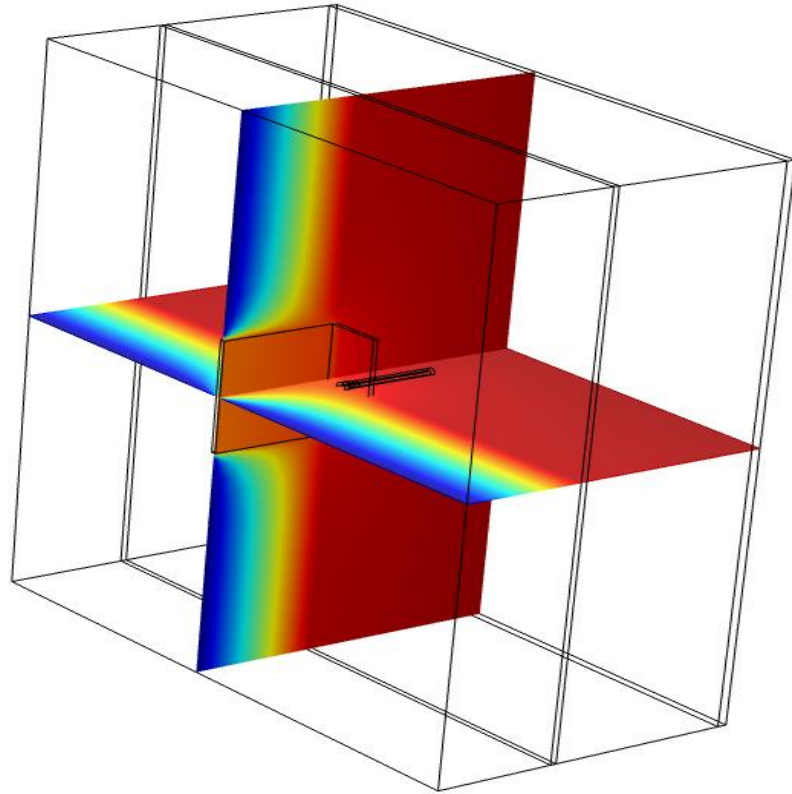




Ventilated façade cladding design according to the Hungarian nZEB regulation

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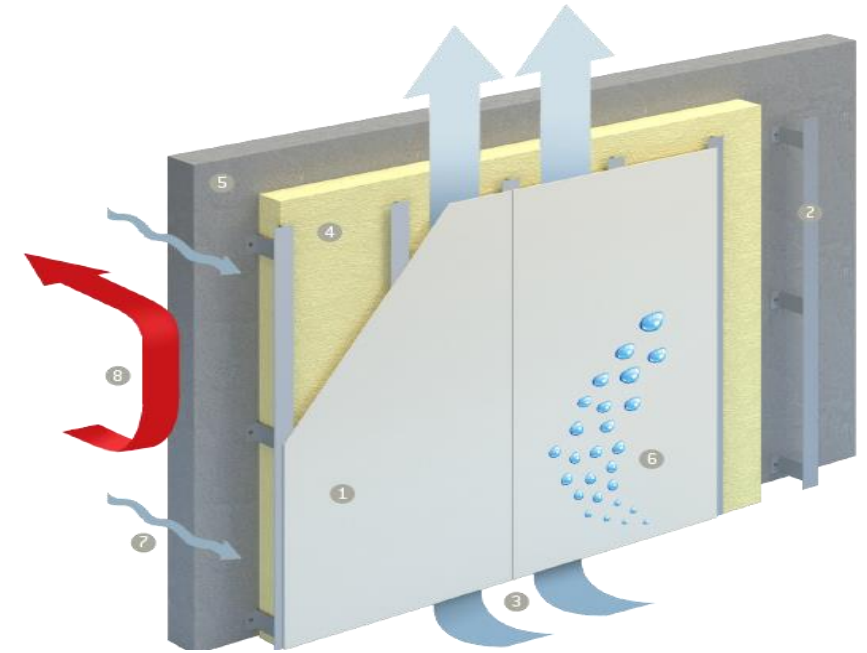
Ventilated façade cladding systems

Prevalence of ventilated façade systems

- can be installed on new construction sites or on buildings undergoing renovation
- aesthetic properties, provide mechanical and acoustic protection for the facade, reduce the energy demand of a given building
- dry-installed technology
- operation: entering air in the cavity flows from bottom to top thanks to the „chimney-effect“

International literature

- only few publicated international literature since 2010
- point-thermal bridges can affect 5-30% difference in heat loss of a building
- thermal-bridge cataloges exist only specified to certain manufacturers (e.g. Hilti)
- there is no overall, fully useable thermal-bridge cataloge
- there is no simplified calculation methodology for point-thermal transmittance which can fit the EU Standards



