Building Science

Adventures In Building Science

presented by www.buildingscience.com
Freeze-Thaw Damage
Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick
Susceptible Brick
Firing Temperature
Vitrification
Calculating capillary rise

\[ h = \frac{2 \sigma \cos \theta}{g \rho r} \]

Diagram showing the relationship between capillary pressure \( P_{\text{cap}} \) and height \( h \) with respect to the wetting angle \( \theta \), radius \( r \), surface tension \( \sigma \), density \( \rho \), and gravitational acceleration \( g \).
Capillary rise versus diameter
Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

Figure 1b. Brick, sintered clay, porosity 40 per cent.
2nd Law of Thermodynamics
<table>
<thead>
<tr>
<th>Phase</th>
<th>Transport Process</th>
<th>Driving Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor</td>
<td>Diffusion</td>
<td>Vapor Concentration</td>
</tr>
<tr>
<td>Adsorbate</td>
<td>Surface Diffusion</td>
<td>Concentration</td>
</tr>
<tr>
<td>Liquid</td>
<td>Capillary Flow</td>
<td>Suction Pressure</td>
</tr>
<tr>
<td></td>
<td>Osmosis</td>
<td>Solute Concentration</td>
</tr>
</tbody>
</table>
Capillarity + Salt = Osmosis

- Mineral salts carried in solution by capillary water
- When water evaporates from a surface the salts left behind form crystals in process called efflorescence
- When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence
- The salt crystallization causes expansive forces that can exceed the cohesive strength of the material leading to spalling
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.
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
Exterior wythe (repointed or coated with polymer cement slurry)

Multi-wythe masonry wall

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

Uninsulated steel stud assembly

Gypsum board

Subfloor held away from wall

Timber decking cut back from wall

Plywood subfloor
Building Science Corporation

Joseph Lstiburek

Liquid applied membrane waterproofing

Flanged window

Air seal

1 1/2" rigid insulation

Plywood spacer

Trim closure

Concrete sill

2x6 wood buck

Exterior wythe (repointed or coated with polymer cement slurry)

Multi-wythe masonry wall

1x2 backdam

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

Uninsulated steel stud assembly

Gypsum board
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
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
1½” semi-rigid mineral fiber insulation
Masonry wall
Interior plaster and lath
Plywood or OSB

Fully-adhered membrane

Metal cap flashing

Plywood or OSB

Metal counter flashing

New roof membrane

Plywood or OSB

Existing roof membrane

Fluid-applied water control layer and air control layer
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
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.