Building Science Graduate Program

Three-Dimensional Analysis of Thermal Bridging in High-Rise Window Wall Systems using the Concept of Linear and Point Transmittance

SCHOOL OF CONSTRUCTION AND THE ENVIRONMENT

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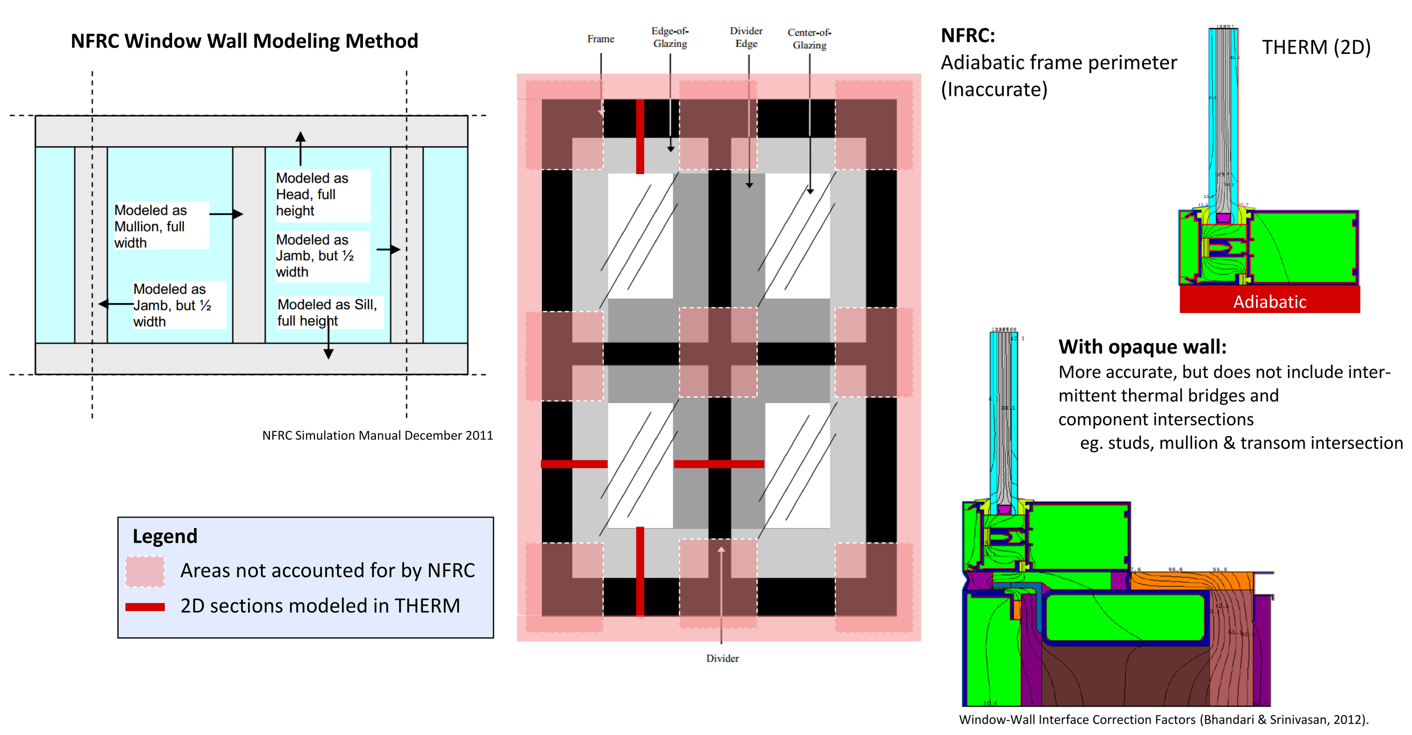
Research Problem

