can only flow via convection across the gap. Convection is far less effective as a heat transfer mechanism. If necessary, one can even minimize convection by injecting polyurethane foam (as a retro fit) into the air gap, or alternatively polystyrene sheeting can be inserted into the gap during construction. Many older houses still have cavity walls.

Unfortunately, cavity walls have long since been discontinued by local builders as standard practice. No form of insulation is currently added to the walls of modern homes, unless specifically requested by the architect or owner. One should consider this if one is currently building a home.

Thermal insulation is implemented as opaque or transparent constructional elements depending on the requirements. Opaque constructions can consist of evacuated or non-evacuated insulating elements. In the vacuum, the heat transfer mechanisms are restricted to the transport of energy through radiation. It is therefore possible to achieve better U-values in relation to the insulation layers thickness. The λ-value of an evacuated panel is five to six times smaller than that of non-evacuated insulation materials. Because of their high production cost, the use of evacuated panels is very limited.

Depending on the ambient temperatures, the heated up exterior surface of the wall leads to a reduced transmission loss or even to a transmission gain through the wall. In both cases the heating energy demand is reduced by the use of the transparent insulation construction. The gain energy per year and square meter area of transparent insulation amounts to 30-120 kWh.

In a typical house, generally loses of energy can be registered from all over. The floor can be a source of heat loose of approximately 5%, the windows – depending on their material can reach a limit between 5 and 15%, the walls and the roof somewhere around 50%, the ventilation exists have a value of 20% and the flue 10%.

IV. IMPLEMENTATION TYPES

Basically there are three possibilities for the positioning of the insulation layer within a structural element. These are external, internal and core thermal insulation. The external one is the most favorable one. The whole building is enclosed within a gapless thermal skin. Thermal bridging and the under-cooling of the buildings structures are avoided. A special form of external insulation is the perimeter insulation which encloses all structural elements having soil contact. The perimeter insulation is positioned vertically at the basement walls and horizontally under the basements floor outside the buildings sealing layer. It has to meet structural stability criteria and long-term endurance to moisture exposition. An example for external insulation is the integrated insulation systems, which are also called a thermal skin. It consists of an insulation layer, a reinforced layer and a final coating. The reinforced layer and the final coating protect the insulation material against mechanical stress and effects of weather [3].

The core insulation is positioned in the cavity of a wall. The cavity is either completely or partially filled with the insulation material, leaving space for an air gap, which can be used as an additional insulating layer or to ventilate the cavity and hence quickens the drying of the insulation material. Disadvantages of this placement are that the building construction is under-cooled in winter and the hardly controllable difficulties related to thermal bridges. Furthermore, the summer overheating problem is increased by the reduction of the thermal capacity on the interior surfaces.

V. MATERIAL REQUIREMENTS

Insulation materials have to keep their shape durable and resistant against mould and parasites. The moisture balance of the construction has to be positive, i.e. the water accumulating inside the construction during the thawing period (winter) has to be removed to the exterior during the evaporating period (summer). The placement of a wind tight layer at the outer surface and an airtight on the inner surface prevent the insulation material form being perused with humid and warm room air from the inside or cold ambient air from the outside. Depending on the field of use, the insulation material has to suffice the safety requirements for fire protection.

With the present design-oriented goals of sustainability and energy efficiency, the proper use of insulation is becoming more important than ever. There are many different ways to insulate a building, and there are dozens of insulation assemblies in existence.

Even though many foam insulation products may be considered expensive than other types of insulating materials, such as fiberglass, cellulose, they are commonly used in buildings where there are space limitations or where very high R-values are desirable. The foam insulation R-values may vary from R-4 to R-8 per inch of thickness (2.54 cm), which is 2 to 3 times greater than most other insulating materials of the same thickness. Attention is required at the installation; foam insulation may control air infiltration more effectively than other types of insulation. Several variables affect the installed R-value of foam insulation, including: the initial density of the foam; the blowing gas used (CO2, air, or some other gases); how the foam insulation is handled (dents and chips adversely effect the R-value); the type of facing used; and the conditions in which the foam is installed.

Fig. 1 Foam insulation

Liquid foam insulation can be applied from small spray containers as a liquid or in larger quantities as a pressure sprayed (foamed-in-place) product. Both types expand and harden as the chemical mixture cures. It also conforms to the shape of the cavity to fill and seal it thoroughly. This type is often used in new construction.

There are also slow curing liquid foams that are designed to flow over obstructions before it expands and cures. This type is often used for empty wall cavities in existing buildings. There are also liquid foam materials that are poured from a container.

Both are generally urethane foams. Latex and organic based foams are available too. These are just alternatives which do not have as high an R-value as urethane-based products.

Polyurethane and polyisocyanurate are both closed-cell foams that contain a low-conductivity gas in the cells (usually one of the HCFC or CFC gases.) The high thermal resistance of the gas gives these foams an R-value of between R-7 and R-8 per inch.

Both types are available as a liquid spray, poured foam and also as rigid boards. They can also be made into laminated panels with a variety of facings. Foamed-in-place applications are usually cheaper than installing foam boards and perform better since it molds itself to all of the surfaces perfectly.

