

R-value and Thermal Mass of Brick Masonry

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Introduction

- Thermal mass can be defined as the ability of materials to store significant amounts of thermal energy and delay heat transfer [1]
- Can be defined as thermal diffusivity (a) which is a function of many thermal properties:

$$a = \frac{k}{\rho C_p}$$

- Thermal mass often characterized by “building envelope” of house or commercial building
 - Masonry
 - Concrete
 - Insulating materials
- Buildings are one of the most significant energy consumers due to loss of heat through/from building envelope [2]

[1] S. A. Kalogirou, G. Florides and S. Tassou, 'Energy analysis of buildings employing thermal mass in Cyprus,' *Renewable Energy*, 27 [3] 353-368 (2002).

[2] Z. Yilmaz, 'Evaluation of energy efficient design strategies for different climatic zones: Comparison of thermal performance of buildings in temperate-humid and hot-dry climate,' *Energy Build.*, 39 [3] 306-316 (2007).

Thermal Mass vs. R-value

- Both are interactive, but not achieved in the same way [3]
 - Insulation materials only increase R-values and affect transmission loads through walls
 - Thermal mass helps to reduce temperature fluctuations and increase time lag
- Greater thermal mass (heavier, denser materials) can store more heat [4]
 - Take longer to release the thermal energy after heat source has been removed

[3] S. A. Al-Sanea, M. F. Zedan and S. N. Al-Hussain, 'Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential,' *Appl. Energy*, 89 [1] 430-442 (2012).

[4] K. Gregory, B. Moghtaderi, H. Sugo and A. Page, 'Effect of thermal mass on the thermal performance of various Australian residential constructions systems,' *Energy Build.*, 40 [4] 459-465 (2008).

Effects of Thermal Mass

- Benefits of thermal mass are:
 - Time lag
 - Decrement factor
- Time lag= time span between attaining peak temperatures at outside and inside surfaces of a wall [3]
- Decrement factor= amplitude of temperature fluctuation on inner surface of wall divided by outer surface [3]

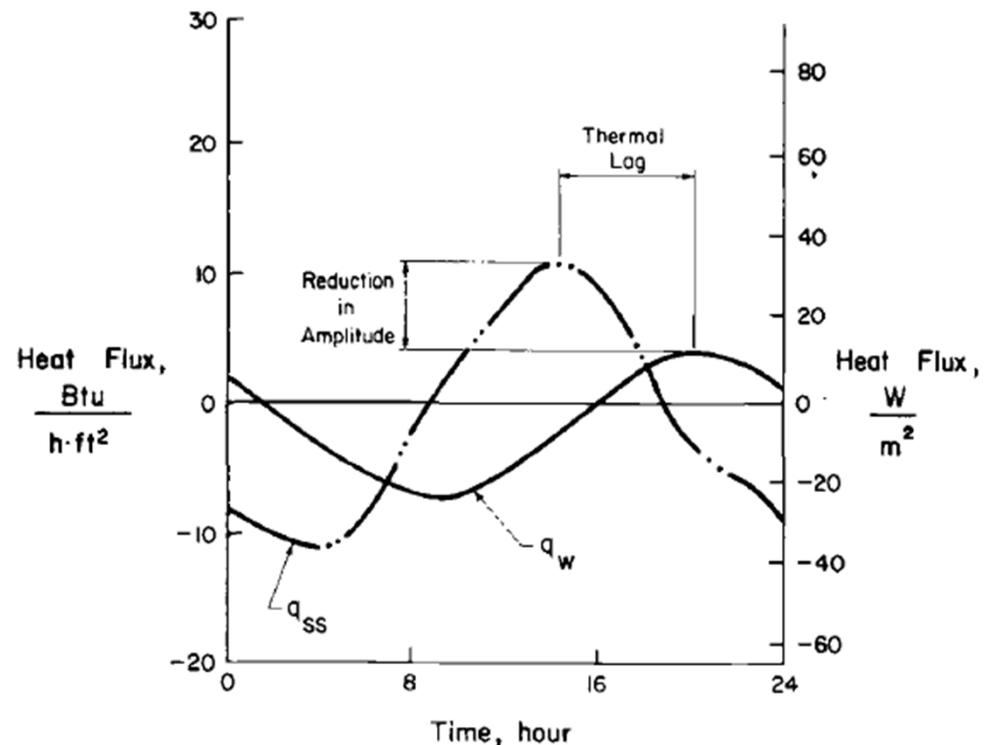


Figure 1: Effects of Thermal Mass [5]

[5] M. G. Van Geem, 'Measuring Thermal Performance of Wall Assemblies Under Dynamic Temperature Conditions,' *J Test Eval*, 15 [3] 178-187 (1987).