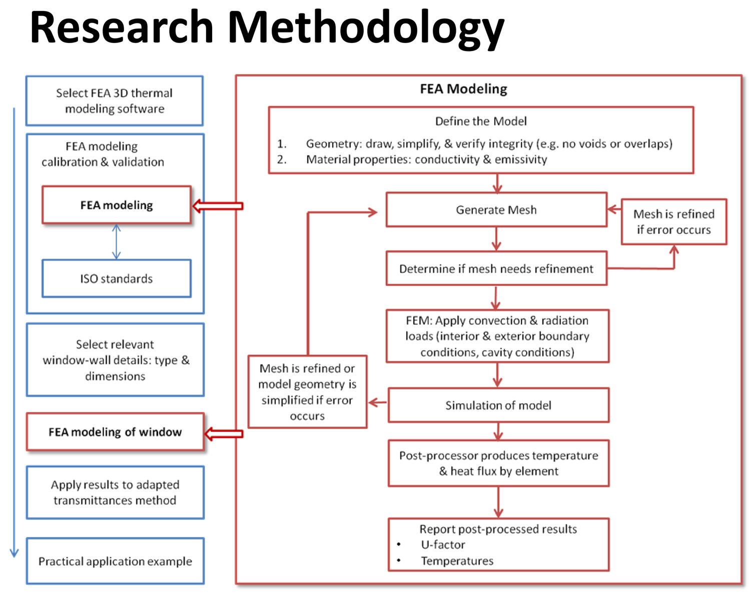
- Current methods of calculating window thermal performance do not fully account for thermal bridging



Objectives

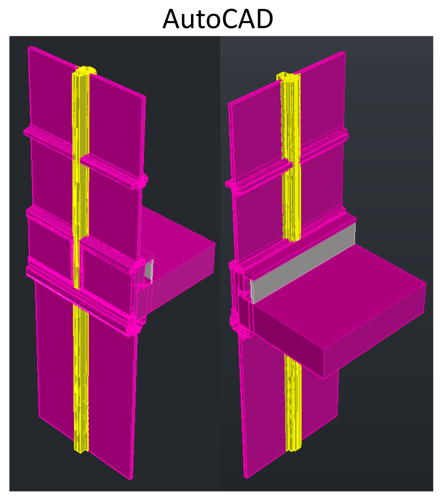
- Develop method for accurately calculating the heat loss through a window wall façade
- Analyze different slab edge transmittances
- Determine the influence of mullions on slab edge thermal transmittance
- *Overarching goal:* To be applied to North American codes and standards, eg. ASHRAE 90.1, NFRC-100

