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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

Participants will :

1. Learn how to link the performance of individual building enclosure components in a holistic framework to achieve high-performance buildings.

2. Explore, through built case studies, how building envelope design determines overall energy conservation and sustainability capabilities

3. Learn innovative practices for avoiding heat loss as well as moisture and air infiltration in enclosure design for healthy new and existing buildings.

4. Understand the role of building enclosure commissioning in the design, construction, and operation and maintenance of commercial facilities.

THERMAL AND ENERGY PERFORMANCE OF AUTOCLAVED AERATED CONCRETE (AAC)

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Overview

- Background
- Experiments
- Simulation (Thermal + Energy)
- Results
- Conclusions

Background

Aerated Autoclaved Concrete

AAC is "a cementitious product based on calcium silicate hydrates in which low density is attained by the inclusion of an agent resulting in macroscopic voids and is subjected to high pressure steam curing ..." *

*According to ASTM C1386 Standard Specification for Precast Autoclaved Aerated Concrete (AAC) Wall Construction Unit

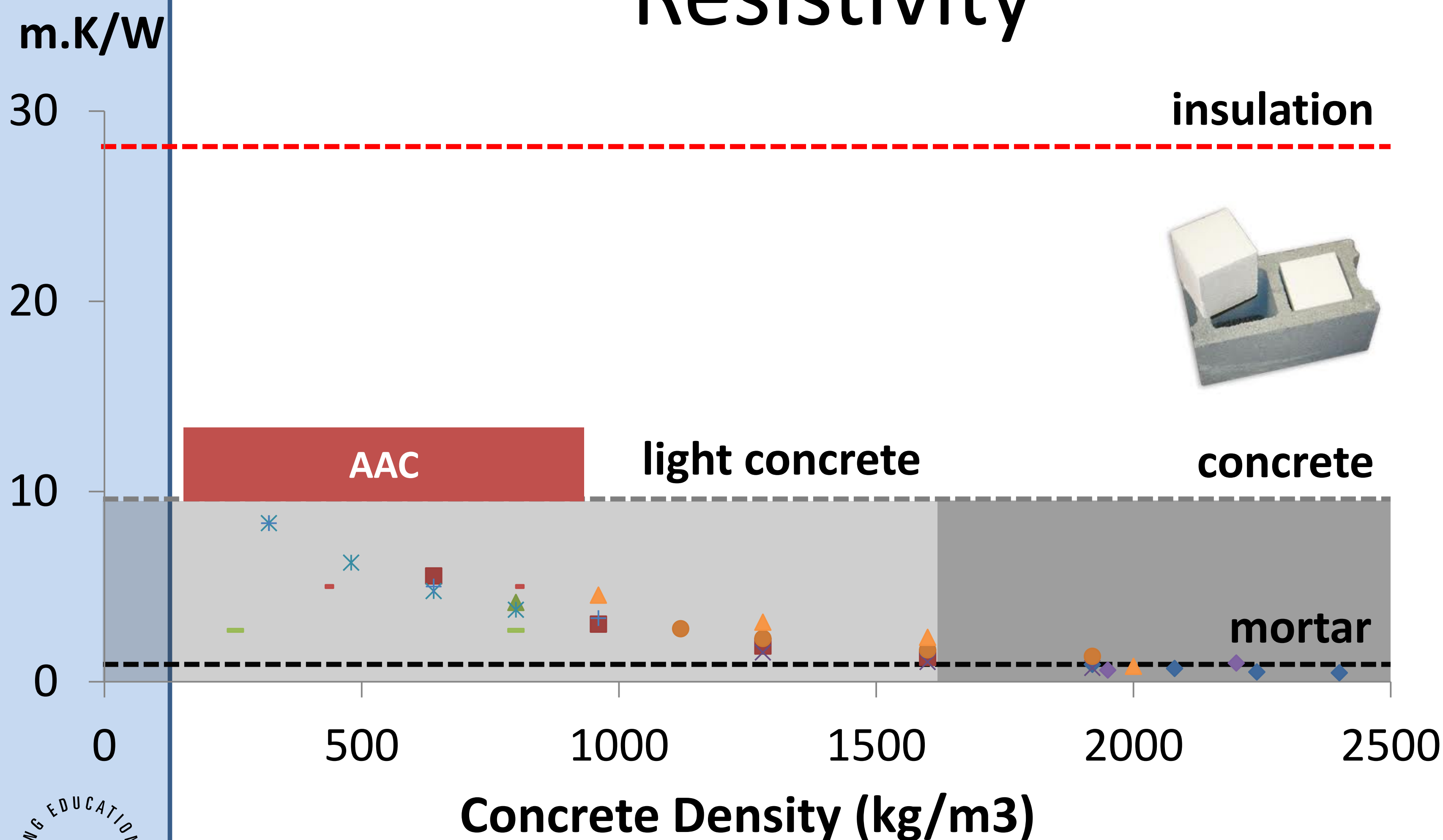
Aerated Autoclaved Concrete

- Invented in mid 1920s by Swedish Architect

Advantages

- Lighter weight
  - 20% the weight of concrete
  - Up to 80% air by volume
- Lower transport cost
- Easier to shape with tools onsite
- Good acoustic properties
- Insulating and energy savings?

