Thermal Bridges and Deep Energy Retrofit

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Agenda

• Introduction

• Army Facilities and Thermal Bridges

• Impact

• Energy loss Mitigation Catalog

• Construction detail sequencing examples

• Conclusion
Introduction
Intro: The Thermal Bridge Issue

- Occurs when a material provides a thermal path that bypasses insulation
- Leads to expensive problems
- Difficult to quantify in models
- Large inventory of Army buildings suffers from it
Definition

Part of the building envelope where the otherwise uniform thermal resistance is significantly reduced by:

- **a)** full or partial penetration of the insulating layers by materials with a different thermal conductivity

- **and/or**

- **b)** a change in thickness of the insulating layers

- **and/or**

- **c)** a difference between internal and external areas, such as occurs at wall/floor/ceiling junctions.
Types of Thermal Bridges

Clear Field

\[ U_o \]

Linear

\[ \Psi \]

Point

\[ \chi \]
Army Facilities and Thermal Bridges
Building weak spots: Thermal bridging locations

Details of Minor Magnitude
1. Wall Corner – Never Usually an Issue
2. Threshold or Door
3. Duct and Service Connections
4. Penetrations at Installations in Roof; PV or Water Tanks

Details of Major Magnitude
1. At Eaves/Ridge
2. Window and Door Fitting – Head, Sill and Jamb
3. At Projections, Shades Or Intermediate Floors
4. Internal Walls to External Walls
5. Intermediate Floors
6. At Grade
Main Offenders

1. At Walls/Roof
2. Window and Door Fitting – Head, Sill and Jamb
3. At Projections, Shades Or Intermediate Floors
4. Internal Walls to External Walls/Roof
5. Intermediate Floors
6. At Grade
Thermal Bridges via IR Imaging

Dinning facility
Thermal Bridges via IR Imaging

Army Reserve Center
Thermal Bridges via IR Imaging

Barracks
Thermal Bridges via IR Imaging

Battalion HQ
Thermal Bridges via IR Imaging

Tactical Equipment Maintenance Facility
Impact
### Quantified Impact: Studied Barracks Building

<table>
<thead>
<tr>
<th>Window Connections</th>
<th>Foundation</th>
<th>Intermediate Slabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head (ft)</td>
<td>502</td>
<td>764</td>
</tr>
<tr>
<td>Sill (ft)</td>
<td>502</td>
<td>764</td>
</tr>
<tr>
<td>Jamb (ft)</td>
<td>840</td>
<td></td>
</tr>
<tr>
<td>Affected Length</td>
<td>502</td>
<td></td>
</tr>
<tr>
<td>Thermal Bridge</td>
<td>0.308</td>
<td>0.360</td>
</tr>
<tr>
<td>Transmittance</td>
<td>0.180</td>
<td>0.486</td>
</tr>
<tr>
<td>(Btu/hr-ft-°F)</td>
<td>0.322</td>
<td></td>
</tr>
</tbody>
</table>

Quantified Impact: Studied Barracks Building

Energy spent due to thermally bridged regions

Thermal Bridging Losses (MMBtu/yr)

- Window Connections: 85.98 MMBtu/yr
- Building Foundation: 27.02 MMBtu/yr
- Intermediate Floor Slabs: 85.60 MMBtu/yr
Energy loss Mitigation Catalog
Thermal Bridge Mitigation Catalog

• Easy to use; condensed guidance for good practices

• Provides building envelope recommended Army construction details.

• Include existing construction practice and corrected architectural drawings.

• Emphasizes the continuity of the tri-barrier envelope system
Thermal transmission reduction resulting from proposed thermal bridge mitigation method. Detailed results are located in the Thermal Performance table.
At Grade Stem Wall
CMU or Concrete Wall with Interior Insulation

Notes
Below grade insulation can be expanded polystyrene or extruded polystyrene. This finish can be cement-based stucco with corrosion-resistant reinforcement, metal or PVC sheets. An aesthetically appealing finish is also often desired.
In case of damp or irrigated landscaping, a dampproofing layer should be attached to the foundation before placing the insulation.
Insulation requires impact protection, and, in the case of foam plastics, ultraviolet radiation. Appropriate protection can be selected based on stucco with corrosion resistant mesh (polymer-modified reinforced with glass fiber), synthetic stucco and cement board materials. Foam insulation can act as a protected pathway for termite access, and hence appropriate flashing, and terminicles should be employed.
The exterior insulation top can be covered using a metal flashing by inserting into a reglet cut into the wall. The thermal performance of this detail can be further increased by increasing the thickness of the insulation and covering more of the exterior, as well as by adding a skirt around the perimeter to reduce losses to the soil.
The reported Ψ-value does not include thermal effects associated to the insulation protection or the top metal flashing.

