HIGROTHERMIC TRANSFER THROUGH THE PASSIVE HOUSE AND ZERO ENERGY HOUSE ENVELOPE

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REZUMAT. În această lucrare se va prezenta o analiză o comportării unei punți termice în cazul unei clădiri eficiente energetic (casă pasivă sau casă zero energie), având în vedere transferul de căldură şi transferul de masă, precum şi corelarea rezultatelor cu coeficientul liniar de transfer termic şi riscul de producere a condensului. Detaliul analizat reprezintă o punte termică constructivă, situată la intersecția în plan orizontal dintre un perete exterior şi un element vertical liniar. Se vor analiza mai multe variante de alcătuire pentru puntea termică, corespunzatoare modelului structural propus pentru cladirea considerată.

Cuvinte cheie: casă pasivă, casă zero energie, cladire eficientă energetic, punte termică, flux de caldură, risc de producere a condensului.

ABSTRACT. This paper has the purpose of analyzing the behavior of a thermal bridge in the case of an energy efficient building (passive house or zero energy building) both regarding heat and mass transfer through a selected construction section , with correlation to the linear thermal transmittance and the condensation risk. The building detail subjected to study is a geometrical thermal bridge (horizontal section through external wall at junction with vertical linear element) and will be presented in multiple detailing solutions, according to the structural system proposed for the considered building.

Keywords: passive house, zero energy house, thermal efficient buildings, thermal bridge, heat flux, condensation risk.

1. INTRODUCTION

The desire to decrease energy consumption in the residential sector has created a large interest in the energy efficient building development, such as passive house and zero energy houses, concepts which might be a model for the way we build our homes in the future. The two low energy buildings have a common objective which is to limit the heat losses through the building envelope in order to reduce energy demands for heating. The design principles require high levels of insulation for the building envelope, air tightness and mechanical ventilation with heat recovery systems, energy efficient windows and rainwater collecting systems. The design also considers passive solar gain techniques (collect solar heat in the winter and reject solar heat in the summer) and active solar technologies (PV-panels for collecting electricity or solar collectors for domestic hot water and space heating) [1].

A passive house is required to obtain a energy consumption for heating and cooling of less than 15 kWh/m^2/year and a total energy consumption of 120 kWh/m^2/year, which can be partially or totally supplied from conventional energy sources [2], whereas the zero energy house has to ensure the total energy demand by renewable technologies, such as on-site windmills for electricity or PV-panels.

One of the main objectives is to reduce thermal heat loss through the building envelope, and also through the building junctions, where the thermal bridge effect increases the heat transfer resulting in additional losses. All connections must be planned with special care in order to avoid the thermal bridge and to ensure the higher performance required for a low energy building.

2. METHODOLOGY

2.1. Structural models for the energy efficient building

The building subjected to this study was designed as a passive house with 144m^2 living area and two floors, conceived as a duplex for residential use. Six structural types with different envelope solutions were submitted to analysis in order to optimize the low energy building envelope. The proposed solutions for the structure of the house are: structural masonry (25 cm) with reinforced concrete columns (25x25 cm) and belts (25x25 cm), non structural masonry (20 cm) with reinforced concrete frames (30x30 cm columns, 25x40 cm beams), reinforced concrete diaphragms (15 cm) , structural timber panel walls (21 cm) with mineral wool (15 cm) between timber studs (15x12 cm) , structural panel walls (21 cm)) with steel profiles (C150/2) and mineral wool (15 cm) between the C sections and steel frames (column square pipe profile 180x180 mm and IPE 180 beams) with Structural Insulated Panels (polystyrene and fiber cement).

The common parameters for each structural type are: the same interior heated volume and area, the same interior surfaces of walls, windows and ground slab. The difference between the envelope types is the thicknesses of the thermal envelopes, which were supplied by PHPP (Passive House Planning Package) in order to fulfill the energy requirements for passive houses. The resulting insulation thicknesses for the external walls are: 35 cm for masonry walls, 35 cm for concrete walls, 27 cm for timber panel walls, 30 cm panel walls with C section profiles and 35 cm for the structural insulated panels.