Thermal Comfort

- Effective use of thermal mass can delay overall peak temperature to later in day
- Dampen large temperature fluctuations during the day
- Reduce heating/cooling loads during the day
 - Reduce building energy consumption
- Provides a thermally comfortable environment

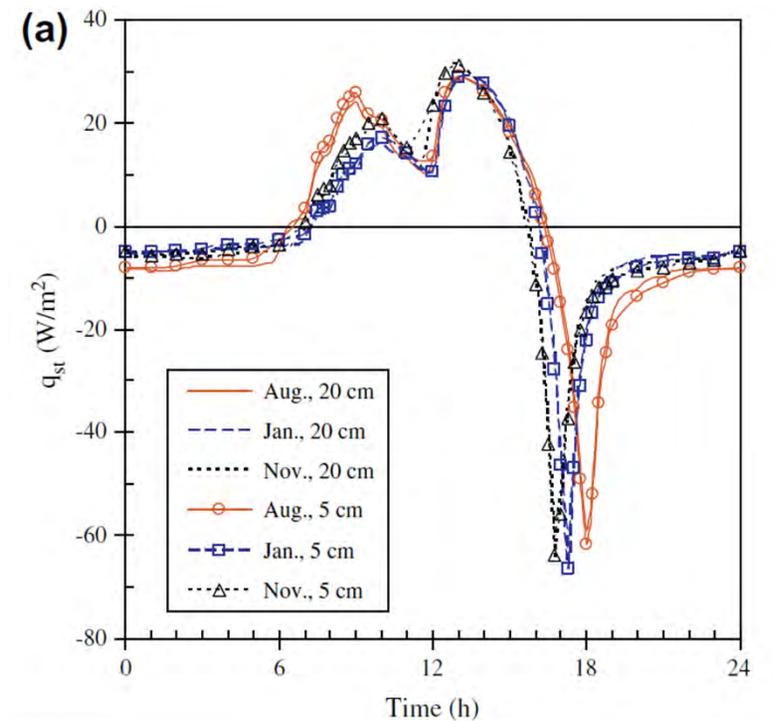


Figure 2: Energy Storage Rate for a Wall System ^[3]

Testing Conditions

- ASTM C1363 – *Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*
 - Steady-state coefficients do not include thermal storage during dynamic testing
 - Steady-state and dynamic tests should be performed to understand thermal performance
 - Thermal lag, peak load, heat flow
- ASTM C1155 - *Standard Practice for Determining Thermal Resistance...*
 - Summation technique
 - Placement of sensors- infrared thermography