Polystyrene insulation is a type of rigid foam insulation which is commonly used in residential and commercial settings. It has an exceptional ability to insulate against noise and extreme temperatures. It is also waterproof and long-lasting. These qualities combine to make polystyrene insulation an exceptionally useful product. Two types of polystyrene are used for insulation: expanded and extruded polystyrene (EPS and XPS). Expanded polystyrene (EPS) also called bead board, has a lower density than the extruded type and is less expensive, but also has slightly less insulating power. The physical properties of EPS vary with the type of bead used, but the density of the board is usually one pound per cubic foot (16.3 kilograms per cubic meter.) Bead board is manufactured at various densities, depending on the application. Bead board for roofing materials has to be dense enough to walk on without damage. Wall insulation boards are several times less dense than roof boards.

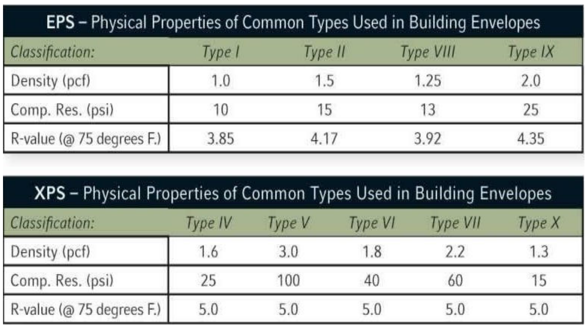
Extruded polystyrene (XPS) foam is a rigid insulation that's also formed with polystyrene polymer, but manufactured using an extrusion process, and is often manufactured with a distinctive color to identify product brand.

This is because of its coarse cells and the fact that they contain only air. Extruded polystyrene, due to the way in which it is made, has other qualities that make it a superior choice for insulation. It begins in the form of solid polystyrene crystals, which are combined with special additives and melted. In an extruder, the temperature and pressure are tightly controlled to convert the crystals into a thick plastic fluid. This liquid is then forced into a mold or dies. These interlocking foam formations are often made with hollow regions that can be filled with concrete which creates a grid of columns and beams when dry.

Polystyrene insulation is manufactured in a variety of board sizes – usually a minimum of 1-inch thick and goes to almost 15 inches on demand. Tapered units are also manufactured for use in roofing assemblies where the insulation is used to create slope for positive drainage. One of the most common uses in roofing is the ballasted single-ply roof assembly, which consists on a roof membrane positioned over the insulation and equilibrated with rock, concrete pavers or some other material.

Polystyrene insulations can be used in asphalt built-up roofing systems but provisions must be made to protect the insulation from heat (hot bitumen or torch) and solvent-based products (adhesives). In addition, certain thermoplastic roof membranes require a separation layer between the layer of insulation and the membrane.

EPS and XPS are resistant to moisture; however, XPS is more common for below-grade waterproofing and roof systems where insulation is placed over the roof membrane.



EPS – Physical Properties of Common Types Used in Building Envelopes

Classification:	Type I	Type II	Type VIII	Type IX
Density (pcf)	1.0	1.5	1.25	2.0
Comp. Res. (psi)	10	15	13	25
R-value (@ 75 degrees F.)	3.85	4.17	3.92	4.35

XPS – Physical Properties of Common Types Used in Building Envelopes

Classification:	Type IV	Type V	Type VI	Type VII	Type X
Density (pcf)	1.6	3.0	1.8	2.2	1.3
Comp. Res. (psi)	25	100	40	60	15
R-value (@ 75 degrees F.)	5.0	5.0	5.0	5.0	5.0

Fig. 2 Common types of ESP and XPS

The materials for polystyrene insulation [4] are often quite expensive and can add approximately five to ten percent onto the cost of building a house. However, the savings on heating and cooling can allow the homeowner to recoup the extra cost over the structure life. The concrete grid in the insulation offers its own benefits apart from the polystyrene. These include being impervious to many pests such as termites that can cause structural damage to an ordinary wood frame home if left unchecked.

As with any alternative building material, polystyrene insulation does have some disadvantages. Apart from the increased cost, it is also flammable and requires a fire-protective coating. It can also slightly degrade if exposed to sunlight or temperatures above 165 degrees Fahrenheit (74 degrees C). However, considering that most home insulation is never exposed to that type of temperature, it presents little practical risk. Expanded Polystyrene is a lightweight, rigid, plastic foam insulation material produced from solid beads of polystyrene (with a diameter of 0,2 to 0,3 mm). Expansion is achieved by virtue of small amounts of pentane gas dissolved into the polystyrene base material during production. The gas expands under the action of heat [5], applied as steam, to form perfectly closed cells of EPS. These cells occupy up to 50 times the volume of the original polystyrene bead. The EPS beads are then molded into appropriate forms suited to their application.

Fig. 3 Expanded Polystyrene (EPS)

There are 5 manufacturing stages:

1. Pre-expansion: polystyrene granules are expanded by free exposure to steam to form larger beads, each consisting of a series of non-interconnecting cells.
2. Conditioning: after expansion, the beads still contain small quantities of both condensed steam and pentane gas. As they cool, air gradually diffuses into the pores, replacing, in part, the other components.
3. Molding: the beads are molded to form boards, blocks or customized products. During molding, the steam causes fusion of each bead to its neighbors, thus forming a homogeneous product.
4. Shaping: following a short cooling period, the molded block is removed from the machine and after further conditioning, may be cut or shaped as required using hot wire elements or other appropriate techniques.
5. Post-production processing: the finished product can be laminated with foils, plastics, roofing felt, fiberboard or other facings such as roof or wall cladding material.