Existing Stem Wall

- External Stucco
- CMU Block
- Interior Plaster
- Insulation Bay with Steel Stud
- Gypsum Board

Reinforced 30MPa Concrete
Crushed Stone
Vapor Barrier
Existing XPS Insulation

Proposed Solution

Bestcase Thermal Performance*
ΔΨ=0.304 W/MK

Metal Flashing Cap
Exterior XPS Insulation
Insulation Cover
Damp Proofing Membrane

Air, Liquid, Vapor Control Layer
External Stucco
CMU Block
Interior Plaster
Insulation Bay with Steel Studs
Gypsum Board
Metal Flashing Cap
Exterior XPS Insulation
Vapor Barrier
Insulation Cover
Damp Proofing Membrane
Reinforced 30MPa Concrete

Close up
Quality Control/Sequencing
1. Excavate around the entire building perimeter until reaching the foundation footing.
2. Dry-clean the exposed surfaces of the foundation wall and footing and/or remove any other surface debris.
3. In the case of high moisture content soil or irrigated landscaping, apply a dampproofing material layer to prevent water infiltration.
4. Measure and cut the selected external foundation insulation to size ensuring it will wrap the entire foundation footing and wall. This should extend from the foundation footing above grade.
5. Use adhesive to attach the selected exterior insulation to the foundation wall.
6. Use protective or cover over the foundation insulation.
7. Install flashing above the insulation by inserting through the reglet cut, making sure to entirely cover the selected insulation.

### Table of Modeling Values

<table>
<thead>
<tr>
<th>Component</th>
<th>Thickness (in)</th>
<th>Conductivity (Btu/h·ft·°F/W/m·K)</th>
<th>Nominal Insulation Thickness (in)</th>
<th>Density (lb/ft³) (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior Film (inside)</td>
<td>-</td>
<td>-</td>
<td>R-0.74 (0.21 RSI)</td>
<td>-</td>
</tr>
<tr>
<td>Internal Film (outside)</td>
<td>-</td>
<td>-</td>
<td>R-0.91 (0.17 RSI)</td>
<td>-</td>
</tr>
<tr>
<td>External Stucco</td>
<td>1 1/2 (25)</td>
<td>0.809 (1.4)</td>
<td>R-0.10 (0.01 RSI)</td>
<td>115 (1855)</td>
</tr>
<tr>
<td>CMU</td>
<td>7 5/8 (194)</td>
<td>0.069 (1.2)</td>
<td>R-0.816 (1.61 RSI)</td>
<td>120 (2000)</td>
</tr>
<tr>
<td>Interior Plaster</td>
<td>5/8 (19)</td>
<td>0.069 (1.4)</td>
<td>R-0.06 (0.014 RSI)</td>
<td>115 (1855)</td>
</tr>
<tr>
<td>Insulation Bay with Steel Studs</td>
<td>6 1/8 (184)</td>
<td>0.069 (1.4)</td>
<td>R-0.816 (1.61 RSI)</td>
<td>120 (2000)</td>
</tr>
<tr>
<td>Gypsum Board</td>
<td>1 1/2 (33)</td>
<td>0.092 (1.6)</td>
<td>R-0.8 (0.08 RSI)</td>
<td>50 (800)</td>
</tr>
<tr>
<td>Exterior XPS Insulation</td>
<td>3 1/2 (89)</td>
<td>0.0187 (0.029)</td>
<td>R-0.372 (0.3 RSI)</td>
<td>1.8 (28)</td>
</tr>
<tr>
<td>Reinforced 30MPa concrete</td>
<td>1.0 (2.4)</td>
<td>-</td>
<td>-</td>
<td>1.0 (2.4)</td>
</tr>
<tr>
<td>Existing XPS Insulation</td>
<td>2 1/2 (63)</td>
<td>0.069 (1.4)</td>
<td>R-0.39 (0.068 RSI)</td>
<td>150 (2400)</td>
</tr>
<tr>
<td>Crushed Stone</td>
<td>2 1/2 (63)</td>
<td>0.0245 (1.6)</td>
<td>R-0.45 (0.079 RSI)</td>
<td>126 (2000)</td>
</tr>
<tr>
<td>Exterior Film (Wall)</td>
<td>-</td>
<td>-</td>
<td>R-0.25 (0.04 RSI)</td>
<td>-</td>
</tr>
<tr>
<td>Exterior Film (Floor) Temp 50°F</td>
<td>10°C</td>
<td>-</td>
<td>R-0.00 (0.00 RSI)</td>
<td>-</td>
</tr>
</tbody>
</table>
Notes
The insulation choice is often limited to products that can resist moisture, some wind, meet fire codes, etc. Thus the choices tend to be foam plastics with some fire resistance and board insulation of EPS, XPS, and semi-rigid stone wool boards.

