Assessing the Freeze-Thaw Resistance of Clay Brick for Interior Insulation Retrofit Projects

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Greetings & Recognitions

- Peter Mensinga, M.A.Sc.
  - formerly of Building Engineering Group at University of Waterloo
  - now at Halsall in Toronto
- John Straube, Ph.D., P.Eng.
  - Professor of Architecture & Engineering at University of Waterloo
  - Senior Partner at BSC
- Thanks for support from
  - University of Waterloo
  - US DOE Building America Program

Outline

- A retrofit opportunity
- Old & New retrofit strategies and problems
- Assessing the risk
  - Old approach: graded bricks
  - Proposed new approach: Limit States Design

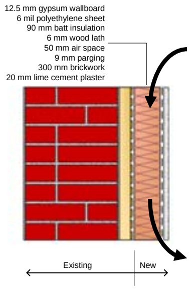
Historic Home Rehab

Institutional Residence Rehab

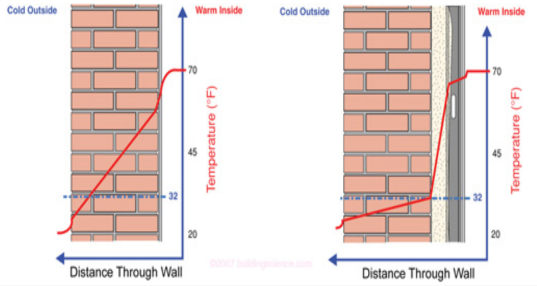
Commercial to MURB Conversion

Industrial to Institutional Office Conversion

Old Retrofit Insulation Strategy



New Retrofit Insulation Strategy



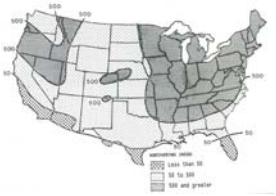
Potential Issues with Insulation Retrofits

- Change in hygrothermal conditions
  - Colder interior surface
  - Reduced drying due to less heat flow
  - Reduced drying due to increased vapor resistance
  - Increased potential for freezing of core & inside layers of masonry

- ~~Air leakage condensation~~
  - Air barrier detailing
  - Control interior humidity levels
- Freeze / Thaw damage
  - Minimize wetting
  - Must assess the risk!

Old Approach: Use Graded Bricks

- ASTM C62 & C67
  - Grade Bricks SW, MW, NW
  - Weather Index = days of cycling around freezing * annual rainfall
  - If weather index > 50, must use SW brick



Old Test Method A: c/b ratio

- SW brick if Saturation Coefficient (c/b) < 0.78 or 0.80
- c = Moisture Content after 24 hr cold soak
- b = Moisture Content after 5 hr boil

	Dry Density **[kg/m³]**	24 Hour Cold Soak Moisture Content **[kg/m³]**	5 Hour Boil Moisture Content **[kg/m³]**	Saturation Coeffienct **[24h soak/5h boil]**	Water Uptake WUFI A value **[kg/m²sec¹ᐟ²]**
I1A - Interior 1st floor A	1907	195	254	0.77	0.187
I1B - Interior 1st floor B	1845	222	289	0.77	
X1 - Exterior ground level 1	1806	234	318	0.74	0.239
X2 - Exterior ground level 2	1809	248	299	0.83	0.248
I3A - Interior 3rd floor A	2018	133	240	0.56	0.104
I3B - Interior 3rd floor B	1706	263	345	0.76	
I3C - Interior 3rd floor C	2029	138	252	0.55	0.102

Old Test Method B: 50 Cycle Freeze-Thaw

- Omni-directional freezing test on whole bricks
- Freezing (20 hrs)
  - Brick in 12 mm of standing water in cold room
- Thawing (4 hrs)
  - Brick submerged in thawing tank
- Repeat 24 hr cycle 50 times & measure loss of dry mass
  - Must be less than 3% for ASTM
  - No cracks

Problems with the Old Methods

- Freeze-Thaw resistance is a misnomer
- Both A & B are digital test methods
- Lead to false positives & negatives
  - Butterworth & Baldwin, 1960s
- Based on incomplete physics of freeze thaw
  - Closed Container (expansion of water as it freezes)
  - Hydraulic Pressure
  - ~~Ice Lensing~~
  - ~~Disequilibrium Theory~~
  - Check out Peter Mensinga's M.A.Sc. Thesis at University of Waterloo

