Evaluation of the thermal bridges of prefabricated concrete large-panel and brick apartment buildings in Estonia

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Importance of thermal bridges

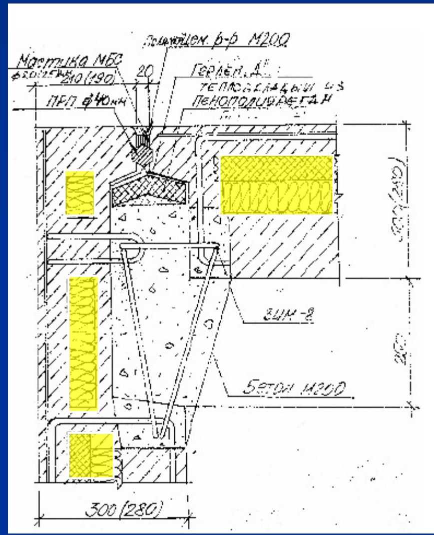
- Old topic about thermal bridges in a cold climate is important for many reasons:
  - Possible mould growth on internal surface of a building envelope
  - Possible surface condensation
  - Increase of heat losses
  - Thermal discomfort due to cold draughts or radiation
  - With improvement of thermal insulation level, the relative significance of heat losses through the thermal bridges has enlarged

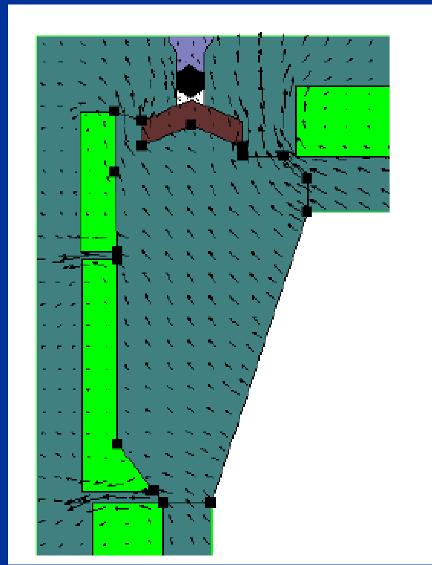
Objectives

- Purpose of the study was to assess the thermal bridges of concrete large-panel and brick apartment buildings:
  - Assess criticality of thermal bridges depending on indoor humidity loads
  - Calculate linear thermal conductance for typical structural joints (do not exist yet for older buildings)
  - Analyze impact of additional internal and external insulation during a retrofit
  - Results of this research can be used as inital data for stochastic analyze in IEA Annex 55 – RAP Retro

Methods – studied buildings

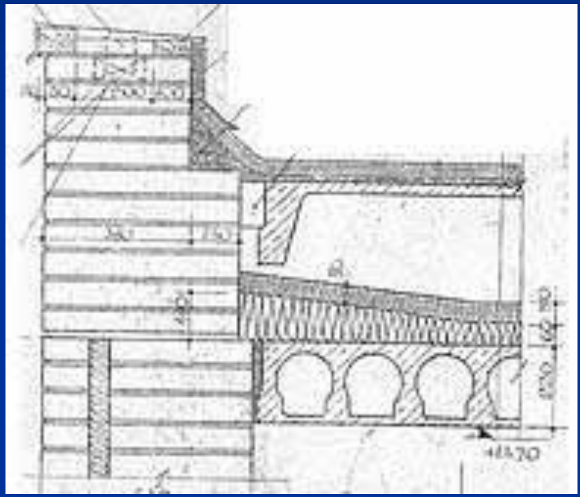
- Prefabricated reinforced concrete large-panel element walls of three layers
  - Thickness of wall panels ~300 mm
  - Insulation - chip-cement, mineral wool, expanded polystyrene or phenoplast
  - Joints of concrete panels contain areas without any thermal insulation
- Thermal transmittance: 0.5-1.0 W/(m^{2}K)

