The Why of Psi
The Why of Psi

Workshop Presenters:
for CertiPHIers Cooperative…

- Chris Petit, CPHD
  Regenerative Design, LLC

- Rolf Jacobson, LEED AP, CPHC
  Research Fellow, Center for Sustainable Building Research, U of M

Copyright © 2017 Chris Petit and Rolf Jacobson. All rights reserved. No part of this presentation may be reproduced without their written permission.
The Why of Psi

Outline
1) Thermal bridge definition, types of TBs, and why controlling them is critical for super-insulated buildings.

2) Typical thermal bridge details and design techniques to reduce thermal bridge heat loss.

BREAK

3) Knowing which thermal bridges to model and entering them in the PHPP/ WUFI Passive.

4) Overview of PHI protocols and techniques for thermal bridge modeling.

BREAK

5) Practice with Flixo
Section 1 – Background + Basics

What is a thermal bridge?
Section 1 – Background + Basics

What is a thermal bridge?

Short answer:
A discontinuity in the thermal envelope.
What is a thermal bridge?

Short answer:
A discontinuity in the thermal envelope.

What types of discontinuities might there be in a thermal envelope?
Section 1 – Background + Basics

What is a thermal bridge?

Short answer:
A discontinuity in the thermal envelope.

What types of discontinuities might there be in a thermal envelope?
• Repetitive bridges (studs, floor joists, rafters)
• Material changes (windows, insulation)
• Penetrations (pipes, fasteners)
• Assembly junctions (roof to wall, wall to floor, etc)
• Corners
## Section 1 – Background + Basics

<table>
<thead>
<tr>
<th>Repetitive TBs</th>
<th>Penetrations (point TBs)</th>
<th>Assembly junctions (linear TBs)</th>
</tr>
</thead>
</table>
| Should be accounted for in calculation of assembly U-values in the PHPP | Usually too minor to be considered for heat loss calculations. But some cases could be a durability concern. Some cases need calculation (ex - commercial facades) | Three types:  
1) Structural (ex – rim joists, prefab wall junctions)  
2) Geometric (ex – wall corners, roof ridge)  
3) Combination (ex – wall to roof, wall to slab) |
# Section 1 – Background + Basics

Repetitive TBs – entry in PHPP

<table>
<thead>
<tr>
<th>Assembly no.</th>
<th>Building assembly description</th>
<th>Heat transfer resistance (m²K/W)</th>
<th>Interior R_\text{w}</th>
<th>Exterior R_\text{w}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0.170</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>6</td>
<td>Basement wall to cellar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area section 1</th>
<th>λ [W/(mK)]</th>
<th>Area section 2 (optional)</th>
<th>λ [W/(mK)]</th>
<th>Area section 3 (optional)</th>
<th>λ [W/(mK)]</th>
<th>t [\text{pc}]</th>
<th>[mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.170</td>
<td>0.000</td>
<td>0.13</td>
<td>0.000</td>
<td>0.000</td>
<td>5/8</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>0.035</td>
<td>Wood (softwood)*</td>
<td>0.13</td>
<td>0.000</td>
<td>0.000</td>
<td>3 1/2</td>
<td>89</td>
</tr>
<tr>
<td>3</td>
<td>0.170</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>5/8</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>0.036</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of sec. 1</th>
<th>Percentage of sec. 2</th>
<th>Percentage of sec. 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>85%</td>
<td>15.0%</td>
<td></td>
<td>12.1 cm</td>
</tr>
</tbody>
</table>

U-value supplement: 0.431 W/(m²K)  
U-Value: 0.431 W/(m²K)  
R-13.2
Section 1 – Background + Basics

Repetitive TBs – entry in WUFI Passive (static side only)
Section 1 – Background + Basics

Circled areas are common linear thermal bridges.

- The wall/foundation intersection is a combination linear TB (structural/geometric)
- The roof/wall intersection is also a combination (structural/geometric)
- The rim joist is purely a structural linear TB
Section 1 – Background + Basics

Thermal bridges – do they matter?

• Thermal bridges make up a small portion of heat loss in a poorly insulated envelope - 16% in a typical insulated 2x6 wall.

• If same details from a standard stud wall were used to construct an R-45 wall, heat loss through thermal bridges would approach 50%.

extrapolated from Christian, J.E. and J. Kosny. 1996
How is that possible?

1. As insulation levels increase, less heat is transmitted, but the remaining heat flow through the uninsulated portions of the envelope make up a greater percentage of that remainder.
2. Heat begins to move laterally through thermal bridges. They can transport more heat than their limited surface area suggests.
Section 1 – Background + Basics

From Pembina Institute, Accelerating Market Transformation for High Performance Building Enclosures, 2016:

“Thermal bridging is underestimated... Morrison Hershfield has calculated that shelf angles, parapets, window perimeters, etc, can result in the underestimation of 20% to 70% of the total heat flow through walls.”