Expanded polystyrene foam (EPS) is usually white. Some new innovative EPS products are grey due to the inclusion of graphite, which substantially increases the insulation performance. EPS is safe, non-toxic and inert.

VI. DEW POINT

All air contains water vapour of varying quantities. The dew point indicates the amount of moisture in the air. The higher the dew point, the higher the moisture content of the air at a given temperature. Conversely, the dew point of humid air will be higher than the dew point of dry air.

Dew point temperature is defined as the temperature to which the air would have to cool (at constant pressure and constant water vapour content) in order to reach saturation. A state of saturation exists when the air is holding the maximum amount of water vapour possible at the existing temperature and pressure.

Condensation of water vapour begins when the temperature of air is lowered to its dew point and beyond. The dew point, like other measures of humidity, can be calculated from readings taken by a hygrometer.

In the figure 4 is presented the absolute humidity function depends of the temperature. For example the **dew point** temperature of air containing 10 grams per cubic metre of water vapour is about 11°C. If air at this temperature contained only 5 grams per cubic metre of water vapour, its relative humidity would be 50.

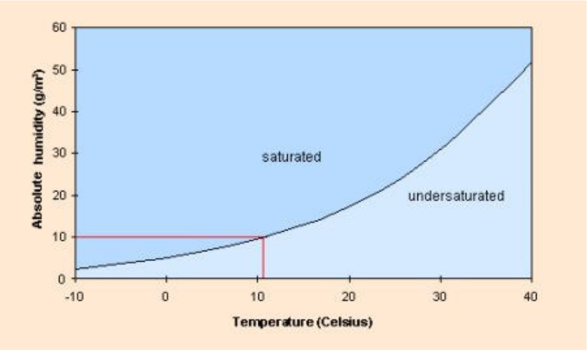


Fig. 4 The dew point – the absolute humidity function

VII. THE HOUSE WALLS MODELLING WITH FINITE ELEMENT

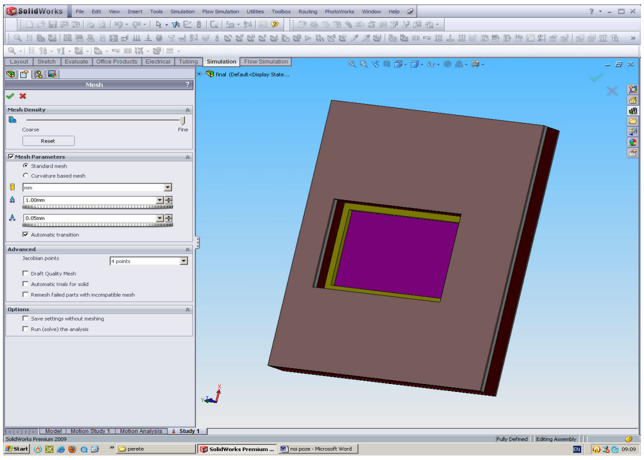
As physical model for finite element analysis we use the window of residential house from Craiova, Romania. The real conditions of building wall execution were used as input data for heat transfer analysis.

Tab. 1 presents the main dimensions for the layers made by different materials – external plaster including decorative paint, expanded polystyrene, Porotherm brick and interior plaster including paint.

Tab. 2 presents the material properties for all type of layers and Tab. 3 presents the temperature for inside of the wall and in exterior and the convection coefficient.

Fig. 4 The residential house used as real model

The figure 4 presents the house and the red frame includes the part from the wall that will be analysed with the finite element method using SOLIDWORKS.



Mesh

Mesh Density: Coarse – Fine

☑ Mesh Parameters

● Standard mesh
○ Curvature based mesh
mm
1.00mm
0.05mm
☑ Automatic transition

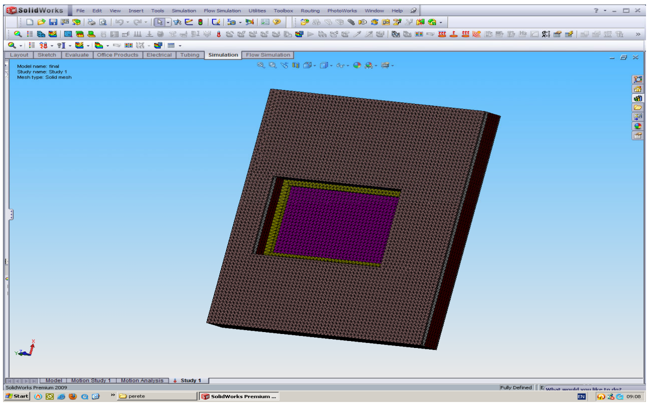
Advanced

Jacobian points: 4 points
☐ Draft Quality Mesh
☐ Automatic trials for solid
☐ Remesh failed parts with incompatible mesh

Options

☐ Save settings without meshing
☐ Run (solve) the analysis

Fig. 5 Mesh properties



Model name: final
Study name: Study 1
Mesh type: Solid mesh

Fig. 6 Building wall meshed

The figure 5 presents the mesh properties – in the left side of the frame used in the finite element analysis. The figure 6 shows the building wall meshed already and all the layers included the window.

