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NUMERICAL AND MEASUREMENT INVESTIGATION OF THE THERMAL BRIDGE CAUSED BY THE PIPE PASSING THROUGH THE INSULATED WALL

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ABSTRACT

The local thermal bridges cause problems on buildings. The aim of the analysis presented in the paper is to study the passage of pipes through a well-insulated exterior wall. Two possible pipe location in thermal insulation have been investigated: just below the exterior surface and fully embedded in the insulation. Numerical 3D calculations using the finite element method showed possible critical areas in this detail with increased relative humidity. Due to the limitations of numerical calculations, similar measurements on a sample with real dimensions were made in climatic chambers. By taking a detailed reading of the temperature and the relative humidity around the pipe in the wall, the results of the numerical calculations have thus been refined.

INTRODUCTION

The issue of carrying out installations and wiring in energy-efficient buildings interferes slightly with their thermal protection, particularly in the area of building envelope (external walls, roofs and often foundation structures) and causing thermal bridges. According to Halahyja [1], the thermal bridge is a structural element with a different thermal conductivity than the other normal section of the structure. At that place, there is usually a higher thermal conductivity and lower internal surface temperature. One of main thermal protection objectives is to reduce fuels needs for the building operation and also to help create healthy and hygienic conditions for people. The thermal bridges in the structure have already been dealt with eg. Sternova [2] and other authors [3], [4], [5], [6], but they have been dealt with construction part of the buildings only, not of the pipeline passage through the structures.

THE SOLUTIONS BY TYPE OF PIPELINE

The passage of water and sewage piping into the building is always carried out in a frost-free depth, either into the underground floor space or through the foundations into the first floor. Due to the restriction of the passage due to freezing, it is also not possible to run the pipe in the thermal insulation on the façade. For rainfall from the roof, the Slovak standard states: "In areas with frequent frosts where ice could clog inlets and cause water to enter the building, additional heating should be considered [7]. For more frequent problematic technical details, such as rain gully, ready-made design solutions and products that eliminate thermal bridges are designed. [6] Power lines, sockets, lamps and other electrical elements can be installed both indoors and outdoors. For the installation of elements of electrical equipment on a façade in thermal insulation, in addition to the installation requirements, thermal breaks and universality of use are also required [9,10]. The gas piping must be routed in a way that no explosive concentration occurs [11]. One way to prevent the formation of explosive concentrations is to trace the pipes through the exterior - in the facade of the building, respectively. It is necessary to ensure constant ventilation of the cavity in which is the pipe stored.

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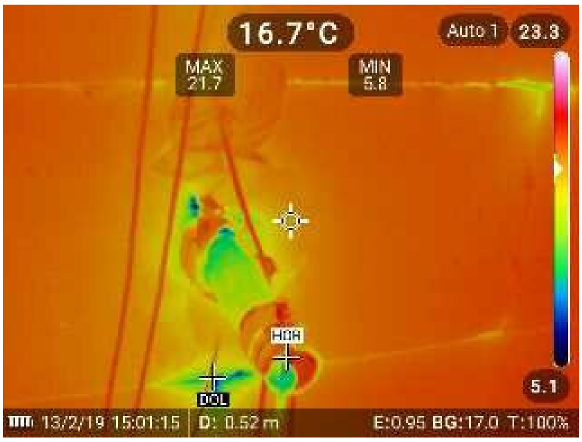

Figure 1. Infrared image from the thermal imaging camera - the passage of the pipe through the wall into the interior.

THE EXPERIMENTAL INVESTIGATION

The purpose of this study is to show an exemplary investigation on the passage of gas pipeline through an external wall. More details of this can be found in Tab. 1 and in the dissertation [12]. We used porous concrete block, because it is the best-selling brick in Slovakia for a long time. With 100 mm polystyrene layer it meets the requirement of thermal resistance for external walls. First, the course of temperature and humidity in the structure is solved, than some variants of possible solution are proposed in order to choose the most suitable alternative. The calculation software Cube 3D was used to assess 3D spatial details - a three-dimensional steady-state heat and water vapor flux [13]. The program works with prism material objects. For the indoor environment was chosen climate with an air temperature θi = 20 ° C and a slightly increased relative humidity φi = 60%. The outside temperature was θe = -15 ° C, relative humidity was φe = 84%, which is typical for the Zilina region. The medium (fuel gas - natural gas) has properties corresponding to its conduction in the outdoor environment, ie natural gas after regulation from medium pressure in the winter period: -15 °C. This is the most common and unfavorable option with regard to the transition to medium pressure pipelines.