1. figure : Operation of ventilated facade claddings



2. figure : Infopark,, Budapest



3. figure : Luther Chapel, Budapest

Calculation of thermal transmittance

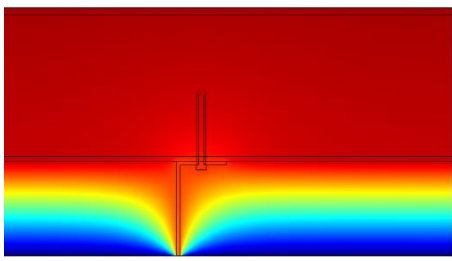
According to hungarian standards (7/2006. TNM) when examining wall's U-value, the effect of the brackets in the case of mechanical fastenings must be taken into account

$$U = \frac{1}{R_{se} + \sum_i \frac{d_i}{\lambda_{2,i}} + R_{si}} + \Delta U_f + \Delta U_g + \Delta U_r + \sum_k n_k * \chi_k$$

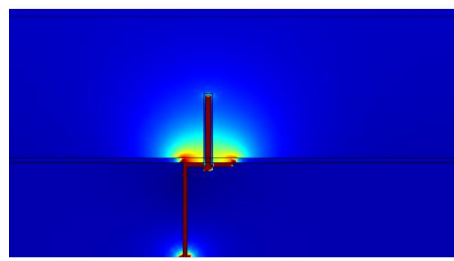
1. Simplified methodology: $\Delta U_f = \alpha * \frac{n_{dw} * A_f * \lambda_f}{d_0} * \left(\frac{R_1}{R_{th}}\right)^2 \left[\frac{W}{m^2 * K}\right]$

2. Numerical methodology: $\chi = L_{3D} - \sum_{i=1}^{N_i} U_i * A_i - \sum_{j=1}^{N_j} \psi_j * l_j \left[\frac{W}{K}\right]$

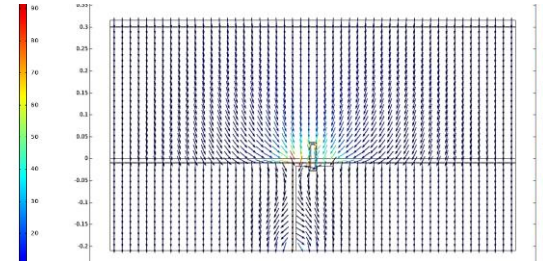
- parameters: wall/brackets/thermal breakers/insulation/dowels
- modeling: isolation/combination of parameters,model extention (4. fg.)
- mesh: independence analysis-optimize number of mistakes and run times (5. fg.)
- analysis of results: point-thermal transmittance→ thermal bridge catalogs
- visualization: temperature ditribution /heat flux density/ heat flux vectors (6-8. fgs.)



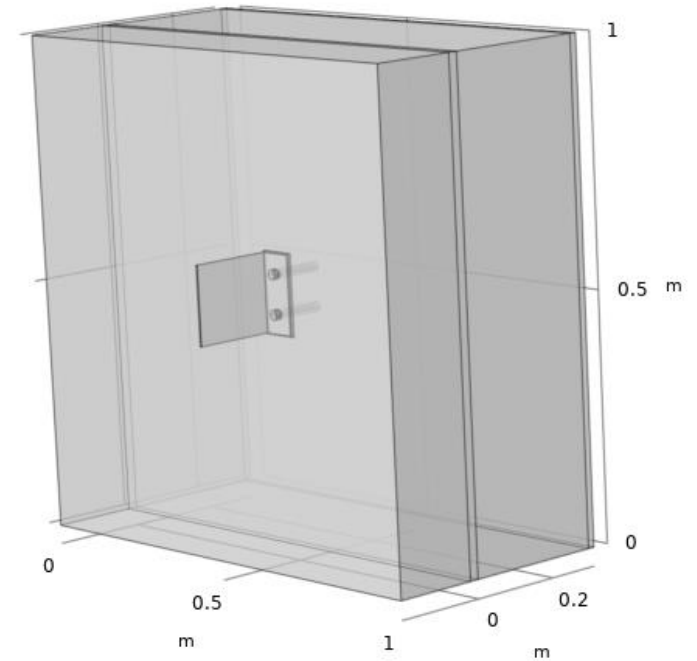
6. figure : Temperature distribution



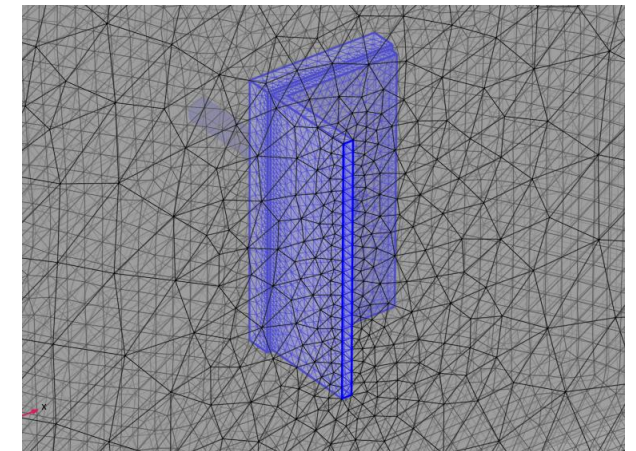
7. figure : Heat flux density



8. figure : Heat flux vectors



4. figure: Geometric model



5. figure: Optimized FEM mesh

Thermal bridge cataloges

- numerical modelling – **41,118** point-thermal transmittance value
- thermal bridge cataloges in Microsoft Excel – sorted datas:
 - properties of anchors, supporting wall, insulation, fasteners
 - existence of thermal breakers
- intreactive browser – make easier to sort datas (10. ábra)