2.2. Thermal Bridge Analysis

The selected thermal bridge for analysis is the junction between an external wall and a vertical linear resistance element (poor thermal insulator) as described in Figures 14-19. The models for each structure type were submitted to a 2-dimensional steady state heat transfer calculation which was used to evaluate the additional heat flows caused by the thermal bridge and the interstitial condensation risk The software used for performing the automated calculation was ANTHERM, and it provided the visualization of heat flux distribution (Fig. 1-6) for heat transfer along with values for the linear thermal transmittance (Table 1), and the visualization of pressure distribution (Fig. 12-18) for vapor transfer analysis. The interior and exterior environments were assumed to meet the following conditions: interior air temperature 20ºC, 60% interior humidity, exterior temperature –15ºC and 80% exterior humidity [3].

3. RESULTS AND DISCUSSIONS

3.1. Heat transfer

The heat flux streamlines (Fig. 1-6) are visibly disturbed in the areas where the different conductivity materials come in contact. The heat flux streamlines, which are perpendicular to the element surface in current homogeneous sections, flow through the path of the most thermally vulnerable material, with the lowest thermal resistance.

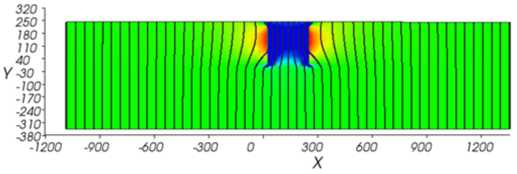

Fig. 1. Heat flux streamlines for 1-st. model.

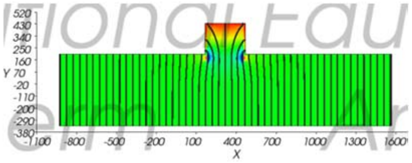

Fig. 2. Heat flux streamlines for 2-nd model.

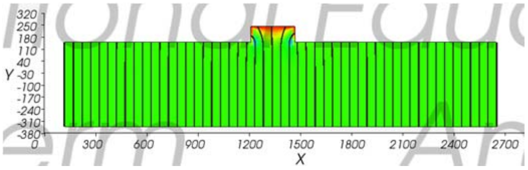

Fig. 3 Heat flux streamlines for 3-rd model

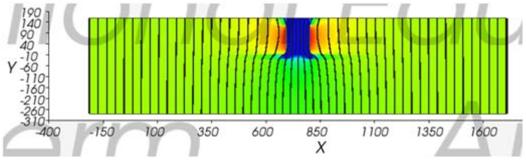

Fig. 4. Heat flux streamlines for 4-th model.

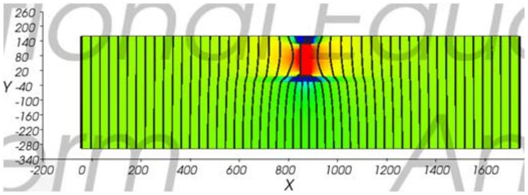

Fig. 5. Heat flux streamlines for 5-th model.

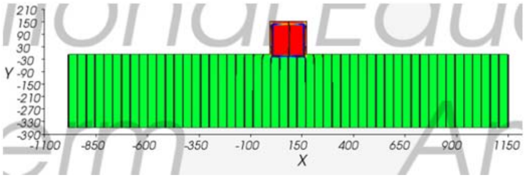

Fig. 6. Heat flux streamlines for 6-th model.

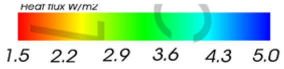

Fig. 7. Heat flux colobar.

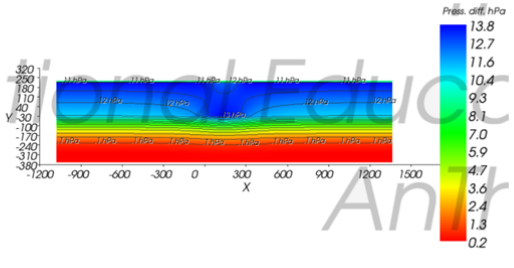

Fig. 8. Pressure difference isolines for 1-st model.

