Inside and Out: Insulating Our Existing Masonry Buildings

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Curated by Jodi Smits Anderson

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In the Northeast, we have the benefit and burden of a large stock of uninsulated masonry buildings of various typologies and conditions. Leaving these buildings as they are is untenable with the global effort to reduce carbon emissions, and will not address climate shifts, the fabric of community, or the health of occupants. We will explore insulating from the interior, exterior, or both. In all cases the approach and design must be informed by retrofit feasibility, durability and toxicity of materials, installation cost, embodied carbon, emissions, labor capabilities, and overall envelope performance including freeze/thaw damage.
Learning Objectives

1. Employ design concepts that promote reliable and durable solutions for upgrading thermal performance existing masonry walls

2. Explain how air sealing and vapor control affect the performance of historic masonry enclosures when insulting from inside

3. Identify and address constraints that inform the decisions in the design process for insulating existing masonry walls

4. Summarize current code considerations informing different solid masonry retrofit options
Introduction
What is “High Performance”? 

User Priorities / Concerns:
1. Comfortable
2. Healthy
3. Energy Efficient
4. Resilient
5. Affordable
6. Aesthetically pleasing

Masonry Priorities / Concerns:
1. It wants to be dry
2. It wants to be seen
Issues

**Building type:**
- Tower in the park
- Within a street

**Exterior**
- Long term maintenance / FISP
- Structure issues
- Code requirements
- Zoning
- Change image

**2022 Building Code:**
- Requires firestopping of combustable material in facades.

**Interior**
- Loss interior space
- Code requirements
- Thermal breaks
- SHPO standards (3 ½”)
- Covers lead paint
Insulation Options

Interior Insulation

Exterior Insulation

Recladding

Overcladding
Masonry Walls – Four Barriers
Contemporary vs. Masonry Walls

Very good - Waterproofing

BARRIER 1 (Waterproofing)

Decent to very poor – absorptive brick (No waterproofing)

Lightweight + Multilayered

Mass + Monolithic
Facade Forms / Functions – Managing Water!

- Projecting bandcourses, ledges, window hoods and sills; gutters = Functional – not just decorative

![Typical facades in Rome](image1.jpg)

![Detailed facade](image2.jpg)

![Planar facade](image3.jpg)
Facade Forms / Functions – Managing Water!

- Projecting bandcourses, ledges, window hoods and sills; gutters = Functional – not just decorative
- Material choices = compatible masonry and mortar (good maintenance – regular repointing)
Contemporary vs. Masonry Walls

**Very good - Waterproofing**

**Insulation (R12+)**

**Vapor Retarder (0.06 perms)**

**Airtight (0.004 cfm/sf)**

**Lightweight + Multilayered**

**Decent to very poor – absorptive brick**  
(No waterproofing)

**Poor – conductive R2**

**Flow through - permeable**  
(0.7 perms)

**Very poor - leaky**  
(0.25 cfm/sf)

**Mass + Monolithic**
Code Issues
New Building Code (In effect 11/7/2022)

Buildings bulletin 2022-013

BC 718.2.6.1.1 requires noncombustible fireblocking at the following locations:
1. Around wall openings;
2. At the floor level for a height of not less than 8 inches;
3. Between different occupancy groups, vertically or horizontally as applicable. BC 1406.2.3 for combustible exterior wall coverings

Covered in the following sections
- BC 1407.16 for MCM
- BC 1408.7 for EIFS
- BC 1409.16 for HPL
- BC 2603.5.5.1 for foam plastic insulation
- BC 2613.5 for FR
Zoning Resolution

12-10 – DEFINITIONS

Not Floor Area

(12) exterior wall thickness, up to eight inches:

i. where such wall thickness is added to the exterior face of a building wall existing on April 30, 2012, provided the added wall thickness has a thermal resistance (R-value) of at least 1.5 per inch

However:

• If residential still have to comply with the Multiple Dwelling Law.
• You are not permitted to go over a property line at a party wall
• Landmarks may limit what you can do
• The thinnest panels we have found are 8.5” (typically 8 to 12”)

This may change with the City of Yes Zoning changes. Sustainable changes are expected to be certified on Earth Day
Exterior Insulation
Harlem River II overcladding

Before

After
Notes:
1) Provide continuity of roof membrane along back of parapet with base coat for air barrier continuity and verify compatibility of roof membrane if in contact with base coat.
2) Completely insulate back side of parapet if necessary to prevent condensation within parapet based on climate conditions.
3) Provide minimum 2.5 inch (63mm) overlap of parapet cap over face of StoTherm®; increase overlap with building height.

