EMPA

Materials Science & Technology

Thermal Performance of VIP Assemblies in Building Constructions

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Vacuum Insulation Panel

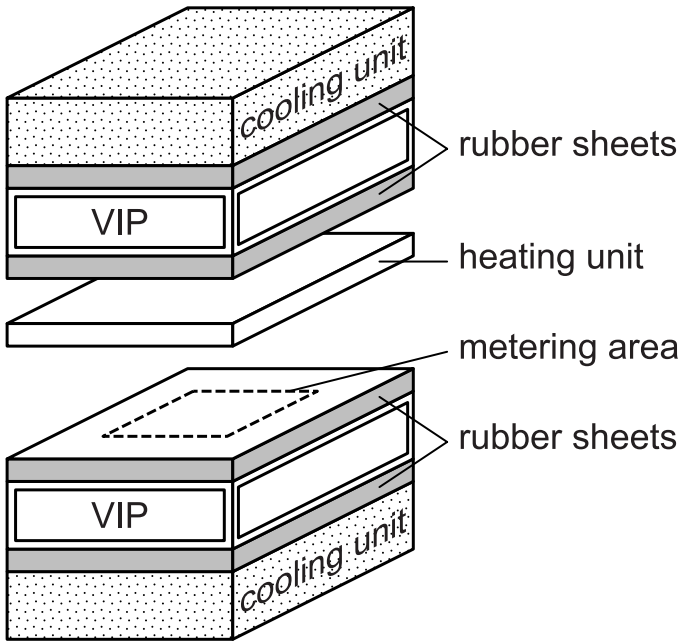
From the thermal point of view: strongly non homogeneous material

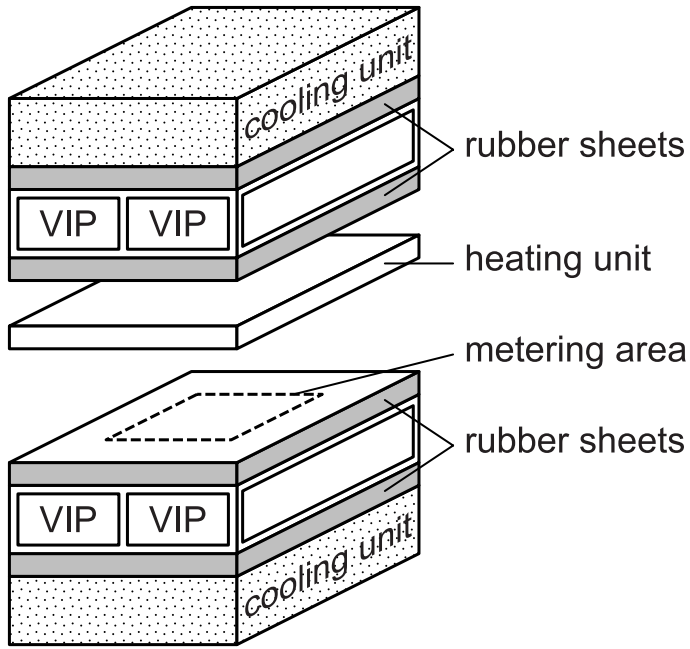
core:	fumed silica	λ = 4 - 7 mW/(m·K)
barrier envelope:	Al-coated polymers	λ_{Al} = 200 W/(m·K)

J	PET	Polyethylene		12 μm
I	AL	Aluminium	30 nm =	0.03 μm
H	PU	Polyurethane		2 μm
G	AL	Aluminium	30 nm =	0.03 μm
F	PP	Polypropylene		18 μm
E	PU	Polyurethane		2 μm
D	AL	Aluminium	30 nm =	0.03 μm
C	PET	Polyethylene		12 μm
B	PU	Polyurethane		2 μm
A	LDPE	Low Density Polyethylene		60 μm

Effective Thermal Conductivity λ_{eff}

Measurements with the Guarded Hot Plate (GHP)