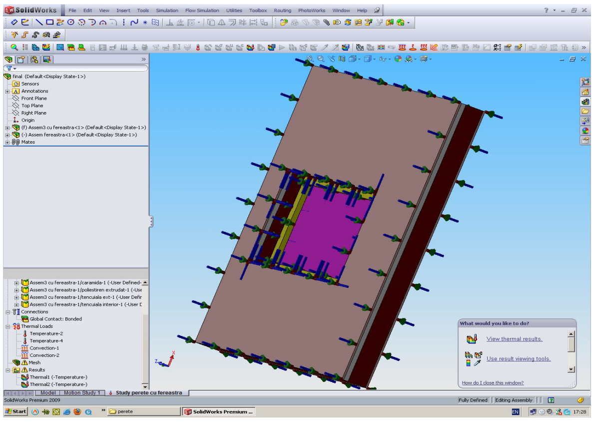


Fig. 7 The building wall modeled in SOLIDWORKS 2009 environment

Table 1 Dimensions for layers

No.	Type of layers	Width [mm]	Height [mm]
1	External Plaster	3000	2500
2	Polystyrene expanded EPS 20	3000	2500
3	Porotherm Brick	3000	2500
4	Interior Plaster	3000	2500
5	Glass 1	1360	860
6	Glass 2	1360	860
7	Air	1360	860
8	PVC	1500	1000

Table 2 Material properties

No.	Materials	Thermal conductivity [W/mK]	Thickness [m]	Mass Density [kg/m^3]	Specific heat [J/kg K]
1	Plaster exterior	0,93	0,02	1800	840
2	Polystyrene expanded EPS 20	0,029	0,05	30	1460
3	Brick Porotherm	0,8	0,2	1300	870
4	Plaster interior	0,93	0,02	1800	840
5	Glass	0,74976	0,004	2457,6	834,61
6	Air	0,027	0,004	1,1	1000
7	PVC	0,147	0,07	1300	1355

Table 3 Temperatures and convection coefficients

Interior Temperature [^{0}C]	External Temperature [^{0}C]	Interior Convection Coefficient α_i [W/m^{2}K]	Exterior Convection Coefficient α_e[W/m^{2}K]
20	-15	7	17
20	-15	7	17

VIII. EXPERIMENTAL DATA

Using SOLIDWORKS 2009 programming environment for the finite element analysis, the thermal results are presented in the nextlowing figures. The mathematical rules used in modelling [6], [7] gives us the results from the next SOLIDWORKS panels.

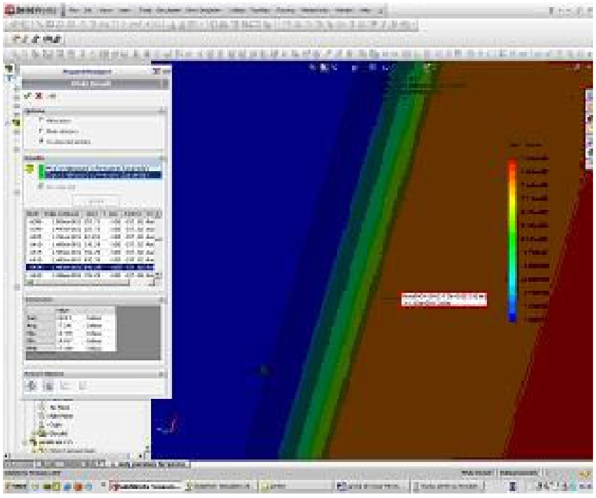


Fig. 8 The dew-point appears in interior of the brick in node 6424 (x=642.2 y=-1083, z=-337.82)