ONLINE AVAILABILITY:

<https://bit.ly/34uWrKH>

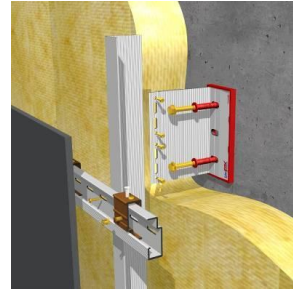
Point-thermal transmittance χ [W/K]								Properties of fasteners			
								λ of brackets [W/mK]			
								17			
								Geometry of brackets [W x H x T]			
								0,06x0,06x0,004			
Design of layers								λ of thermal breakers [W/mK]			
Properties of anchors		Drill hole length[m]	Properties of supporting wall			Properties of insulation		0,25		0,5	
								Thickness of thermal breakers [m]			
number of anchors	λ [W/mK]		type of material	width [m]	λ [W/mK]	thickness [m]	λ [W/mK]	0,005	0,02	0,005	0,02
1	17	0,05	ceramic brick	0,25	0,25	0,1	0,03	0,005414	0,005010	0,005563	0,005377
							0,04	0,004959	0,004539	0,005109	0,004906
						0,2	0,03	0,006079	0,005725	0,006209	0,006032
							0,04	0,005866	0,005502	0,005996	0,005810
						0,3	0,03	0,005745	0,005483	0,005843	0,005713
							0,04	0,005638	0,005374	0,005735	0,005601
			reinforced concrete		0,1	0,03	0,009332	0,008738	0,009621	0,009414	
						0,04	0,009600	0,008901	0,009932	0,009675	
					0,2	0,03	0,008525	0,008053	0,008730	0,008519	
						0,04	0,008838	0,008309	0,009066	0,008823	
					0,3	0,03	0,007374	0,007046	0,007518	0,007369	
						0,04	0,007611	0,007256	0,007765	0,007601	

9. figure: Thermal break catalogue (sample)

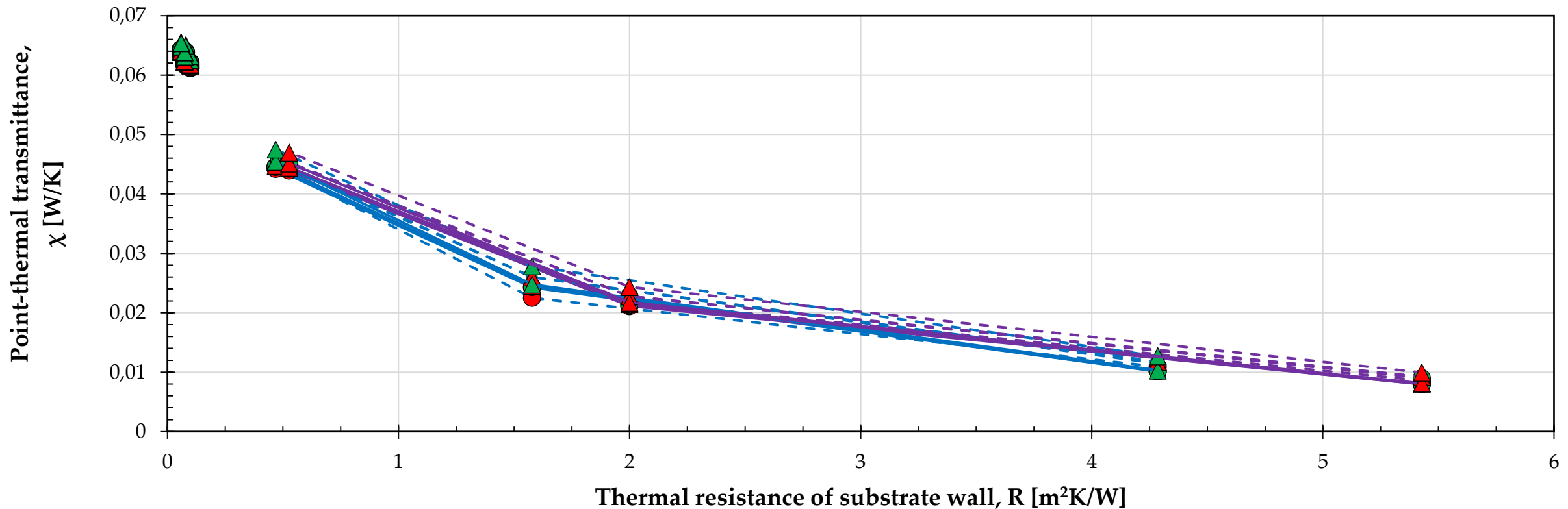
properties of anchors			properties of substrate wall			properties of insulation		properties of brackets		properties of thermal breakers		point-thermal transmittance
number	λ [W/mK]	drill hole length [m]	material	width [m]	λ [W/mK]	thickness [m]	λ [W/mK]	λ [W/mK]	geometry [m x sz x d]	λ [W/mK]	thickness [m]	χ [W/K]
1	17	0,05	ceramic brick	0,25	0,25	0,1	0,03	17	0,06x0,06x0,004	0,25	0,005	0,0054135

10. figure: Interactive browser

Main findings I.

