BS 2019 2-4 SEPT ROME
16th IBPSA INTERNATIONAL CONFERENCE AND EXHIBITION
INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOCIATION

Application Of A Method Of 1-D Equivalent Wall To Multidimensional Geometries : Impact On Building Energy Performance

Paper ID : *210182*

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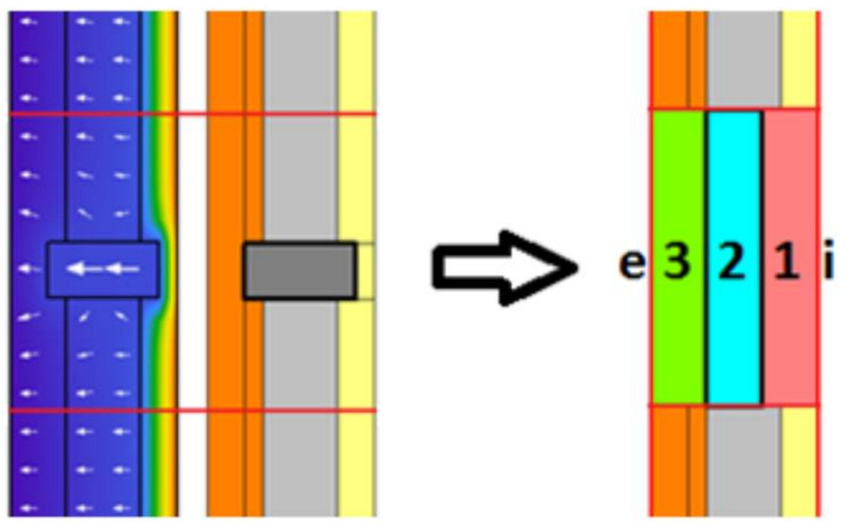
Context

A classic simplification in building energy simulation software is to consider the heat flux as being 1-D*. Thermal bridges (2-D or 3-D geometries) are responsible for 4% up to 39% of the heat losses of a building. With this simplification, their real dynamic effects cannot be taken into account. That can lead to inaccurate results and to a wrong sizing of heating and cooling systems, mainly if the inertia of the thermal bridge is different from that of the clear wall. A new method is needed.

$$^{*}\ q_{i,classic}(t) = q_{i,1D}(t) + \Psi \times L \times \left(T_e(t) - T_i(t)\right)$$

→ Accurate (for evaluation of the heat flux $q_i(t)$ through inside surface of the wall), for any time step and boundary conditions ?
→ Easy to integrate into any existing building energy software ?
→ Requiring low computational resources (avoiding a 2-D/3-D modelling coupled to the building simulation over one year) ?

Mixed equivalent wall method



$$F = \sqrt{\sum_{t=400h}^{t=2000h} \left(q_i(t) - q_i'(t)\right)^2}$$

Determine R_m and C_m (m = 1, 2, 3), fixe $\mathbf{e_m}$ and $\boldsymbol{\rho_m}$, deduce $\mathbf{k_m}$ and $\mathbf{c_m}$ → Energy building software

