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# World Sustainable Energy Days 2023

28. February - 3. March 2023 Wels, Austria

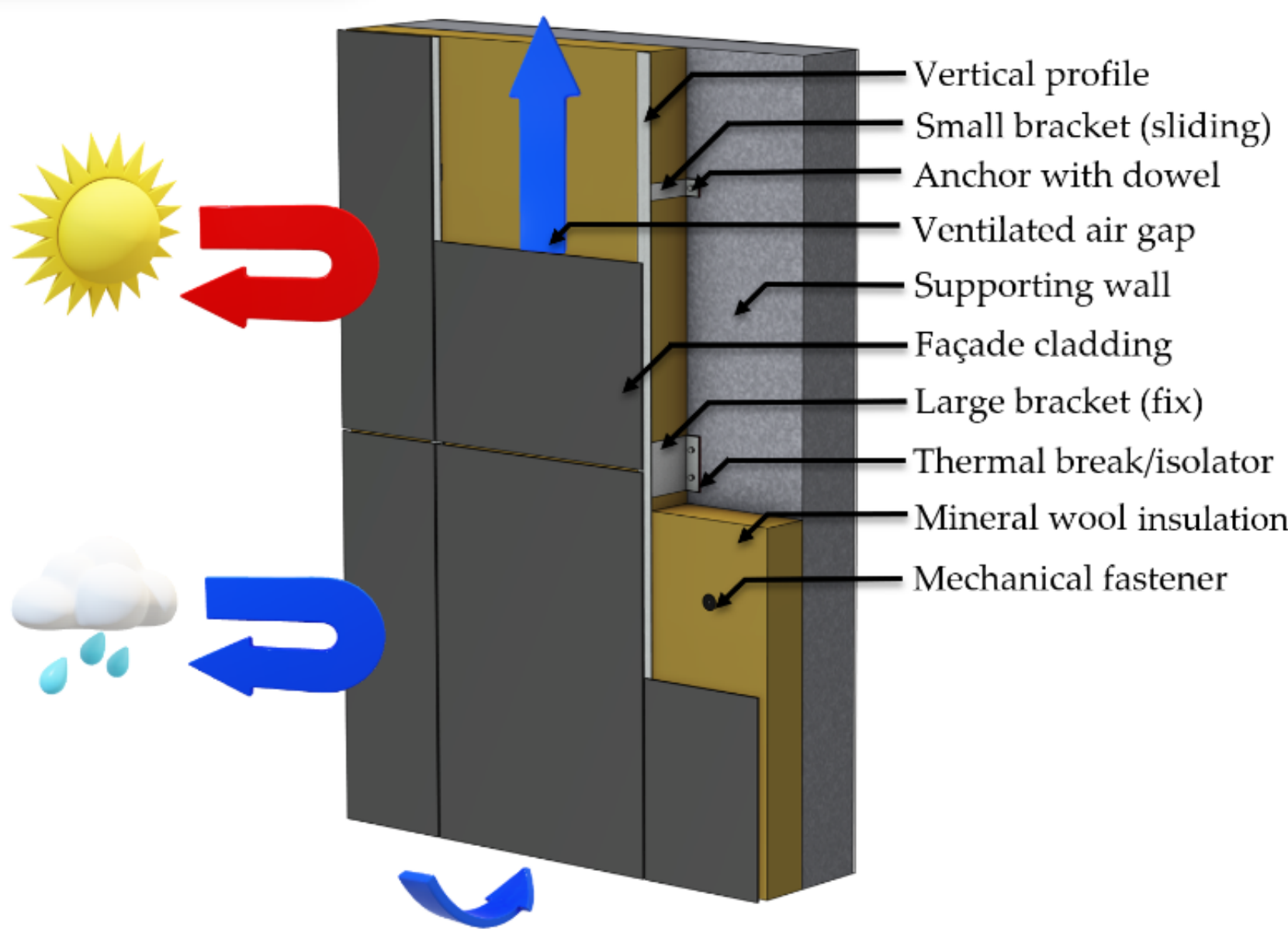


## Energy-efficient ventilated façade cladding design according to nZEB standards

The prevalence of ventilated façades is not only due to their aesthetics but because they provide mechanical and acoustic protection for the façade and can increase energy-efficiency. However, point thermal bridges of the fastening system with brackets and anchors are often neglected during energy calculations. The reason practitioners do not consider them in their calculation is the lack of comprehensive thermal bridge catalogue available. This study aims to evaluate the point thermal transmittances created by the brackets and anchors of the ventilated façade claddings by using 3D numerical thermal modelling. A broad thermal bridge catalogue was created, considering multiple factors of the facades. The FEM-based results show that thermal breaks could reduce the point thermal transmittances by only 2-28%, depending on the isolator type. The brackets' properties could cause up to 70% difference between thermal transmittances, as well as significant differences between the results if the brackets were applied to different kinds of walls. This study also aims to examine the energy and cost savings implications of neglecting thermal breaks, thus after preparing the energy certification of the chosen nZEB, we prepared budgets for different brackets and thermal insulation thicknesses and analyzed the global costs over 30 years. The study could help architect and engineers to decide which fastening system is should preferred and to help optimizing their energy-efficient design.

### 1) Ventiladed Façades

Ventilated façade cladding systems have received considerable attention in recent years, as they have several advantages. Therefore, façade claddings are widely used, particularly in energy-efficiency renovations and new office buildings. The ventilated façade cladding design protects and keeps the walls dry and insulation of the building, reducing the thermal stress and movement of the walls, thus ensuring a longer service life. The cladding, in fact, acts as a parasol or umbrella, protects the substrate walls against external meteorological loads, and provides thermal and acoustic insulation. The main goal of the research was to design, model and compare the energy performance of such façades based on numerical methods.