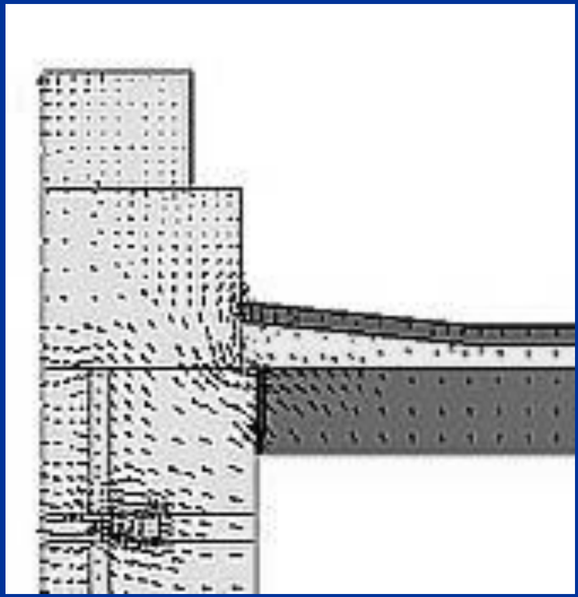




Methods – studied buildings

- Calcium silicate or ceramic brick walls of three layers
  - Steel rods or rows of bricks as bonding
  - 60-120 mm mineral wool insulation
  - Joints without thermal insulation
- Thermal transmittance: 0.5-1.0 W/(m^2K)



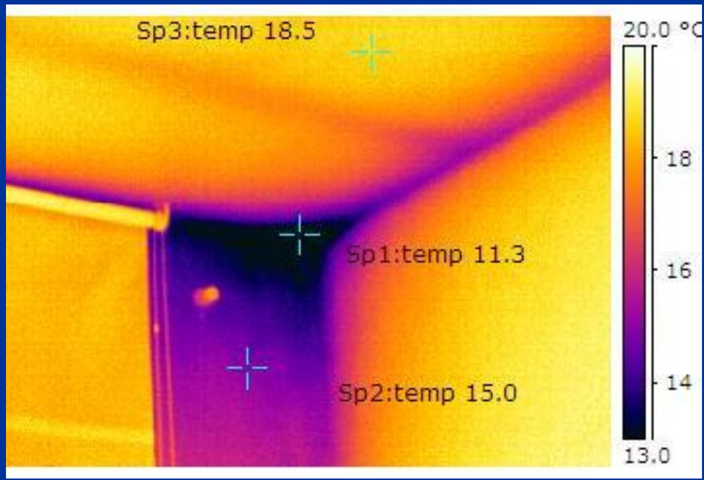


$\Psi_j = (\bar{U} - U) \cdot x$, W/(m·K)

Methods - measurements

- Field study by infrared thermography

$$f_{Rsi} = \frac{R_T - R_{si}}{R_T} = \frac{t_{si} - t_e}{t_i - t_e}$$



f_{Rsi}= temperature factor, -

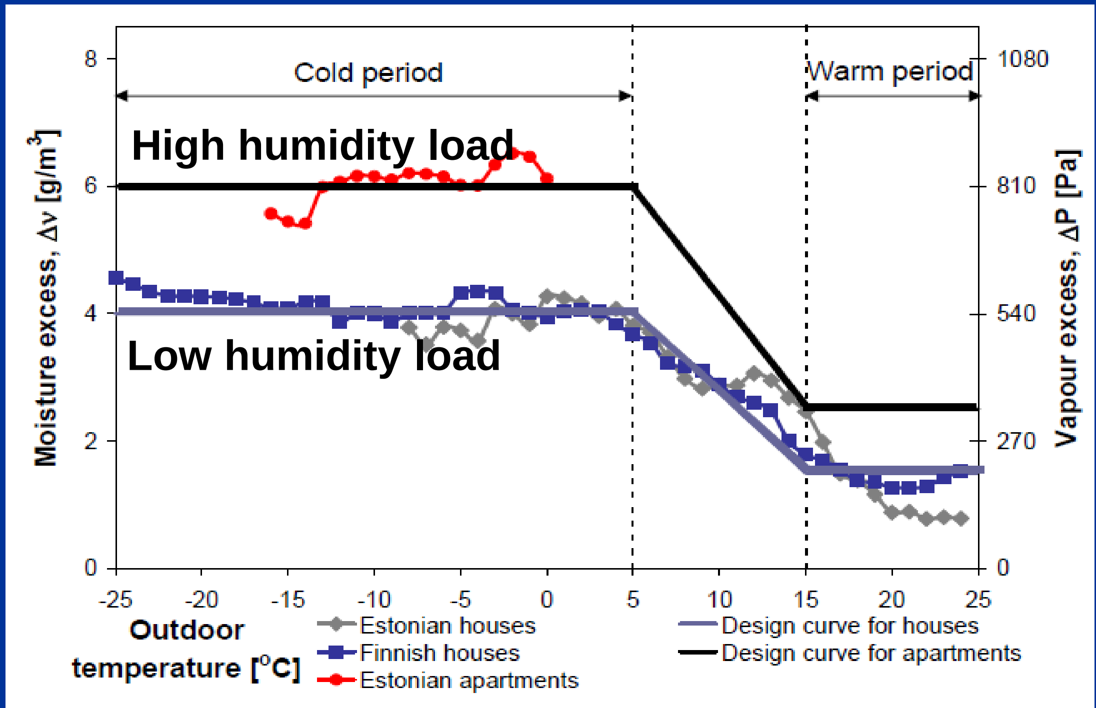
t_{si} = temperature of internal surfice, ºC

t_i = temperature of the indoor air, ºC

t_e = temperature of the outdoor air, ºC.