Concrete Density vs Thermal Resistivity



Building Energy Codes

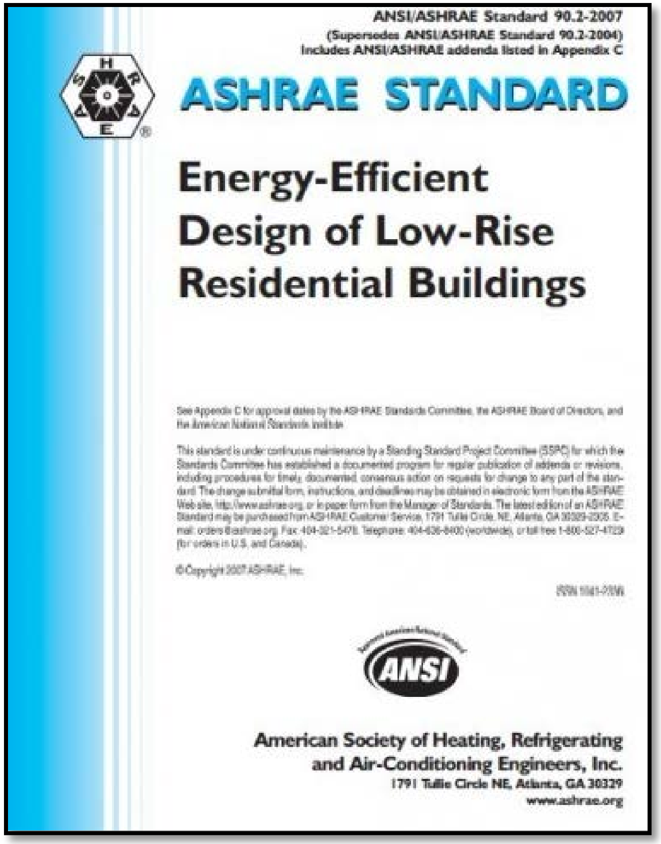
Provide thermal mass credit for certain weight classes of concrete. These may fail to represent the insulating benefits of lightweight concrete.

Thermal Mass Credit in ASHRAE 90.1 and 90.2 & IECC

IECC Insulation Requirement for a Mass Wall (From Table R402.1) (ICC 2012)

Climate Zone	Mass Wall R-Value[1]
1	3/4
2	4/6
3	8/13
4 except Marine	8/13
5 & Marine 4	13/17
6	15/20
7 & 8	19/21

[1] Second R-value applies when more than half of the insulation is on the interior of the mass wall.



Data Gaps Exist

Thermal properties of some types of lightweight concrete were not well represented in the literature.

AAC Concrete Strength Classes

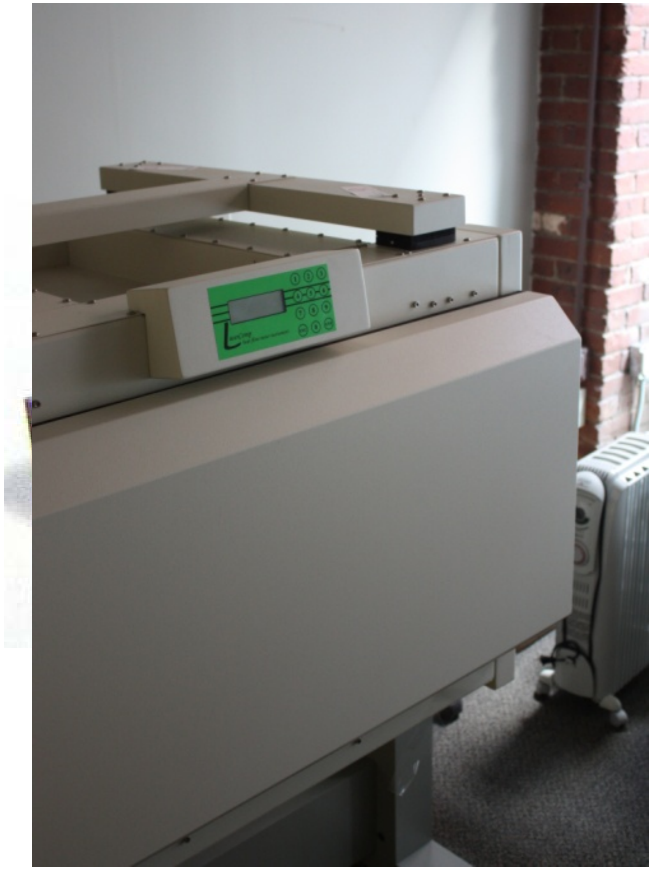
Concrete Class Strength (MPa)	Nominal Dry Bulk Density, kg/m^3	Density Limits, kg/m^3	Average Drying Shrinkage, %
AAC-2	400	350-450	≤ 0.02
	500	450-550	
AAC-4	500	450-550	
	600	550-650	
	700	650-750	
AAC-6	600	550-650	
	700	650-750	
	800	750-850	