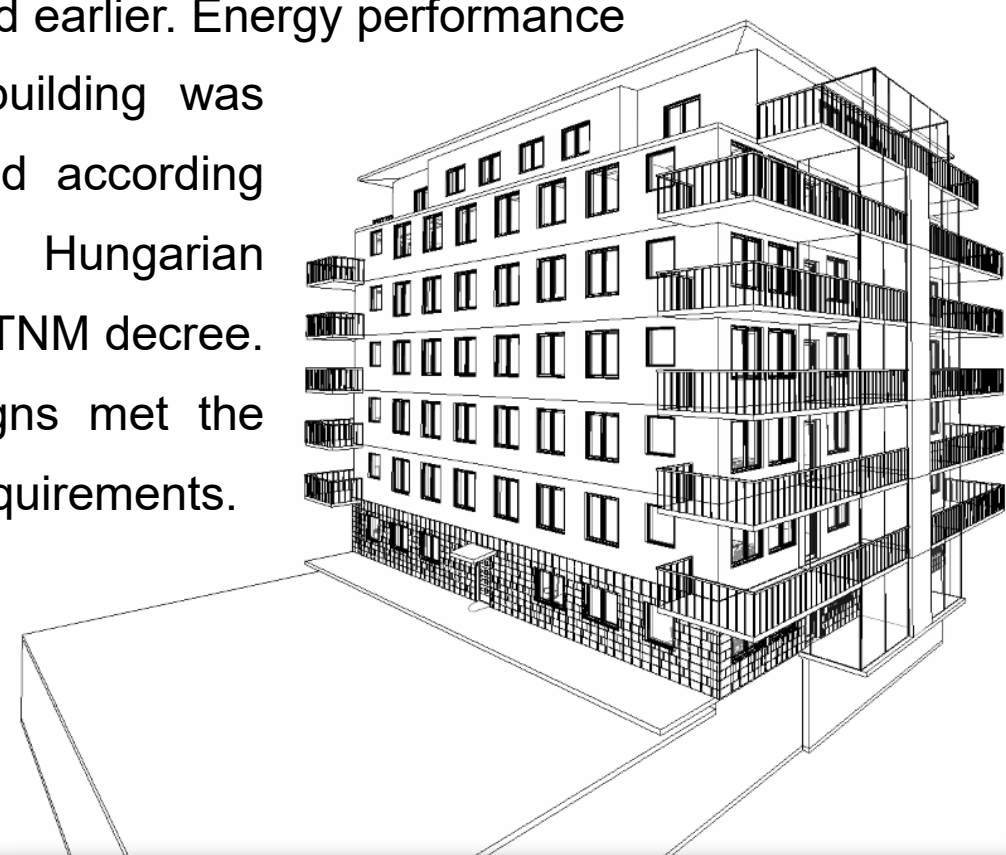
### 4) Case Study



| Type of thermal insulation      | Type of brackets              | Thickness of insulation (cm) | Thermal transmittance of the façade, U <sub>façade</sub> (W/m²K) | Estimated net investment cost of the façade (EUR/year) | Estimated global costs for 30 years (EUR) |
|---------------------------------|-------------------------------|------------------------------|------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------|
| Mineral wool (Rockwool Firecho) | steel                         | 25                           | 0.234                                                            | 4,307                                                  | 124,257                                   |
|                                 | steel with isolator           | 24                           | 0.235                                                            | 4,309                                                  | 125,355                                   |
|                                 | stainless steel               | 22                           | 0.233                                                            | 4,305                                                  | 157,391                                   |
|                                 | stainless steel with isolator | 22                           | 0.231                                                            | 4,302                                                  | 155,660                                   |
|                                 | aluminium                     | 27                           | 0.235                                                            | 4,309                                                  | 149,924                                   |
|                                 | aluminium with isolator       | 26                           | 0.233                                                            | 4,305                                                  | 150,429                                   |

The ventilated façade cladding with 25 cm thermal insulation and steel bracket system (without thermal isolator) achieved the lowest estimated net investment and global costs for a 30 years period based on the calculations made in 2022 using Hungarian energy costs and construction material and labour prices. The analysis was prepared by following the methodology described in 244/2012/EU.

The case study building was a 7-storey high residential building with reinforced concrete structure designed to meet the Hungarian nZEB standard and requirements. The building was modelled in BIM, which supported the quantity take-off for the cost and energy performance calculations. In case of the ventilated façade, we designed it using mineral wool and 6 alternative fixing system of different materials (steel, stainless steel and aluminium) for the claddings. We used the point thermal transmittances of the brackets from the catalogue we made and described earlier. Energy performance of the building was calculated according to the Hungarian 7/2006. TNM decree. All designs met the nZEB requirements.