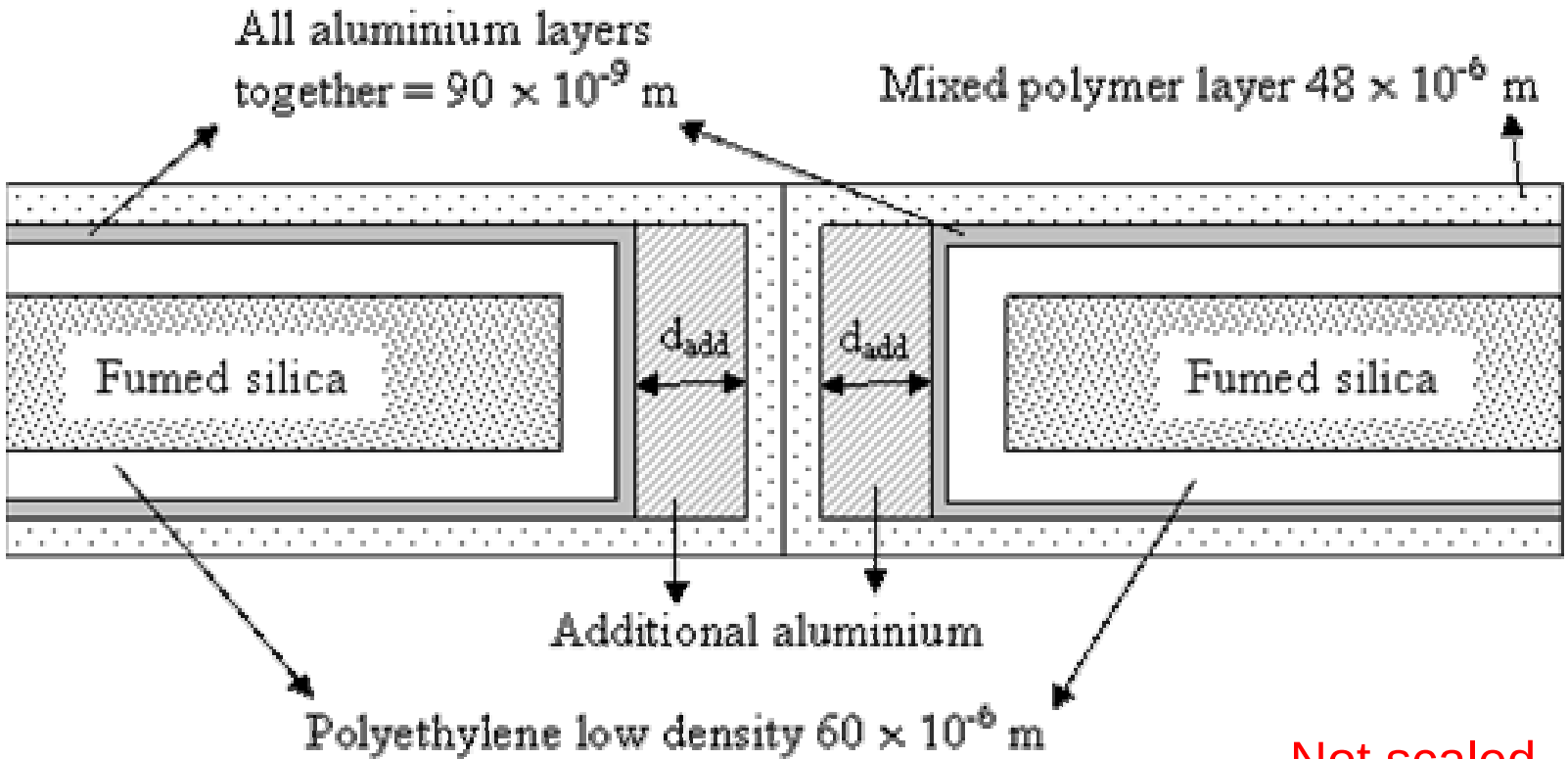


$$\psi_{joint} = \left(\frac{1}{R_{VIP+joint}} - \frac{1}{R_{VIP}} \right) \cdot \frac{A_m}{L_{joint,m}} = 2\psi_{VIP}(d)$$