Thermal conductivity measurements missing from the literature

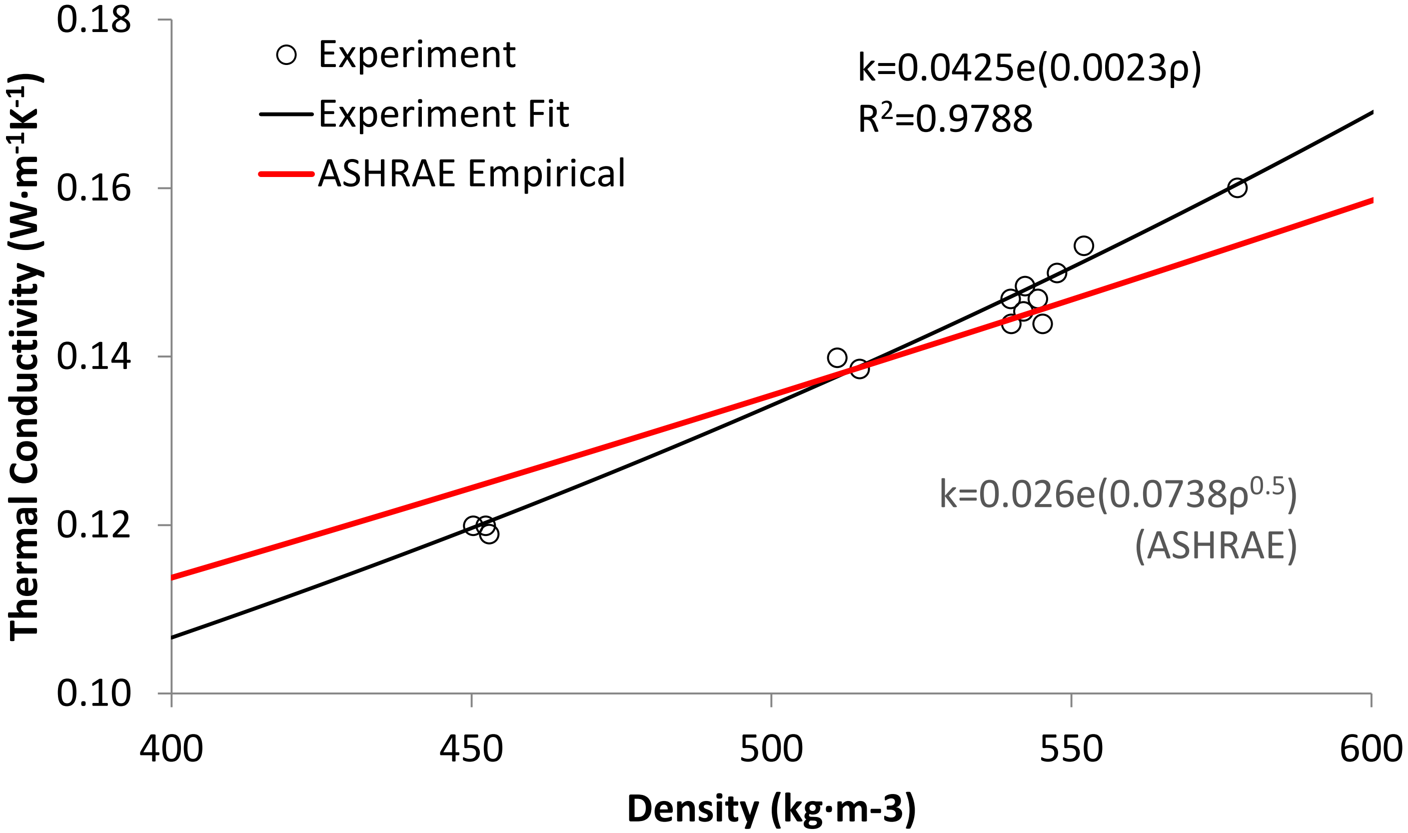
Experiment

Experimental Approach

- Receive batch of 14 AAC-4/500 samples from manufacturer
- Dry samples in thermal chamber until weight reaches equilibrium
  - We used 52.5 °C and 5% RH to prevent condensation on the isothermal plates during testing
- Weigh samples (to measure density)
- Measure thermal conductivity in Heat Flow Meter Apparatus
- Weigh samples to confirm moisture content has not changed



Thermal Conductivity of Concrete vs. Density



Simulation

Simulation Challenges

3D heat transfer not easily modeled in whole building simulation tools. Material descriptions must be 1D layers.

Equivalent Wall Theory

- Represent 3D assemblies as a series of fictitious 1D material layers that produce the same thermal response