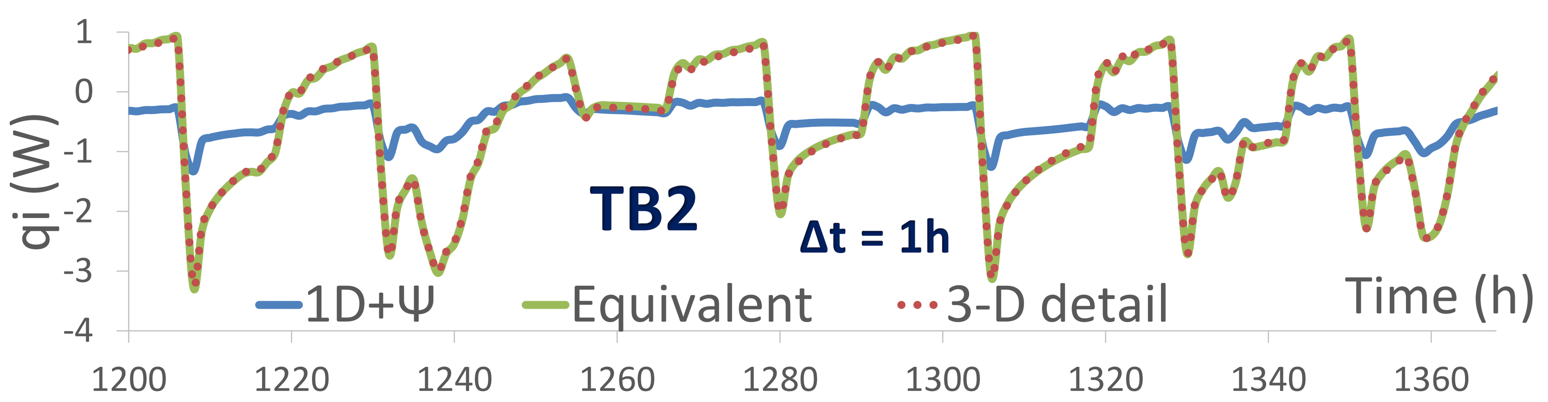
Conditions for the 1-D equivalent wall :

- ✓ Same values of **R** and **C**
- ✓ Same values of structure factors ($\boldsymbol{\phi_{ii}}$, $\boldsymbol{\phi_{ie}}$, $\boldsymbol{\phi_{ee}}$)
- ✓ Close response to sinusoidale sollicitations → **min. F**
  - $T_e(t)$: sum of representative harmonics
  - $T_i(t)$: sinus signal (Period = 24h)