Methods – limit value for temperature factor

Humidity loads of dwellings	Limit value for temperature factor f_{Rsi},-	
	Mould growth	Surface condensation
Low humidity loads: low occupancy and good venti-lation (moisture excess during cold period $\leq$+4 g/m^3	$\geq$ 0.65	$\geq$ 0.55
High humidity loads: high occupancy or/and low venti-lation (moisture excess during cold period $\leq$+6 g/m^3	$\geq$ 0.8	$\geq$ 0.7



$\Psi_j = (\bar{U} - U) \cdot x$, W/(m·K)

Methods - calculations

- Calculations with two-dimensional heat transfer simulation program THERM 6.0

$$\Psi_j = (\bar{U} - U) \cdot x, \ \mathrm{W/(m \cdot K)}$$

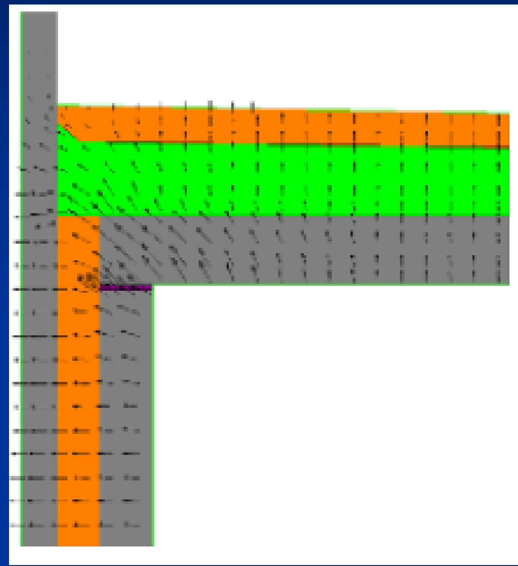
Ψ_j - linear thermal conductance, W/(m·K)

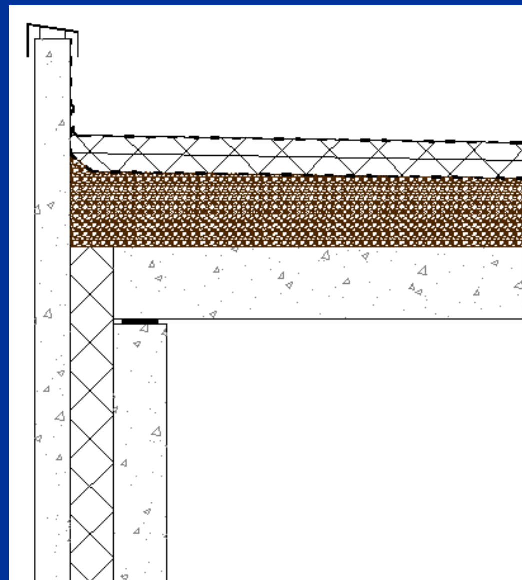
U - thermal transmittance with thermal bridge, W/(m^{2}K)

Ū - thermal transmittance without thermal bridge, W/(m^{2}K)

x - length, m

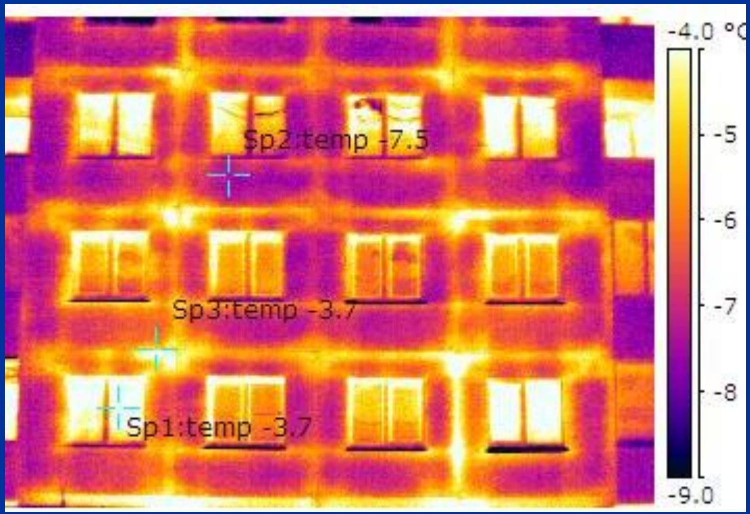
- Results of measurements and calculations were compared