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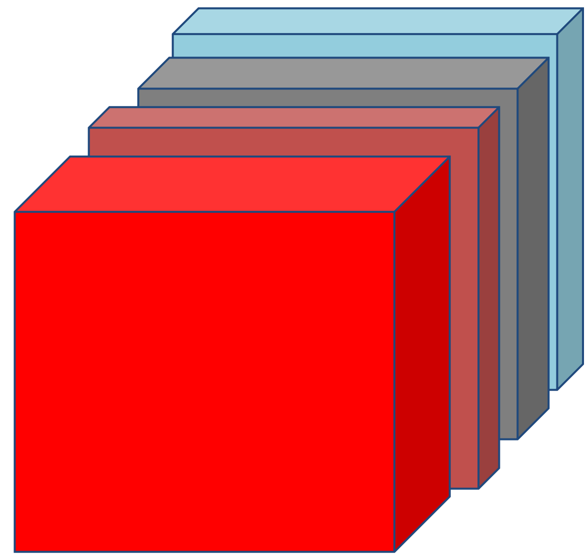
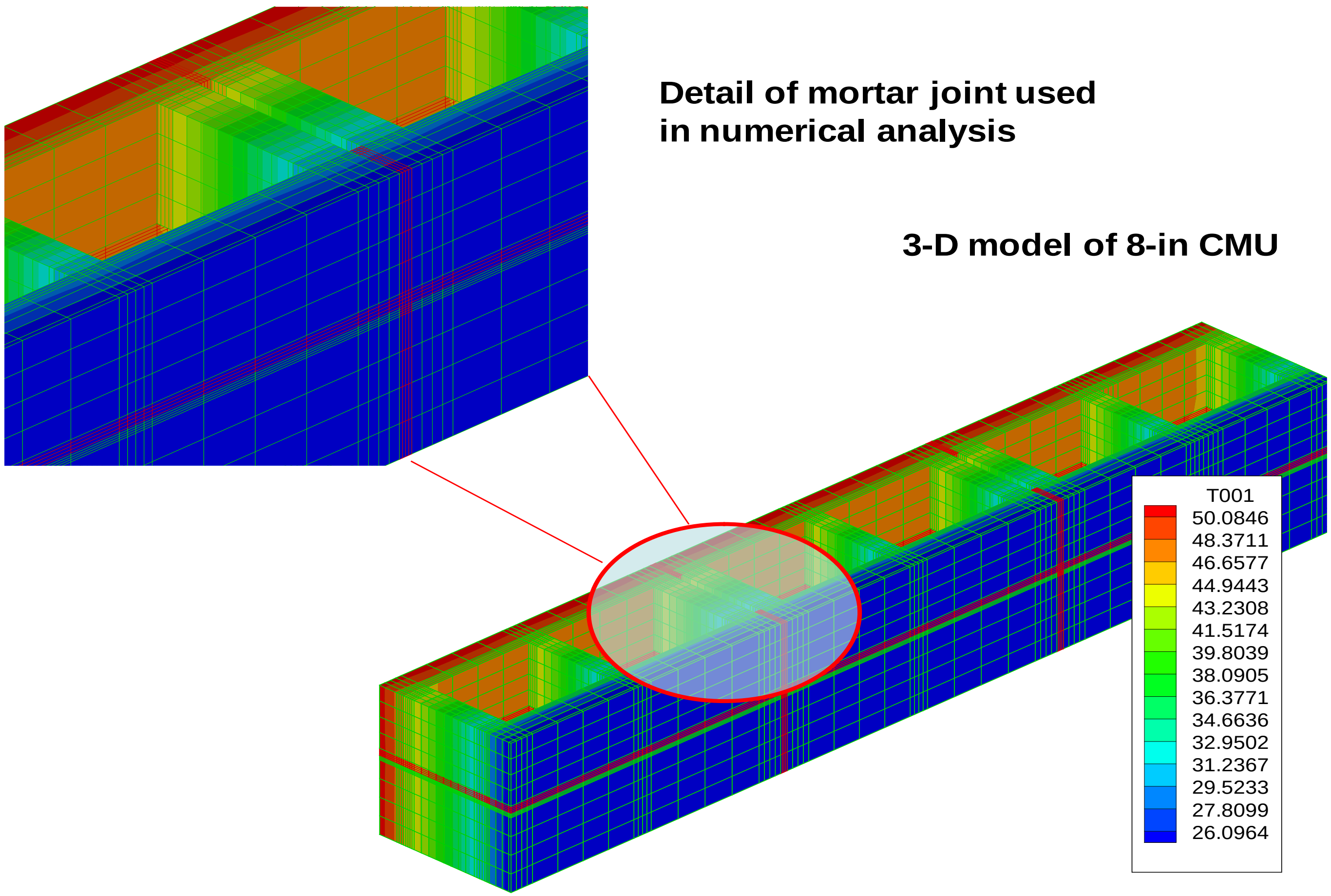


3D Simulation of Concrete with Mortar Joint

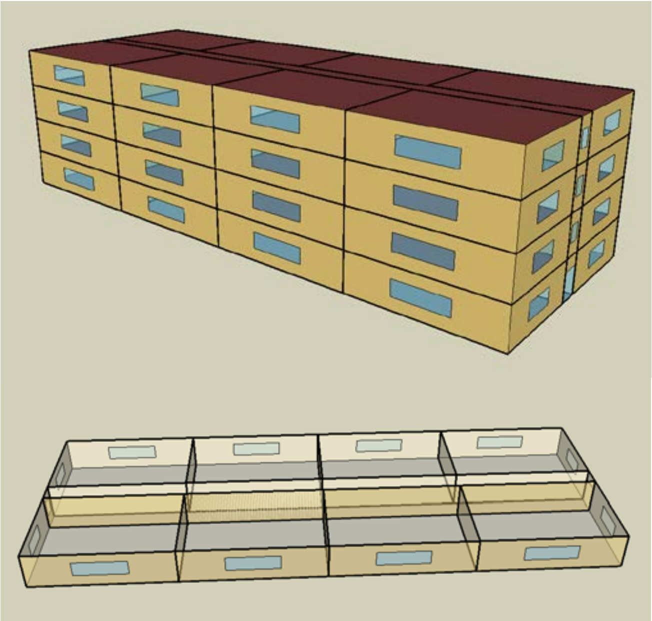


Simulation Cases

- DOE Reference Building for Mid-Rise apartment building

- ASHRAE Climate Zones 4 and 5
  - New York and New Jersey
  - Cold winters, warm summers

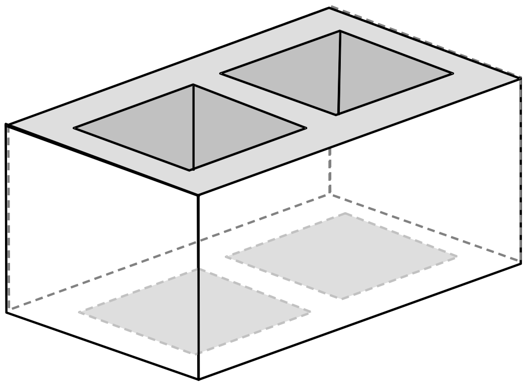
- 5 Wall Configurations
  - 3 CMU configurations
  - 2 AAC configurations