IMPORTANT: Components not illustrated as this is a functional sketch and may not represent full product details. Always consult the product data sheet and installation document.
Exterior Insulation

Exterior Panels
Panel make up

01 High thermal and acoustical performance steel reinforced polymer windows

02 Non-combustible stone wool insulation

03 Powder coated aluminum cladding

04 Sheet metal vapor barrier

03 High performance gaskets for a dry connection

06 Non-combustible vapor permeable sheathing, includes weather and water protection layer
Image 3 is a 3-D image of the typical panel that was modeled in Heat3. The typical panel size was modeled as 7.6" wide (or 90") and 10' high (or 120'). These dimensions were provided based on the expected horizontal and vertical spacing of the joints. The horizontal spacing of the vertical purlins are 24", for a total of three in the main cavity in addition to the two at the joint.

HEAT3 MODELING RESULTS

The results of the Heat3 modeling are summarized in table 1 and figure 1. Cases 1.0 through 4.0 represent each of the four thicknesses of exterior insulation modeled with interior insulation. Cases 1.1 through 4.1 are the same but without interior insulation. The final two cases (Code 1 and 2) were modeled to compare the R-Value requirement to the corresponding U-Value requirement for DC and Philadelphia (Code 1) and New York City (Code 2).

The red text in figure 1 indicates that the U-Value does not meet energy code in any of the three cities evaluated. Blue text indicates that DC and Philadelphia are met, and green text indicates all three cities are met.

Table 2: Heat3 modeling results for all cases.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>U Value (Btu/hr-ft²F)</td>
<td>R Value (ft²°F/Btu)</td>
<td>U Value (Btu/hr-ft²F)</td>
<td>R Value (ft²°F/Btu)</td>
<td>U Value (Btu/hr-ft²F)</td>
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<tr>
<td>Case 1.0</td>
<td>6</td>
<td>2</td>
<td>0.0431</td>
<td>22.2</td>
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<td>Case 2.0</td>
<td>6</td>
<td>2</td>
<td>0.0373</td>
<td>26.8</td>
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<tr>
<td>Case 3.0</td>
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<td>0.0304</td>
<td>32.8</td>
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<td>Case 1.1</td>
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<td>0.0552</td>
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<td>0</td>
<td>0.0452</td>
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<td>0.0610</td>
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<td>0</td>
<td>0.0384</td>
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<td>Case 1.0*</td>
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<td>2</td>
<td>0.0567</td>
<td>17.6</td>
<td>0.0610</td>
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<td>0.0547</td>
<td>18.3</td>
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<td>Case 3.0*</td>
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<td>0.0503</td>
<td>19.9</td>
<td>0.0610</td>
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<td>0</td>
<td>0.1112</td>
<td>9.0</td>
<td>0.0610</td>
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<tr>
<td>Case 2.1*</td>
<td>6</td>
<td>0</td>
<td>0.0989</td>
<td>10.1</td>
<td>0.0610</td>
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<tr>
<td>Case 3.1*</td>
<td>10</td>
<td>0</td>
<td>0.0893</td>
<td>11.2</td>
<td>0.0610</td>
</tr>
</tbody>
</table>

*These cases were modeled with no perforations in the studs.
Interior Insulation

Thermal Bridging Issues
Interior Approach
Interior Approach
Interior Insulation

Architectural Issues
OPTION 2: R-20.18 (TOTAL: EXISTING+NEW)

TOTAL DEPTH OF NEW ASSEMBLY: 3.3"