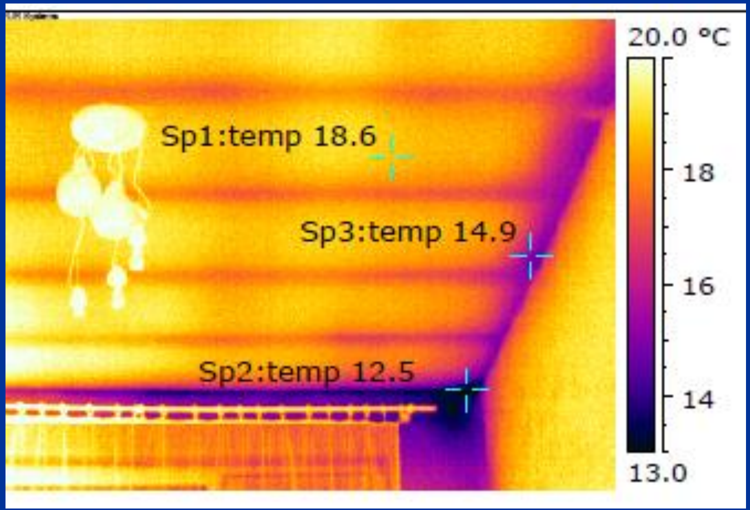




Results – concrete large-panel buildings

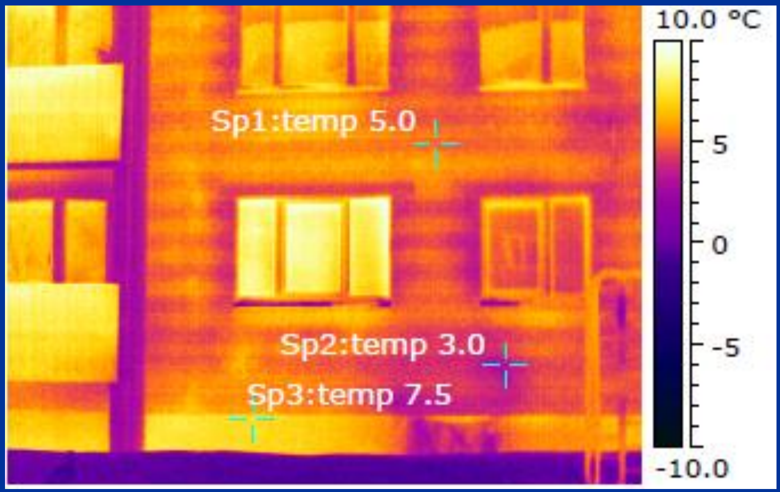
- Main thermal bridges are:
  - horizontal and vertical joints between external wall panels
  - junctions of the external wall and the balcony slab
  - junctions of the external wall (especially end sides) and the flat roof
  - bonds of panel`s internal and external layers of the external walls
  - foundation wall panels
  - perimeters of windows and doors