### 2) Thermal modelling of the façades

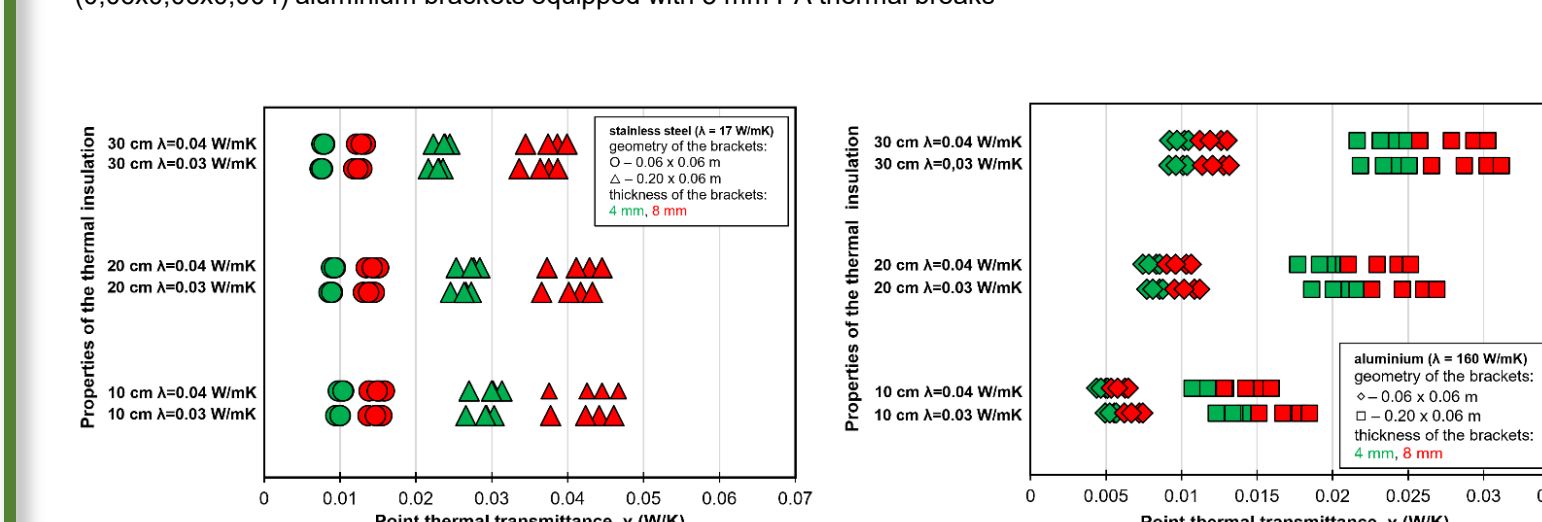
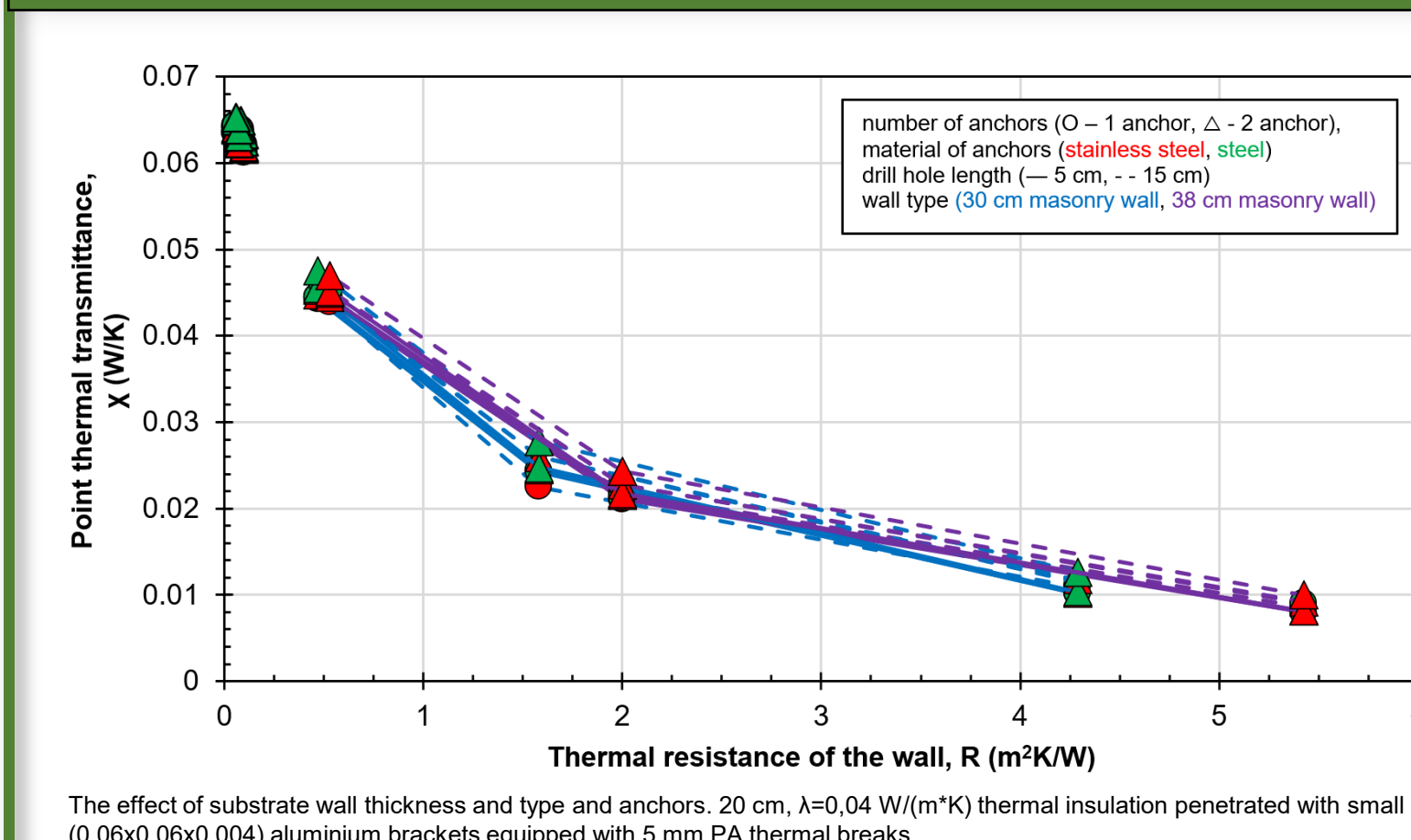
Ventilated façade systems' thermal performance was calculated according to ISO 6946:2017. The goal was to meet the Hungarian nZEB requirements, which maximized the U-value of the façades in 0.24 W/m²K. This U-value shall include the thermal resistance of the substrate wall and mineral wool insulation, and ΔU<sub>f</sub> thermal transmittance correction due to the mechanical fasteners of the thermal insulation and χ point thermal transmittances of the brackets sticking through the mineral wool causing significant point thermal bridges in the construction. The χ point thermal transmittances of different brackets were calculated using Finite Element Method (FEM) based numerical thermal modelling considering ISO 10211:2017. The following equations were used to calculate the U-value of the façade, ΔU<sub>f</sub> and χ:

$$U = \frac{1}{R_{se} + \sum_i \frac{d_i}{\lambda_{2,i}} + R_{si}} + \Delta U_f + \sum_k n_k * \chi_k \quad \Delta U_f = \alpha * \frac{n_{dw} * A_f * \lambda_f}{d_0} * \left( \frac{R_1}{R_{th}} \right)^2 \left[ \frac{W}{m^2 * K} \right] \quad \chi = L_{3D} - \sum_{i=1}^{N_i} U_i * A_i - \sum_{j=1}^{N_j} \psi_j * l_j \left[ \frac{W}{K} \right]$$

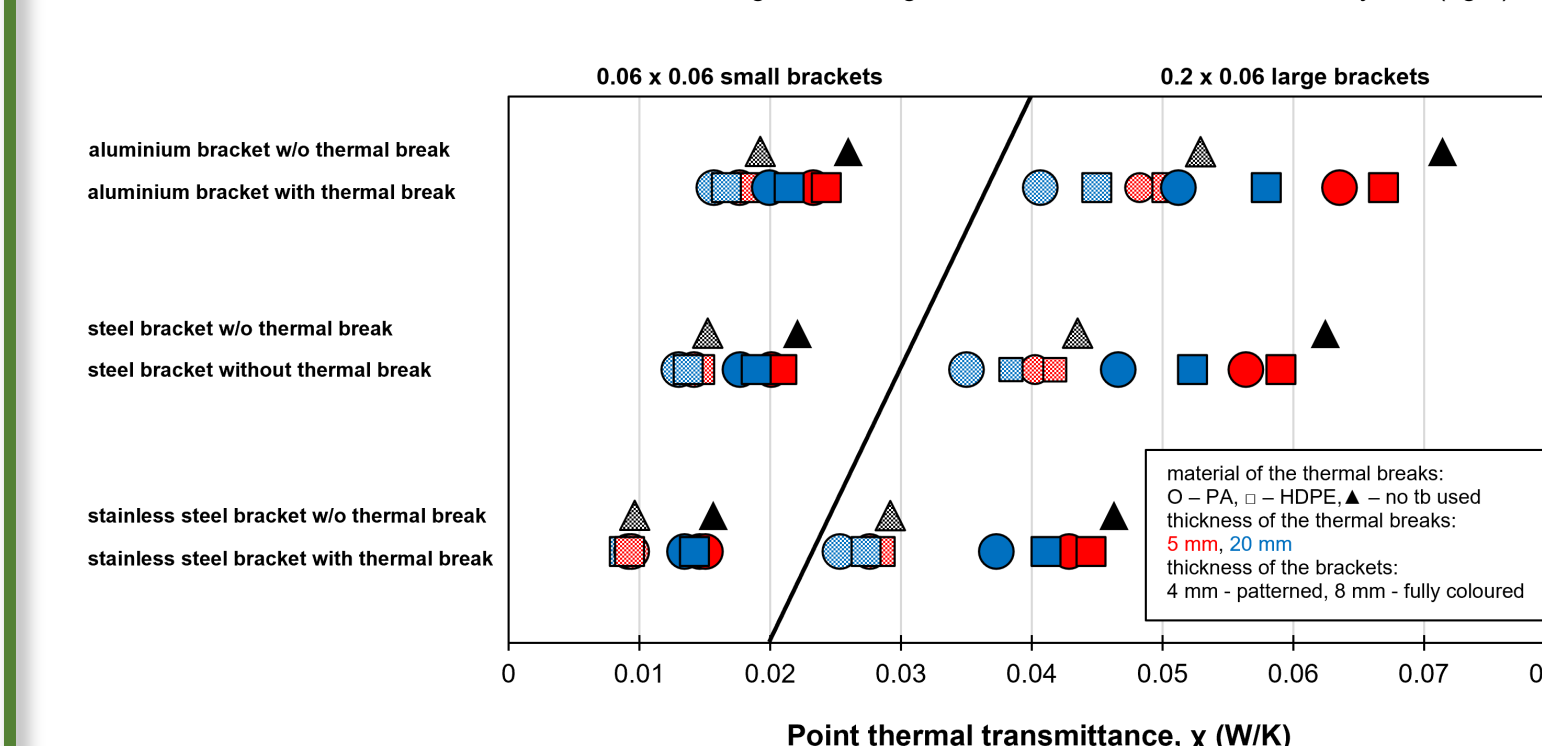
The challenge was to obtain χ point thermal transmittances of an extensive amount of different systems to create a point thermal bridge catalogue. We modelled 41,118 different system using steel, stainless steel and aluminium brackets. The models of the brackets, anchors, dowels and isolators were based on available datasheets of existing systems. We tested multiple substrate walls and thermal insulations, respectively. We used a FE environment and obtained L<sub>3D</sub> thermal coupling coefficient needed to get the point thermal transmittances from steady-state thermal models.