Basis of the New Method:

- Fagerlund (Lund University, 1970s)
- *No such thing* as a freeze-thaw resistant material!
- There is a *critical degree of saturation* , S_{crit}
- Below S_{crit} no freeze-thaw damage will occur regardless of number of freeze-thaw cycles
- Above S_{crit} damage is measurable after only a few cycles

Limit States Design Approach

- Quantify the point at which a brick fails
  - Measure critical degree of saturation, S_{crit}
- Establish a limit for moisture content during freeze-thaw
  - Set allowable degree of saturation, S_{allow}
- Designer predicts hygrothermal conditions in assembly
  - Using well established & accepted computer programs
  - Assess boundary conditions at site
  - Material properties
  - Geometry
- Compare predicted and allowable degree of saturation during predicted freeze-thaw events (the limit state)

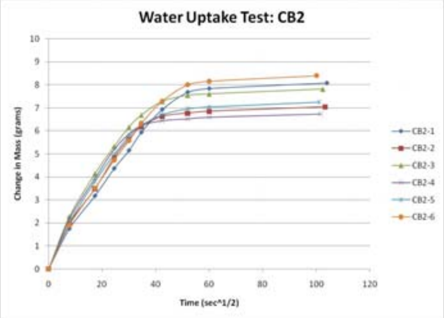
Testing for the New Method

- As inputs to the hygrothermal model:
  - Dry density
  - Liquid water uptake (A-value)
  - Saturation moisture content
- For the purposes of evaluating the limit state:
  - Critical degree of saturation
- For research purposes or to satisfy others
  - 24 hr cold soak
  - 5 hr boil
  - Saturation coefficient (c/b)

Collect REAL Materials Properties

Dry Density

Liquid Water Uptake



Preparing Brick Slices

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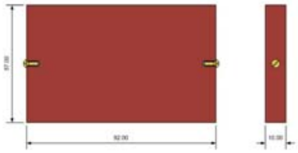


Figure 4-2 Typical brick sample with measuring pin targets.

Saturation Moisture Content

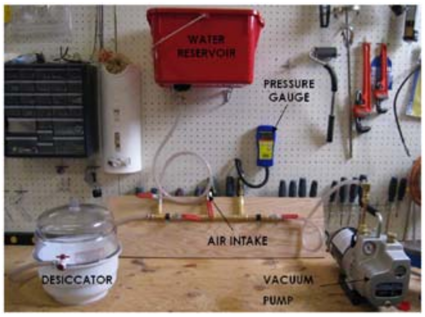


Image: P. Mensinga, UofW BEG

Saturation Moisture Content

- Remove air from the brick slices

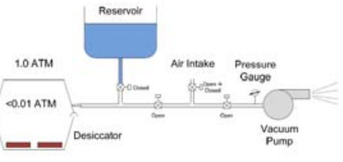


Figure 5-9 Vacuum saturation apparatus; pressure in desiccator less than 0.01Atm

Image: P. Mensinga, UofW BEG

Saturation Moisture Content

- Isolate vacuum pump from desicator

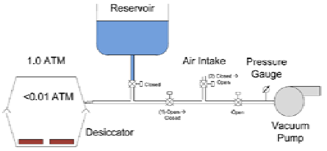


Figure 5-10 Vacuum pump isolated from desiccator

Image: P. Mensinga, UofW BEG

Saturation Moisture Content

- Fill desiccator (and voids in brick slices) with distilled water

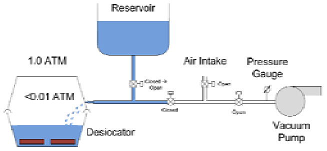
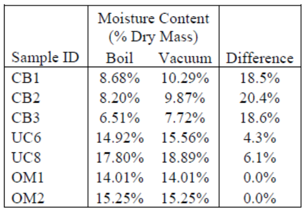


Figure 5-11 Specimens in the desiccator are submersed in distilled water

Image: P. Mensinga, UofW BEG

Vacuum Saturation vs 5 hr boil

- Vacuum saturation not necessarily the same as the saturation after 5 hr boil!