$$\lambda_{eff} = \lambda_{core} + \psi_{VIP}(d) \cdot d \cdot p / A$$

Effective Thermal Conductivity λ_{eff}

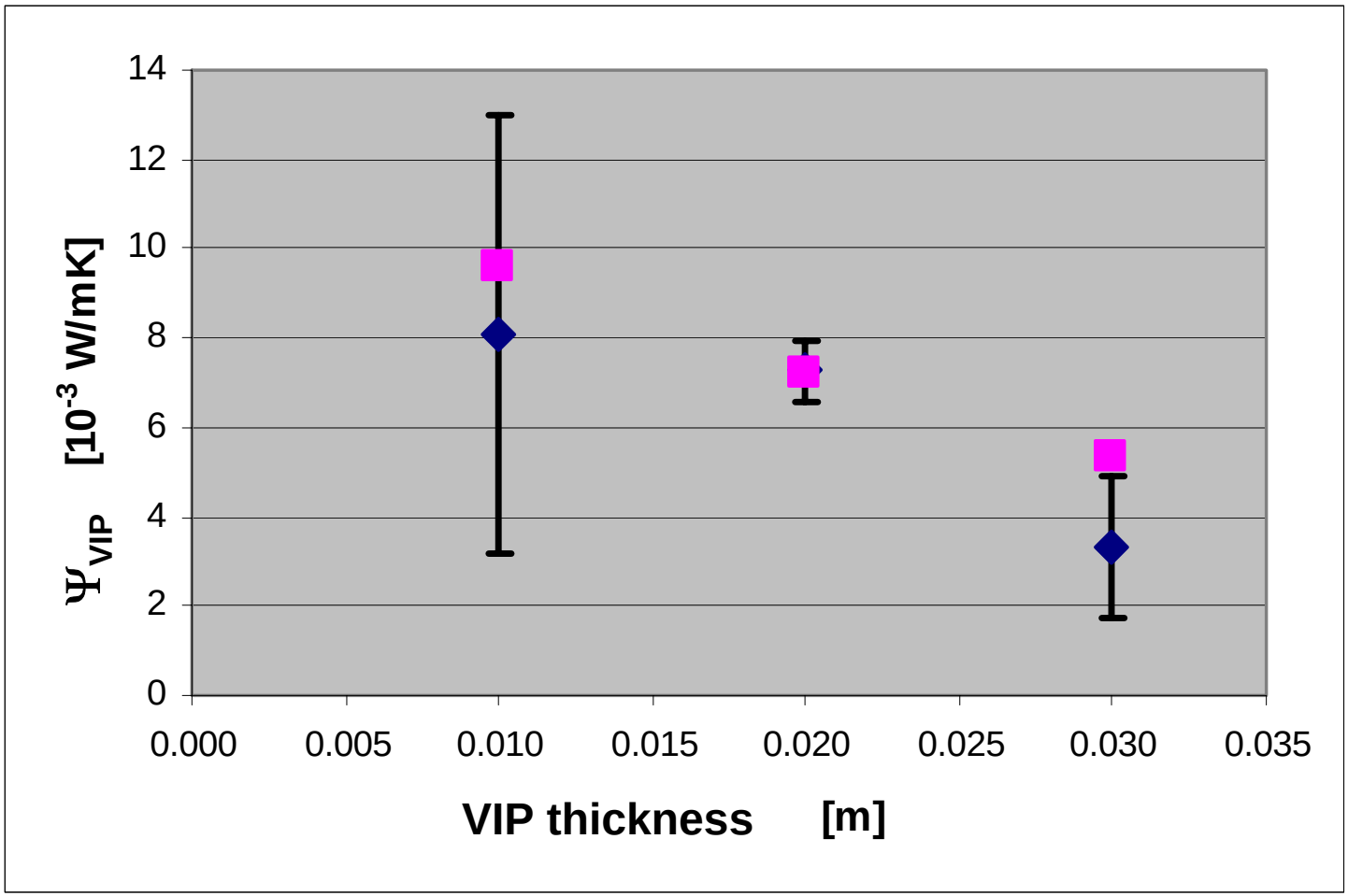
Numerical Analysis 2D Steady State Heat Transfer TRISCO®



Not scaled

Linear Thermal Transmittance Ψ_{VIP}

Adjusting the Calculation Model to the Measurement Results



Effective Thermal Conductivity λ_{eff}

Examples:

Length m	Width m	Thickness m	λ_{core} W/(m·K)	λ_{eff} * W/(m·K)
1.00	0.60	0.01	0.0050	0.0055
1.00	0.30	0.01	0.0050	0.0058
0.50	0.50	0.01	0.0050	0.0058
1.00	0.60	0.02	0.0050	0.0058
1.00	0.30	0.02	0.0050	0.0063
0.50	0.50	0.02	0.0050	0.0062
1.00	0.60	0.03	0.0050	0.0058
1.00	0.30	0.03	0.0050	0.0064
0.50	0.50	0.03	0.0050	0.0063

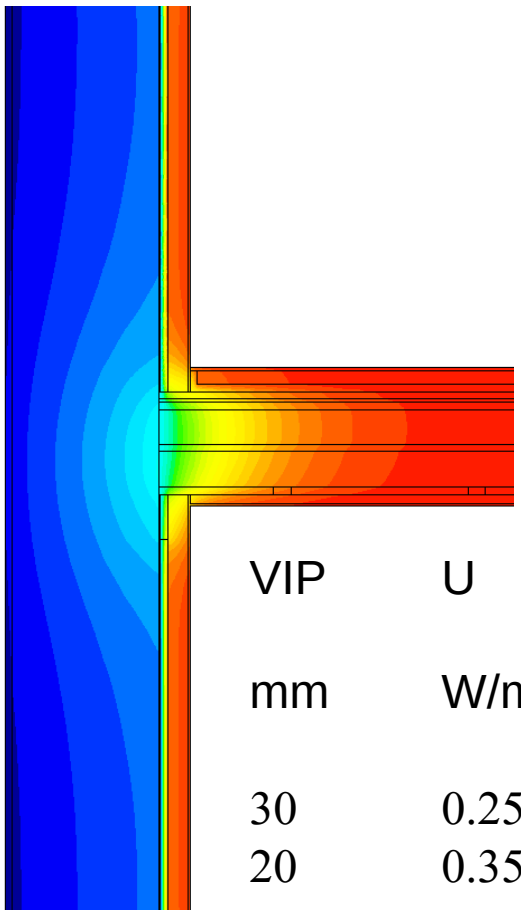
Advantageous: large size and square shaped VIP's