<table>
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<tr>
<th>Description</th>
<th>R-value</th>
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<tbody>
<tr>
<td>Outside air film</td>
<td>0.17</td>
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<tr>
<td>4&quot; Brick</td>
<td>0.4</td>
</tr>
<tr>
<td>6&quot; CMU</td>
<td>1.67</td>
</tr>
<tr>
<td>1 3/8&quot; airspace</td>
<td>1</td>
</tr>
<tr>
<td>5/8&quot; plaster</td>
<td>0.39</td>
</tr>
<tr>
<td>1.97&quot; K9 Internal Insulation</td>
<td>14.5</td>
</tr>
<tr>
<td>7/8&quot; Furring Strip (AIR GAP)</td>
<td>0.92</td>
</tr>
<tr>
<td>1/2&quot; gypsum board</td>
<td>0.45</td>
</tr>
<tr>
<td>inside air film</td>
<td>0.68</td>
</tr>
</tbody>
</table>

**Total R-Value:** 20.18  
**Total U-Value:** 0.049554

OUTLET BOXES TO BE SURFACE MOUNTED
*VAPOR/AIR BARRIER TBD BASED ON HYGROTHERMAL ANALYSIS

WOULD COMPLY WITH 2020NYCECC U-VALUE MAXIMUM
Retain existing interior finishes

GWB Finishes
Stud Framing
Insulation
(E) Plaster Finishes
(E) Terracotta Block
(E) Brick Masonry
(E) Air Space

1' - 10 1/2"
6 - 1/2"

1' - 3 1/2"

Remove existing interior finishes
Interior Insulation

Freeze/Thaw and Moisture issues
“Wants” in Conflict

Dryer Brick vs. Wetter Brick

Inefficient/Uncomfortable vs. Comfortable/Efficient

Freeze-Thaw or Mold Damage?
Freeze/Thaw Damage Triangle

Water Absorption (Capillary Suction)

- Water Freezes at ~32°F
- Water expands ~9% when it freezes

Freeze

Over-stressed Condition
“Bad Brick” and Capillary Suction

Well-Fired Brick  Poorly-Fired Brick

Exterior Wythe
Middle Wythe
Interior Wythe
Freeze Thaw Destruction Is A Whole Systems Failure

The masonry must be saturated (95% RH). How did it get saturated?

And the weather must be well below freezing for an extended period.

The Questions Is: How to avoid system failure, and achieve high performance?
Freeze Thaw?
Yes, but not an insulation problem

Freeze Thaw Damage – only at top of wall
Inspect and address the masonry

Pull everything away from the brick

Expose the Problems & Repair

(with possible exception of plaster at party walls)
# Evaluating Brick Properties

<table>
<thead>
<tr>
<th>In-Situ Performance</th>
<th>Brick Durability</th>
<th>Hygric Properties</th>
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<tbody>
<tr>
<td>Observations</td>
<td>ASTM C67 Testing</td>
<td>ASTM C20 Testing</td>
</tr>
<tr>
<td></td>
<td>- Compressive Strength</td>
<td>- Density</td>
</tr>
<tr>
<td></td>
<td>- Absorption</td>
<td>- Porosity</td>
</tr>
<tr>
<td></td>
<td>- Saturation Coefficient</td>
<td>ISO 15148 Testing</td>
</tr>
<tr>
<td>Refiring Method</td>
<td>- Freezing and Thawing</td>
<td>- Free Water Saturation</td>
</tr>
<tr>
<td></td>
<td>- Firing Temperature</td>
<td>- Water Absorption Coefficient</td>
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<tr>
<td>Mercury Intrusion Porosimetry</td>
<td>- Maage Index</td>
<td>ASTM E96 Testing</td>
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<tr>
<td></td>
<td></td>
<td>- Water Vapor Diffusion Resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM C1498 Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Equilibrium Moisture Content</td>
</tr>
</tbody>
</table>
Custom Brick Properties

Bulk Density (ASTM C20)

Porosity (ASTM C20)

Free Water Saturation (ISO 15148)

Reference Water Content (ISO 15148)

Water Absorption Coefficient (ISO 15148)
Uninsulated vs. Insulated Masonry

Face brick ("good")
Common brick ("bad")