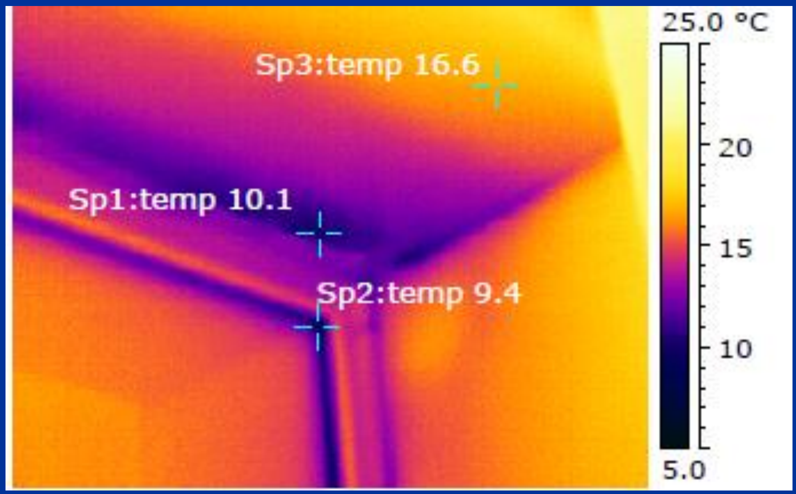




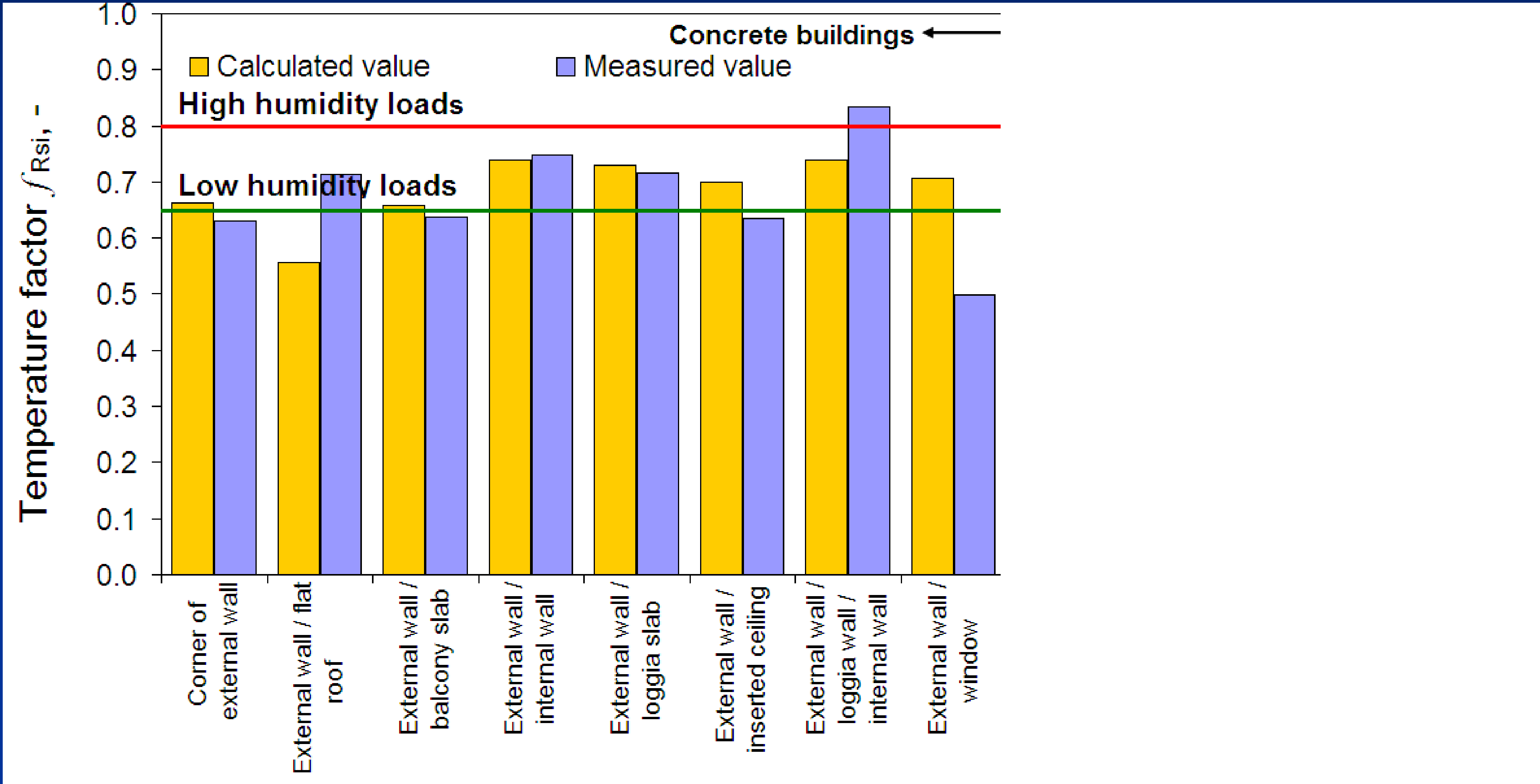
Results – brick buildings

- Main thermal bridges are:
  - junctions of the external wall and flat or pitched roof
  - junctions of the external wall and the balcony or loggia slab
  - perimeters of windows and doors
  - junction between foundation wall panels and external wall
  - bonding bricks