* no aging effects included

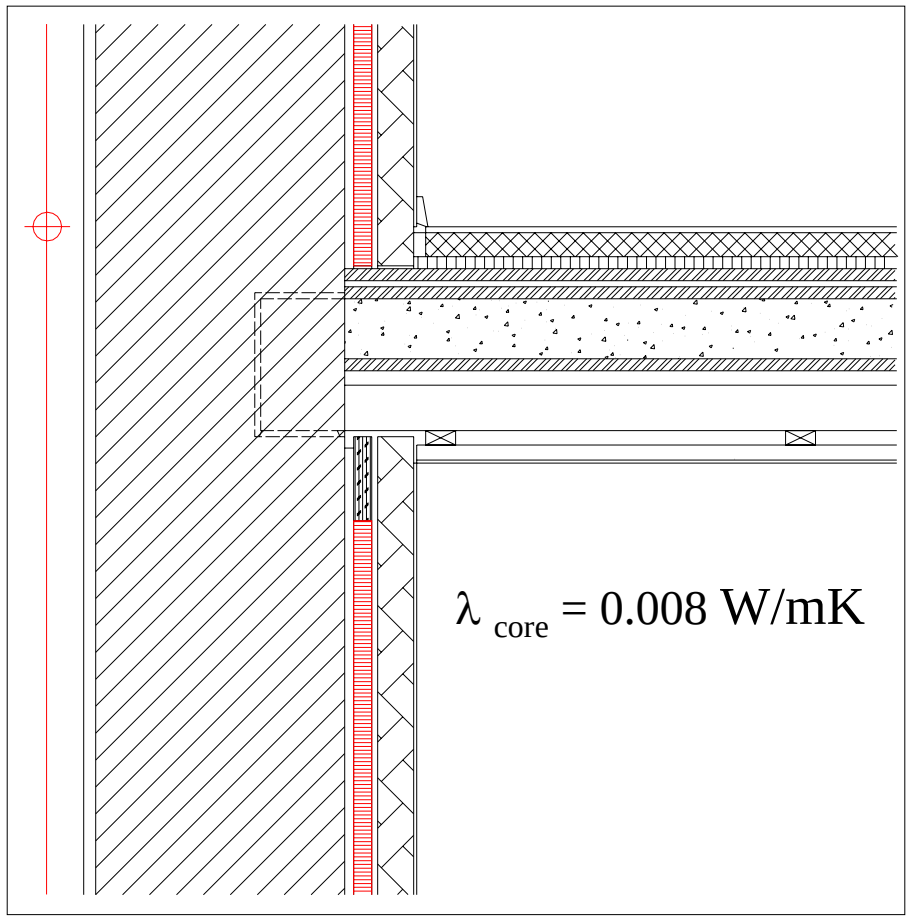
Building details containing VIP's

Internal insulation (retrofit)

a) using the complex model for the VIP

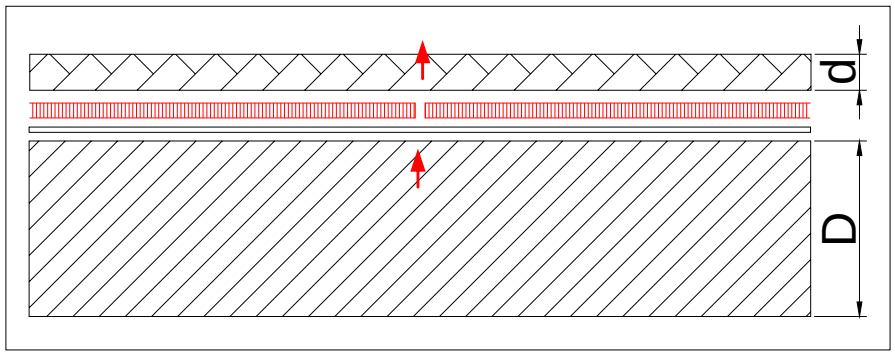


VIP	U	Ψ
mm	W/m²K	W/mK
30	0.25	0.37
20	0.35	0.36



Building details containing VIP's

Internal insulation (retrofit) b) VIP : homogeneous layer with λ_{eff}



Ψ_{VIP} 30mm [mW/m K]		d [mm]		
		30	60	90
D [mm]	300	9.7	9.3	8.9
	420	9.3	9.0 (1)	8.6
	540	9.0	8.7	8.4