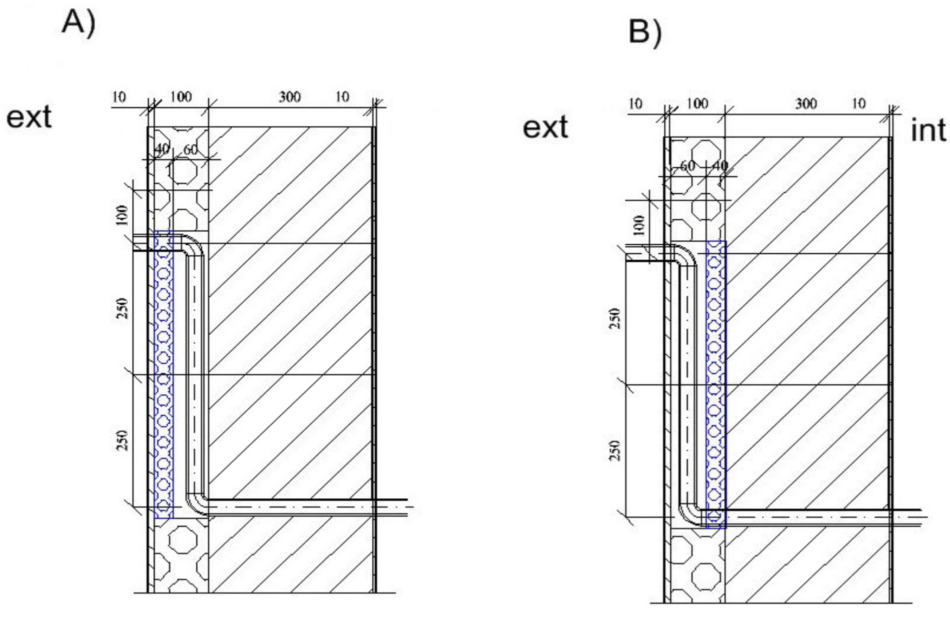

Figure 2. Variants of gas pipe routing in a thermal insulation system with different location of the pipe routing cavity (the thermal insulation is shown in blue).

Table 1. Description of construction and material solution of the wall

Num.	Material	d [m]	λ [W/mK]	ρ [kg/m^3]	c [J/kgK]	δ .10^9[s]
1	Weber internal wall plaster	0.01	0.860	2000	840	0.01
2	Porous concrete block Ytong P2-400	0.30	0.108	400	1000	0.0377
3	Polystyrene Isover EPS 70F	0.10	0.039	20	1270	0.0027
4	Reinforcement grid + plater	0.01	0.8	1500	790	0.005

These are approximate values, varying according to ambient temperature, bearing depth, cable length, sunlight exposure, operating time, etc. The lowest temperature occur at the time of heating peak by the lowest outdoor temperatures. The advantage of the computational investigation is the possibility to observe interesting quantities in a greater numbers of points than by measuring, respectively. The aim of the measurement in climatic chambers was to clarify the course of temperatures and humidity in the structure in selected critical points and that way to confirm the calculation. As before a different locations of the gas pipeline in the thermal insulation on the facade are chosen: A) - the pipeline is on the inside of the façade thermal insulation, B) - the pipeline is on the outside of the façade thermal insulation (Fig. 2).

THE RESULT OF CALCULATION

When we compared result of calculation for two variants of solution (Fig. 3), the most unfavorable course of temperatures and humidity in the structure for variant A) is evident. In both cases, the surface temperature in the interior is higher than the critical surface temperature for the formation of molds, so there is no condensation risk on the inner surface. The temperature at the contact between masonry and insulation decreased (compared to the case without gas pipeline in insulation θ = + 4 ° C) to the temperature in case A) θ = -14 ° C, in case B θ = -1 ° C. At these temperatures, water vapor should be iced inside the structure in the air cavity for the gas pipeline. The basic anticorrosive protection of the steel pipe is the primer and the top coat. Flush-mounted pipes should have increased corrosion protection. Condensation was also calculated under the outer plaster layer at the gas pipeline. The calculation was carried out under stationary and unfavorable conditions. In fact, it is a state that lasts several tens of minutes, and there is no need for a critical temperature reduction. The course of temperatures in the structure is significantly deformed along the entire length of the pipeline (Fig.3).

