Minimization of a point thermal bridge by a roof restraint system holder

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Abstract. Roof restraint systems are designed for flat roofs for safe maintenance and repairs. By anchoring them, considerable point thermal bridges are created, which can also lead to condensation in the roof cladding. We deal in this work with the design of minimization of these point thermal bridges.

1. Introduction

Roof restraint systems are systems that allow workers moving on a flat roof to be secured to ensure safe work. It is therefore not a structural part of the building, but an additional system used for maintenance. This leads to the fact that this structure is underestimated in terms of its impact on the building as a whole and is solved mainly in terms of static load-bearing capacity. However, since it usually perforates the waterproofing plane, the issue of waterproofing is also addressed. However, no attention is paid to the issue of thermal insulation or the question of water vapor condensation in the structure.

2. Roof restraint system

Figure 1 shows roof restraint systems [1]. They consist of a steel foot to which a stainless steel rod with an internal thread is welded. An overhead part with an eye is then screwed into this thread, which serves to guide the retaining ropes. The feet differ slightly depending on the material of the roof structure. If it is made of reinforced concrete, the foot may be smaller, if it is made of trapezoidal steel sheets, then it must be larger so that it is anchored on two corrugations of the support plate.
Figure 1. Roof restraint system, steel trapezoidal sheet variant (a) and reinforced concrete structure variant (b).

It can be seen from the figures that the stainless steel pipe with an internal thread passes from the supporting structure, which is below the plane of the thermal insulation through this thermal insulation and further through the waterproofing up to the exterior. This solution causes two problems. The first is that a relatively significant thermal bridge is formed here, the second problem is that the steel bar is very cooled from the outside and therefore cold along its entire height, and water vapor, which is in the roof cladding, condenses on it.

Condensation of water vapor cannot be calculated in the general case, as its amount is not known. In addition to the parameters of the external environment, this depends on many other factors, which include: indoor temperature, relative humidity in the interior, the specific composition of the structure, especially the diffusion factors of the materials used and their thickness. However, all of these factors can be specified. The biggest difficulty in this problem, however, is the quality of the individual joints, such as sealing the individual trapezoidal sheets to each other and, of course, the material used and sealing the anchors anchoring the roof retaining system to the supporting structure of the roof. Since all these data are variable, we decided to only state this problem and compare the temperature of the structure before and after the proposed measures. The temperatures of the steel structure (measured from the exterior) are evident from graph in figure 2, where the temperatures for individual variants with a load-bearing structure made of trapezoidal sheet steel are shown, and from graph in figure 3, where the temperatures for individual variants with a load-bearing structure made of reinforced concrete are given. The calculations were performed in the Quickfield program [2] in accordance with ČSN EN ISO 10211 [3].
Figure 2. Graph of the course of the temperature of the steel structure of the restraint system in the structure with the supporting structure made of trapezoidal sheet steel. The distance is from the exterior, and its measurement originates on the outer surface of the waterproofing.

Figure 3. Graph of the course of the temperature of the steel structure of the restraint system in a structure with a load-bearing structure made of reinforced concrete. The distance is from the exterior, and its measurement originates on the outer surface of the waterproofing.

The steel bar of the roof restraint system passing through the thermal insulation causes a considerable thermal bridge. Figure 4 graphically shows the temperature distribution of the building details shown in figure 1 in the steady state, where the considered temperature is -15 °C in the exterior and the considered temperature in the interior is +21 °C.
Figure 4. Temperature distribution, steel trapezoidal sheet variant (a) and reinforced concrete structure variant (b).

This solution causes a point thermal bridge with a point heat transfer coefficient $\chi = 0.0652 \text{ W/K}$ for a load-bearing structure made of trapezoidal sheet steel, resp. $0.0952 \text{ W/K}$ for reinforced concrete load-bearing structure. In the first design step, a 3 mm thick plastic washer was installed under the metal layer, interrupting the heat flow between the steel anchor of the restraint system and the supporting structure of the roof, as shown in figure 5.

Figure 5. Roof restraint system, variant steel trapezoidal sheet metal with plastic washer to interrupt the heat flow th. 3 mm (a) and variant reinforced concrete with a plastic washer to interrupt the heat flow th. 3 mm (b).

The resulting temperature distribution is shown in figure 6.
Figure 6. Temperature distribution, variant steel trapezoidal sheet with plastic washer th. 3 mm (a) and variant reinforced concrete with plastic pad th. 3 mm (b).

This solution causes a point thermal bridge with a point heat transfer factor $\chi = 0.0671$ W/K for a load-bearing structure made of trapezoidal sheet steel, resp. $0.0937$ W/K for reinforced concrete load-bearing structure.

In the next step, we strengthened the plastic washer to 5 mm. This led to a reduction of the point heat transfer factor to the value $\chi = 0.0657$ W/K for the load-bearing structure made of trapezoidal sheet steel, resp. $0.0920$ W/K for reinforced concrete load-bearing structure.

This reduction in the point heat transfer coefficient is still too high for buildings that are to have a minimum energy intensity. Therefore, we proposed the use of Purenit, very strong thermal insulation. The solution of the building detail is evident from figure 7.
Figure 7. Roof restraint system, variant steel trapezoidal sheet with washer for interrupting heat flow from Purenit (a) and reinforced concrete with washer for interrupting heat flow from Purenit (b).

The temperature distribution at steady state then corresponds to this material, see figure 8.

Figure 8. Temperature distribution, variant steel trapezoidal sheet with Purenit (a) and variant reinforced concrete with Purenit (b).
This point corresponds to the point heat transfer coefficient $\chi = 0.0342$ W/K for the load-bearing structure made of trapezoidal sheet steel, and $\chi = 0.0593$ W/K for the load-bearing structure made of reinforced concrete.

3. Results and discussions
The work proved the possibility of a significant reduction of the point thermal bridge in the roof restraint system. The proposed solution is based on the existing design solution of the restraint system, which consists in anchoring the steel bar to the roof structure and then screwing the steel eye. Another possibility would be to use other materials that have lower thermal conductivity, such as composite materials. The solution with composite materials could bring other problems, especially those associated with UV resistance. Below is Table 1 summarizing the observed point heat transfer factors $\chi$.

| Variant: | Trapezoidal sheet metal [W/K] | Concrete [W/K] |
|----------|-------------------------------|----------------|
| simple detail | 0.0698 | 0.0952 |
| with plastic. washer th. 3 mm | 0.0671 | 0.0937 |
| with plastic. washer th. 5 mm | 0.0657 | 0.0920 |
| with Purenit | 0.0342 | 0.0593 |

4. Conclusions
From the above, it is clear that a suitably chosen modification of the building detail can achieve a significant reduction in thermal bridges. In this particular case of the solution of the roof restraint system holders, there was a significant reduction in the point thermal bridge. The construction detail was solved in several different variants, of which the use of Purenit proved to be the most suitable solution.

References
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