Adding at least 2" of interior insulation along the interior ceiling will reduce the heat flow through the parapet section. Naturally, interior building access will be required.

The thermal performance results incorporate the effects associated with the interior and exterior film coefficients, metal cap flashing and roof finish material.

The thermal performance can be further augmented by increasing the insulation thickness and covering more or all the exterior. Thermally-breaking the heat flow by replacing the parapet base support CMU with a low thermal conductivity block will provide the best thermal best parapet thermal performance.

Table of Modeling Values

<table>
<thead>
<tr>
<th>Component</th>
<th>Thickness (mm)</th>
<th>Conductivity (W/m K)</th>
<th>Nominal Resistance (1/m K)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-0.7 (0.12 RSI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsum Board</td>
<td>1/2&quot; (13)</td>
<td>0.0003 (0.16)</td>
<td>R-0.0.023 (0.020 RSI)</td>
<td>50 (0.005)</td>
</tr>
<tr>
<td>1 5/8&quot; x 1 5/8&quot; Steel Studs (16&quot; v.c) with Top Tracks</td>
<td>1.5&quot;-2.0&quot; (41)</td>
<td>0.0003-0.0005 (0.16-0.18)</td>
<td>-</td>
<td>50 (0.005)</td>
</tr>
<tr>
<td>Air in Stud cavity</td>
<td>1 5/8&quot; (41)</td>
<td>-</td>
<td>R-0.9 (0.16 RSI)</td>
<td>0.075 (1.2)</td>
</tr>
<tr>
<td>Concrete Wall</td>
<td>8’ (243)</td>
<td>0.04 (1.8)</td>
<td>-</td>
<td>140 (2250)</td>
</tr>
<tr>
<td>Water Resistive Barrier Adhesive</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Insulation Board</td>
<td>4’ (122)</td>
<td>0.023 (0.039)</td>
<td>R-0.15 (2.64 RSI)</td>
<td>1.1 (16)</td>
</tr>
<tr>
<td>Lamina</td>
<td>1.5” (4)</td>
<td>0.02 (0.8)</td>
<td>R-0.04 (0.015 RSI)</td>
<td>120 (1972)</td>
</tr>
<tr>
<td>Concrete Slab &amp; Parapet</td>
<td>8” (203)</td>
<td>0.04 (1.8)</td>
<td>-</td>
<td>540 (2250)</td>
</tr>
<tr>
<td>Roof Insulation</td>
<td>4’ (122)</td>
<td>-</td>
<td>R-0.20 (3.5 RSI)</td>
<td>1.8 (28)</td>
</tr>
<tr>
<td>Parapet Insulation</td>
<td>1” (25)</td>
<td>-</td>
<td>R-0.6 (0.58 RSI)</td>
<td>1.8 (28)</td>
</tr>
<tr>
<td>Parapet Insulation – Fully Insulated</td>
<td>3’ (91)</td>
<td>-</td>
<td>R-1.15 (2.64 RSI)</td>
<td>1.8 (28)</td>
</tr>
<tr>
<td>Wood Blocking</td>
<td>5/8” (16)</td>
<td>0.052 (0.09)</td>
<td>R-3.1 (1.8 RSI)</td>
<td>27.8 (440)</td>
</tr>
</tbody>
</table>

Quality Control/Sequencing
1. Remove the parapet metal cap (also known as the parapet coping)
2. Remove the parapet wood blocking
3. Remove the roof covering (asphalt, roofing membrane, etc.) to expose the roof insulation
4. Add rigid insulation to the rear vertical face of the parapet. This vertical piece of insulation must have contact at its bottom with the roof insulation (they should maintain continuity). The attached vertical insulation should be able to reach the top of the parapet.
5. Add rigid insulation on the top section of the parapet. Make sure that it is contiguous with the insulation placed in the rear vertical face of the parapet and the front (already in place) exterior insulation board of the wall.
6. Replace the entire previously removed roof covering, so that continuous protection to both the roof and the parapet is restored
7. Re-attach the wood blocking
8. Re-attach the parapet metal cap
Window Sill
Steel Stud Wall with Interior & Exterior Insulation

Notes
Key to the success of this detail is ensuring good structural attachment of the window and alignment of the window thermal bridge. Every window section is likely to have a slightly different solution, but all will have clear water and air control layers identified and continuous. Designers will also need to complete the exterior clamping to ensure that the insulation and the air/water control layers are not visible and are protected from sun and direct rain impingement. It is also critical that the head flashing provide air sealing and direct water outwards.