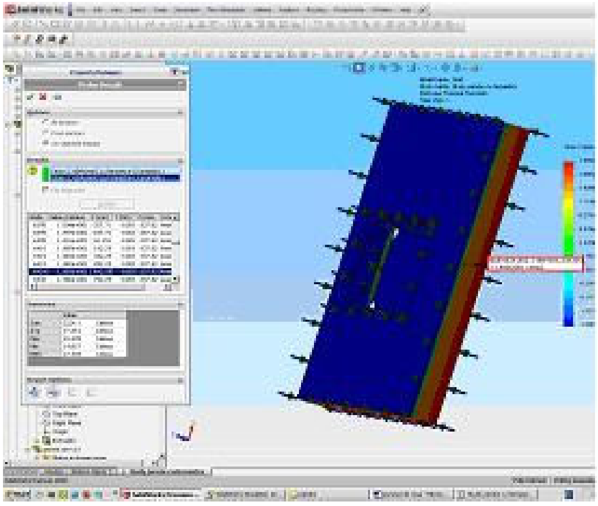


Fig. 9 The temperature map in all the layers of the wall

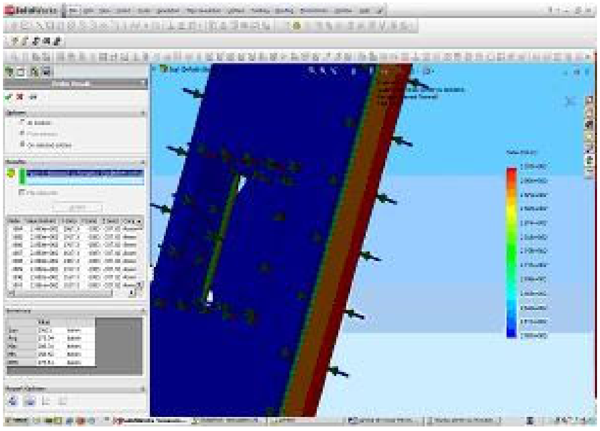


Fig. 10 The temperature of 14°C is obtained for the 1884-1891 nodes (z=-333.82)

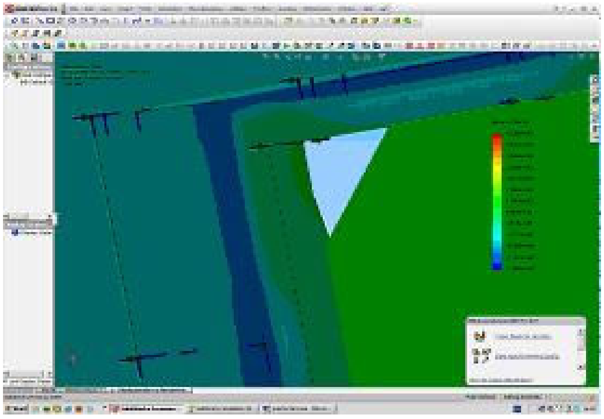


Fig. 11 The thermal bridge around the windows

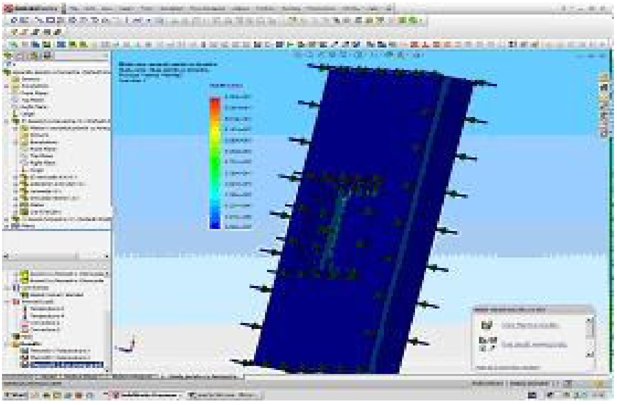


Fig. 12 The resultant gradient of temperature map

Figure 8 presents the apparition of the dew-point in the interior of the brick. This is a very bad situation for the chemical and mechanical stability of the material when the problem is one for the long time (four-five month per year). The dew-point appears in interior of the brick in node 6424 (x=642.29, y=-1083, z=-337.82).

Figure 9 reveals the temperature map in all the layers of the wall and the figure 10 shows that the 14°C temeprature is obtained for the 1884-1891 nodes (z=-333.82) inside the brick.

Figure 11 presents the thermal bridges around the windows with big differencies in temperature because of the bad technology in building.

Figure 12 shows the resultant gradient of temperature map in the wall and the figure 13 presents the resultant heat flux on Z axis in the wall.

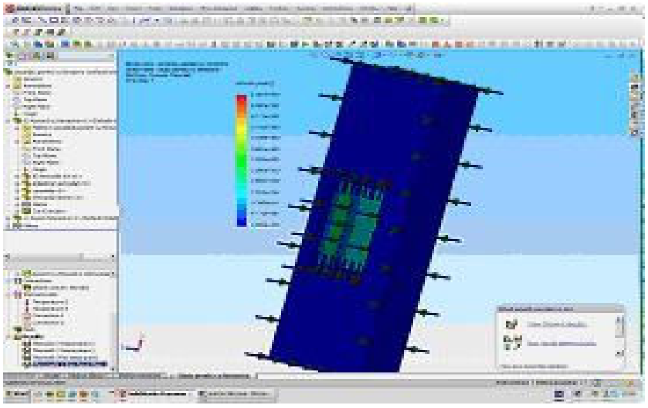


Fig. 13 The resulting heat flux on z axis

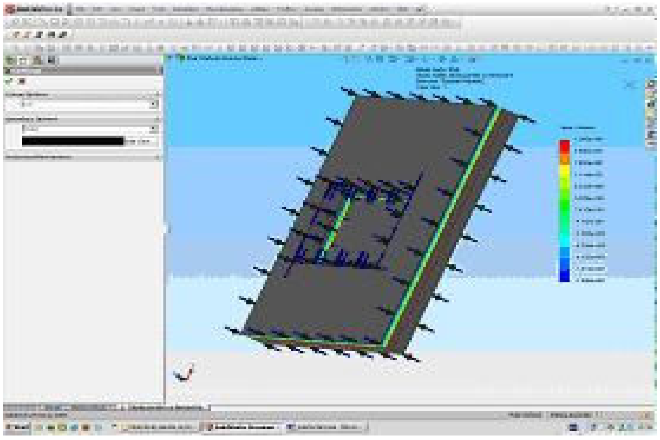


Fig. 14 The separation line between the layers from the wall and the distribution of the temperature in the exterior

The figure 14 shows the separation between the layers from the wall (brick, EPS insulation, exterior and interior plaster) and the distribution of the temperature.