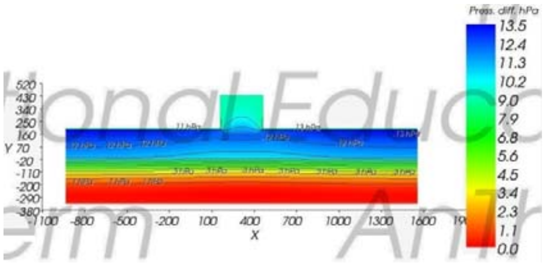

Fig. 9. Pressure difference isolines for 2-nd model.

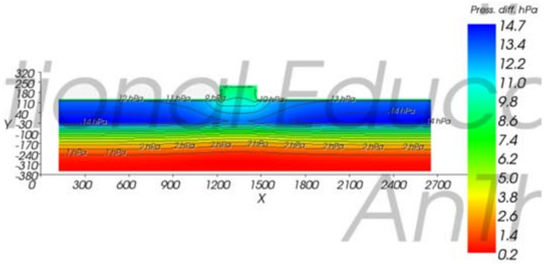

Fig. 10. Pressure difference isolines for 3-rd model.

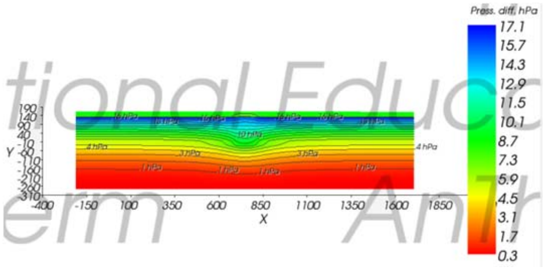

Fig. 11. Pressure difference isolines for 4-th model.

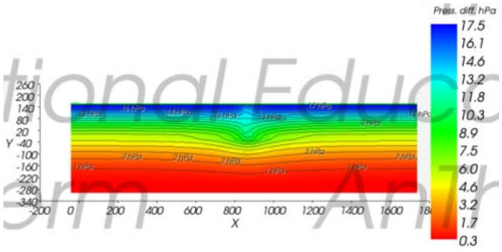

Fig. 12. Pressure difference isolines for 5-th model.

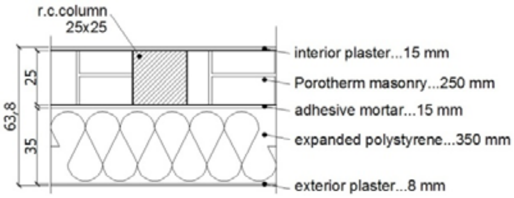

Fig. 14. Detail 1-st model.

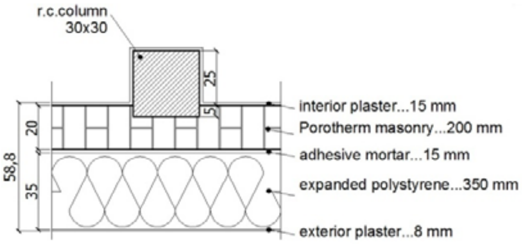

Fig. 15. Detail 2-nd model.

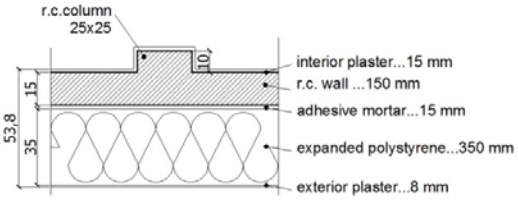

Fig. 16. Detail 3-rd model.

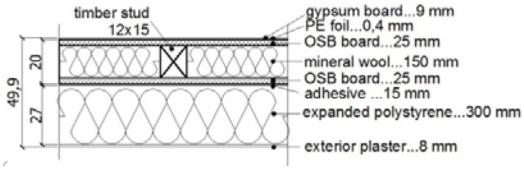

Fig. 17. Detail 4-th model.