Research Methodology

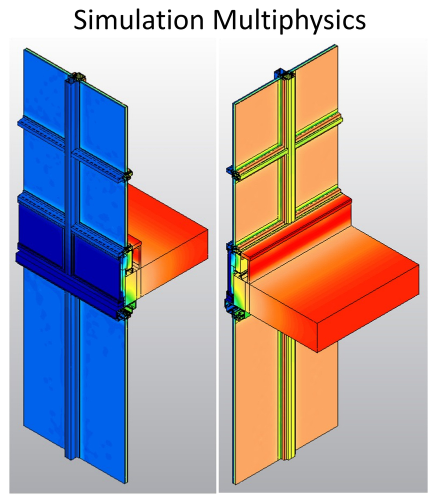



Tools

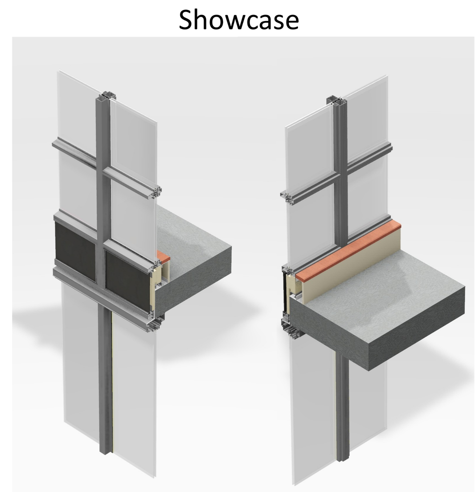
AutoCAD



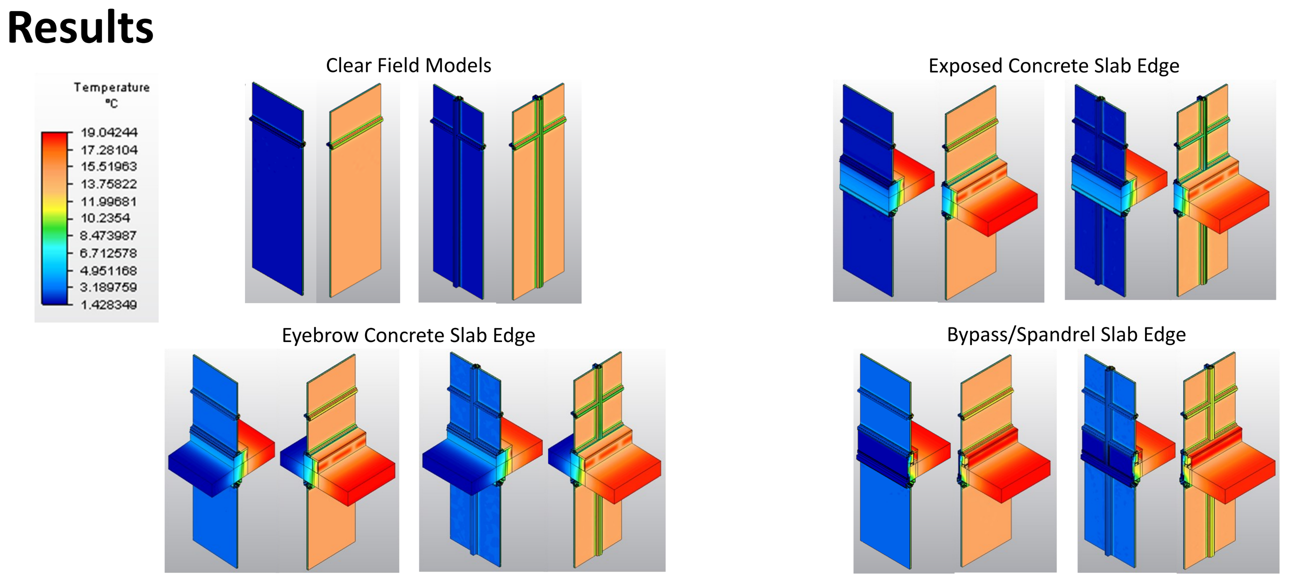
Simulation Multiphysics



Showcase



Results



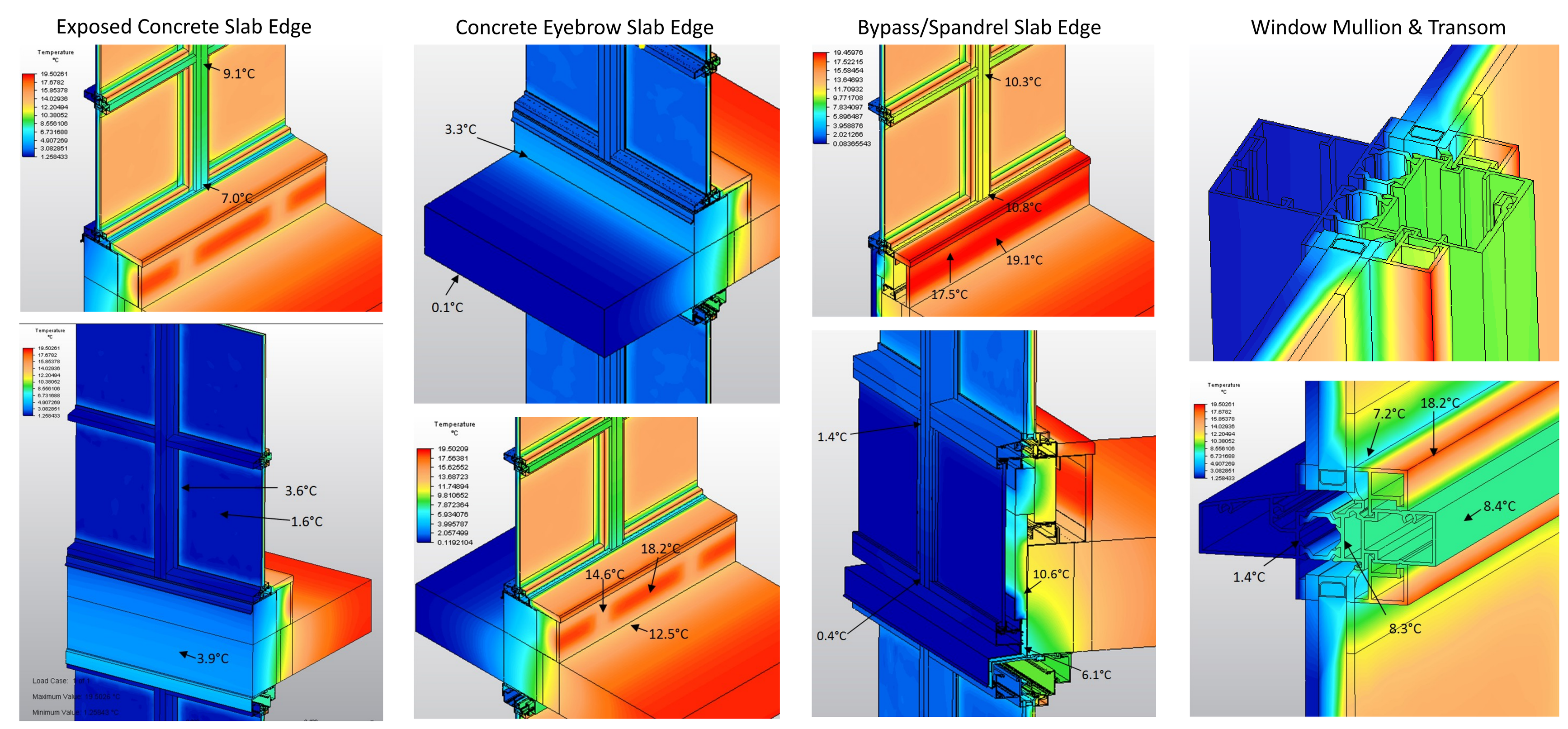
Tables of transmittances obtained from 3D modeling and simulation:

Model Type	Linear Transmittance Ψ (W/m K)
Concrete	1.29
Eyebrow	1.27
Bypass/Spandrel	0.26

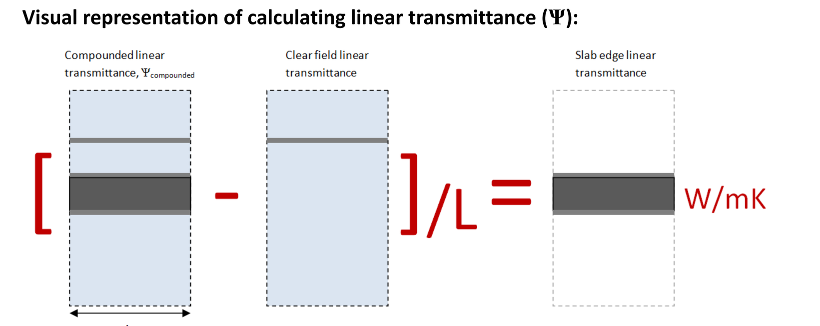
Model Type	Mullion Point Transmittance χ (W/K)
Concrete	0.50
Eyebrow	0.51
Bypass/Spandrel	0.25

	Compounded Linear Transmittance $\Psi_{Compounded}$ (W/mK)			
Model Type	Glazing	Frame	Opaque	Total
Concrete	3.20	0.71	1.50	5.40
Eyebrow	3.20	0.71	1.49	5.40
Bypass/Spandrel	3.11	0.44	0.83	4.38
	Mullion Point Transmittance χ (W/K)			
	Glazing	Frame	Opaque	Total
Concrete	-0.15	0.66	0.00	0.50
Eyebrow	-0.15	0.66	0.00	0.51
Bypass/Spandrel	-0.15	0.44	-0.04	0.25

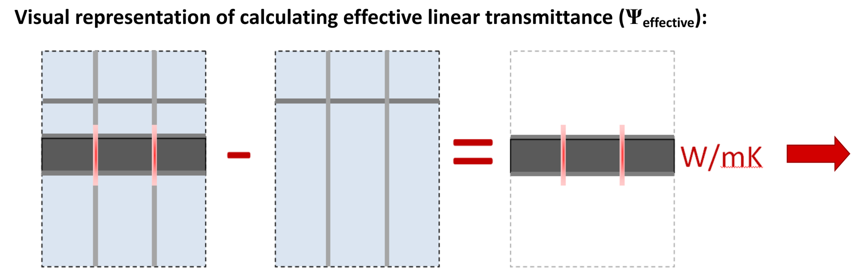
Observations: Model Temperature Gradients