Polymeric self-adhered membranes are nonconductive and can be used to connect the water control layer on the face of the wall to the metal flashing. This approach must ensure that the polymeric flashing does not sag due to unsupported flashing, which can trap water within the wall.

The hollow space in open window frames will promote an undesired natural convective heat flow. This can be reduced by filling voids with factory installed, custom-shaped foam plastic or rigid stone wool sections.

Often an overlooked principle, aligning the thermal control part of the window frame with the thermal control layer of the wall, is important to avoid cold-weather condensation and thermal. In aluminum-framed windows, the thermal break provides a clear indication of the thermal control layer. For fiberglass, vinyl-, and wood-framed windows, the thermal resistance of the frame is more uniform, hence thermal control layer alignment is enhanced (as the frame is wider than the thermal break).

**Table of Modeling Values**

<table>
<thead>
<tr>
<th>Component</th>
<th>Thickness (inches)</th>
<th>Conductivity (Btu/hr•ft•°F/W)</th>
<th>Nominal Resistance (r2•ft•°F/Wu)</th>
<th>Density (lb/ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Sill</td>
<td>3.4 (86)</td>
<td>0.74</td>
<td>1.02</td>
<td>110</td>
</tr>
<tr>
<td>Brick</td>
<td>3.5 (90)</td>
<td>0.57</td>
<td>0.95</td>
<td>100</td>
</tr>
<tr>
<td>Air Cavity</td>
<td>2' (61)</td>
<td>0.12</td>
<td>0.23</td>
<td>120</td>
</tr>
<tr>
<td>Insulation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Cavity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sill Finish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber</td>
<td>1.5 (38)</td>
<td>0.03</td>
<td>0.05</td>
<td>252</td>
</tr>
<tr>
<td>Steel Studs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rockwool Insulation (1&quot;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rockwool in Sill Studs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsum Board</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&quot; (25)</td>
<td>0.062</td>
<td>0.18</td>
<td>0.16</td>
<td>50</td>
</tr>
</tbody>
</table>

**Proposed Solution**

**Thermal Performance**

- **Bestcase Thermal Performance**: \( \Delta \psi = 0.383 \text{ W/MK} \)

**Quality Control/Sequence**

1. Remove old window reveals and necessary CMU blocks, sill, and up to 8 courses of bricks around window.
2. Fasten treated timber block to CMU around window opening, seal corners with self-adhesive membrane, connect with air/water membrane.
3. Install backdam anchor to all 4 sides of reveal over installed plywood.
4. Replace 1" rigid insulation on top of wood back. This insulation should have a 45° slope for drainage.
5. Place lintel over window hole and add sidedam to lintel sides.
6. On top of window opening, connect wall sheathing air/water barrier and window lintel. Attach self-adhesive membrane barrier from the top exposed wall down to the lintel.
7. Replace the complementary 1" rigid insulation from step 4, but ensure 45° angle is located at the bottom edge of insulation. It must also make contact with membrane barrier.
8. Replace concrete brick sill and bricks.
9. Apply sealant to reveal onto backdam anchor and install window against seal and backdam.
Construction detail sequencing examples

Different materials, different ways to “do the stuff”
Material Alternatives: At Grade Solutions for Structural Thermal Breaks

Aerated Concrete (courtesy of Aercon)

Foam Glass (courtesy of Perinsul)

EPS Concrete (courtesy of Bremat)

Foam Glass Gravel (courtesy of Perinsul)

Foam Glass (courtesy of Perinsul)
Material Alternatives: Readily Available Low Conductivity Structural Breaks

PU structural thermal break (image courtesy of General Plastics)

PVC Structural thermal break (image courtesy of Armatherm)

Wood – courtesy of the forest 😊
Design Solutions for Structural Thermal Breaks

As per structural e.g. 36” to 48” (900 to 1200 mm) o.c.