Exterior Wall Configurations

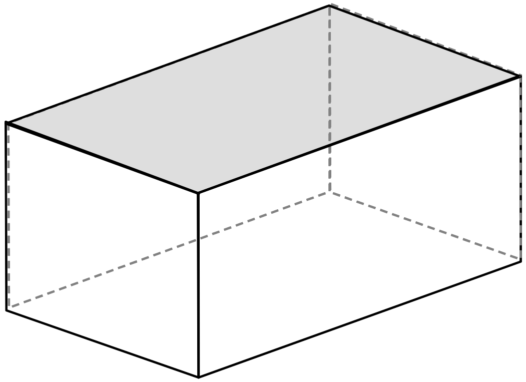
Concrete Masonry Units

- *200mm CMU + 63mm XPS*
- *250mm CMU + 63mm XPS*
- *300mm CMU with vermiculite core*



Aerated Autoclaved Concrete

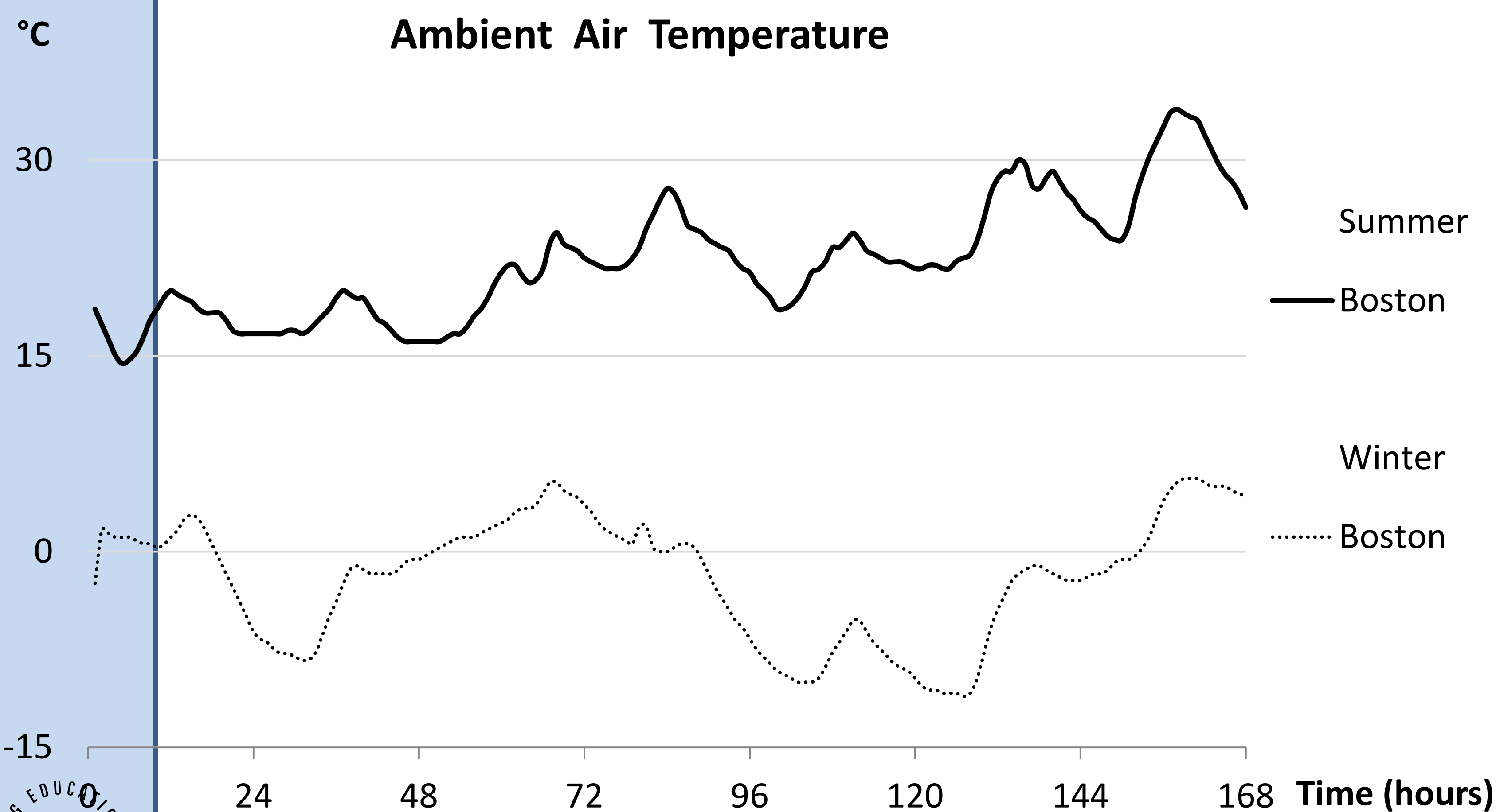
- *250mm AAC*
- *300mm AAC*



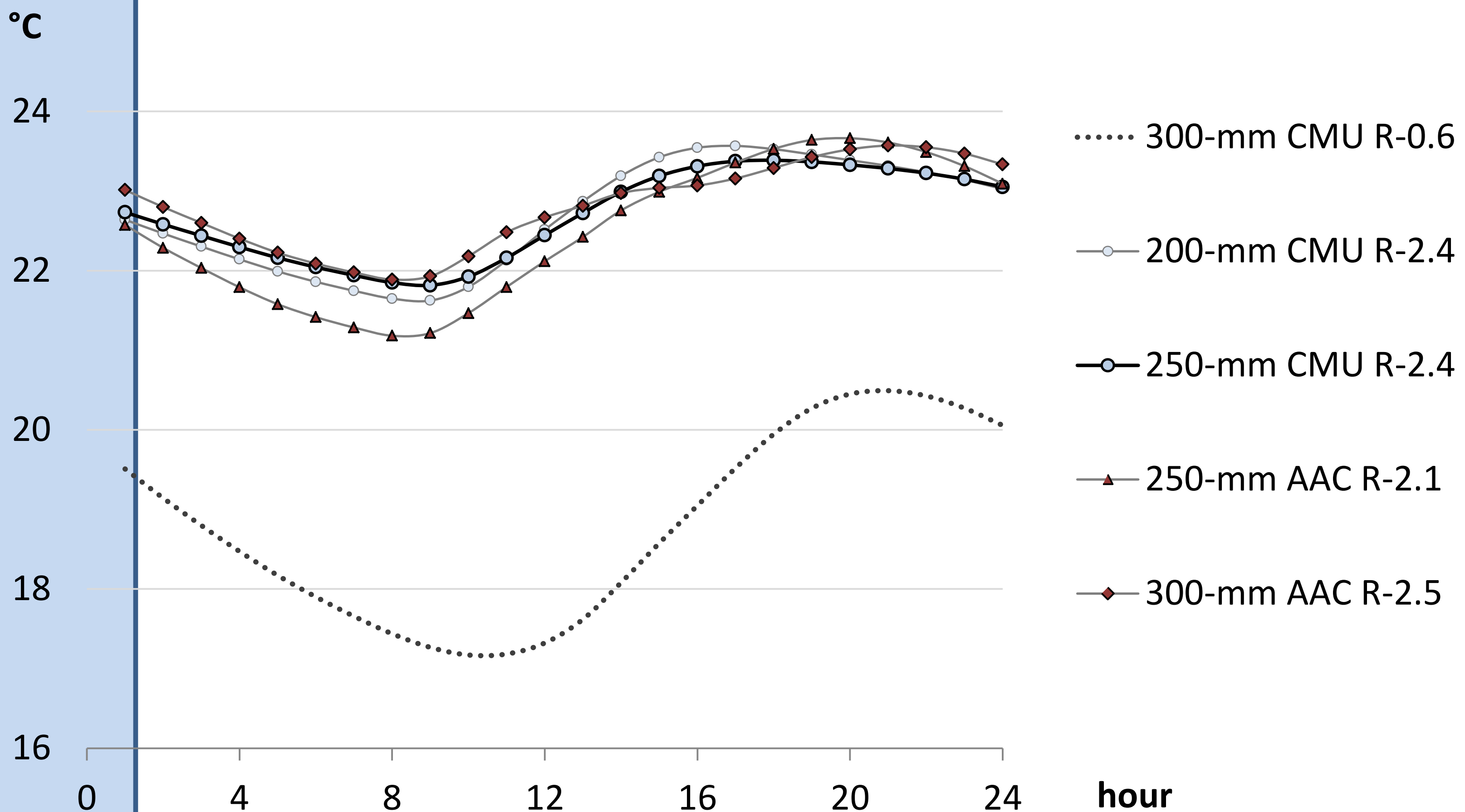
Wall Configurations with Equivalent Layer Simulation Properties

Wall Assembly	Thickness (mm)	Conductivity k (W/m·K)	Density (kg/m³)	Specific Heat (kJ/kg·K)	Surface-to-surface R-SI (R-value)
200mm CMU + 63mm XPS	25.4	0.015	1600	0.04	2.37
	25.4	0.043	1600	0.04	
	25.4	1.019	1600	0.62	
	25.4	0.175	1600	3.17	
250mm CMU + 63mm XPS	25.4	0.015	1600	0.05	2.39
	25.4	0.044	1600	0.05	
	25.4	1.003	1600	0.66	
	25.4	0.155	1600	4.27	
300mm CMU with vermiculite core	25.4	0.259	1600	2.38	0.59
	25.4	0.120	1600	1.33	
	25.4	0.130	1600	0.99	
	25.4	0.225	1600	3.35	
250mm AAC	250.8	0.114	450	0.84	2.09
300mm AAC	301.6	0.114	450	0.84	2.51