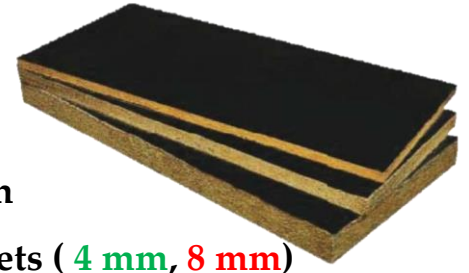


1. Thermal resistance [thickness of the wall (30 cm ceramic brick, 38 cm ceramic brick) /thermal conductivity of the wall] of the substrate wall has a significant effect on point thermal transmittance (χ) of the brackets
2. Point thermal transmittance (χ) of the brackets are not significantly affected by the number ($\circ$ – 1 anchor, $\triangle$ - 2 anchor), and material (stainless steel, steel) of anchors and drill hole length (— 5 cm, - - 15 cm)

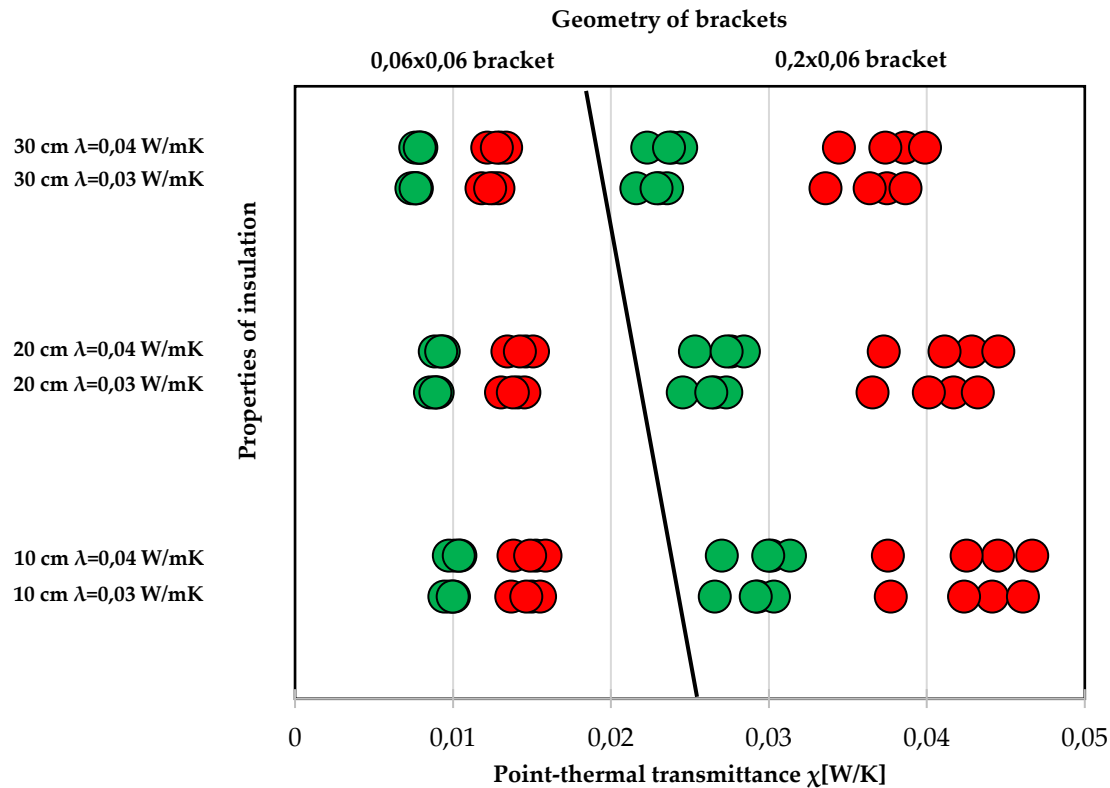


11. figure: The effect of anchors on substrate wall with 20 cm, $\lambda=0,04\text{W/mK}$ insulation penetrated with small (0,06x0,06x0,004) aluminium brackets equipped with thermal breakers