	Moisture Content (% Dry Mass)		
Sample ID	Boil	Vacuum	Difference
CB1	8.68%	10.29%	18.5%
CB2	8.20%	9.87%	20.4%
CB3	6.51%	7.72%	18.6%
UC6	14.92%	15.56%	4.3%
UC8	17.80%	18.89%	6.1%
OM1	14.01%	14.01%	0.0%
OM2	15.25%	15.25%	0.0%

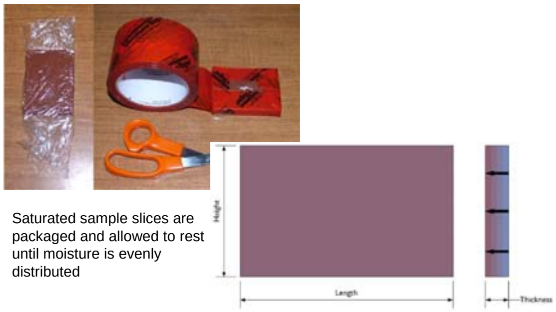
Measuring Brick Slices before F/T test

Preparing Saturated Samples for F/T testing

S = 0 to 0.6

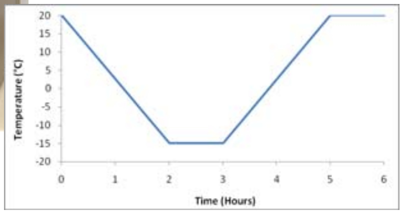
S = 0.6 to 1.0

Preparing Saturated Samples for F/T testing



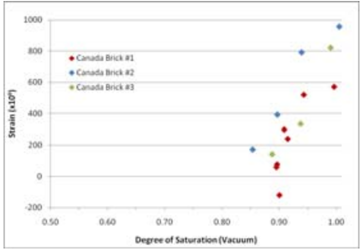
Saturated sample slices are packaged and allowed to rest until moisture is evenly distributed

Determining Critical Degree of Saturation



Critical Degree of Saturation

- Assess strain at various degrees saturation
- Critical degree of saturation at x-intercept



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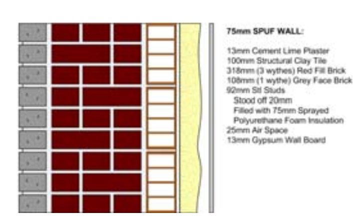
Hygrothermal Simulations

- Use variables from laboratory testing
  - Dry Density
  - A-value (water uptake)
  - Saturation (vacuum or 5 hour boil)
- Compare current conditions to insulated conditions predicted using hygrothermal simulation
- Conservative predictions using worst case scenario
  - Orientation, moisture contents, RDF

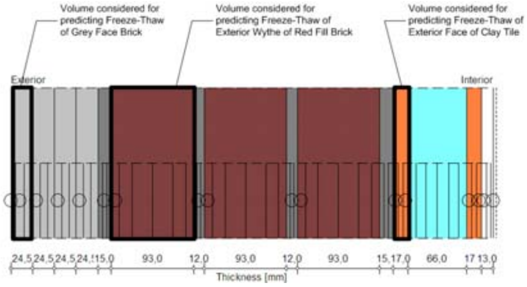
Hygrothermal Simulations



75mm SPUF WALL:

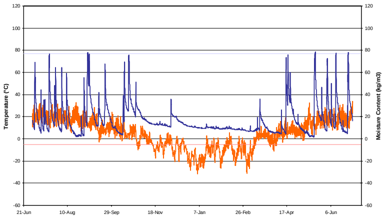
13mm Cement Lime Plaster
100mm Structural Clay Tile
318mm (3 wythes) Red Fill Brick
108mm (1 wythe) Grey Face Brick
92mm Stl Studs
  Stood off 20mm
  Filled with 75mm Sprayed
  Polyurethane Foam Insulation
25mm Air Space
13mm Gypsum Wall Board

Hygrothermal Simulations



Assessment

- Freeze Thaw Event
  - Brick must have higher moisture than Critical Degree of Saturation
  - Brick must freeze/thaw (<-5C and >0C)



Thank You for your Interest