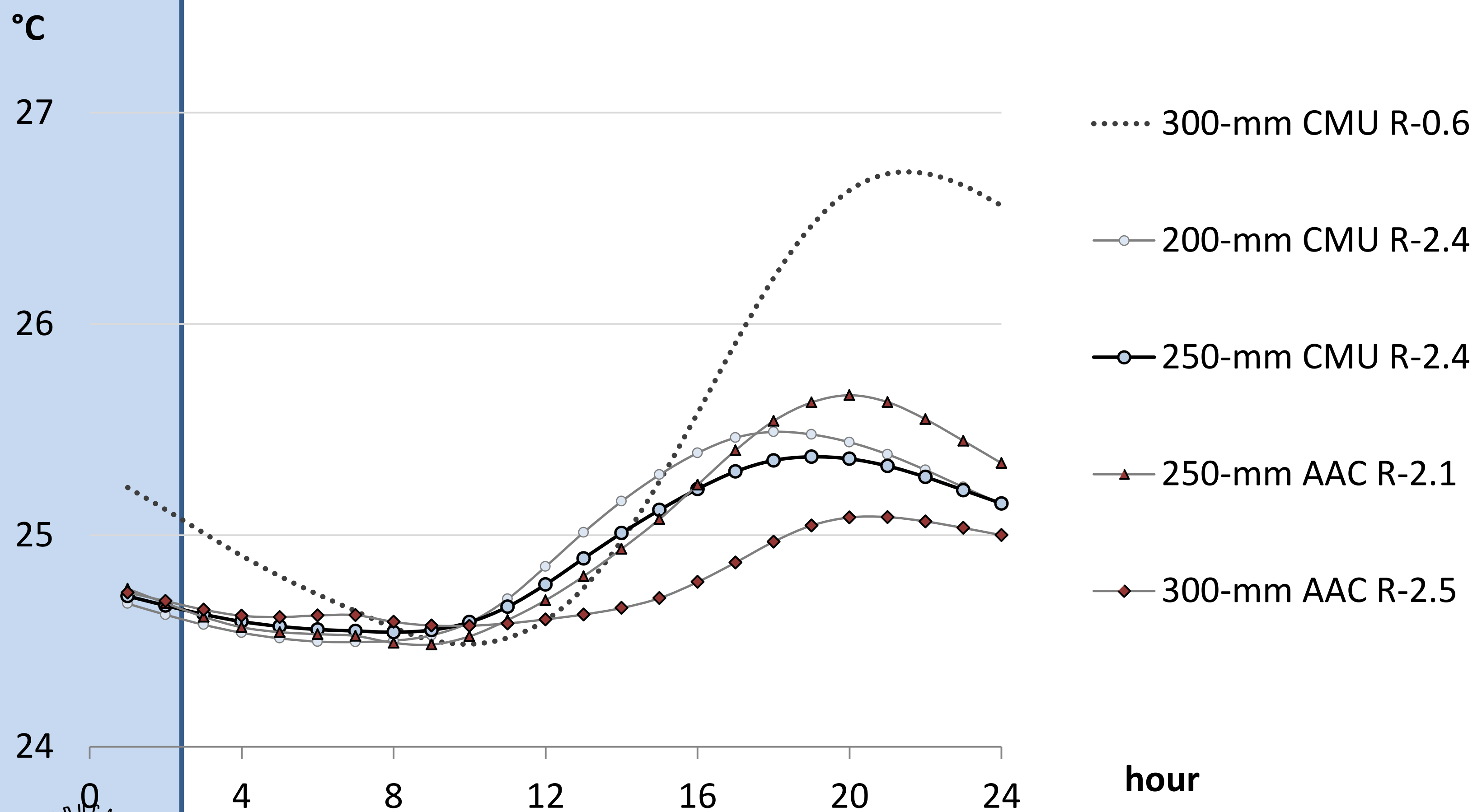
Representative Summer and Winter Week Temperature Data



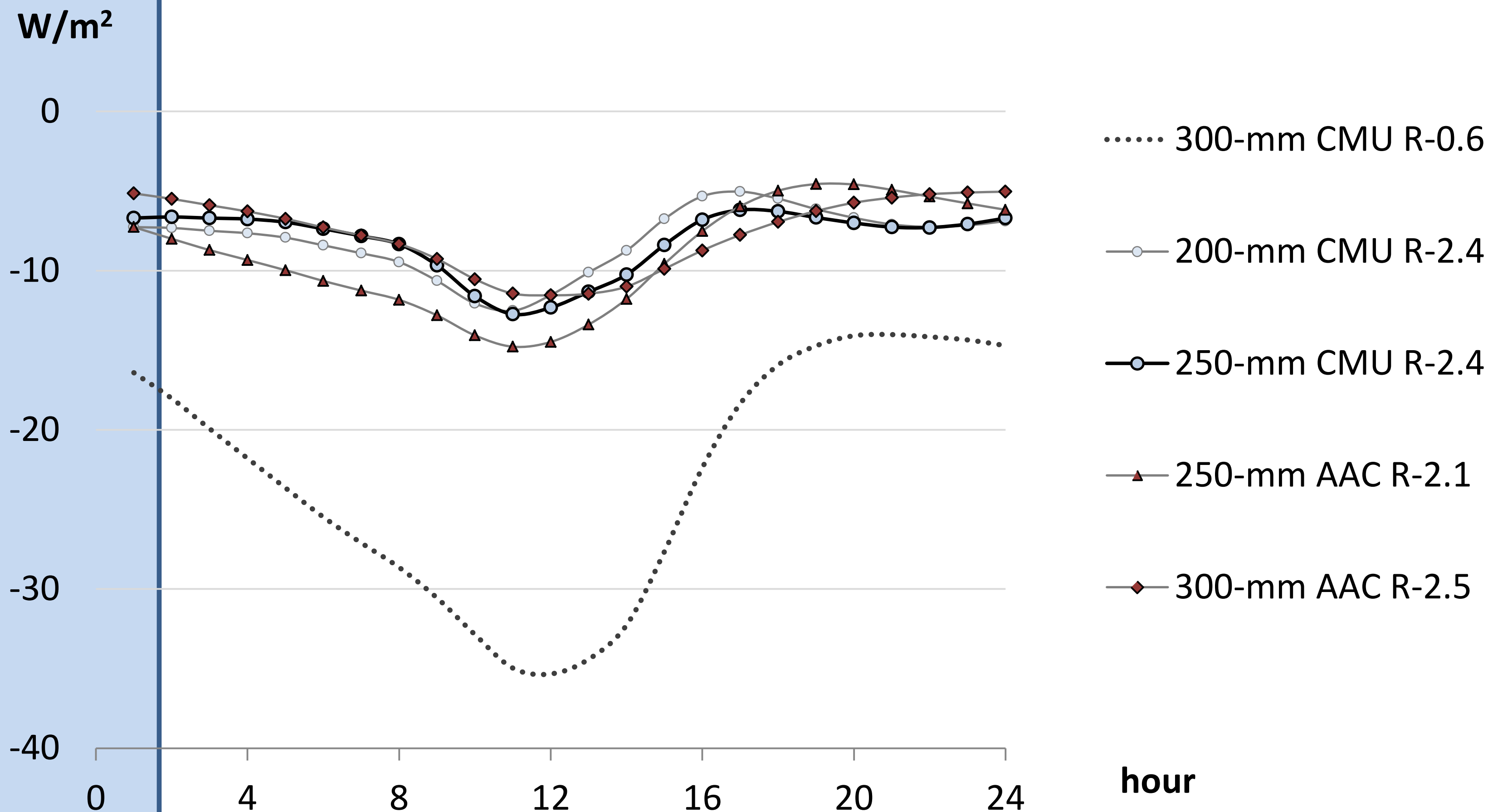
Interior South Wall Surface Temperatures on a Winter Day