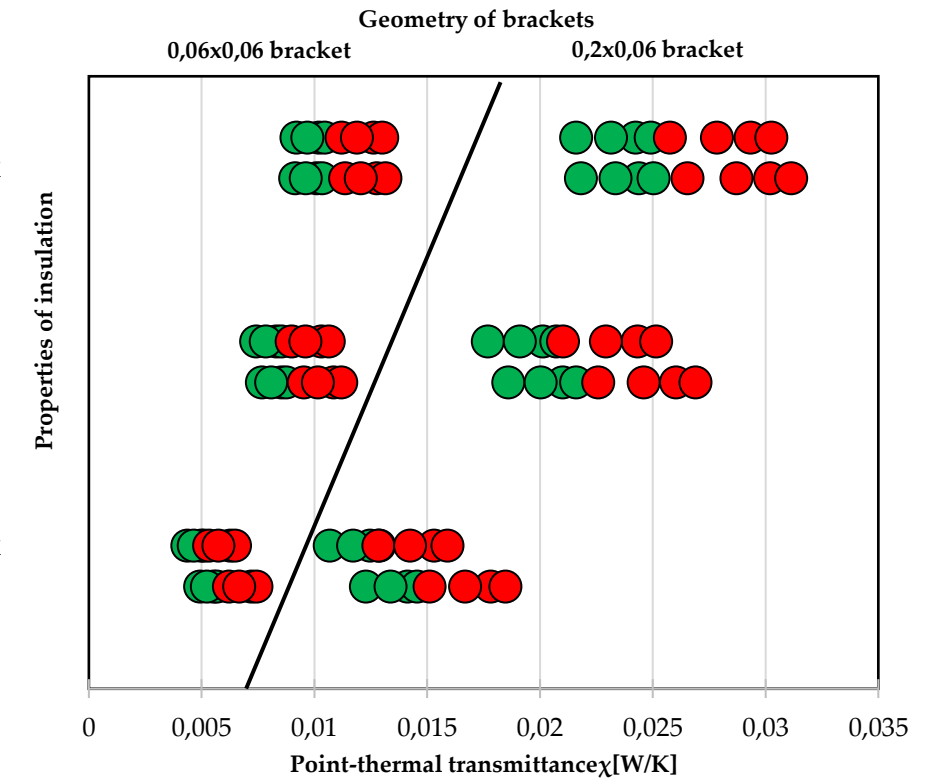
Main findings II.



3. Point thermal transmittance (χ) of the brackets are not significantly affected by thermal conductivity of insulation
4. Point thermal transmittance (χ) of the brackets are significantly affected by the thickness of insulation and brackets (4 mm, 8 mm)

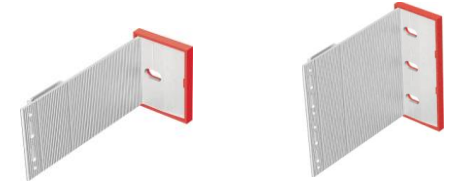


13. figure: Stainless steel brackets with thermal breaker fixed in 5 cm long drill hole with one steel anchor on 20 cm thick reinforced concrete wall



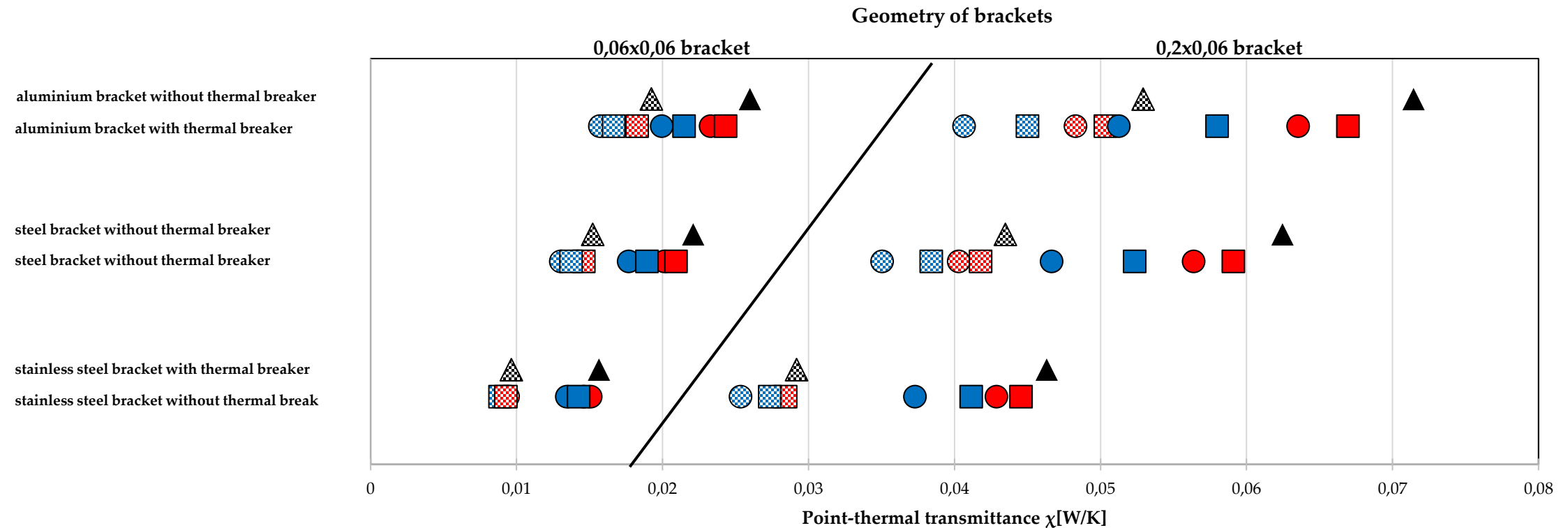
14. figure: Aluminium brackets with thermal breaker fixed in 5 cm long drill hole with one steel anchor on 30 cm thick ceramic brick wall

Main findings III.