Gap ≤ bolt diameter
Base plate
W-section beam
Weld
Cast-in plate
Concrete slab
Attachment Clips for Cladding and Finishing Systems

Rubber pad connections used as thermal breaks (generic solution)

Reduced steel shelf angle support (courtesy of Fero)

Rubber pad connections used as thermal breaks (generic solution)

Thermally broken connections (image courtesy of Cascadia)
Mitigation Strategy: Wrapping

0.428 BTU/hr.ft.F

0.039 BTU/hr.ft.F

90%
Mitigation Strategy: Thermal Breaking

0.247 BTU/hr.ft.F

0.006 BTU/hr.ft.F

100%
Mitigation Strategy: Correct Window Fitting

(image courtesy of Building Science Corporation)
Mitigation Strategy: Correct Window Fitting

(image courtesy of Building Science Corporation)
Construction detail sequencing examples

Different materials, different ways to “do the stuff”
Parapet with Concrete Roof
Parapet with Concrete Roof

Old Junction

Option 1: Insert thermal break

Option 2: Wrap the parapet
Option 1: Insert thermal break

CMU Wall at Parapet

Problem:
Discontinuity of insulation between wall and roof
Option 1: Insert thermal break

Step 1 requires the removal of the parapet capping
Option 1: Insert thermal break

Next, remove flashing and roofing asphalt to expose the CMU parapet
Option 1: Insert thermal break break

The roofing asphalt will have to be removed sufficiently to expose the insulation.
Option 1: Insert thermal break

Cut back and remove some of the roof insulation

The CMU parapet is now fully exposed
Option 1: Insert thermal break

Remove brick veneer until insulation is exposed
Option 1: Insert thermal break

Next, remove top insulation board
Option 1: Insert thermal break break

Next, remove top insulation board to expose the wall to roof junction.
Option 1: Insert thermal break

Remove the CMU parapet
Option 1: Insert thermal break

Remove the CMU parapet
Option 1: Insert thermal break

Add an air tightness barrier whilst the parapet is removed
Option 1: Insert thermal break

Add a course of AAC blocks

Anchor bolts or structural dowels should be added if needed to reinforce the junction
Option 1: Insert thermal break

Extend external insulation to provide complete overlap with newly inserted thermal break.
Option 1: Insert thermal break

Reinstall insulation on the roof to abut the inserted thermal break

The wall and roof insulation are now “thermally connected”
Option 1: Insert thermal break

The exterior brick veneer can now be replaced
Option 1: Insert thermal break

The exterior brick veneer can now be replaced
Option 1: Insert thermal break

Add roof covering waterproof layers
Option 1: Insert thermal break

Finally, replace parapet capping
Option 1: Insert thermal break

Old Junction: 0.247 BTU/hr.ft.F

New Junction: 0.010 BTU/hr.ft.F
Option 2: Wrap the Parapet

CMU Wall at Parapet

Problem:
Discontinuity of insulation between wall and roof
Option 2: Wrap the Parapet

A

B

C

D

E

F
Option 2: Wrap the Parapet

Old Junction:

New Junction:
Parapet with Concrete Roof

Old Junction

Option 1: Insert thermal break

Option 2: Wrap the parapet

0.247 BTU/hr.ft.F

0.010 BTU/hr.ft.F

0.039 BTU/hr.ft.F
At Grade Transition/ Building Foundation

At Grade Transition
At Grade Transition/ Building Foundation
At Grade Transition/ Building Foundation

The remaining soil can then be added.

This may also be an opportunity to add a gravel drain depending on site conditions.
Steel Stud Building Windows

Window Head, Jamb and Sill
Steel Stud Building Windows

No thermal break in the existing window will cause very high losses.

Thermal bridge result will be dubious as there is huge losses from the frame itself.

Condensation may occur on the inside of this frame in cold weather.

0.403 BTU/hr.ft.F
Steel Stud Building Windows

A 1.5” thick timber break can be used to bridge the insulation layer to the thermal break in the window.

0.045 BTU/hr.ft.F
Steel Stud Building Windows

A  B  C  D  E  F  G.1  G.2  H.1  H.2  I  J  K
Steel Stud Building Windows
Thus the detail is complete
Summary

• Thermal bridges are liable to occur where a path between the two sides of the building envelope is present.
• Infra-red (IR) reveled opportunities for that Army facilities improvements.
• Overall TB impact varies from building detail.
• The mitigation catalog provides potential energy solution
• Next steps: incorporate catalog recommendations in future Army guidelines
Acknowledgments

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