Table 4 The result heating flux distribution per node

Node	HFLUXX	HFLUXY	HFLUXZ	HFLUXN
1	1.08331e+000	5.04996e+000	1.49503e+002	1.49592e+002
2	-4.15171e-005	4.64487e+000	1.49569e+002	1.49641e+002
3	3.59438e-005	4.09991e+000	1.49580e+002	1.49636e+002
4	1.21351e-004	4.09944e+000	1.49564e+002	1.49620e+002
5	-1.43984e+000	4.09718e+000	1.49524e+002	1.49587e+002
6	-5.39643e+000	2.04747e+000	1.49484e+002	1.49595e+002
7	-6.47271e+000	-2.00077e-003	1.49462e+002	1.49602e+002
8	-6.47294e+000	-2.11895e-003	1.49465e+002	1.49605e+002
9	-6.47301e+000	-2.16148e-003	1.49466e+002	1.49606e+002
10	-6.47301e+000	-2.16145e-003	1.49466e+002	1.49606e+002
11	-6.47390e+000	-1.82326e-003	1.49474e+002	1.49615e+002
12	-6.47360e+000	1.58692e-003	1.49470e+002	1.49610e+002
13	-5.39681e+000	-2.04761e+000	1.49489e+002	1.49601e+002
14	-1.44139e+000	-4.09766e+000	1.49533e+002	1.49596e+002
15	-3.18748e-004	-4.09946e+000	1.49564e+002	1.49621e+002

Table 5 Node coordinates and corresponding Heat Flux

Node	X (mm)	Y (mm)	Z (mm)	HFLUXN (W/m^2)
6997	294.539	1160.68	-507.705	5.00674e+002
7001	440.495	1157.2	-500.446	4.94665e+002
6947	1028.71	-113.144	-503.961	4.90309e+002
6918	1031.22	936.392	-502.262	4.83897e+002
7008	736.304	1164.33	-503.942	4.83185e+002
7086	-60.7218	-55.1474	-512.288	4.79583e+002
6939	1032.34	174.952	-502.748	4.79200e+002
1544	57.4487	-380.748	-537.817	4.78588e+002
1491	914.591	-380.748	-537.817	4.78346e+002
6931	1032.34	476.078	-502.75	4.77876e+002
6954	935.996	-425.232	-505.456	4.77778e+002
6943	1031.58	18.9316	-501.437	4.76650e+002
6935	1032.42	331.436	-501.888	4.76283e+002

Table 4 presents the result heating flux distribution per node and on X, Y, Z directions and table 5 presents the distribution on the heat flux in the corresponding node coordinates. Table 6 presents the node coordinates and corresponding temperature gradient.

Figure 15 presents the transversal plane where the dew-point occurs (interior of the brick) and figure 16 shows the transversal section through the wall (wall – window).

The section through the wall with included window shows the thermal heat flux distribution in the figure 18. Around the window, the thermal bridge leeds to the map from the figure 17 – for example in the plane (-150, 14°, 57°).

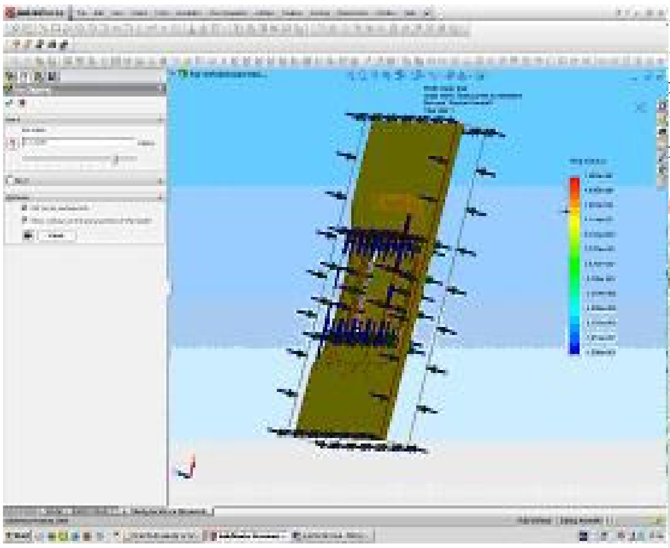


Fig. 15 The transversal plane where the dew-point occurs (interior of the brick)

Table 6 Node coordinates and corresponding temperature gradient

Node	X (mm)	Y (mm)	Z (mm)	GRADN (K/m)
1076	596.411	827.156	-532.438	5.54242e+003
1226	541.216	938.204	-533.127	5.54240e+003
1227	612.882	938.204	-533.127	5.54239e+003
1078	612.882	824.871	-533.127	5.54233e+003
1090	291.809	-64.8552	-532.701	5.54232e+003
1113	701.02	747.029	-530.817	5.54232e+003
1098	612.882	824.871	-530.128	5.54232e+003
1079	541.216	824.871	-533.127	5.54232e+003
1096	291.809	10.7004	-532.701	5.54229e+003
1091	735.755	29.1843	-532.324	5.54229e+003
1116	701.02	671.474	-530.817	5.54229e+003
1175	701.02	67.0294	-530.817	5.54229e+003
1084	735.755	-46.3713	-532.324	5.54228e+003
1197	701.02	218.141	-530.817	5.54228e+003
1080	739.018	632.371	-532.471	5.54228e+003
1092	664.088	29.1842	-532.324	5.54227e+003
1099	701.02	822.585	-530.817	5.54227e+003
1172	664.088	29.1842	-529.324	5.54227e+003

Low energy constructions are sensible to thermal bridges.