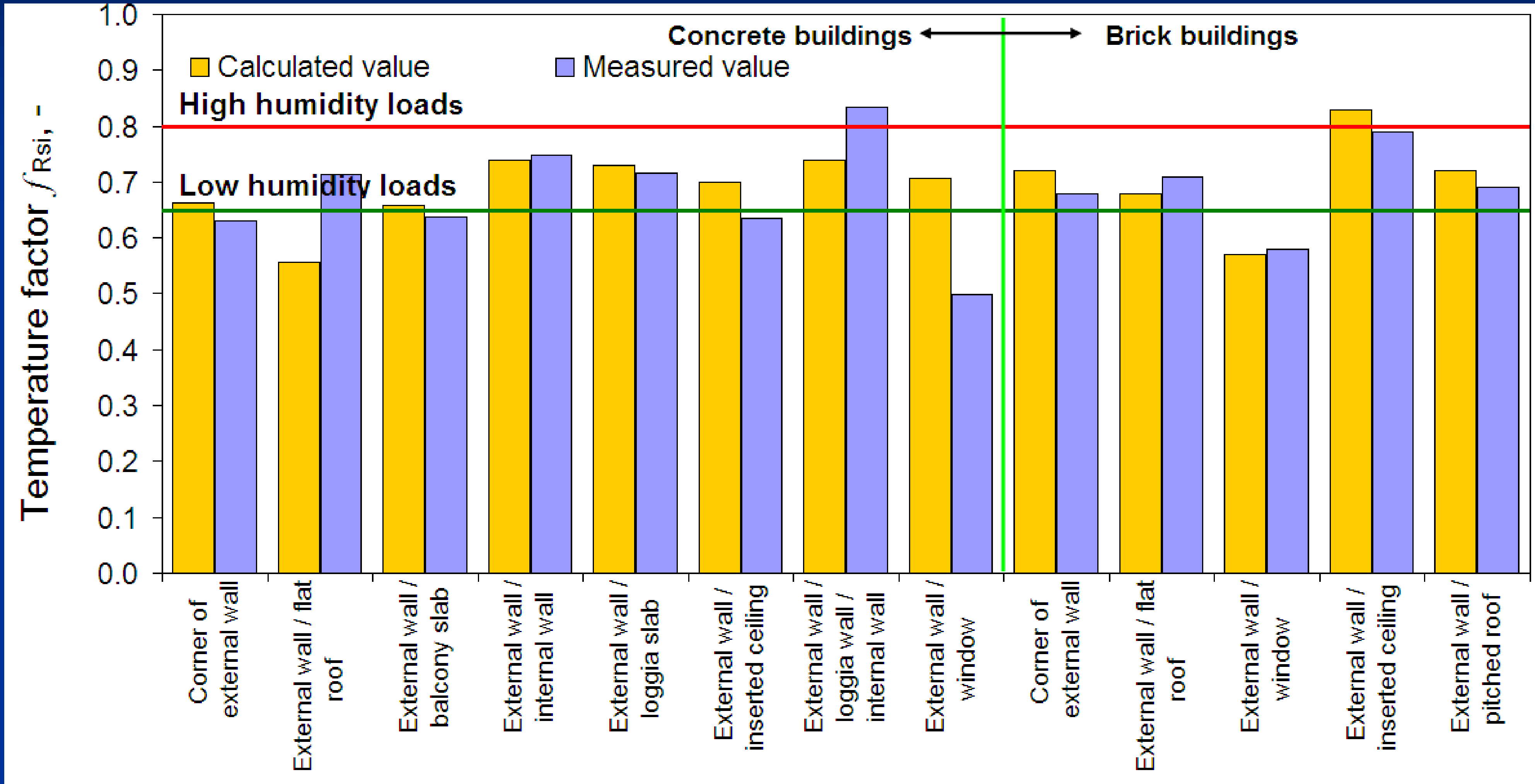


Results – temperature factors