Morrison Hershfield, Building Envelope Thermal Bridging Guide (2014)
Section 1 – Background + Basics

Effect of window conductance on whole wall R-Value

Impact of window U-value on effective thermal resistance of complete wall assemblies
(based on 18% glazing ratio compared to total wall area)

Overall Wall Effective R-value

Opaque Wall Effective R-value

Energy Star Window  Vinyl double glazed clear  Single glazed wood

graph from Building Science Corp
Section 1 – Background + Basics

• Heat loss through a linear thermal bridge is measured with a $\Psi$ value.

• A $\Psi$ value is like a U-value for thermal bridges:
  \[ U \times A \times dT = \text{heat loss from a surface, of area } A \]
  \[ \Psi \times L \times dT = \text{heat loss from a linear thermal bridge, of length } L \]

• $\Psi$ values $\leq 0.01 \text{ W/mK}$ qualify as “thermal bridge free” according to Passive House.

• To calculate $\Psi$ values, a 2-D heat flow simulation model (such as THERM or Flixo) is used.
Section 1 – Background + Basics

For PHPP, the thermal bridge heat loss is conceptually the difference between the “true” heat loss, calculated using 2-dimensional simulation (THERM or Flixo), and the heat loss calculated using the typical U·A method (U x A x deltaT = heat loss (or gain))
Section 1 – Background + Basics

“2D heat loss” – $U_1 L_1 - U_2 L_2 = \Psi$
Section 1 – Background + Basics

"2D heat loss" – $U_1L_1 - U_2L_2 = \Psi$

$L2d - U_1L_1 - U_2L_2 = \Psi$

Image from David White, Right Environments, 2010
Section 1 – Background + Basics

\[ L_{2d} - U_1 L_1 - U_2 L_2 = \Psi \]

(heat flux) \[ \Phi / \Delta T - U_1 L_1 - U_2 L_2 = \Psi \]
Section 1 – Background + Basics

\[ L_{2d} - U_1 L_1 - U_2 L_2 = \Psi \]

(heat flux)

\[ \Phi / \Delta T - U_1 L_1 - U_2 L_2 = \Psi \]

(equivalent U-value)

\[ U_{eq, total} - U_1 L_1 - U_2 L_2 = \Psi \]
Section 1 – Background + Basics

As used in the PHPP, the psi value is always based on a comparison of heat flows - a comparison between the actual heat flow and the estimated heat flow. **In this sense, psi is a correction factor.**
Section 1 – Background + Basics

Details coming up...

1. Wall corners
2. Rim joists
3. Footings
4. Parapets
5. Windows
When calculating heat loss, $U \times A \times dT$

- Using exterior dimensions, area $A = 40 \times 10 = 400\text{sf}$
- Using interior dimensions, area $A = 36 \times 10 = 360\text{sf}$

Which area $A$ gives the correct heat loss?
When calculating heat loss, \( U \times A \times dT \)
- Using exterior dimensions leads to an overestimate
- Using interior dimensions leads to an underestimate

PH convention is to use exterior dimensions, so heat loss is overestimated.
Section 2 – Common Linear Thermal Bridges

2x6 wall, no studs: $\Psi = -0.058 \text{ W/mK}$
2x6 wall, 2-stud: $\Psi = -0.040 \text{ W/mK}$

• By subtraction, negative psi values correct for overestimate of heat loss at exterior corners.
• The lower (more negative), the better. Higher psi values indicate increasing heat loss.
•Positive psi values above 0.01 W/mK indicate net heat transfer (heat gain in summer, heat loss in winter) that should be accounted for in PHPP.

Step 1 – Avoid bridging elements.
Section 2 – Common Linear Thermal Bridges

2x6 wall: $\Psi = -0.040$ W/mK

2x8 wall: $\Psi = -0.045$ W/mK

Is the 2x8 wall corner a “better” detail?
Section 2 – Common Linear Thermal Bridges

2x6 wall: $\Psi = -0.040$ W/mK

2x8 wall: $\Psi = -0.045$ W/mK

No.
A thicker wall section needs a larger correction factor due to larger overestimate of heat loss.
Section 2 – Common Linear Thermal Bridges

Is the psi value really an indicator of a detail’s thermal quality?
Is the psi value really an indicator of a detail’s thermal quality?
Yes and no.

At geometric bridges, it does two things at once – it is both a correction factor and an indicator of heat flow – *but primarily a correction factor.*
Is the psi value really an indicator of a detail’s thermal quality?
Yes and no.