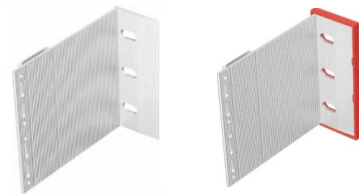
5. Point thermal transmittance (χ) of the brackets are significantly affected by geometry, material and thickness (■ – 4 mm, ■ – 8 mm) of brackets:

- Thicker brackets can increase χ by at least 26 % (short stainless steel brackets), up to 60 % (tall aluminium brackets)
- Brackets with higher thermal conductivity can increase χ by at least 27 % (tall brackets), up to 48 % (short brackets)
- Choosing taller brackets can increase χ by 61-67 %



15.figure: brackets fixed in 5 cm long drill hole with one steel anchor on 20 cm thick reinforced concrete wall with 20 cm thick $\lambda=0,04$ W/mK insulation

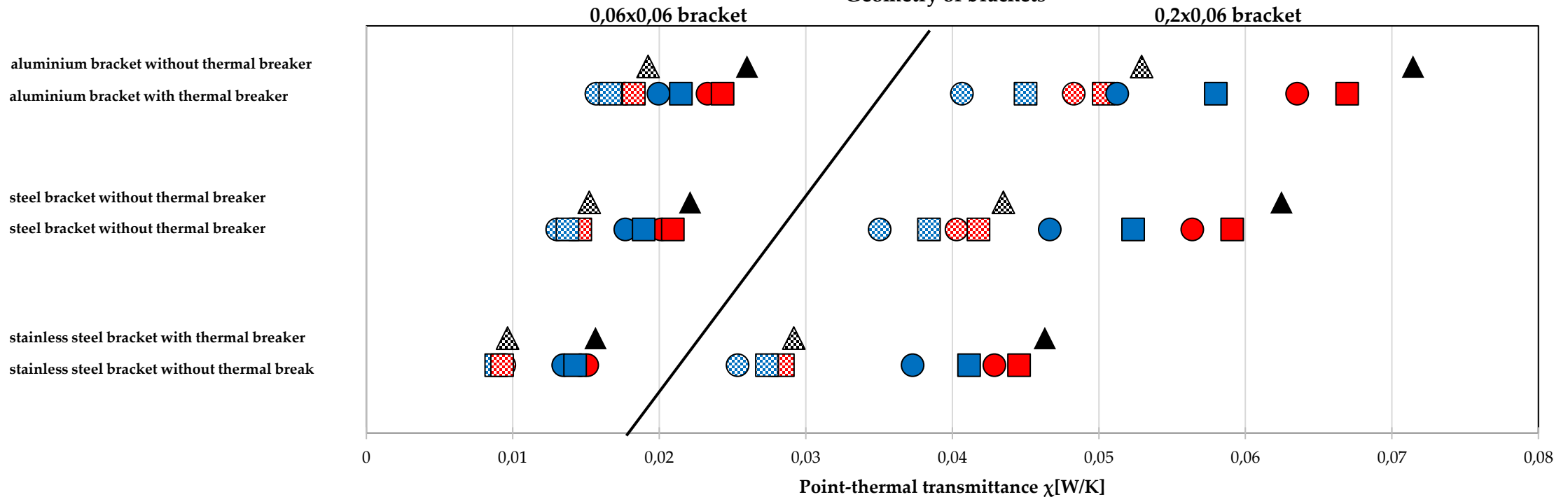
Main findings IV.



6. The existence, material (○ – PA, □ – HDPE, ▲ – nincs) and thickness (5 mm, 20 mm) of thermal breakers (○ – PA, □ – HDPE, ▲ – no tb.) can reduce the point-thermal transmittance (χ) of brackets

- thicker thermal breaker can reduce χ by at least 2% (short ss.bracket), up to 24% (tall aluminium bracket)
- thermal breaker with lower thermal conductivity can reduce χ by at least 2% (short ss.bracket), up to 12% (tall aluminium bracket)
- the existence of thermal breakers can reduce χ by at least 2% (HDPE 5mm), up to 28% (PA 20mm) – economic aspects

