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R-value and Thermal Mass of Brick Masonry

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Outline

- Introduction
  - What is thermal mass??
- Thermal Mass vs. R-value
- Effects of Thermal Mass
  - Time lag
  - Decrement factor
- Thermal Comfort
- Testing Conditions
- Measurements
  - Steady-state
  - In Situ- Dynamic
  - Infrared Thermography

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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. Yılmaz, '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).

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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]

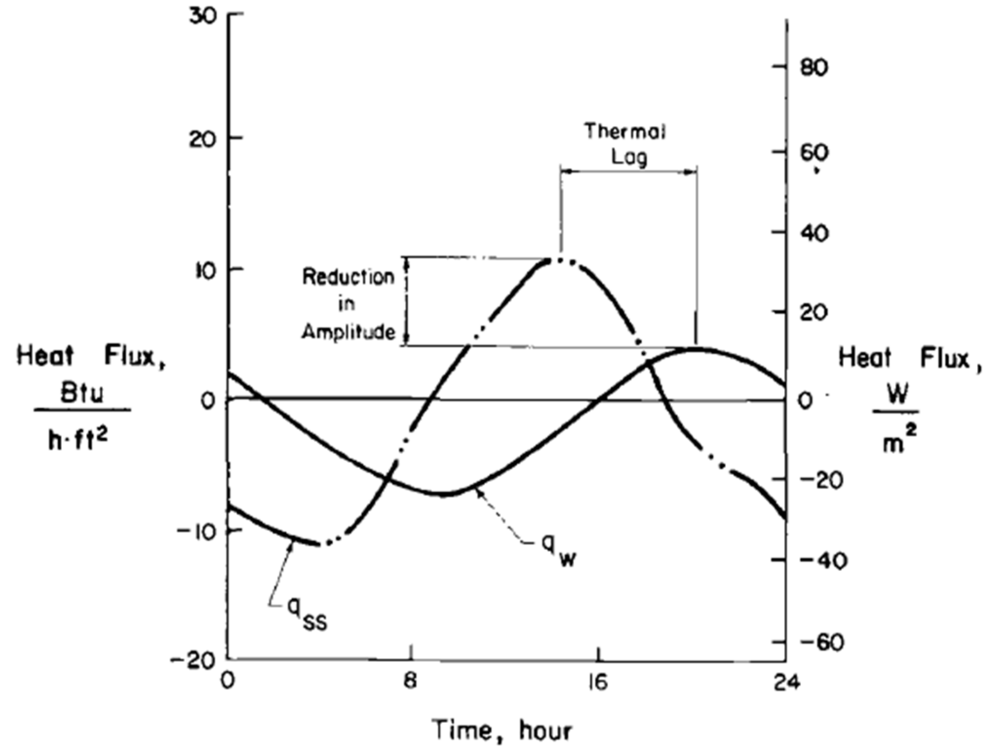


Figure 1: Effects of Thermal Mass [5]

[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

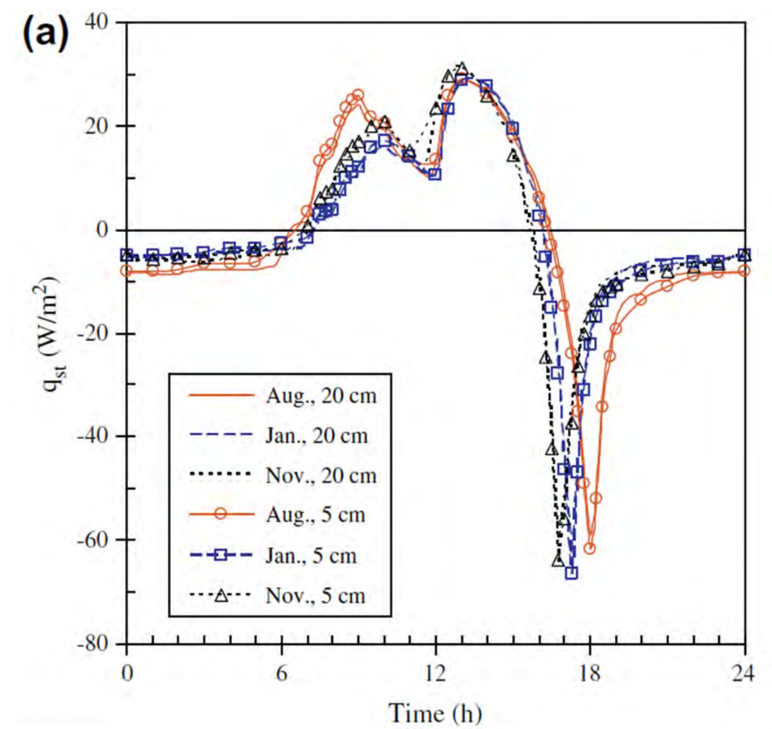


Figure 2: Energy Storage Rate for a Wall System [3]