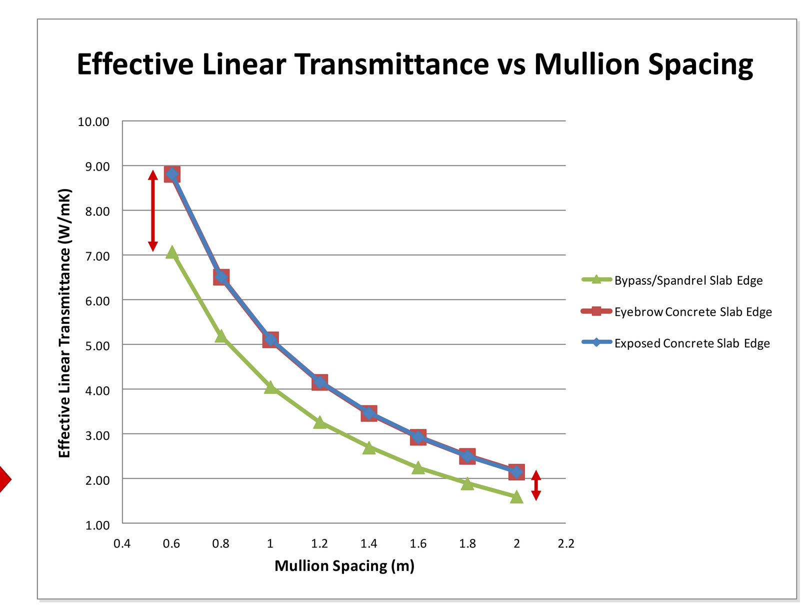


Visual representation of calculating linear transmittance (Ψ):

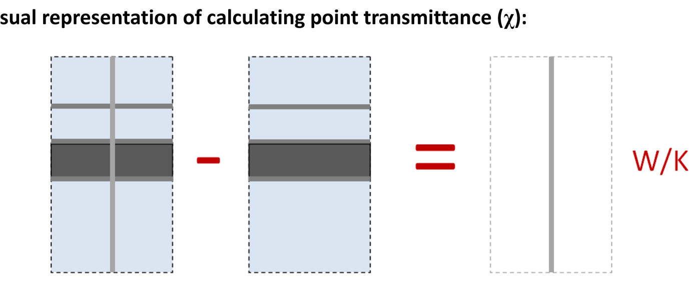


Visual representation of calculating effective linear transmittance ($\Psi_{effective}$):





Visual representation of calculating point transmittance (χ):

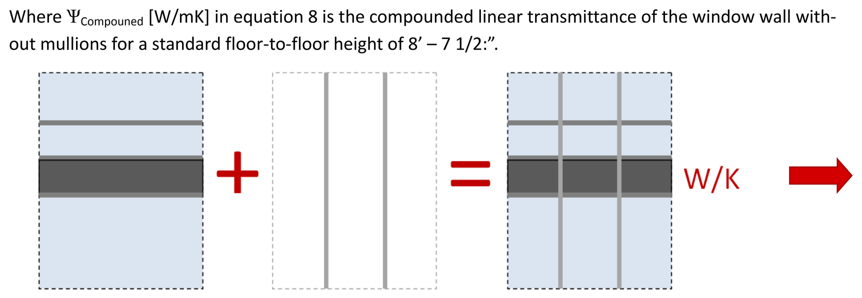


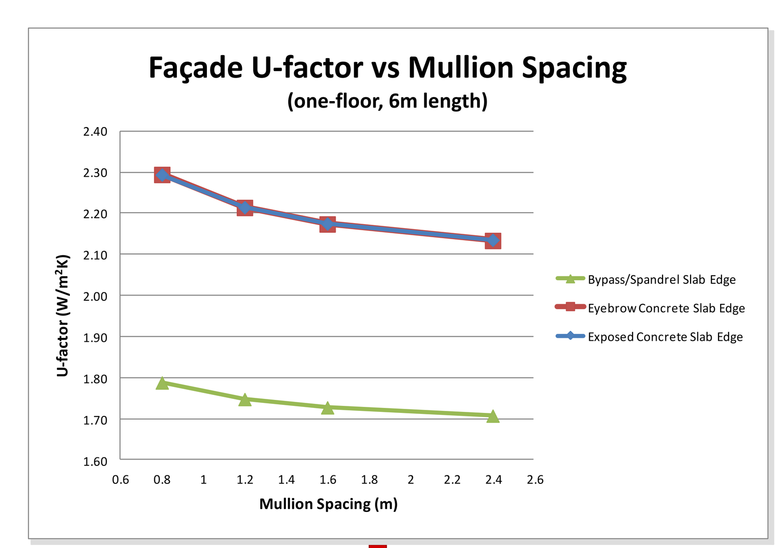
Visual representation of calculating wall assembly transmittance (Q):