At geometric bridges, it does two things at once – it is both a correction factor and an indicator of heat flow – but primarily a correction factor.
Section 2 – Common Linear Thermal Bridges

Rim joist, fib. batt (R-11): $\Psi = 0.089$ W/mK  
Rim joist, rim board (R-11): $\Psi = 0.129$ W/mK

- Rim joist thermal bridge - challenging to achieve the $\Psi = 0.01$ W/mK target.
- Maintaining continuity and alignment of insulation layers is a good first step.

STEP 2 – Align insulation layers
Section 2 – Common Linear Thermal Bridges

rim joist, fib. batt (R-11) : $\Psi = 0.089$ W/mK
rim joist, 2x4 wall w 1” exterior XPS (R-13):
$\Psi = 0.047$ W/mK

- Exterior insulation helps control heat flow through uninsulated studs and plates.

STEP 3 – Use continuous exterior insulation to isolate bridging elements
Section 2 – Common Linear Thermal Bridges

rim joist, 2x4 wall w 1” exterior XPS (R-13):  \[ \Psi = 0.047 \text{ W/mK} \]

rim joist, 2x4 wall w 4” exterior XPS:  \[ \Psi = 0.011 \text{ W/mK} \]

Use enough exterior insulation, and the psi value can be driven down below 0.01 \text{ W/mK}
Section 2 – Common Linear Thermal Bridges

rim joist, 2x4 wall w 4” exterior XPS: \( \Psi = 0.011 \) W/mK

rim joist, 2x6 wall w 4” exterior XPS: \( \Psi = ? \)

Question – are the psi values for these two details the same or different?
Section 2 – Common Linear Thermal Bridges

rim joist, 2x4 wall w 4” exterior XPS: 
\( \Psi = 0.011 \text{ W/mK} \)

rim joist, 2x6 wall w 4” exterior XPS: 
\( \Psi = 0.020 \text{ W/mK} \)

Is the detail on the left a “better” detail? 
Is heat flow through the detail on the right really 2x higher than the heat flow on the left? 
Does 4” of exterior foam guarantee a good psi value?
Section 2 – Common Linear Thermal Bridges

rim joist, 2x4 wall w 4” exterior XPS:  
Ψ = 0.011 W/mK

rim joist, 2x6 wall w 4” exterior XPS:  
Ψ = 0.020 W/mK

No.  
For the 2x6 wall, there’s now simply a larger difference between the higher R-value wall assembly and the rim joist R-value, which has remained the same.
Section 2 – Common Linear Thermal Bridges

Is the psi value really an indicator of a detail’s thermal quality?
Is the psi value really an indicator of a detail’s thermal quality?
Yes and no.

At structural thermal bridges, a psi value is a comparison between the U-value of the assembly(ies) and the U-value of the junction. A junction detail that “passes” (0.01 W/mK) for one assembly may not pass with another.
Section 2 – Common Linear Thermal Bridges

2x6 wall, no studs: $\Psi = -0.058 \text{ W/mK}$

2x6 wall, 2-stud: $\Psi = -0.040 \text{ W/mK}$

When is a performance comparison valid?
When the two models being compared have the same assemblies and the same geometry - the only difference is at the junction. Example above.
Section 2 – Common Linear Thermal Bridges

- Thermal bridge at the foundation is typically the most challenging to address.
- The concrete stem wall and FPSF footing acts as a radiation fin.

**STEP 4 – Avoid accidental “radiation fins”**.
Section 2 – Common Linear Thermal Bridges

FPSF (well insulated): $\Psi = 0.013 \text{ W/mK}$

FPSF: $\Psi = 0.160 \text{ W/mK}$

Thick layers of continuous insulation can improve the performance of the detail, but even a very well insulated FPSF is still close to the 0.01 W/mK limit.

STEP 4 - Avoid accidental radiation fins - even well-insulated ones
Section 2 – Common Linear Thermal Bridges

Thermally broken stem wall provides an insulated break between the stem wall and the floor slab, effectively cutting off the “radiation fin”.

Aligning exterior insulation layers at junction of stem wall and above grade wall also helps!

STEP 5 – An insulated break between the exterior wall and floor slab works best.
Section 2 – Common Linear Thermal Bridges

ICF parapet: $\Psi = 0.200 \text{ W/mK}$

Foamglas thermal break: $\Psi = -0.071 \text{ W/mK}$

Another good location to cut off the radiation fin.
Section 2 – Common Linear Thermal Bridges

Window positioned outside of thermal envelope, $\Psi = 0.10$ W/mK
Effectively, R-value of window reduced by 20 - 30% depending on window size

Window positioned on edge of thermal envelope, $\Psi = 0.04$ W/mK
R-value of window reduced by 5 - 10% depending on window size
Window centered in plane of insulation, $\Psi = 0.02$ to $0.03$ W/mK
R-value of window is almost preserved
Break
Section 3 – Using psi values in PHPP

How do I know which thermal bridges need to be modeled and entered in PHPP?
Section 3 – Using psi values in PHPP

How do I know which thermal bridges need to be modeled and entered in PHPP?