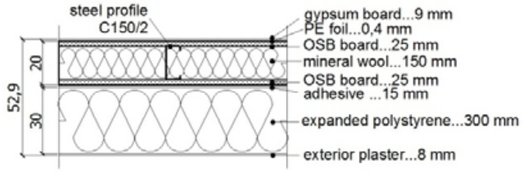

Fig. 18. Detail 5-th model.

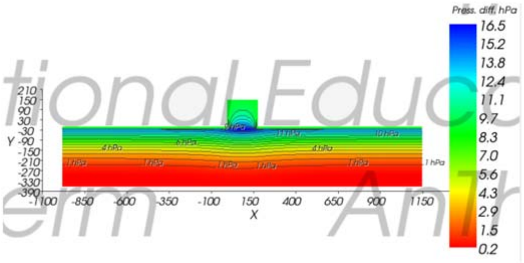

Fig. 13. Pressure difference isolines for 6-th model.

The images suggest increased heat transfer for details *1* and *4*, where the penetrating vertical resistance element has a lower thermal performance than the surrounding materials (concrete vs. masonry and timber vs. mineral wool). The details with the least influence of thermal bridge effect are 3 and 6 because the normal direction of the streamlines (perpendicular to the surface) is very little disturbed and the contact between the two different materials is partial and limited.

The Ψ value (linear thermal transmittance) which represents the additional two-dimensional heat loss in comparison to the one dimensional reference heat loss in the adjacent elements of the thermal bridge [4], is presented in the Table 1 for the 6 models analyzed.

The smallest values of the thermal linear transmittance are encountered in the case of the 3-rd and 6-th detail, and as predicted from the simple visual analysis of the streamlines, these details have the best performance.

Table 1. **Ψ-value for the analyzed thermal bridges**

Model nr.	Value of Ψ [W/mK]
1	0.00222
2	0.000417
3	0.000022
4	0.00594
5	0.00517
6	0.00014

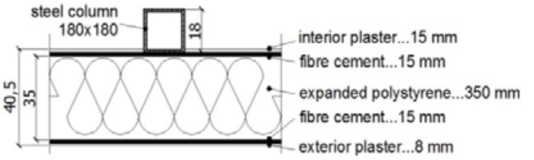

Fig. 19. Detail 6-th model.

The least performing results were obtained for details *1, 4* and *5*, with the highest Ψ values, and the strongest disturbances of the heat flux streamlines.

Another observation is that the linear thermal transmittance values for the six models are very small. The limit considered for low energy building thermal bridges is 0.01 [W/mK], [2] which means the effects of the thermal bridges analyzed can be neglected in thermal calculations.

3.2. Vapour transfer

The second series of isolines (fig.8-13) represent the difference between the saturation pressure and the partial vapor pressure inside the elements. The difference resulting smaller than zero leads to the condensation phenomenon inside the building envelope element. The layers considered with best behavior for the vapor diffusion are the PE foil used for details 4 and 5, with μ = 50 000, and the interior plaster for the other details, with μ = 2500.

The behavior of elements with the PE foil (details 4 and 5) is better, the minimum difference between the pressures is 0.3, whereas the other elements have a 0.2 difference and the 2-nd element has a 0 minimum difference which implies the necessity to improve vapor transfer layering.

4. CONCLUSIONS

The thermal bridge analysis of the selected details points out a high performance for heat transfer, with Ψ values much smaller than the 0.01 W/mK limit, which indicates the possibility of neglecting their effects. The study indicates a lower performance for the details with a total penetration of an insulated layer by a material with smaller conductivity in comparison with the details where the perturbing element is only partially introduced in the main layer, at the face of the layer towards the interior space, or has the same thermal properties as the interrupted layer.

The vapor diffusion analysis indicates that condensation is not a problem for the interior surface of the elements, but exterior condensation can occur for some cases. In order to increase the pressure differences and assure a better protection of the wall, vapor barrier materials are required to be displayed at the inner side of the wall.

Acknowledgement

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