$$R_e = \frac{\sum_{k=1}^M \Delta T_{sk}}{\sum_{k=1}^M q_k}$$

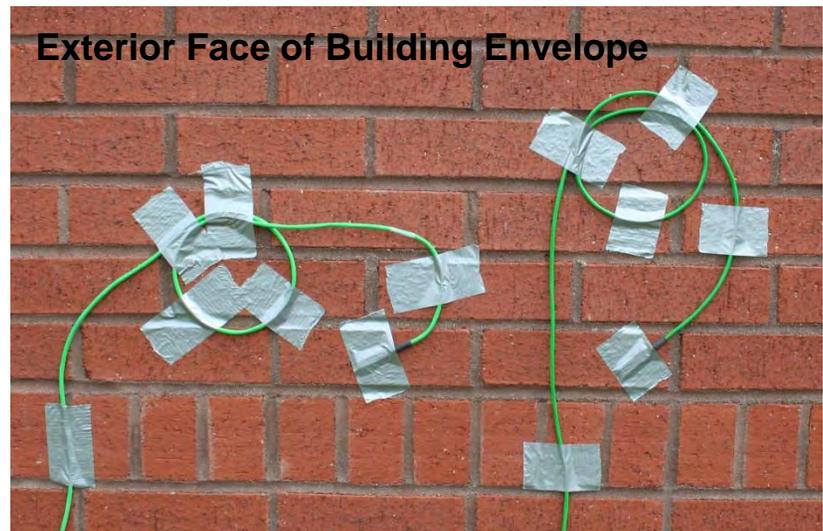
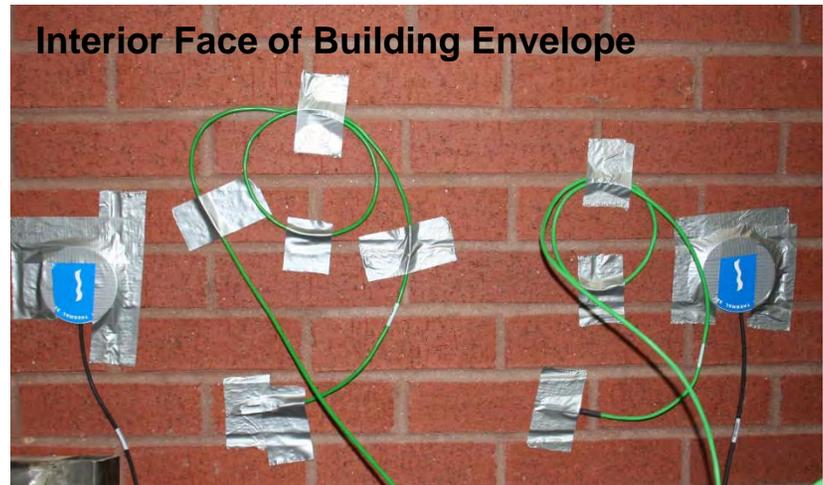
Steady-state Measurements

- Netzsch HFM 436
- Steady-state, one dimensional heat flow measurements
- ASTM 518 and 1058
- Multiple set points
- Calculates apparent thermal resistance and thermal conductivity



In Situ Measurements - Dynamic

- Hukseflux thermal sensors
 - Two pairs of thermocouples
 - Two heat flux sensors
- Thermal resistance (TR) calculated by simultaneous measurement of:
 - Time averaged heat flux (Φ)
 - Differential temperature (ΔT)
- $TR = \Delta T / \Phi$
- ASTM C1155 and C1046
 - Thermal measurements of building envelope components



Infrared Thermography - FLIR

- Qualitative observations
 - Placement of heat flux sensors
- All objects with a temperature greater than absolute zero emit infrared energy [6]
- Allows for engineers to see where most heat is being lost through building envelope



Figure 3: Exterior Wall at NBRC

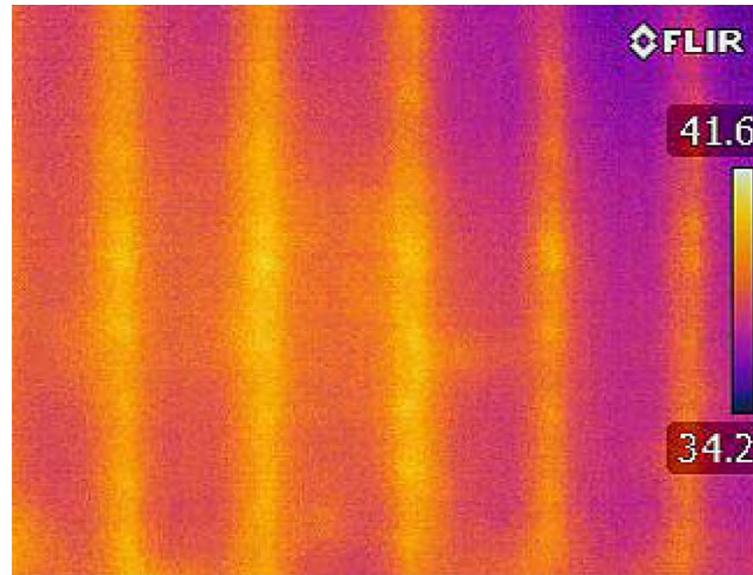


Figure 4: FLIR E60 Image of Wall

[6] M. R. Clark, D. M. McCann and M. C. Forde, 'Application of infrared thermography to the non-destructive testing of concrete and masonry bridges,' *NDT E Int.*, 36 [4] 265-275 (2003)

Any Questions???