PHI requires 1 of 2 paths:
1) Model all thermal bridges, enter psi values for both + and -
2) Model and enter only thermal bridges with psi values over 0.01 W/mK

Path 2 begs the question – how do I know which TBs will be over 0.01 W/mK, before I’ve modeled them?

Image source:
http://www.theblaze.com/blog/2013/01/24/finally-the-answer-sort-of-for-what-came-first-the-chicken-or-the-egg/
Section 3 – Using psi values in PHPP

Eaves:
Most details will have negative psi value

Rim joist:
Almost always positive psi value - MODEL.

Wall to slab/footing:
Only well-designed details will have negative psi value - MODEL

Roof ridge:
Most details will have negative psi value

Footing below bearing wall or post:
Only well-designed details will have psi value < 0.01 W/mK - MODEL
Section 3 – Using psi values in PHPP

Rake: Most details will have negative psi value

Window/door sill on slab: MODEL, BUT... Can be entered as a window sill TB + wall-to-slab TB (requires two separate psi values)

Window head: If overinsulated, probably no need to model. If not – MODEL

Window sill: Almost always positive psi value since overinsulation is difficult – MODEL
Section 3 – Using psi values in PHPP

Exterior corner: Most details will have negative psi value

Interior corner: Almost always positive psi value – MODEL

Window jamb: If overinsulated, probably no need to model. If not – MODEL

Wall junction: If insulation layers are interrupted - MODEL
Section 3 – Using psi values in PHPP

Other places to keep in mind for possible thermal bridges
• Plumbing stacks
• Rain pipes (interior)
• ERV vent penetrations (to the exterior)
• Sump pumps
• Radon remediation pipes (if interior to the building)
Section 3 – Using psi values in PHPP

<table>
<thead>
<tr>
<th>No.</th>
<th>Thermal bridge - denomination</th>
<th>Group No.</th>
<th>Assigned to group</th>
<th>Quantity</th>
<th>Length [m]</th>
<th>Subtraction length [m]</th>
<th>Length [m]</th>
<th>User determines ( \Delta )Wert [W/(mK)]</th>
<th>User determined ( \Delta x_{\text{ref},0.25} ) (optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TB rim joint</td>
<td>15</td>
<td>Thermal bridges Ambient</td>
<td>1</td>
<td>52.38</td>
<td>-</td>
<td>52.38</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Plumbing vent stack</td>
<td>15</td>
<td>Thermal bridges Ambient</td>
<td>1</td>
<td>1.00</td>
<td>-</td>
<td>1.00</td>
<td>0.120</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| A   | Thermal bridges Ambient       | 15        | 53.38              | m        |
| P   | Perimeter thermal bridges     | 16        | 0.00               | m        |
| B   | Thermal bridges FS/BC         | 17        | 0.00               | m        |

CertiPHIers®
Section 3 – Using psi values in PHPP

### A tool for thermal bridge conversion to exterior dimensions

<table>
<thead>
<tr>
<th>psi Interior dimensions</th>
<th>W/(m·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Diff. TB</td>
<td>K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjacent area I</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Diff. Δθ I</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>Exterior - Interior Dim.</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>U-Value building assembly I</td>
<td>W/(m²·K)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjacent area II</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Diff. Δθ II</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>Exterior - Interior Dim.</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>U-Value building assembly II</td>
<td>W/(m²·K)</td>
<td></td>
</tr>
</tbody>
</table>

| Y Exterior Dimensions   | W/(m·K) |

### Auxiliary calculation rain water pipes

<table>
<thead>
<tr>
<th>Nominal width:</th>
<th>100 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insul. thickness:</td>
<td>50 mm</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>0.040 W/(m·K)</td>
</tr>
<tr>
<td>Interior pipe diameter:</td>
<td>0.100 m</td>
</tr>
<tr>
<td>Exterior pipe diameter:</td>
<td>0.200 m</td>
</tr>
<tr>
<td>α-Surface</td>
<td>6.80 W/(m²·K)</td>
</tr>
<tr>
<td>ψ′-value</td>
<td>0.285</td>
</tr>
<tr>
<td>Reduction factor</td>
<td>0.64</td>
</tr>
</tbody>
</table>

ψ′-value 0.182 W/(m·K)  
To enter as group 15 thermal bridge
Section 3 – Using psi values in WUFI Passive