Building Science

Adventures In Building Science

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Freeze-Thaw Damage
Freeze-Thaw Damage
Freezing Temperatures
Water
Susceptible Brick
Susceptible Brick
Firing Temperature
Vitrification
Calculating capillary rise

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

\[ P_{\text{cap}} \]

\[ 2r \]

\[ P_0 \]

\[ z \]

\[ \text{ambient pressure} \]

\[ \frac{2 \sigma \cos \theta}{r} \]

\[ \Delta z \]

\[ g \rho \Delta z \]

\[ \text{pressure} \]
Capillary rise versus diameter
Surface area vs. particle size

From Straube & Burnett, 2005
Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

Figure 1b. Brick, sintered clay, porosity 40 per cent.
1. **Evaporation**
   - Water with salt in solution travels in porous material via capillary flow to surface where evaporation occurs.

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

3. **Water Rush**
   - 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
Coping/cap flashing over top of parapet

Embedded wood timber roof structure

Exterior wythe (repointed or coated with polymer cement slurry)

Multi-wythe masonry wall

Fully-adhered membrane roofing extending up interior and over top of parapet wall

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

Timber decking

2" sprayed cellulose fire-proofing ("K-13")

Dropped ceiling structure

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

Uninsulated steel stud assembly

Gypsum board
Multi-wythe mass wall

Interior lining (gypsum board)

Interior framing

Spray-applied polyurethane foam (2 lb/ft³ density)
Multi-wythe mass wall

Cellulose or fiberglass cavity insulation

Wood frame wall (2x6)

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

Interior lining (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
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

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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
From the US Army Corps Engineers Extreme Frost Penetration (in inches) based on state averages.
Frost Line