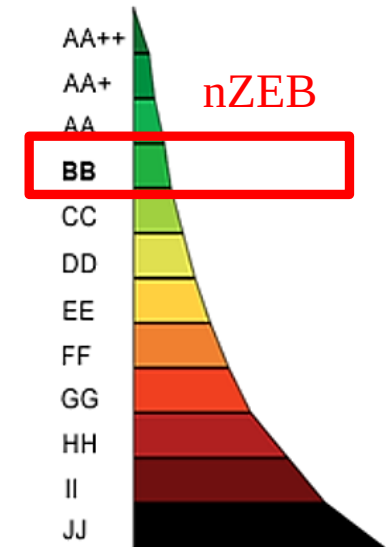
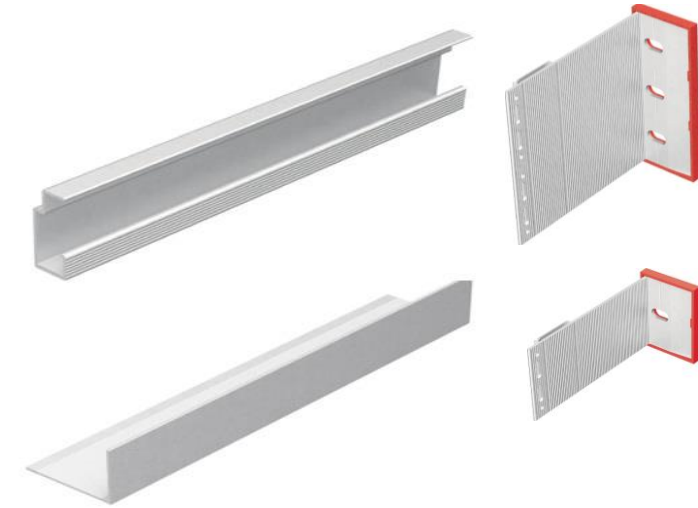
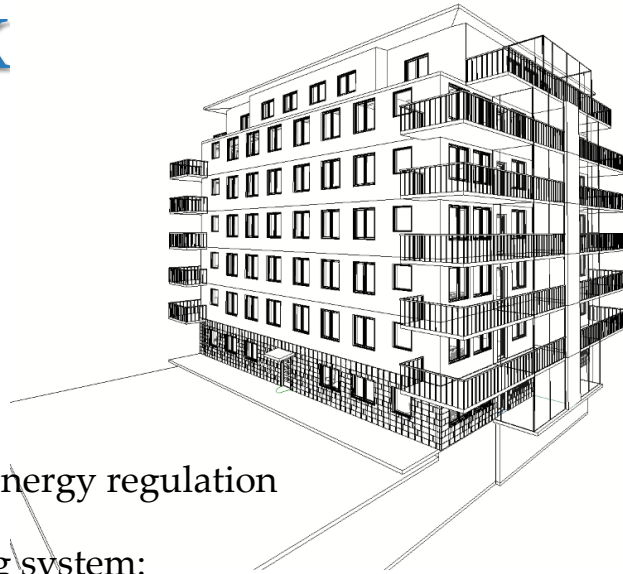
Geometry of brackets



16.figure: brackets fixed in 5 cm long drill hole with one steel anchor on 20 cm thick reinforced concrete wall with 20 cm thick $\lambda=0,04$ W/mK insulation

Design work

- Chosen building:
 - residential house
 - groundfloor + 6 levels
 - flat roof
 - Hungarian nearly zero energy regulation
- Ventillated facade cladding system:
 - Equitone Natura Pro: fibre cement facade panel
 - Hilti MLZ/k-v-00 crossed profile system
 - 3 types of brackets:
 - >stainless steel (Hilti), steel (Rothoblaas), aluminium (Hilti)
 - different type of insulation + dowels:
 - >different thermal conductivity: rock wool, hemp insulation, wood wool, - optimizes based on economic and energy considerations



18. figure: The system of the designed ventilated facade cladding

Cost optimization

- Net investment costs
 - 3 types of insulations / brackets / with or without thermal breakers
- Estimated global costs for 30 years
 - energy prices: unchanged, reduced by 1,5% / year, risen by 5% / year
- Biggest difference between net costs: 66 598 EUR - % of total costs

Cost optimization								
type of insulation	thickness of insulation [cm]	type of brackets	thermal transmittance of the wall [W/mK]	estimated energy cost [Ft/year]	net investment cost [Ft]	estimated global costs for 30 years with unchanged energy prices [Ft]	estimated global costs for 30 years with energy prices risen by 5% /year [Ft]	estimated global costs for 30 years with energy prices reduced by 1,5% /year [Ft]
rock wool (Rockwool)	24	steel bracket with thermal breaker	0,234958	4 309 EUR	125 355 EUR	204 173 EUR	280 114 EUR	191 713 EUR
	25	steel bracket without thermal breaker	0,234108	4 307 EUR	124 257 EUR	203 075 EUR	279 015 EUR	190 614 EUR
	22	stainless steel bracket with thermal breaker	0,231044	4 302 EUR	159 660 EUR	238 478 EUR	314 418 EUR	226 018 EUR
	22	stainless steel bracket without thermal breaker	0,232684	4 305 EUR	157 391 EUR	236 208 EUR	312 149 EUR	223 748 EUR
	26	aluminium bracket with thermal breaker	0,233144	4 305 EUR	150 429 EUR	229 247 EUR	305 187 EUR	216 786 EUR
	27	aluminium bracket without thermal breaker	0,235024	4 362 EUR	149 924 EUR	228 742 EUR	304 682 EUR	216 282 EUR
hemp insulation (Canna Flex)	22	steel bracket with thermal breaker	0,230879	4 301 EUR	160 712 EUR	239 530 EUR	315 470 EUR	227 070 EUR
	22	steel bracket without thermal breaker	0,233922	4 450 EUR	157 180 EUR	235 998 EUR	311 939 EUR	223 538 EUR
	20	stainless steel bracket with thermal breaker	0,229573	4 299 EUR	190 238 EUR	269 056 EUR	344 996 EUR	256 596 EUR
	20	stainless steel bracket without thermal breaker	0,231563	4 302 EUR	187 969 EUR	266 787 EUR	342 727 EUR	254 326 EUR
	25	aluminium bracket with thermal breaker	0,233007	4 305 EUR	190 855 EUR	269 673 EUR	345 613 EUR	257 212 EUR
	25	aluminium bracket without thermal breaker	0,237460	4 314 EUR	188 261 EUR	267 079 EUR	343 019 EUR	254 619 EUR
wood wool (SteicoFlex)	22	steel bracket with thermal breaker	0,238204	4 315 EUR	147 865 EUR	226 683 EUR	302 623 EUR	214 223 EUR
	23	steel bracket without thermal breaker	0,234108	4 307 EUR	146 806 EUR	225 624 EUR	301 564 EUR	213 164 EUR
	20	stainless steel bracket with thermal breaker	0,238818	4 303 EUR	178 264 EUR	257 082 EUR	333 023 EUR	244 622 EUR
	22	stainless steel bracket without thermal breaker	0,219624	4 280 EUR	180 406 EUR	259 224 EUR	335 164 EUR	246 764 EUR
	25	aluminium bracket with thermal breaker	0,233144	4 305 EUR	178 952 EUR	257 770 EUR	333 710 EUR	245 310 EUR
	25	aluminium bracket without thermal breaker	0,235024	4 309 EUR	176 358 EUR	255 176 EUR	331 117 EUR	242 716 EUR