| Component        | Thickness (cm)/Width × Height (cm) | Material        | Thermal conductivity (W/m·K) |
|------------------|------------------------------------|-----------------|------------------------------|
| Internal plaster | 1.5                                | Lime-cement     | 0.2                          |
| Wall             | 25                                 | Masonry         | 0.25                         |
|                  | 30                                 |                 | 0.07, 0.19, 0.64             |
|                  | 38                                 |                 | 0.07, 0.19, 0.72             |
| External plaster | 1.5                                | Lime-cement     | 0.8                          |
| Insulation       | 10, 20, 30                         | Mineral wool    | 0.03, 0.04                   |
| Dowels           | 0.2                                | PA              | 0.25                         |
| Anchors          | 5, 15                              | Stainless-steel | 17                           |
|                  | 5, 15                              | Steel           | 50                           |
| Isolators        | 0.5, 2                             | PA              | 0.25                         |
|                  | 0.5, 2                             | HDPE            | 0.5                          |
|                  | 0.2, 0.4/6 × 6, 6 × 20, 10 × 20    | Stainless-steel | 17                           |
| Bracket          | 0.2, 0.4/6 × 6, 6 × 20, 10 × 20    | Steel           | 50                           |
|                  | 0.2, 0.4/6 × 6, 6 × 20, 10 × 20    | Aluminium       | 160                          |

### 3) Point thermal transmittances



Stainless steel brackets with thermal breaks fixed with a single 5 cm long anchor steel anchor in 20 cm thick RC wall (left)  
Aluminium brackets with thermal breaks fixed with a single 5 cm long steel anchor in 30 cm thick masonry wall (right)



Brackets fixed using a single 5 cm long steel anchor in 20 cm thick reinforced concrete wall with 20 cm thick λ=0.04 W/mK insulation systems"

The main findings of the numerical modellings are:

- Thermal resistance (thickness of the wall/thermal conductivity of the wall) of the wall significantly affects the point thermal transmittance (χ) of the brackets.
- Point thermal transmittance (χ) of the brackets is not significantly affected by the number, the material of anchors, dowels, and drill hole length.
- Point thermal transmittance (χ) of the brackets is not significantly affected by the thermal conductivity of thermal insulation.
- Point thermal transmittance (χ) of the brackets is significantly affected by the thickness of thermal insulation.
- Point thermal transmittance (χ) of the brackets is significantly affected by their geometry (size), material and thickness of brackets.
- Thermal breaks can reduce the point thermal conductivity much less than expected, especially when stainless steel brackets are used.

The effect of the brackets on the point thermal transmittance is significant. Using the results of tens of thousands of numerical models, we created a point thermal bridge catalogue. This can be used in cost-effectiveness studies to support design.

The complete research study on „FEM-based evaluation of the point thermal transmittance of various types of ventilated façade cladding fastening systems" can be found here:



### 5) Conclusions

By preparing budgets and comparing the total costs of a ventilated façade system of a case study nZEB building, we confirmed that the lowest estimated global cost is obtained by using steel brackets and omitting the thermal isolators. The brackets' properties could cause up to 70% difference in the point thermal transmittances, and thermal isolators are only reducing the point thermal transmittances of the brackets by 2-28%. However, the price difference between the aluminium, stainless steel, and steel brackets was also significant, and we found that it was worth considering the cheapest steel brackets and the neglect isolator elements and rather increase the applied thermal insulations by 1-2 cm for the case study building.