Ψ_{VIP} 20mm [mW/m K]		d [mm]		
		30	60	90
D [mm]	300	12.0	11.3	10.8
	420	11.4	10.8 (2)	10.3
	540	10.9	10.3	9.8

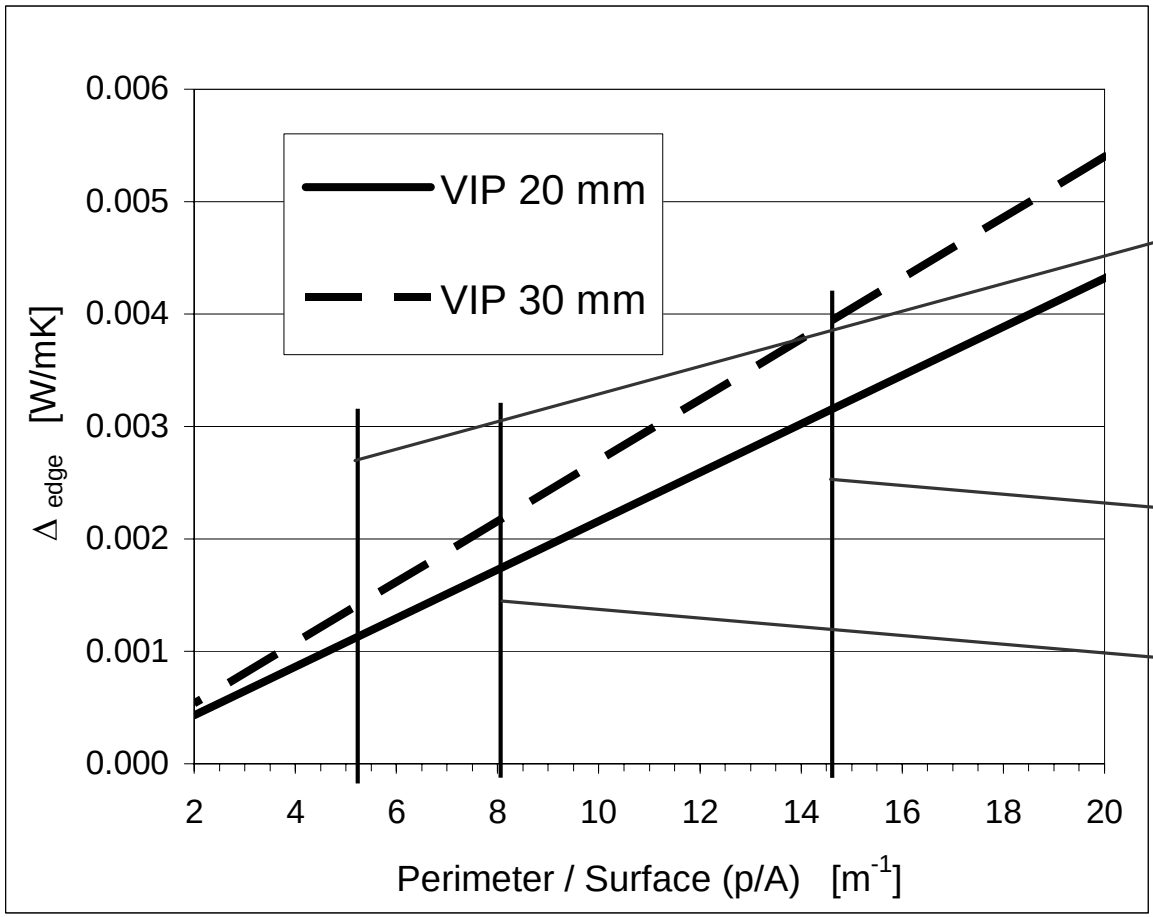
(1): applies to VIP's of the size: 1.3 x 0.6 x 0.03 m^3