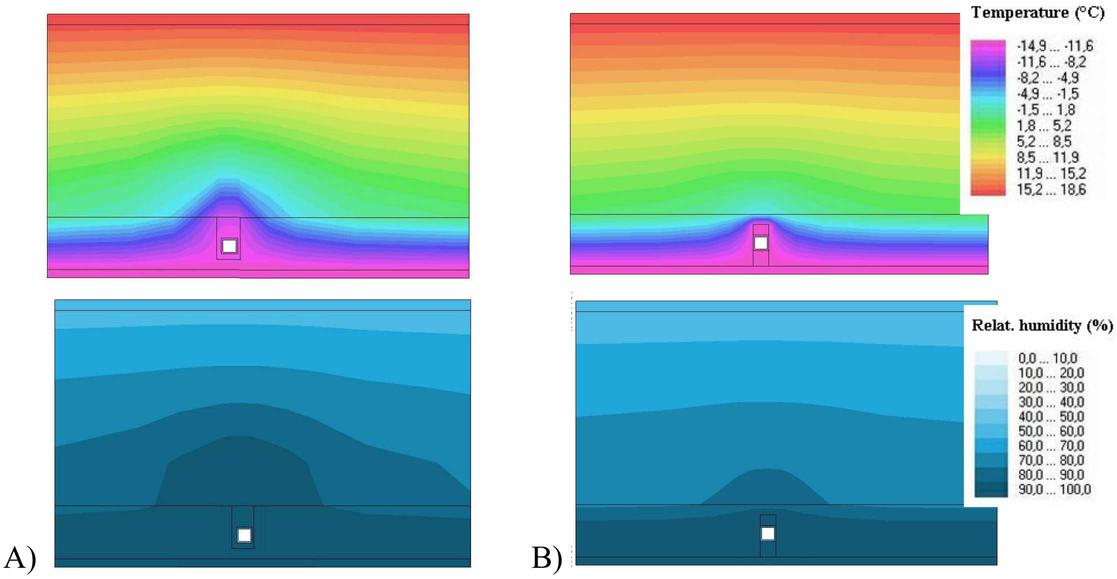

Figure 3. Results from the 3D finite element calculation variant A) and variant B).

A low temperature also occurred at the inlet of the duct to the interior room, by significantly cooling below the dew point temperature (according to the resulting simulation program protocols): var. A) + 4.22 ° C; var. B) + 8.69 ° C. In the layer of lightweight concrete masonry near the pipeline a condensation zone is created inside the structure and the thermal insulation properties of the masonry can deteriorate.

THE MEASUREMENT RESULTS

It is not possible to make an accurate and stable adjustment of the external relative humidity at temperatures below freezing point in the climatic chamber; in experimental measurements it varied between 84% to 93% for variant A and 70% to 80% for variant B.

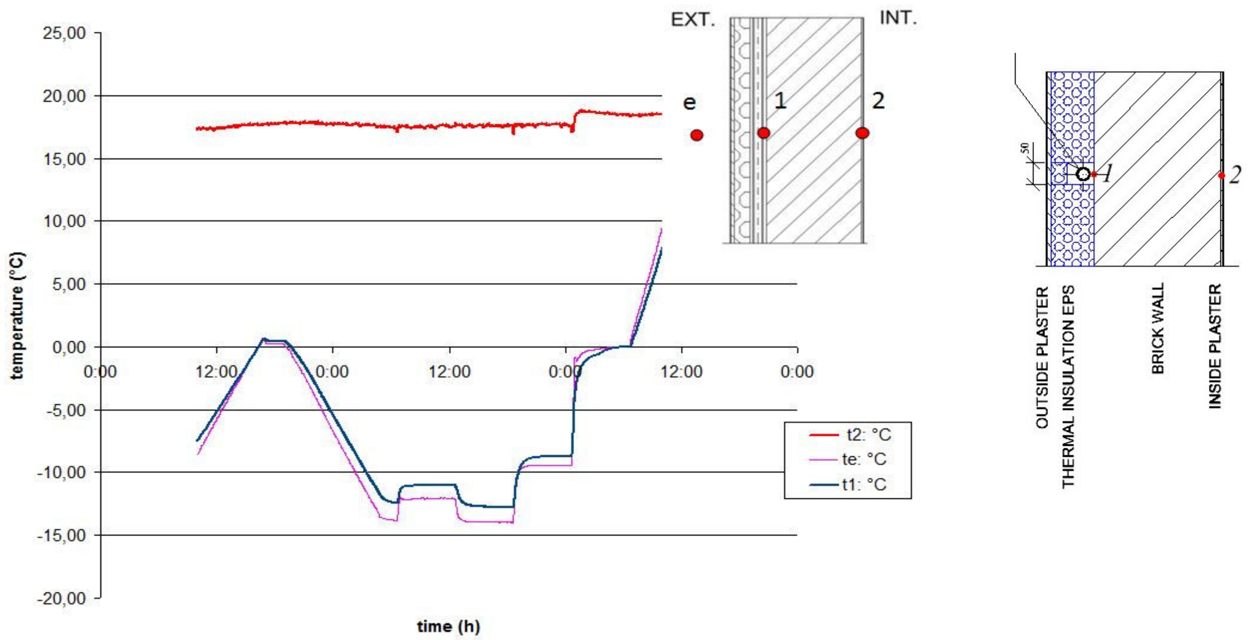

Figure 4. The temperature recordings from measurement in climate chambers for variant A.