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

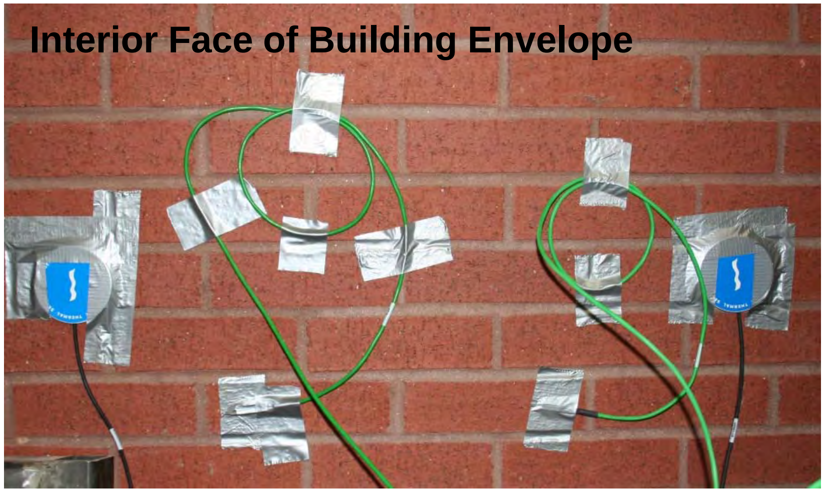
In Situ Measurements - Dynamic

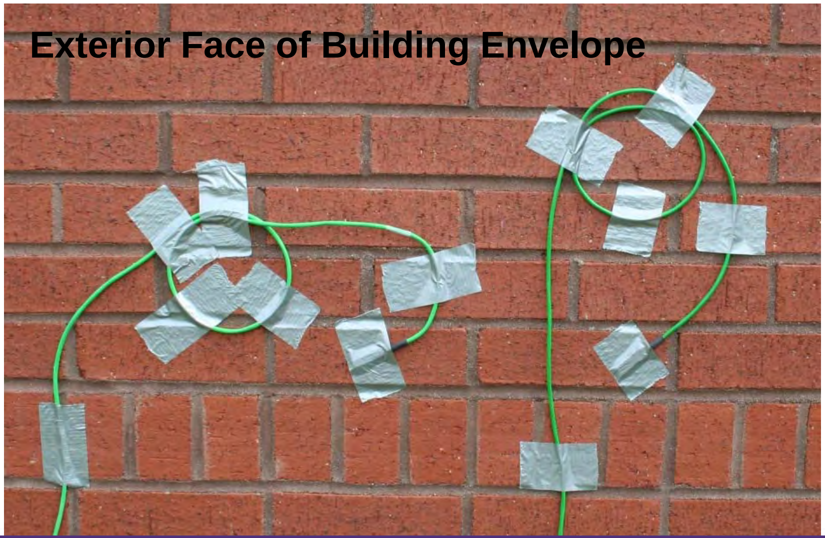
- Hukseflux thermal sensors
  - Two pairs of thermocouples
  - Two heat flux sensors

- 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

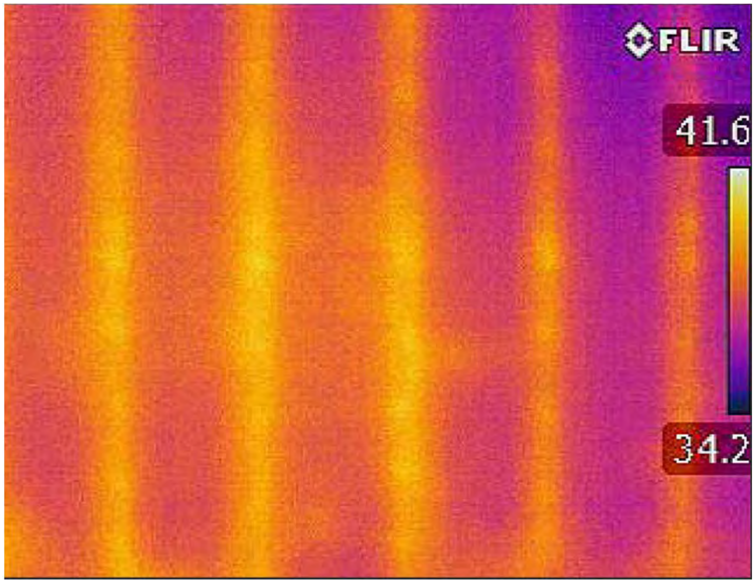


Figure 4: FLIR E60 Image of Wall

[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)

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Any Questions???