Conclusion

Main results:

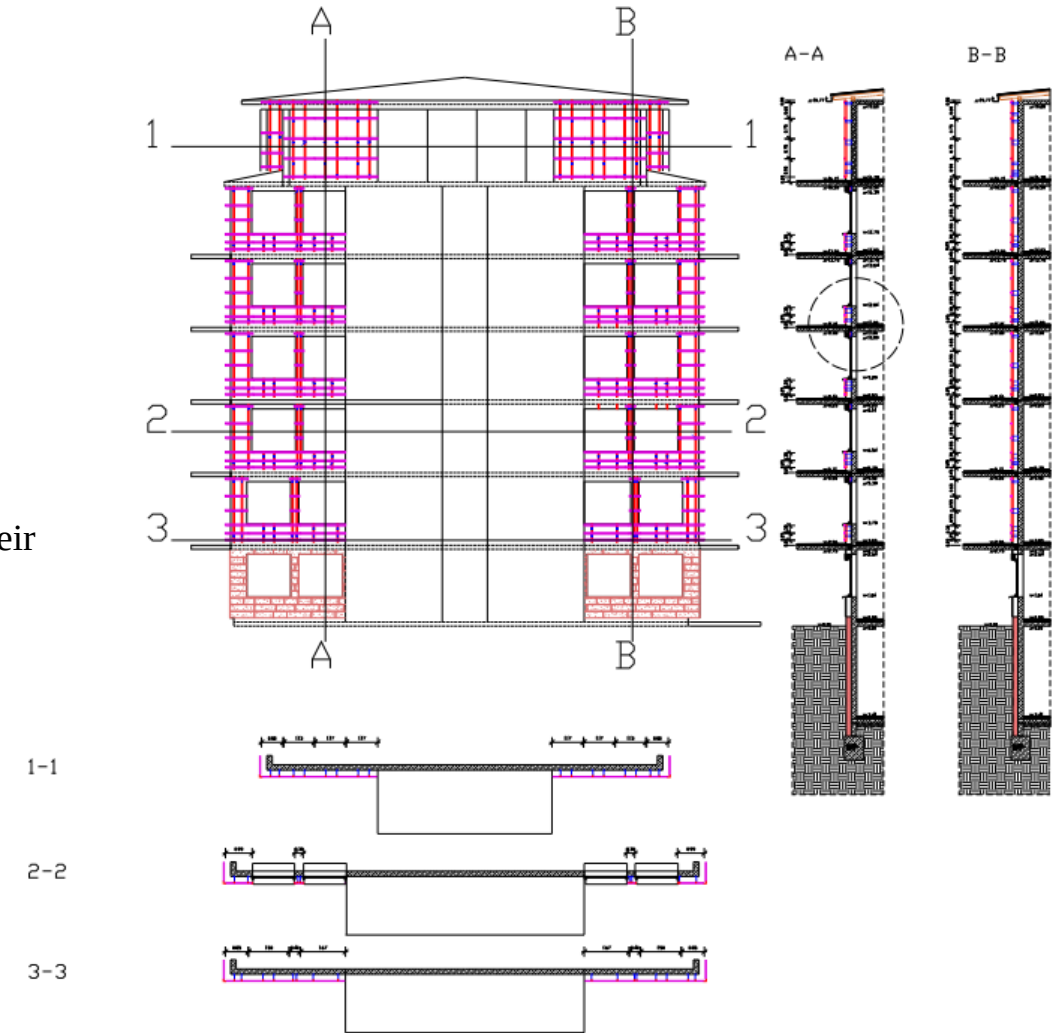
- thermal bridge catalogues are applicable in domestic and international practice
- findings to support energy efficient and cost-effective design

Industrial applicability of the research:

- thermal bridge catalogues can be used directly in industry design
- can also be used in cost-effectiveness studies
- promotes the further development of load-bearing structures and the development of their design
- publishing research, sharing numerical modeling experiences

Further research opportunities:

- further investigation of the relationship between the parameters
- multiphysical tests (eg combined heat and moisture transport)
- structural analysis (eg effect of construction inaccuracies, deformation of the bracket)
- examination of building information modeling (BIM)





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