Exterior Wythe  Middle Wythe  Interior Wythe

Exterior Wythe  Middle Wythe  Interior Wythe  Closed-cell spray foam  Air Space  Interior Gypsum
Let’s Look At Some Assemblies

Albany, NY

**Insulation:**
Dense-Pack Cellulose
Mineral wool etc

**Outboard:**
Shed water
Windtight
Vapor open

**Inboard**
Airtight
Vapor Retarding

**At Red Dot**
- Moisture load?
- Mold potential?
- Helping or hurting freeze-thaw potential?
WUFI: 4” Fiberglass & Airtight Drywall
4” Cellulose Without Vapor Control
4” Cellulose With Smart Vapor Control
6” Cellulose With Smart Vapor Control
Assessment of RH % on brick/cellulose interface (condensing surface)

Overhangs - Keep it dry

Assessment of masonry

Stays below 80% RH
**Balancing act – heat loss vs masonry health (and interior space)**

<table>
<thead>
<tr>
<th></th>
<th>U-value (w/m²K)</th>
<th>Area</th>
<th>red factor</th>
<th>UA factor</th>
<th>Heat loss %</th>
<th>Areas %</th>
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<tbody>
<tr>
<td>Floor</td>
<td>0.19</td>
<td>142.6</td>
<td>75%</td>
<td>20.3</td>
<td>24%</td>
<td>25%</td>
</tr>
<tr>
<td>Brick wall</td>
<td>0.213</td>
<td>136.7</td>
<td>1</td>
<td>29.1</td>
<td>34%</td>
<td>24%</td>
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<tr>
<td>Larson wall</td>
<td>0.149</td>
<td>93.49</td>
<td>1</td>
<td>13.9</td>
<td>16%</td>
<td>16%</td>
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<tr>
<td>Flat roof</td>
<td>0.111</td>
<td>48.1</td>
<td>1</td>
<td>5.3</td>
<td>6%</td>
<td>8%</td>
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<tr>
<td>Gable walls</td>
<td>0.127</td>
<td>33.34</td>
<td>1</td>
<td>4.2</td>
<td>5%</td>
<td>6%</td>
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<tr>
<td>Pitched roof</td>
<td>0.114</td>
<td>114</td>
<td>1</td>
<td>13.0</td>
<td>15%</td>
<td>20%</td>
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M% check (stay below 15M%)
In 3 exposed orientations (N,E,W)
5” Mineral wool boards + INTELLO Plus (pinned) + service cavity

No thermal bridges, material efficient
5” Mineral wool boards + INTELLO Plus – MONITORED

Omnisense monitoring of inner brick surface (M\%) - 14 months – M\% <18
Interior Insulation

Air Flow Issues
AIR CONTROL

Why is airtightness so important?

It disproportionately affects fundamental aspects of building performance

Order of importance
1. Water control
2. Air control
3. Vapor control
4. Thermal control

Indoor Air Quality
Comfort
Durability
Energy Consumption
Defining the Thermal Envelope / Air Barrier
1. Robust materials
2. Simplify the details
3. Consider the sequence
4. Seal penetrations
5. Repairable and verified
6. Protected
Air Control

To optimize insulation **surround it** with airtightness on all 6 sides.

- Primary Inboard
- Secondary Outboard (windtight)

[Diagram showing air control and insulation strategies]

Ref: [http://passiv.de/passivmedia_en](http://passiv.de/passivmedia_en)
Make Airtight Inboard & Outboard

Optimal Airtightness Is Inboard Of Insulation

It keeps conditioned/humid air away from cold surfaces

Hydrosafe Smart Vapor Control

From vapor closed in winter (0.13 perms – low Class II)

To vapor permeable in summer (13 perms)

Minimizes wetting
Maximizes drying potential

SECTION

EXISTING MASONRY WALL
REPAIR & REPOINT AS
REQUIRED TO SHED WATER AT
EXTERIOR FACE

EXISTING MASONRY WALL
REPAIR & REPOINT AS
REQUIRED TO SHED WATER AT
EXTERIOR FACE

PROVIDE SUFFICIENT GAP
BETWEEN MASONRY AND
TIMBER CONSTRUCTION

MASONRY TREATMENT/SECONDARY
AIR BARRIER: REPAIR & REPOINT
AS REQ’D. APPLY VISCONN LIQUID
MEMBRANE OR LIME PLASTER.

