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POINT THERMAL BRIDGES IN WALLS WITH EXTERNAL STONE LAYER

PUNKTOWE MOSTKI TERMICZNE W ŚCIANACH Z OKŁADZINĄ Z KAMIENIA NATURALNEGO

A b s t r a c t

The main aim of the following article is to define the impact of anchorage of external stone wall cladding on their thermal insulation. The results of FEM and approximate calculations of point thermal bridges at steel anchors, fixing façade boards, are compared in the following article.

Keywords: *thermal bridges*, *stone claddings*, *anchors*

S t r e s z c z e n i e

Celem artykułu jest określenie wpływu zakotwienia okładzin kamiennych ścian zewnętrznych na ich izolacyjność termiczną . W artykule przeprowadzono analizę obliczania punktowych mostków termicznych tworzonych przez stalowe kotwie mocujące płyty elewacyjne.

Słowa kluczowe: *mostki termiczne*, *okładziny kamienne*, *zakotwienia*

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1. Introduction

Natural stone is one of the oldest known construction materials. Historically it was used to raise buildings, nowadays, however natural stone is used as a finishing element giving the building proper architectural design. Stone boards are applied in exterior and interior modern facades and connected to the ground with stainless steel or aluminum anchors. Stone linings may be used in buildings raised in various technologies from brick constructions as well as frameworks.

Modern stone facades decorate prestigious buildings and are often used as the linings of high buildings in big metropolitan areas. Stone boards used in modern facades are fixed to the ground by means of anchor-elements made of stainless steel. Thanks to the application of ventilating gap and proper thermal insulation, stone facade constructions allow for the protection or at least limitation of bad influence of atmospheric factors having an effect on the construction. Ventilated air layer allows for diffusing of water vapor from the inside of the building and it makes it easier for stone lining to dry. Nowadays, fixing boards to the constructional ground by means of anchors made of flat stainless steel bars, is the most popular method of natural stone lining assembly [1]. The assembly comprises drilling a hole in the ground and putting an anchor in it with mortar on which lining boards are put. Each slab is supported at four points on horizontal or vertical edges of the boards. The schemes of facades with stone lining fixing on steel anchors are presented in Figs. 1, 2.

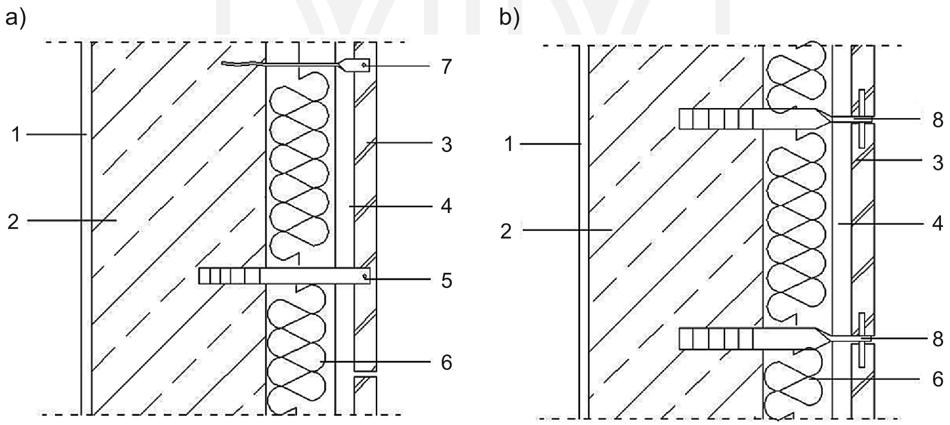

Fig. 1. Schemes of stone slabs connected with steel anchors: a) slabs fixed on the vertical edges, b) slabs fixed on the horizontal edges. Markings: 1 – interior plaster. 2 – construction layer, 3 – stone cladding, 4 – air void, 5 – bearing anchor fixed in the vertical joint, 6 – thermal insulation of the wall, 7 – stabilization anchor, 8 – bearing anchor fixed in the horizontal joint

2. Technology of thermal insulation of the walls with stone cladding

In order to provide proper thermal insulation of the walls made with stone lining, layers of mineral wool thermal insulation are applied. It is advisable to use semi-hard boards made of rock wool with brand-made layer of wind insulation made with the veil of glass fibre on the exterior side of the board. Rock wool is fixed to the ground mechanically with 6–9 pins per square meter of the wall.