To illustrate the proportion of the total transmission loss through the building envelope, which is due to thermal bridges, calculations have been made /1/. Ventilation losses are not included in these calculations.

The thermal bridges are divided into 3 groups:

· low value: if great care is taken to reduce heat losses;

· medium value: typical design

· high value.

When a structure is built with a large thermal bridge, e. g. a solid construction between the front and rear leaves of a wall.

In the same way as for the structural details, three levels of transmission loss (U-values) are set out:

· low value - typical for low energy constructions;

· Medium value - corresponds to the Romanian building regulations;

· high value - represents a substantially larger heat loss than the medium value (as the 1970s).

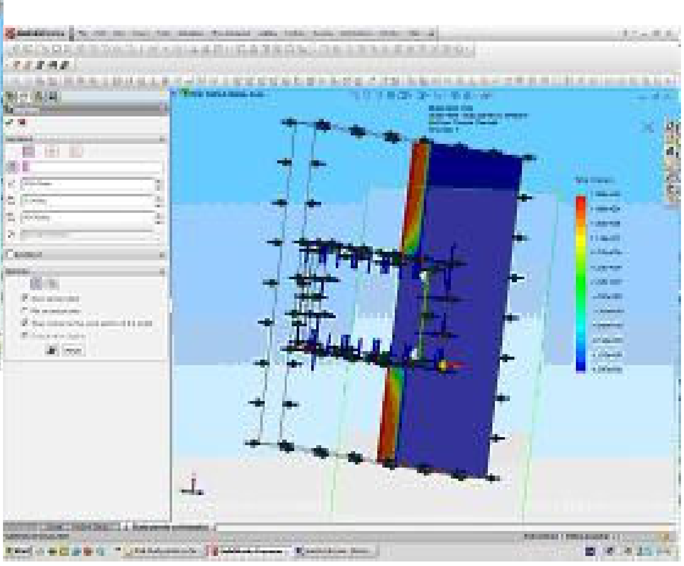


Fig. 16 The transversal section through the wall (wall – window)

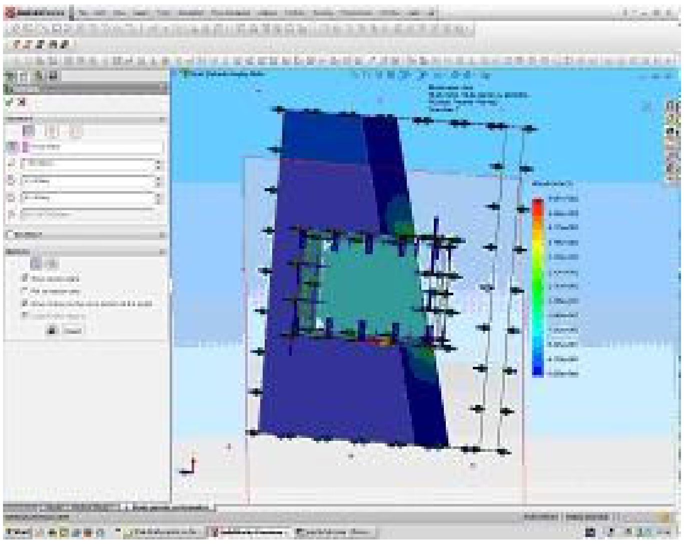


Fig. 17 The resultant heat flux in the plane (-150.00, 14°, 57°)

In this way 2 buildings have been calculated one single storey building (floor area 120 m^2 - windows + doors 21,6 m^2) and one 3-storey building (floor area 432 m^2 windows + doors 265 m^2). The most important results show that:

· Thermal bridges around the windows (not the panes) give the largest individual contribution (31.48%).

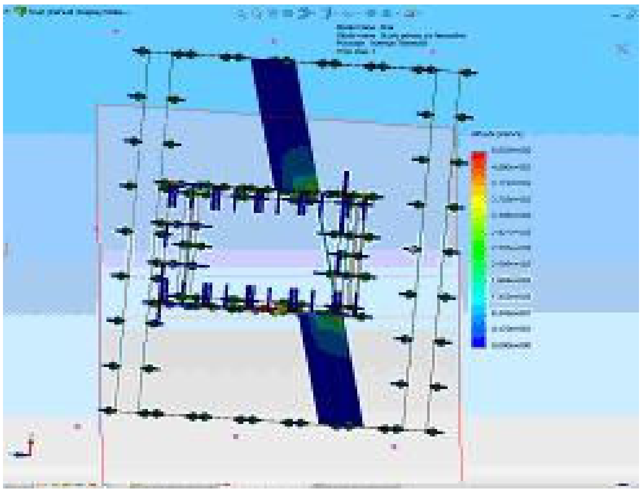


Fig. 18 Section with the resulting heat flux

· The heat loss from the junctions of the external walls is in the low end (1.3%).