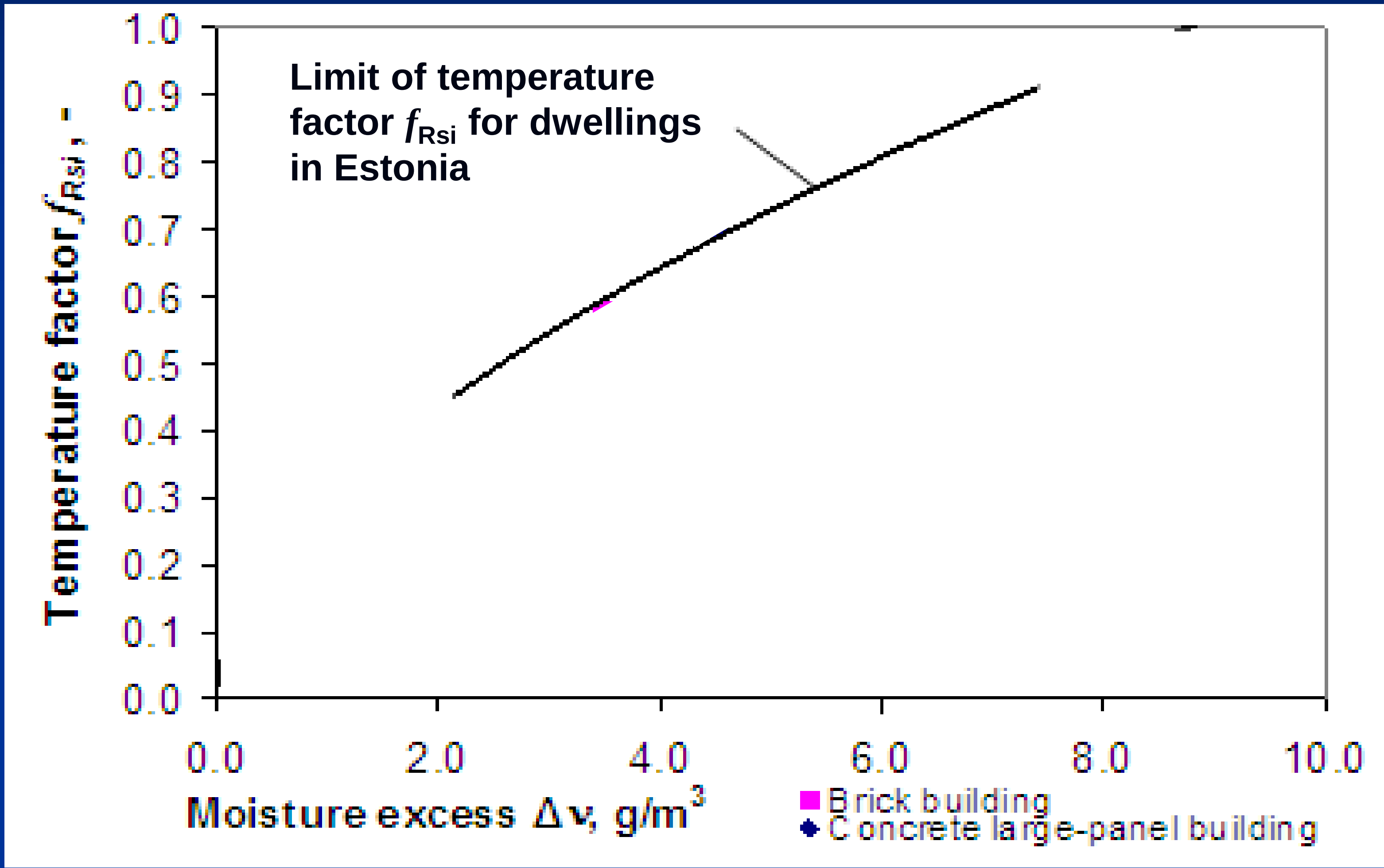
92% of the temperature factors f_{Rsi}<0.8 ($\Delta\nu$ ~ 6 g/m^3)