(2): applies to VIP's of the size: 1.3 x 0.6 x 0.02 m^3

Building details containing VIP's

Internal insulation (retrofit)

b) VIP : homogeneous layer with λ_{eff}

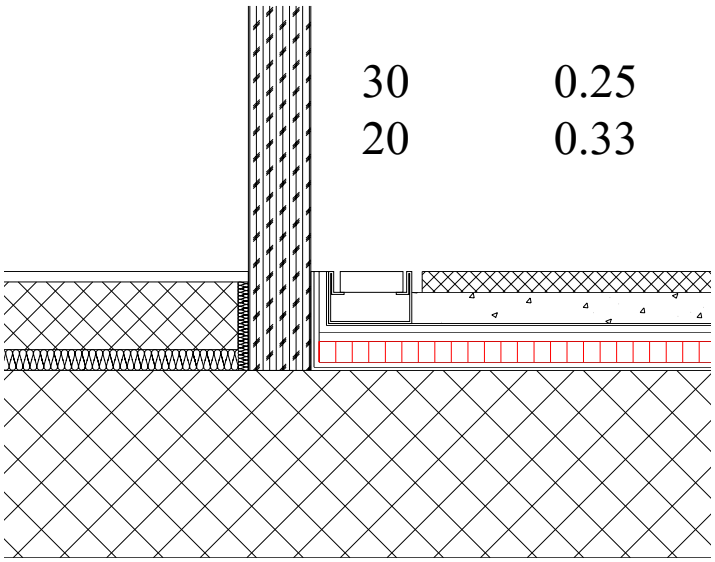


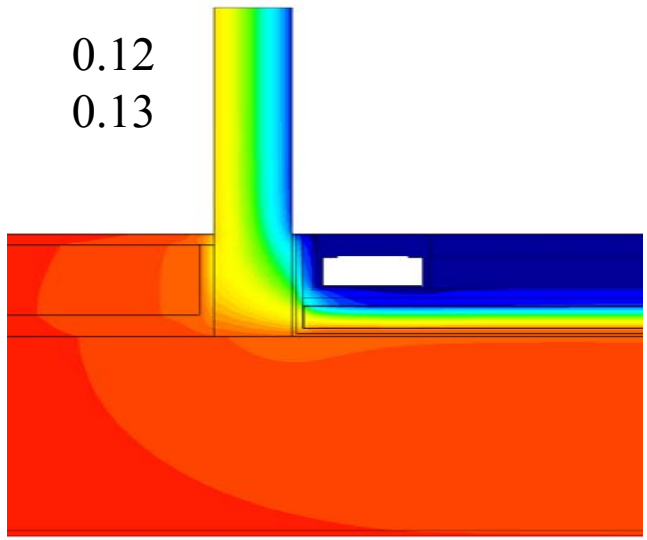
Length [m]	Width [m]	p/A [m^{-1}]
1.00	0.60	5.33
1.00	0.30	8.67
0.60	0.50	7.33
0.60	0.25	11.33
0.30	0.25	14.67
1.00	0.50	6.00
0.50	0.50	8.00
1.00	0.65	5.08
0.50	0.65	7.08

Building details containing VIP's

Terraces

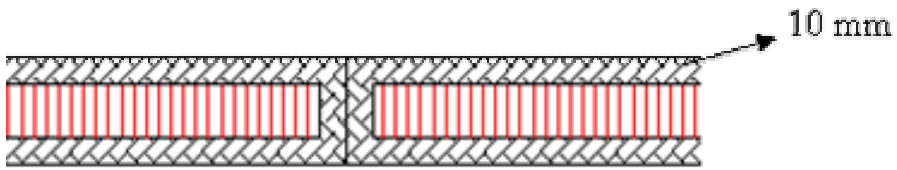
VIP	U_{floor}	U_{frame}	Ψ
mm	W/m²K	W/m²K	W/mK
30	0.25	1.77	0.12
20	0.33	1.77	0.13