PRIMARY AIR BARRIER: INTELLO
PLUS/INTELLO X /DB+ AIRTIGHT
SMART VAPOR RETARDER

SERVICE CAVITY WITH
OPTIONAL BATT INSULATION

2X HORIZONTAL BATTENS
20°0.C.
Make Brick Windtight/Airtight

- Existing lime plaster that is in good condition or new lime plaster can be used as a vapor-open air barrier.
- Repointing/parching might be enough.
- Liquid applied air barrier is a fast and effective airseal. (cost vs speed)
Dangerous **Toxic** ingredients
Unacceptable **fire accelerant**
Global warming potential Installation problems
Unreliable performance

Reversible?

Not optimal.

Woods Hole, MA 2011
Air Control Progression

What is airtight?
(factor of 15 range)

- Historic: 5 ACH50
- 2012 IECC (zones 4-8): 3 ACH50
- US Bldg Science: 1.5 ACH 50
- Passive House Certification: 0.6 ACH 50
THE BLOWER DOOR DOESN’T LIE
Service cavity protects airtight layer
Hidden Condensation Due to Air Flow

Low Pressure

Condensation within wall

Dew point location

High Pressure

Air flow direction
Surface Condensation Due to Air Flow

- Poorly sealed joint
- Condensation (at cold concrete)
- Air Path
- Gap in finishes
Air Flow – Masonry Walls

Precast Concrete Wall
(Cold Surface)

Mass Masonry Wall
(Cold Surface)

CONDENSATION
(at cold surface)
Air Leakage
Floor – Wall Connection
Roof – Wall Connection
Cost
# EIFS Costs

<table>
<thead>
<tr>
<th>INSULATION TYPE</th>
<th>R-VALUE (per inch)</th>
<th>THICKNESS 2&quot;</th>
<th>THICKNESS 3&quot;</th>
<th>THICKNESS 4&quot;</th>
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<tr>
<td></td>
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<td>Dryvit</td>
<td>STO</td>
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<td>EPS</td>
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<td>Wool</td>
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<td>$40</td>
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Note: Prices are estimates from manufacturers. An average between the two manufacturers was used for pricing.
Panel Costs

Interior Costs

<table>
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<th>Interior Insulation</th>
<th>$ / SQ. FT.</th>
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<tr>
<td>Option I</td>
<td>$28 to $32</td>
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<tr>
<td>Option II</td>
<td>$24 to $32</td>
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**Panelized System Cost ($/SQ.FT.)**

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<tr>
<th>INSULATION TYPE</th>
<th>R-VALUE</th>
<th>COST</th>
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<tbody>
<tr>
<td>Mineral Wool</td>
<td>22.1</td>
<td>$66.19</td>
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Conclusions
Determining Risk

- Condition of existing masonry
  - Reflective of quality and ability to withstand new exposure conditions

- Similarity between interior and exterior wythe / face stone
  - Estimate durability based on building history.

- Exposure
  - Review interior and exterior environmental conditions

- Reduce water penetration (mortar, repairs, flashing, etc.)

- Review material properties (mortar and brick)
  - Reliability of hygrothermal analysis results is questionable
  - Test brick masonry samples to determine properties

Exterior

- Protects existing facade
- Reimages the project
- Less resident disruption

Interior

- Covers lead paint
- Requires resident relocation
- Issue of code clearances

EIFS

- No thermal breaks
- Variety of textures
- Lower cost
- More frequent maintenance

Panels

- Choice of material finishes.
- Structural Issues (how do you support)
- Thermal break issues
- Less frequent maintenance
- Higher Costs
Components of High Performance

1. Robust enclosure
2. Quality daylighting
3. Less toxic and more sustainable/low carbon
4. Healthy indoor air quality
5. More predictable and durable
Thank you!
Questions?

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