Results – temperature factors

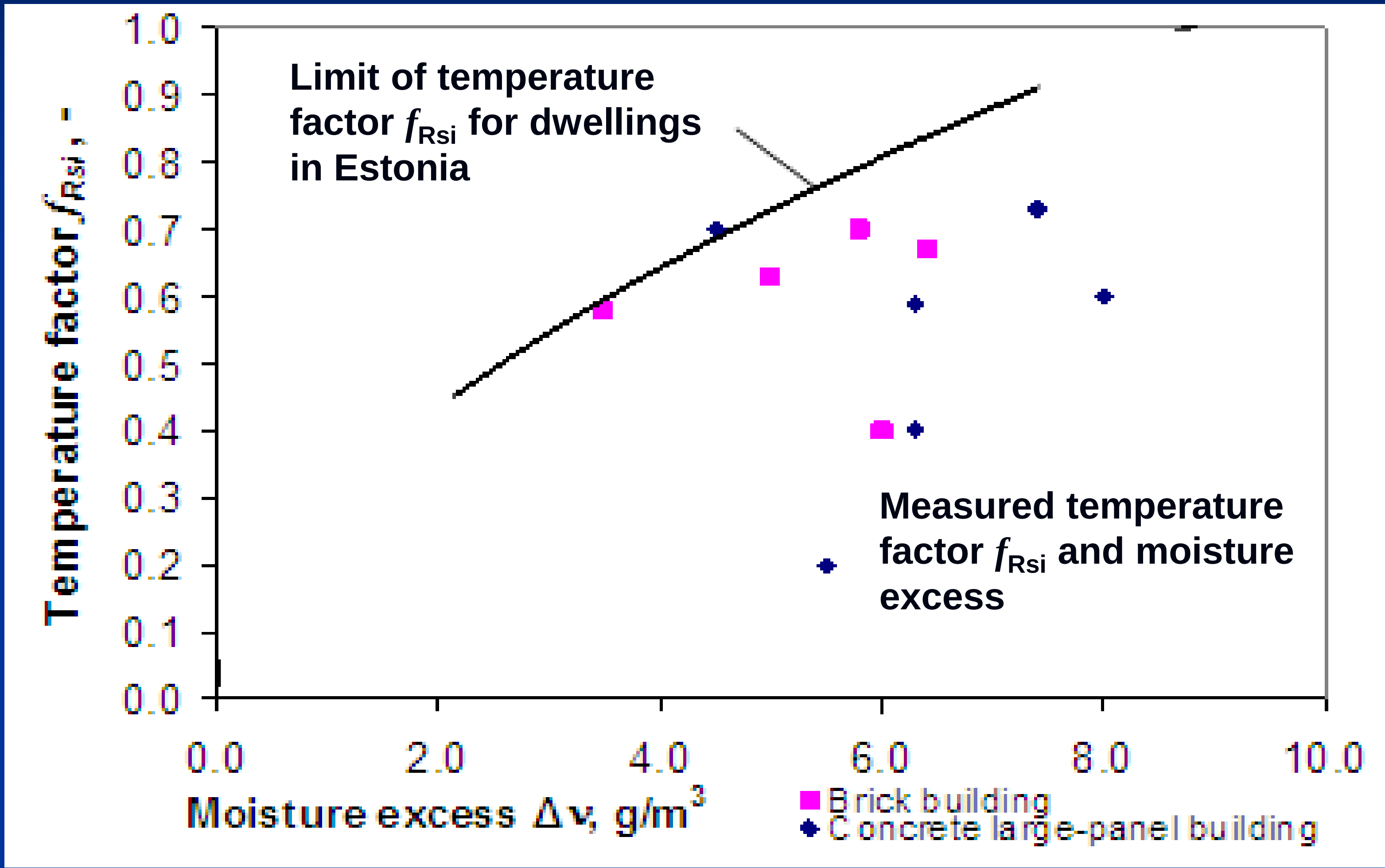


92% of the temperature factors f_{Rsi}<0.8 ($\Delta v \sim 6$ g/m^3)

Results – mould growth



Results – mould growth on thermal bridges



Mould growth was visually detected in:
46% of concrete large-panel and in 33% of brick buildings

Temperature factor f_{Rsi} can be used as design value to avoid mould growth

Results – thermal conductances

Location of the thermal bridge	Original / additionally insulated (mm)	Thermal conductance ψ, W/m·K Concrete large-panels*
Corner of external walls	Original	1.17
	150	0.26
External walls/internal walls (without joint insul.)	Original	1.03
	150	0.08
External walls / inserted ceiling	Original	0.77
	150	0.05
External wall / pitched roof	Original	-
	150	-
External walls / flat roof	Original	0.49
	150	0.40
External walls/ windows (without insulated cheek)	Original	0.07
	150	0.14
External walls and loggia/ balcony slab	Original	0.76
	150-200*2	0.49

Thermal transmittance of a wall may increase up to 100%!

Results – thermal conductances

Location of the thermal bridge	Original / additionally insulated (mm)	Thermal conductance ψ, W/m·K	
		Concrete large-panels*	Calcium silicate or ceramic bricks
Corner of external walls	Original	1.17	0.23-0.29
	150	0.26	0.15
External walls/internal walls (without joint insul.)	Original	1.03	0.00
	150	0.08	0.00
External walls / inserted ceiling	Original	0.77	0.01
	150	0.05	0.00
External wall / pitched roof	Original	-	0.41...0.58
	150	-	0.42...0.49
External walls / flat roof	Original	0.49	0.33...0.48
	150	0.40	0.21
External walls/ windows (without insulated cheek)	Original	0.07	0.35...0.49
	150	0.14	0.36...0.51
External walls and loggia/ balcony slab	Original	0.76	0.01
	150-200*2	0.49	0.13

Thermal transmittance of a wall may increase up to 100%!

Conclusions

- Mould growth on the internal surfaces of thermal bridges is unavoidable without additional external insulation and/or lowering internal humidity loads
- Heat losses through thermal bridges and plane partitions are in a same scale
- Economically rational thickness of additional insulation (~150 mm) is larger than is needed to eliminate thermal bridges (~50-70 mm)
- Additional internal insulation is not acceptable since it lowers temperature on former internal surface in insulated apartment and also in neighboring apartment
- Additional external insulation rises temperature on internal surface, reduces heat losses, improves thermal comfort and in addition - protects facade from climate loads