Building details containing VIP's

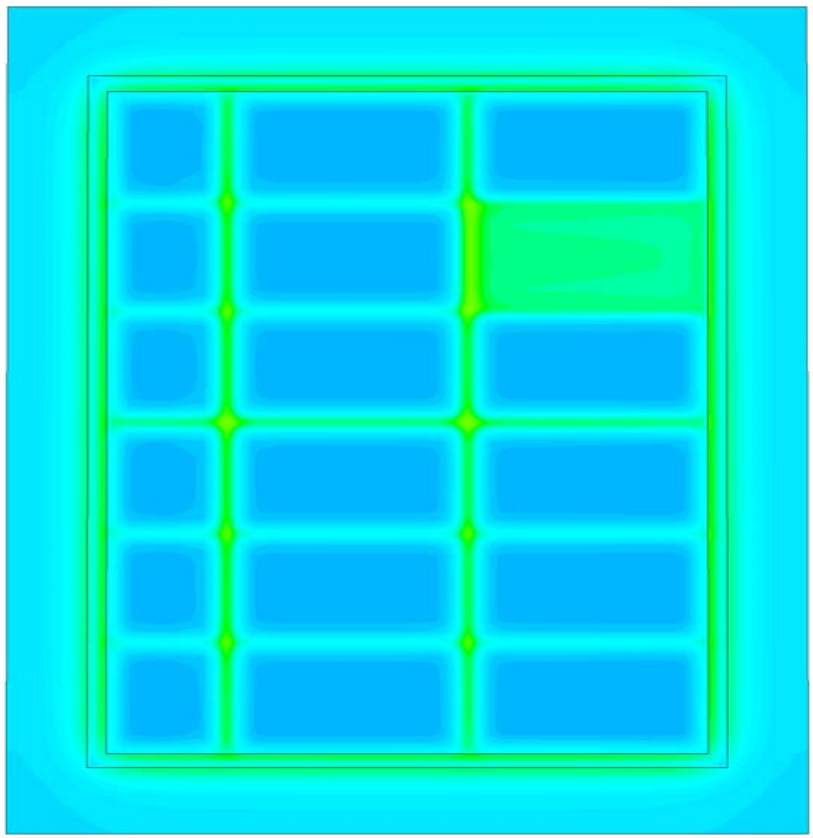
VIP's surrounded by a homogeneous material

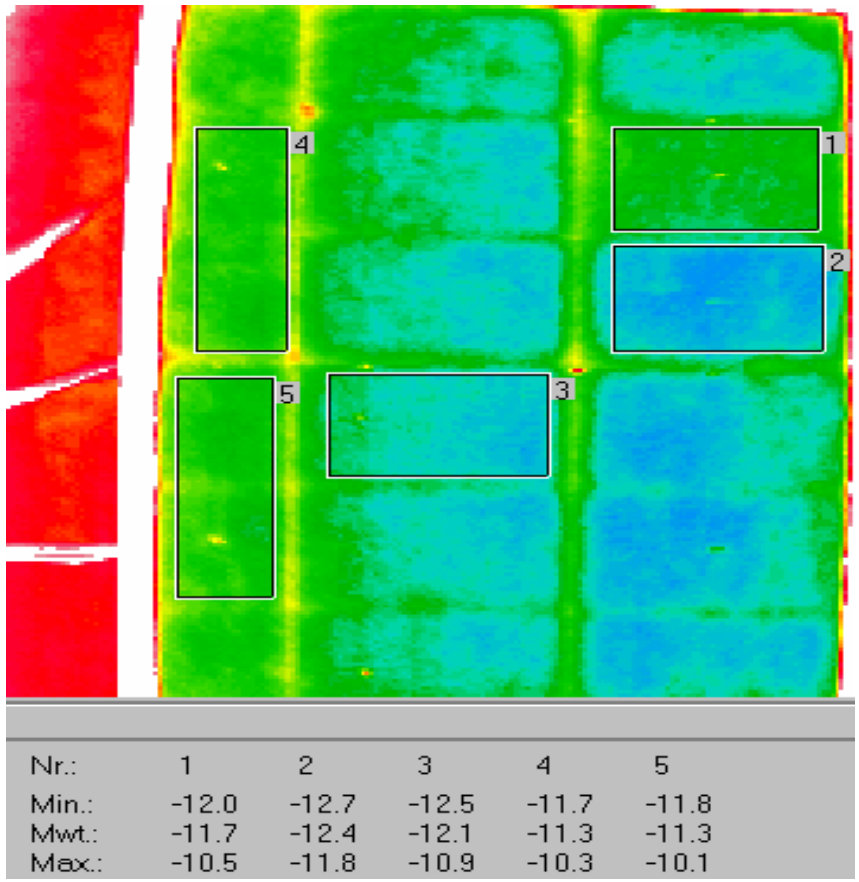


Thermal conductivity of the surrounding material [W/m.K]	Ψ [W/m.K]	
	VIP Thickness 20 mm	VIP Thickness 30 mm
	including the barrier foil	including the barrier foil
1.000	0.580	0.452
0.600	0.349	0.273
0.250	0.146	0.115
0.140	0.082	0.066
0.080	0.046	0.038
0.040	0.022	0.019
0.025	0.013	0.012