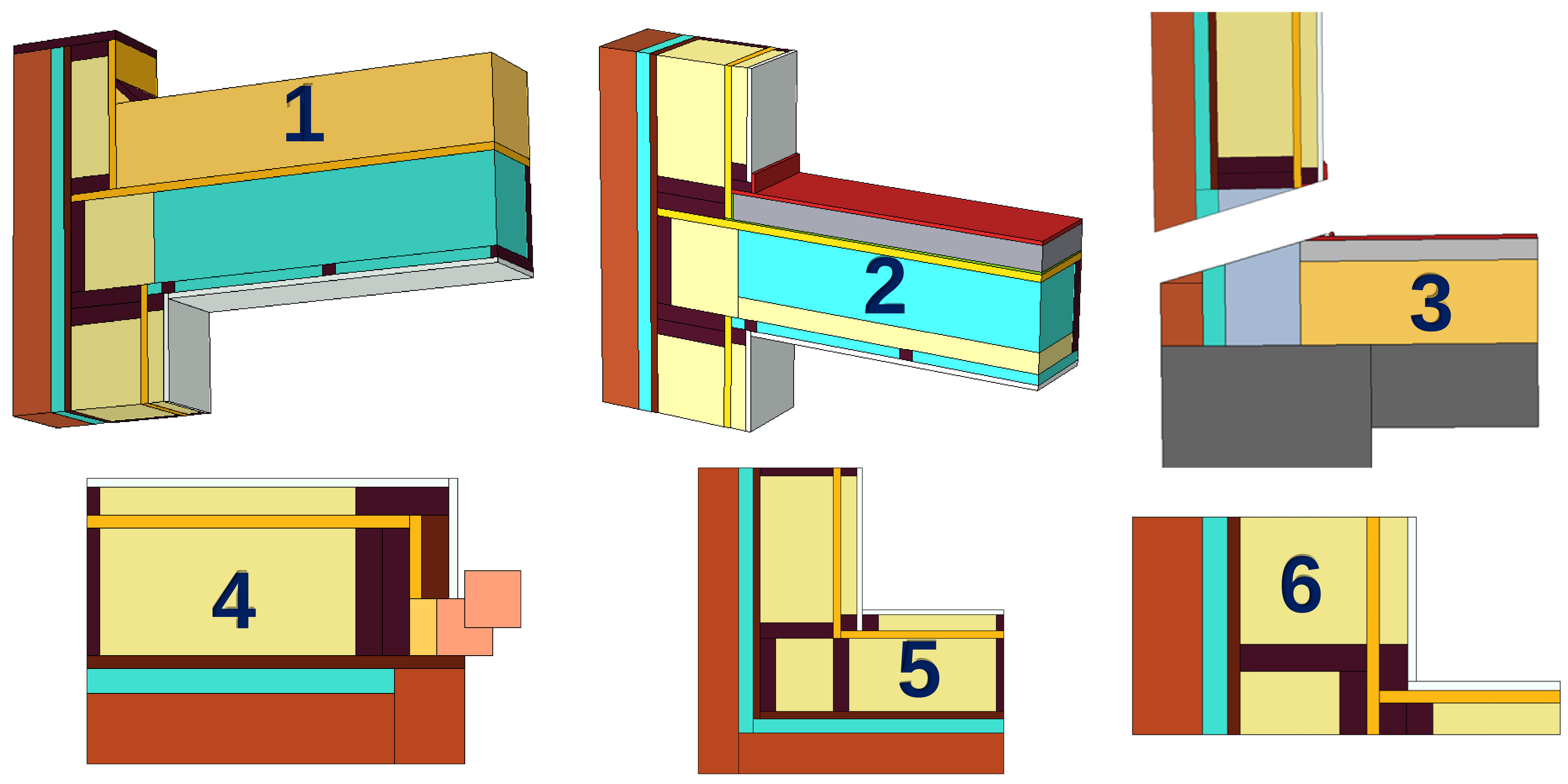
Validation of equivalent walls

- T_e, solar heat flux : hourly meteorological data (Brussels)
- T_i : hourly data (variable), error indicators : E_{int} and ε_{moy}

TB	Model	E_{int} (%)	ε_{moy}(W/m)	$\varepsilon_{moy} \cdot L$ (W)	Ψ (W/mK)
1	Classic	17	1.5	55	-0.039
	Equiv.	0.01	0.2	5.4	-
2	Classic	5	4.3	**160**	0.044
	Equiv.	0.1	0.1	4.7	-
3	Classic	0.47	2.0	73	0.021
	Equiv.	0.51	0.1	3.7	-
4	Classic	9	0.6	42	0.048
	Equiv.	0.05	0.4	29	-
5	Classic	8	1.1	18	-0.107
	Equiv.	0.04	0.1	1.5	-
6	Classic	2	0.4	13	0.005
	Equiv.	0.3	0.2	7.2	-



Studied thermal bridges (TB)



→ Impact on building energy performance ?

- Belgian two-storey detached house : one-zone model
- Good thermal insulation (U_{wall} < 0.2, U_{window} < 0.6 W/m²K)
- Good air-tightness (n_{50} = 0.6 h^{-1})
- V = 558 m³, A_{losses} = 414 m², A_{floor} = 2 x 87m², A_{win} = 27 m²
- 1-D heat flux on 43% of external area
- Air ventilation rate = 0.35 h^{-1}, internal gains = 600 W
- Heat recovery system, solar protections

Building simulation (Brussels)

- *No TB* : Impact of TB not considered
- *Static TB* : Steady-state effects of TB considered (Ψ)
- *Dynamic TB* : Dynamic effects of TB considered (equiv.)

Heating (20-16°C, 4 kW max)			Cooling (25°C, 2 kW max)		
kWh/m²/year			kWh/m²/year		
No TB	*TB stat*	*TB dyn*	*No TB*	*TB stat*	*TB dyn*
8.66	9.15	9.04	7.75	7.53	7.07
	+5.7%	+4.4%		-2.8%	-8.8%

→ Natural T_i : slightly higher inertia for *Dynamic TB*
→ *Static* vs *Dynamic TB* : very low impact on heating needs
→ Impact of TB on cooling needs : x3 for *Dynamic* model

- Δ = 0,46 kWh/m²/year

→ Power gap up to 450 W (cooling) and 600 W (heating)
→ Study other buildings and compare with 3-D modelling

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