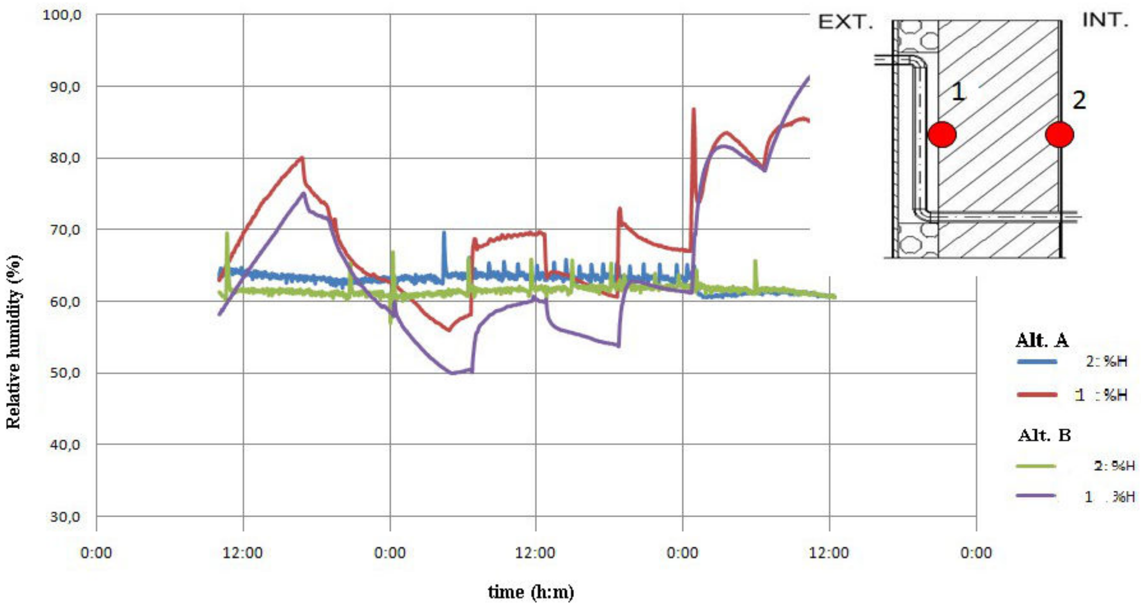

Figure 5. The humidity recordings from measurement in climate chambers for both variants.

The flow of medium at -15 ° C through the pipe was performed in the experiment by a slight overpressure of air in the external climate chamber. Temperature and humidity values on sensors outside the line of contact with the masonry are more favorable (temperature higher by approx. 2 to 4.5 ° C) for variant B.

Temperatures for experimental measurements under the most unfavorable conditions (temperature -15 ° C, approx. measurement) approximates the values according to computer simulation. On the experimental wall, the surface temperature did not decrease below the dew point temperature - for variant A) + 15.5 ° C, humidity 65%, for variant B) + 17 ° C, humidity 63%.

CONCLUSION AND DISCUSION

The passage of the pipe through the external wall forms a thermal bridge. It is necessary to consider and evaluate these details systematically, similarly to other thermal bridges. This work suggests how it could looks like. For a particular selected pipe passage, in which the medium flows through the wall, it is concluded that for use in practice and from a thermo-physical point of view, the variant B) where the pipeline is on the outside of the façade thermal insulation is recommend. This is for the following reasons:

1) Temperature and humidity is more favorable for variant B) for routing the pipe in the thermal insulation groove. The area of potential water vapor condensation at the thermal insulation and masonry contact is smaller over the entire length of the conduit in the contact thermal insulation system.

2) The temperature of the pipe and the wall near the pipe is higher for variant B), which presents a reduced risk of water vapor condensation on the inner wall surface.

3) Pipe routing in the thermal insulation system allows ventilation of the cavity in order to comply with the gas pipeline routing requirements in confined spaces [11].

4) No changes are necessary to allow the pipe to pass through the load-bearing masonry. Filling and sealing the hole in the masonry around the pipe by spraying polyurethane foam positively affects the temperature inside the masonry near the gas pipeline passage

5) The realization of pipeline routing in the contact thermal insulation system will at least increase the time and cost of the implementation.

Although the pipeline construction is more complicated in this way, it only minimally increases the costs. However, the heat and moisture conditions in the adjacent building structure will be significantly improved. It is necessary to adapt to the fact that the metal pipeline is joined by welding at high temperatures, which makes it impossible to work in the vicinity of the thermal insulation. The pipe may be welded elsewhere and inserted into the wall and fastened through the insulation. It seems to be another problem that all pipes have to be already introduced into the building at the beginning of façade insulation process. But the small part of an insulation can be easily inserted under the pipe before.

ACKNOWLEDGEMENT

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