Building details containing VIP’s

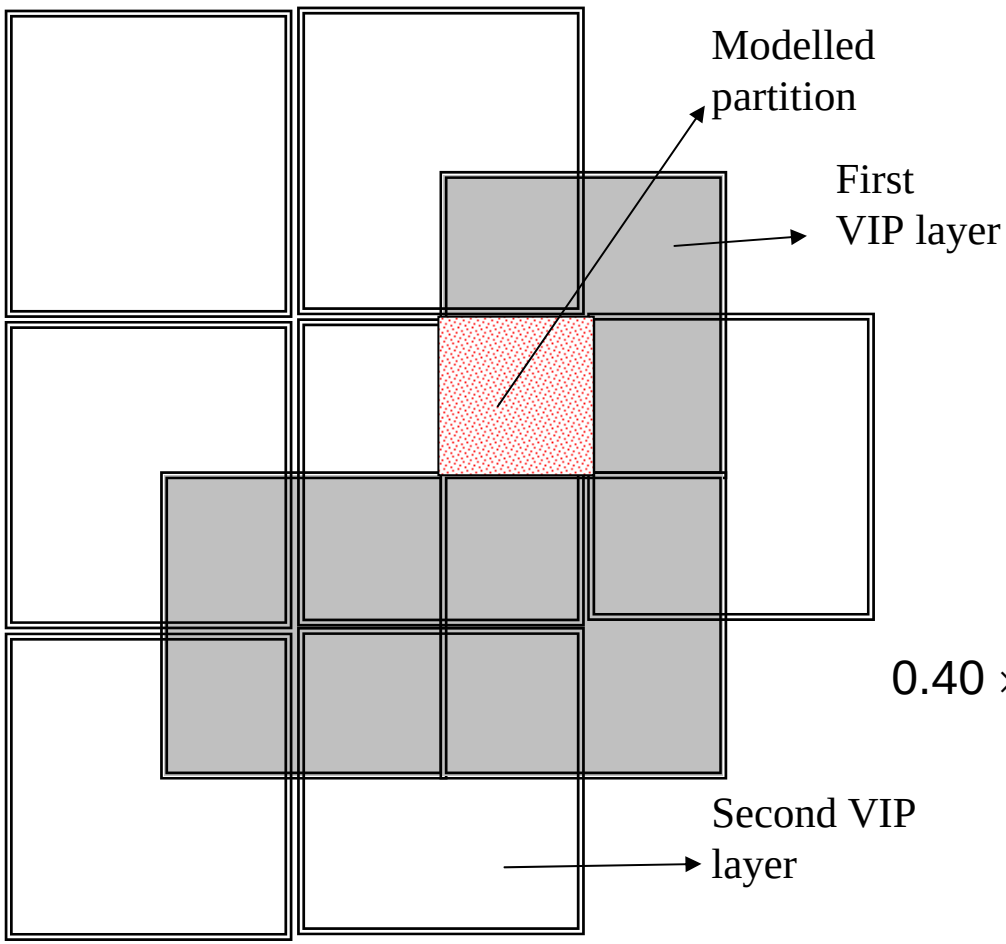
VIP’s surrounded by a homogeneous material
(applied to a concrete wall) Calculation versus IR-Thermography





Building details containing VIP's

Staggered double layers



When comparing to a single layer keep in mind:

Panel size dependent

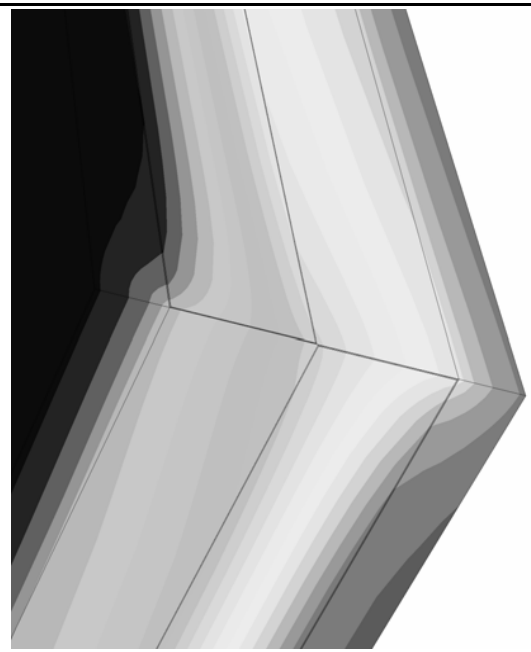
Doubled total length of joints

Small panel sizes on the edges

$0.40 \times 0.40\ m^2$

Building details containing VIP's

Staggered double layers

VIP assembly	Temperature distribution Temperature gradient of 20 K	Ψ *[W/m.K]*
5 mm Insulation 2 staggered layers of 10 mm VIP 5 mm Insulation		0.0016
5 mm Glass 2 staggered layers of 10 mm VIP 5 mm Glass		0.0027
5 mm Insulation 2 staggered layers of 20 mm VIP 5 mm Insulation 0.40×0.40 m^2		0.0012

Linear thermal transmittance for three different assemblies of staggered double layers of VIP's covered on both sides with two different materials