· The heat loss through the windows gives the biggest contribution to the total heat loss.

· In older Romanian buildings (high value) with average thermal bridges the proportion of heat loss from thermal bridges for both building types is 19.20%.

· With a modern Romanian insulation standard (medium value), but unchanged (medium value) thermal bridges, their contribution will rise to 30.32%. With heavy thermal bridges (high value) the contribution will be 58%. With minimum thermal bridges their contribution will be reduced to 13%.

· In low energy buildings (low value) with average thermal bridges the proportion of heat loss from thermal bridges for both building types is 48.51%. With a modern insulation standard (medium value) but unchanged thermal bridges, their contribution will amount to 30.32%.

It is evident that it is important to assess linear thermal bridges where there are a lot of these around windows and along horizontal lines, while the contribution due to external vertical edges on walls is normally moderate.

Besides the additional heat costs caused by thermal bridges, there are consequences for the following items:

1. Health
2. Maintenance
3. Comfort

Thermal insulation normally has the greatest relative significance for heat loss in new buildings. When the insulation is very thick, thermal bridges have a great relative significance for the total heat loss. In new buildings low temperatures occur mostly around windows and at penetrations for services.

Thermal bridges also have considerable significance in existing buildings. When supplementary insulation is installed, it is generally easier to reduce the extent of thermal bridges, if the insulation is applied on the outside, than if fitted on the inside.

Generally speaking, supplementary insulation applied on the outside will always raise the surface temperature on the inside. If supplementary insulation is fitted on the inside, there will often be isolated areas on the inside of the building envelope, where the surface temperature is lower than before supplementary insulation.

In existing buildings there are a number of problems at present due to a level of humidity that is too high in relation to moisture production, air change rate and the class of thermal bridge. If the surface temperatures were higher, these problems would be more limited in scope.

Maintenance and health

The consequences of condensation or a very high relative humidity at the surfaces are that the maintenance requirement is increased, because surface treatment has to be applied more frequently.

Another problem with condensation is the risk for mould growth causing allergy and other health problems.

Comfort

Thermal bridges can also cause thermal comfort problems. If there is large poorly insulated or uninsulated areas of the walls, the surfaces will be cold in the winter which can cause cold draughts. Leakages in the building envelope can also lead to draughts. The cold draughts will cause low floor temperatures. The cold draughts and low surface temperatures can both give thermal comfort problems [8].

IX. Results interpretation

The dew point temperature is defined as the temperature at which the air becomes saturated with water vapor when the air is cooled by removing sensible heat. It is very important because it is directly related to the amount of water vapor in the air and it can be used to determine other variables (e.g., vapor pressure, relative humidity, wet bulb temperature, and vapor pressure deficit). In addition, the dew point measured during nighttime is often a good approximation for the minimum temperature of next morning. Consequently, it is extremely important for freeze protection of crops.

During nighttime, there is a net loss of long wave radiation from the surface to the sky. This causes the surface to cool and sensible heat, which is measured with a thermometer, is convicted downward from the air to the surface to partially replace the heat loss. However, the surface cools faster than the air above and this usually leads to an inversion (i.e., the temperature increases with height).

When the surface temperature reaches the dew point temperature, dew will form. The dew does not fall from the sky. Water vapor, like other gases, moves at sonic speeds and continually strikes the surface.

The dew-point in brick cladding is typically in the interior of the cladding, increasing the chance of the condensing the moisture within the wall, possibly freezing and causing damage.

The thermal bridges occur around the windows due the bad insulation with EPS in those areas.

X. Conclusions

The EPS is seen as a recyclable product, with a long life – having a stable R value and possibility of placing below grade and utilized for inverted assemblies, but with some properties like the fact that exposure to sun will deteriorate the product, solvents or solvent based materials cause irreversible changes, temperatures above 74°C or 165°F will melt the material, the incompatibility with certain thermoplastics, polystyrene insulations are known to draw plasticizers out of thermoplastic membranes causing permanent degradation and the need for a proper placement due to the fact that is flammable transforms its existence and utilization into a permanent debate.

The important conclusion is that the EPS insulation has to be more than 5 cm thick, at least 8 cm to influence the dew-point migration from exterior of the brick to inside EPS cladding for better execution and exploitation.

For a winter in Southern East Europe such in Craiova, Romania, where the medium temperature is -10°, the negative influence of the dew-point occurring in the brick wall is maintained for 4 months annually. Even the quality of the Porotherm brick is very good as humidity resistance, in time the negative effects will appear.

In order to avoid condensation in buildings with severe thermal bridges, it is necessary to ensure that relative humidity in the room is sufficiently low. This is achieved by making sure that production of moisture is low, and that there is a sufficiently large rate of air change. In the case of supplementary insulation on the inside, there may also be a risk that the air change rate has to be increased; this may give rise to increased energy consumption.

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