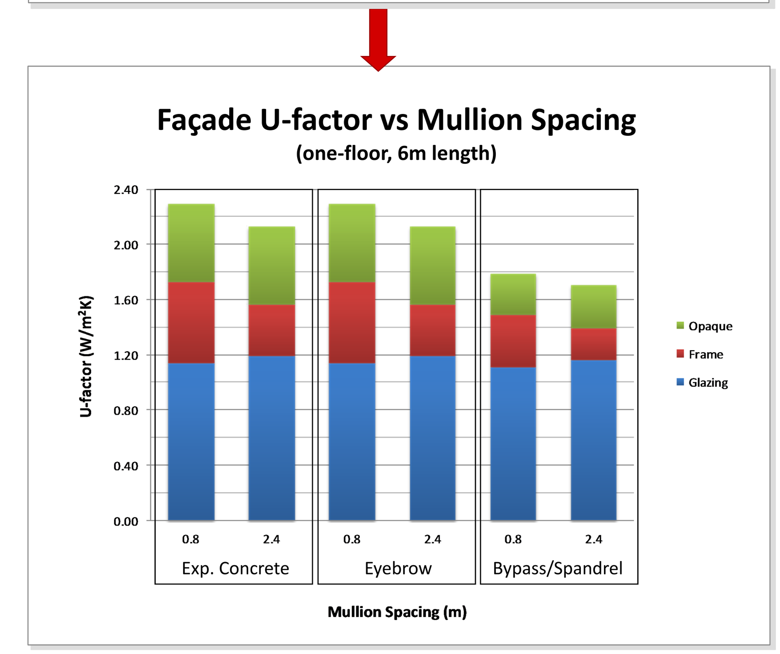
Compounded linear transmittance x Length + ΣPoint transmittance = Assembly heat flow with anomalies

$(\Psi_{Compounded} \times L) + \Sigma \chi = Q$ [W/K]

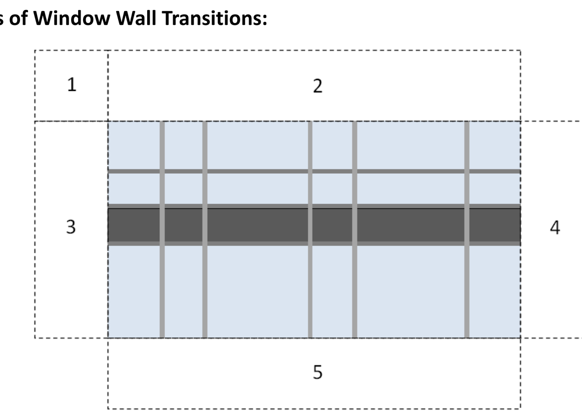
Where $\Psi_{Compouned}$ [W/mK] in equation 8 is the compounded linear transmittance of the window wall without mullions for a standard floor-to-floor height of 8' – 7 1/2:".







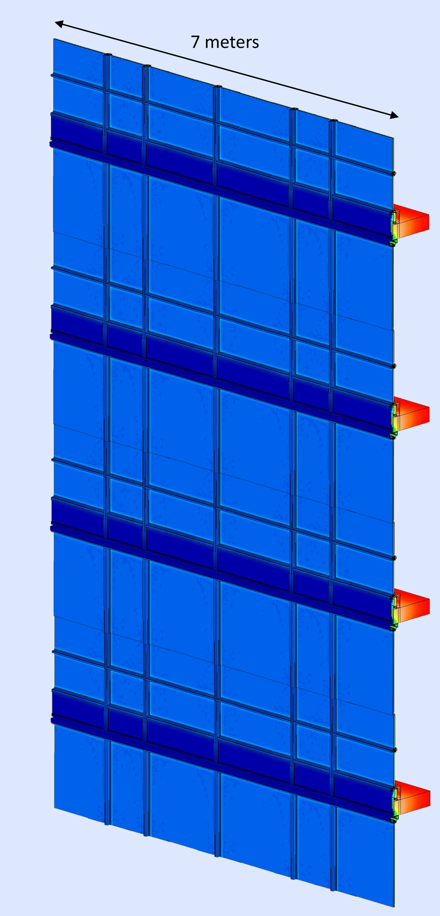
Examples of Window Wall Transitions:



1. Parapet corner to window wall corner
2. Parapet to window wall
3. Window wall to window wall corner
4. Window wall to opaque wall
5. Window wall with certain slab edge to window wall with different slab edge

Example: Four-floor bypass slab edge façade

Façade type: Bypass/spandrel slab edge
Outdoor temperature: 5°C
Indoor temperature: 23°C
Length per floor: 7 meters
Number of mullions per floor: 5



Case 1: Total heat loss through façade

$Q = (\Psi_{compounded} * L) + \Sigma(\chi)$

$Q = (4.38 \text{ W/m K})*(4 \text{ floors})*(7 \text{ m}) + [(5 \text{ mullions/floor})*(4 \text{ floors})*(0.25 \text{ W/K})]$

$Q = 127.7$ W/K

Total heat loss through the façade = $Q*\Delta T = (127.7)*(23 – 5) =$ <u>2300 W</u>

Case 2: Total heat loss through façade categorized by wall components (Detailed method)

$Q_{glazing} = (3.11 \text{ W/m K})*(4 \text{ floors})*(7\text{m}) + [(5 \text{ mullions/floor})*(4 \text{ floors})*(-0.151 \text{ W/K})] = 84.1$ W/K

$Q_{frame} = (0.44 \text{ W/m K})*(4 \text{ floors})*(7\text{m}) + [(5 \text{ mullions/floor})*(4 \text{ floors})*(0.443 \text{ W/K})] = 21.2$ W/K

$Q_{opaque} = (0.83 \text{ W/m K})*(4 \text{ floors})*(7\text{m}) + [(5 \text{ mullions/floor})*(4 \text{ floors})*(-0.038\text{W/K})] = 22.5$ W/K

$Heat_{glazing} = (84.1 \text{ W/K})*(18\text{K}) = \underline{1510 \text{ W}}$

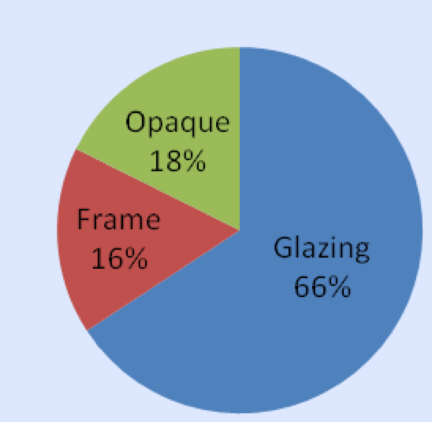
$Heat_{frame} = (21.2 \text{ W/K})*(18\text{K}) = \underline{382 \text{ W}}$

$Heat_{opaque} = (22.5 \text{ W/K})*(18\text{K}) = \underline{405 \text{ W}}$

$Heat_{total} = \underline{2300 \text{ W}}$

Heat loss percentage contributions:

	Glazing	Frame	Opaque
Heat Loss (W)	1510.0	382.0	405.0
Percentage	66%	17%	18%



$U\text{-factor}_{effective} = 2300\text{W}/[(4*2.6289\text{m}*7\text{m})*(18\text{K})] = \underline{1.74 \text{ W/m}^2 \text{ K}}$

Conclusion

- This adapted transmittances method allows for accurate but simple calculation of window wall façade thermal performance
  - Accounts for 3D thermal bridging effects (i.e. more accurate than area weighted average approach)

Future Work

- Transient analysis to determine dynamic thermal performance
- Include effects of solar radiation
- Quantitative comparison with area weighted average method
- Modeling of window wall transitions

Acknowledgements:

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