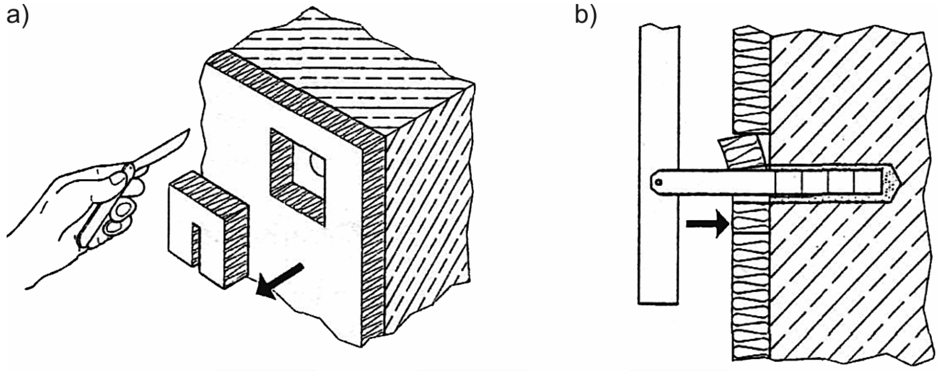

Fig. 2. The technology of areas anchoring stone board insulation: a) cutting thermal insulation, b) filling up thermal insulation [2]

The next stage is to fix stone lining anchors in the bearing ground of the wall. Steel anchors are fixed in the holes made in the rock wool in the areas of anchors. When the process of mortar setting in the anchor areas is complete, all gaps in rock wool are filled up, so that the continuity of the thermal insulation layer can be provided (refer to Fig. 2).

3. Point thermal bridges in the walls with stone cladding

It is necessary to be very careful when creating walls with stone external layers fixed on steel anchors. Knowledge of thermal physics of building is also indispensable. While fixing layers of thermal insulation, stainless steel mechanical fasteners cause point thermal bridges. According to [3] the presence of mechanical fasteners can be calculated approximately by the formula (1):

$$U_c = U + \Delta U \quad (1)$$

where:

- U – thermal transmittance of the building component without point bridges [W/(m^{2}K)],
- ΔU – correction to the thermal transmittance for mechanical fasteners [W/(m^{2}K)].

$$\Delta U_f = \alpha \cdot \frac{\lambda_f A_f n_f}{d_0} \left(\frac{R_1}{R_{T,h}} \right)^2 \quad (2)$$

where:

- α – factor describing the depth of penetration of insulating layer by the fastener,
- λ_f – thermal conductivity of the fastener [W/(mK)],

A_f – the field of linking section [m^2],
n_f – the number of fasteners per square meter,
d_0 – thickness of the insulation layer containing the fastener [m],
R_1 – thermal resistance of the insulation layer penetrated by the fastener [m^2 K/W],
$R_{T,h}$ – total thermal resistance of the component ignoring any thermal bridges [m^2 K/W].

The other way of taking into consideration the impact of point bridges may be the detailed numeral analysis of thermal transmittance of the component with the use of a 3D model. According to [3] the correction for the thermal transmittance with mechanical fasteners is described by the following formula (3):

$$\Delta U_f = n_f \cdot \chi \tag{3}$$

where:
n_f – as for the formula (2),
χ – point thermal transmittance according to the formula (4).

$$\chi = L_{3D} - U_i \cdot A_i \tag{4}$$

where:
L_{3D} – the factor of thermal coupling gained from the calculation of component 3-D [W/K],
U_i – thermal transmittance of component 1-D [W/(m^{2}K)],
A_i – the area of the component [m^2].

4. An example of the analysis of point thermal bridges in walls with stone cladding

The analysis of point thermal bridges in the walls with stone lining was conducted on the basis of the office building handed over for use in 2013 in Katowice. Stratification of the walls and an example of arrangement of fasteners in the analyzed building is presented

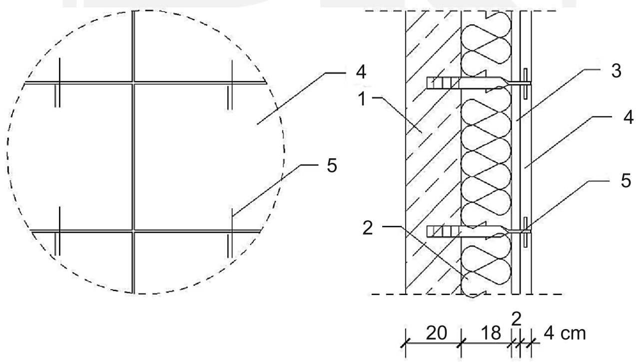

Fig. 3. Arrangement of anchors of the board and stratification of the analyzed division. Markings: 1 – reinforced concrete wall, 2 – rock wool Wentirock, 3 – ventilated air aperture, 4 – sandstone board, 5 – bearing anchor made of stainless steel with the section 6 × 35 mm

in Figure 3. The analyzed surface of the facade has regular anchorage setting, with 3.16 anchors per square meter.

Calculation analysis of the thermal transmittance of building component was conducted with Psi-therm 3D 2012 program. The thermal transmittance through 1square meter of the component was checked on the assumption that the edge conditions inside the building and in the ventilated aperture are stable. For the needs of the calculation the difference between the temperature inside and outside the building was taken into account. It is about 25 (+20 the air inside and – 5 the air in the ventilated air layer).

