Retrofits – Mass Buildings
Freeze-Thaw Damage
Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick
Susceptible Brick
Firing Temperature
Vitrification
Kelvin Equation

\[ \ln \frac{p}{p_0} = \frac{2\gamma V_m}{rRT} \]
Calculating capillary rise

\[ h = \frac{2 \sigma \cos \theta}{g \rho r} \]
Capillary rise versus diameter
Surface area vs. particle size
From Straube & Burnett, 2005
Stucco rendering

Masonry wythe

Vertical wood furring

Plaster and lath

Exterior

Interior
Diagram showing a sill with a kerf and a mass wall. Below the sill, there is a sealant drip edge.
Building Science Corporation
1. **Evaporation**

   Water with salt in solution travels in porous material via capillary flow to surface where evaporation occurs.

2. **Salt is left behind as water evaporates; process leads to an ever-increasing concentration of salt as evaporation continues.**

3. **Water rushes to dilute concentration of salt leading to potentially huge hydrostatic pressures.**

4. **“Spalling”**

   Surface breaks apart and flakes when hydrostatic pressure due to “osmosis” exceeds cohesive strength of material.
Diffusion + Capillarity + Osmosis = Problem

- Diffusion Vapor Pressure: 3 to 5 psi
- Capillary Pressure: 300 to 500 psi
- Osmosis Pressure: 3,000 to 5,000 psi
Mortar “eaten” away as drying happens from within the mortar matrix.

Salts left behind on surface in the form of crystals ("efflorescence")

Evaporation from surface film of water

Capillary flow of salts in solution
Lime mortar “eaten” away over time “sacrificing” itself to protect brick and masonry units

Evaporation from thick lime-based mortar rendering

Capillary flow of salts in solution
**Moisture Flow**

- **Dampproofing**
- **Filter fabric**
- **Coarse gravel (no fines)**
- **Perforated drain pipe**
- **Concrete footing**
- **Concrete slab**
- **Polyethylene vapor barrier**
- **Granular capillary break and drainage pad (no fines)**
Capillary break on exterior foundation wall

Capillary break under slab

Capillary break on top of footing
Wood floor framing embedded into masonry wall

Stainless steel cap flashing regletted into exterior wythe

Vapor permeable layer to prevent evaporation or drying inward

1.5 χ

Sacrificial layer

χ

Wood floor framing embedded into masonry wall

Stainless steel cap flashing regletted into exterior wythe

3/4 χ

Stainless steel capillary break regletted 1/3 of wall thickness

Vapor permeable layer to prevent evaporation or drying inward

Sacrificial layer

χ
Multi-wythe mass wall

- Interior lining (gypsum board)
- Interior framing
- Rock wool or Roxul rigid mineral wool insulation
- Fluid-applied water control layer (vapor semi-permeable)
- Cementitious rendering
Multi-wythe mass wall

Interior lining (gypsum board)

Cellulose or fiberglass cavity insulation

Wood frame wall (2x6)

Fluid-applied water control layer (vapor semi-permeable)
Multi-wythe mass wall

Interior lining (gypsum board)

"Strapped wall": horizontal framing

Membrane "smart vapor barrier"

Cellulose or fiberglass cavity insulation

Wood frame wall (2x6)

Fluid-applied water control layer (vapor semi-permeable)

Cementitious rendering
Drainage mat
Spray polyurethane foam
Interior frame
Interior lining (gypsum board)
Concrete “cap”
Extruded polystyrene rigid insulation (XPS)
Wood sheathing subfloor
Crushed stone (no fines)
Interior perimeter drain
Existing concrete slab
Epoxy vapor barrier
Geotextile (filter fabric)
Liquid applied membrane waterproofing

Flanged window

Trim closure

Concrete sill

2x6 wood buck

Exterior wythe (repointed or coated with polymer cement slurry)

Multi-wythe masonry wall

Air seal

1 1/2" rigid insulation

Plywood spacer

1x2 backdam

2" spray applied foam insulation (closed-cell, high-density)

Uninsulated steel stud assembly

Gypsum board
Stucco
<table>
<thead>
<tr>
<th>Stucco Type</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Lime Stucco</td>
<td>Greater than 20 perms</td>
</tr>
<tr>
<td>Lime/Portland Cement Stucco</td>
<td>5 to 10 perms</td>
</tr>
<tr>
<td>Portland Cement Stucco</td>
<td>1 to 5 perms</td>
</tr>
<tr>
<td>Polymer Modification</td>
<td>Less than 1</td>
</tr>
</tbody>
</table>
Horizontal “scoring” provides mechanical bond and “shelf” for water during “wet” curing.
Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

Figure 1b. Brick, sintered clay, porosity 40 per cent.
Ancient Modification Additives
Cow Dung
Egg Whites
Pig Blood
Stainless steel flashing

Reglet

Plaster “filler” for slope

Cladding “offset”
Parapet cap flashing sloping to interior with drip edges

Parapet flashing

Slope

Drip

Plaster “filler” for slope supporting flashing
1x4 wood furring attached through rigid insulation to 2x4 wood furring

2x4 wood furring mechanically attached to masonry wall

Fluid-applied water control layer and air control layer

Cladding

Joints offset horizontally and vertically with each layer taped

Masonry wall

Interior plaster and lath
2" semi-rigid mineral fiber insulation; seams offset horizontally and vertically

2x4 wood furring mechanically attached to masonry wall

Fluid-applied water control layer and air control layer

Metal hat channel

Fiber cement panel

“Reveal” in panel joint

Spacer/joint backer

1 1/2” semi-rigid mineral fiber insulation

Masonry wall

Interior plaster and lath
Plywood or OSB

Fully-adhered membrane

Metal counter flashing

New roof membrane

Plywood or OSB

Metal cap flashing

Existing roof membrane

Fluid-applied water control layer and air control layer
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.
Frost Line
Retrofits – Frame Buildings
3” spray polyurethane foam (2 lb/ft³ density)

1½” metal stud wall

Gypsum board thermal barrier

¾” drainage mat (filter fabric side facing up)

2” extruded polystyrene (XPS)

New concrete slab

Existing slab
Four layers of 2” rigid insulation
Sheathing tape
Wood siding
Membrane strip
1x4 furring strip
Trim
Flashing
Fully-adhered membrane
Plywood
Asphalt shingles
Fully-adhered membrane
Plywood
Tar paper
Board sheathing
Five layers of 2” rigid insulation
New roof deck
New crown molding
New fascia
New soffit
New dentil molding
New second frieze board
Original dentil molding removed
Original frieze board remains
Siding