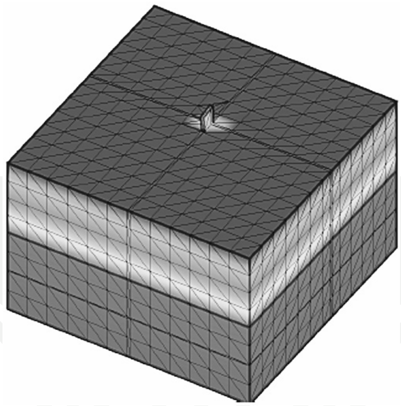

Fig. 4. The model of the component altogether with the temperature isotherms

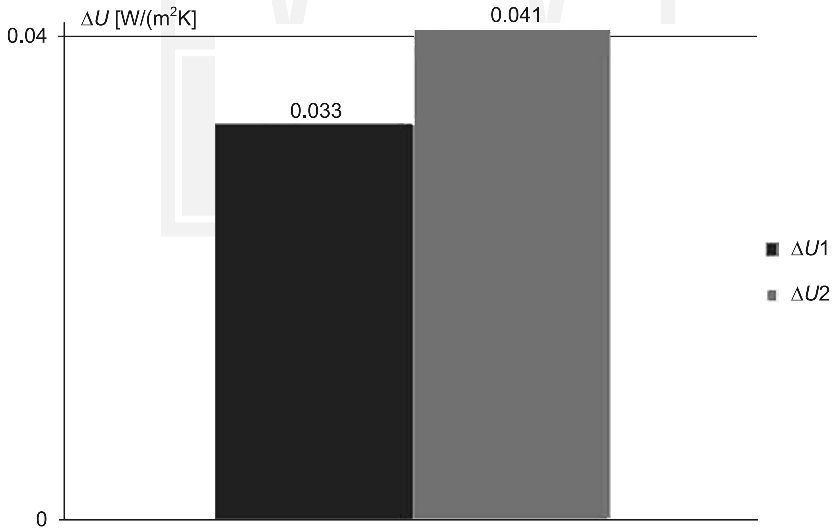

Fig. 5. Results of FEM and approximate calculations of the corrections to the thermal transmittance due to mechanical fasteners. Markings: $\Delta U1$ – correction gained as a result of FEM calculations and formula (3), $\Delta U2$ – correction gained as a result of approximate calculations according to formula (2)

The anchorage was modeled as a single flat bar with the cross section 6 × 35 mm for 0.316 m of the component. The thermal transmittance of the component was analyzed in the three-dimensional FEM model. The component was modeled with a regular net consisting of 9962 tetrahedral elements. The results of the conducted analysis are presented in Fig. 4.

On the basis of the formula (2) and formula (3) calculations for the correction of the thermal transmittance, including the impact of fasteners on the thermal insulation of the wall with the stone lining, were conducted. The results of the calculations are presented in Fig. 5.

5. Conclusions

The analyzed example was chosen in order to cover the largest congestion of anchorages. The cross section area of the fixing anchors was also suitable for the largest available sections used so far in the technology of fixing stone layers. That is why the results of the conducted analysis show the maximum effects of the impact of anchorages on the thermal insulation of component with external stone layer. On the basis of the conducted analysis it can be estimated that there is a 24% difference of correction value for the thermal transmittance value including mechanical fasteners described according to the formula 2 and FEM analysis (refer to Fig. 5). Approximate calculation method of the influence of point thermal bridges is sufficient to determine the total thermal transmittance of building components with stone layer. Values of the factor U_c calculated according to formula 1 and taking into consideration corrections calculated numerically and analytically differ only insignificantly (3%). The results of the FEM analysis with the usage of formula (3) are more accurate. The derived value of the correction ΔU makes it possible to define necessary thickness of additional thermal insulation, which must be applied to equalize the impact of thermal bridges created because of the boards' anchorages. For the analyzed example, recommended additional thickness of rock wool is 4 cm.

The span and section of the anchorages of stone boards is chosen according to the needs of architectural projects and construction needs individually for each façade. Due to this fact, those who are responsible for the project should check value of thermal transmittance for each project and it must be done in a detailed way after receiving information about the choice of anchorages of façade boards.

In the analyzed example, currently permissible value of the total thermal transmittance factor U_c for the external walls is met (U_c = 0.24 W/(m^{2}K)). Planned further tightening of the requirements according to [7] will lead to the necessity of the application of thicker thermal insulation and anchors with larger cross section. Cross section area of anchor applied in the analyzed example is maximal considering the drilling technique of anchors with traditional methods. Any further increase of thickness of thermal insulation would result in the necessity of using drill rigs applied for making anchor areas or the change of the technique of stone claddings fixing by the application of substructure to suspend boards described in [6].

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