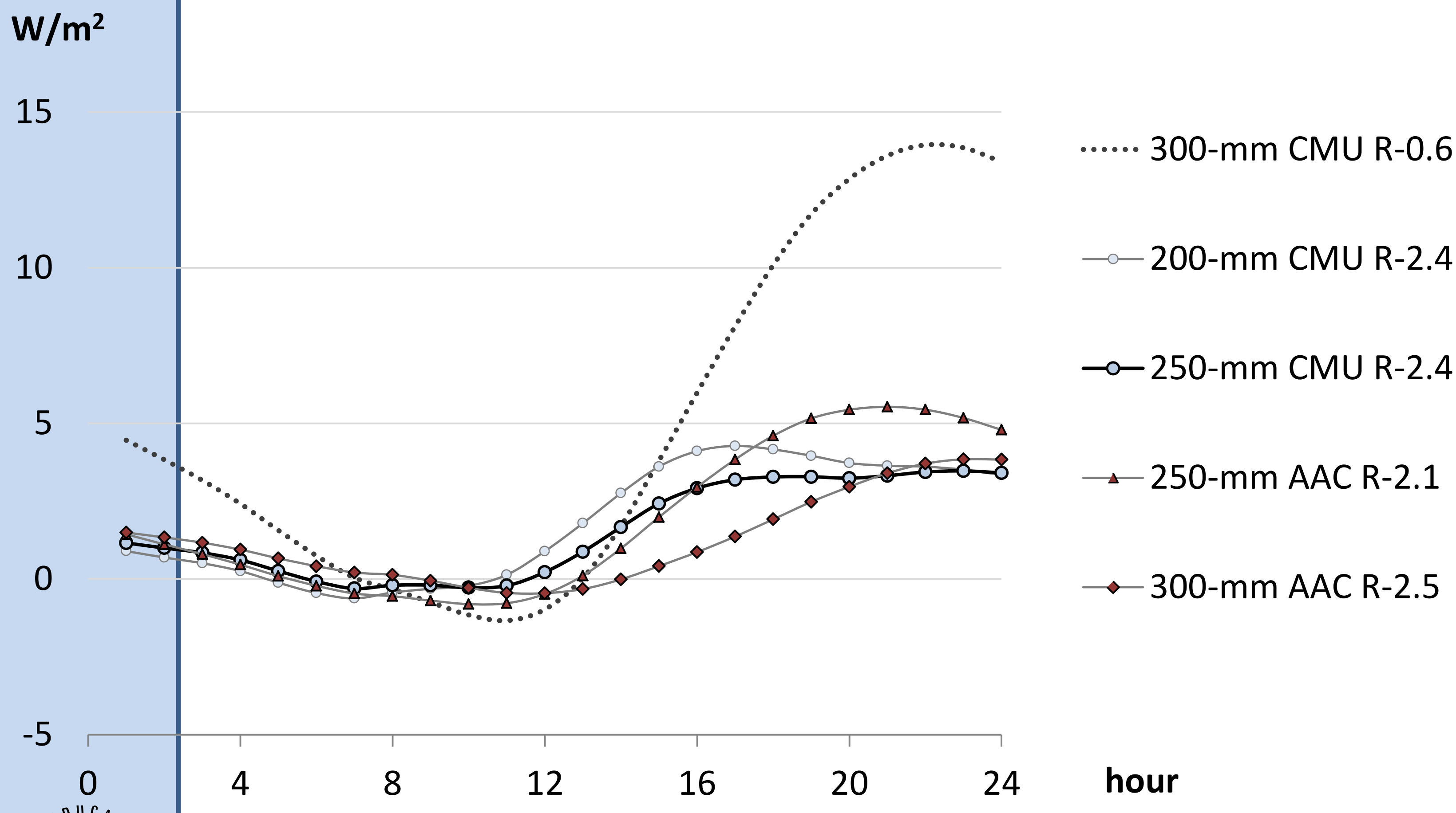
Interior South Wall Surface Temperatures on a Summer Day



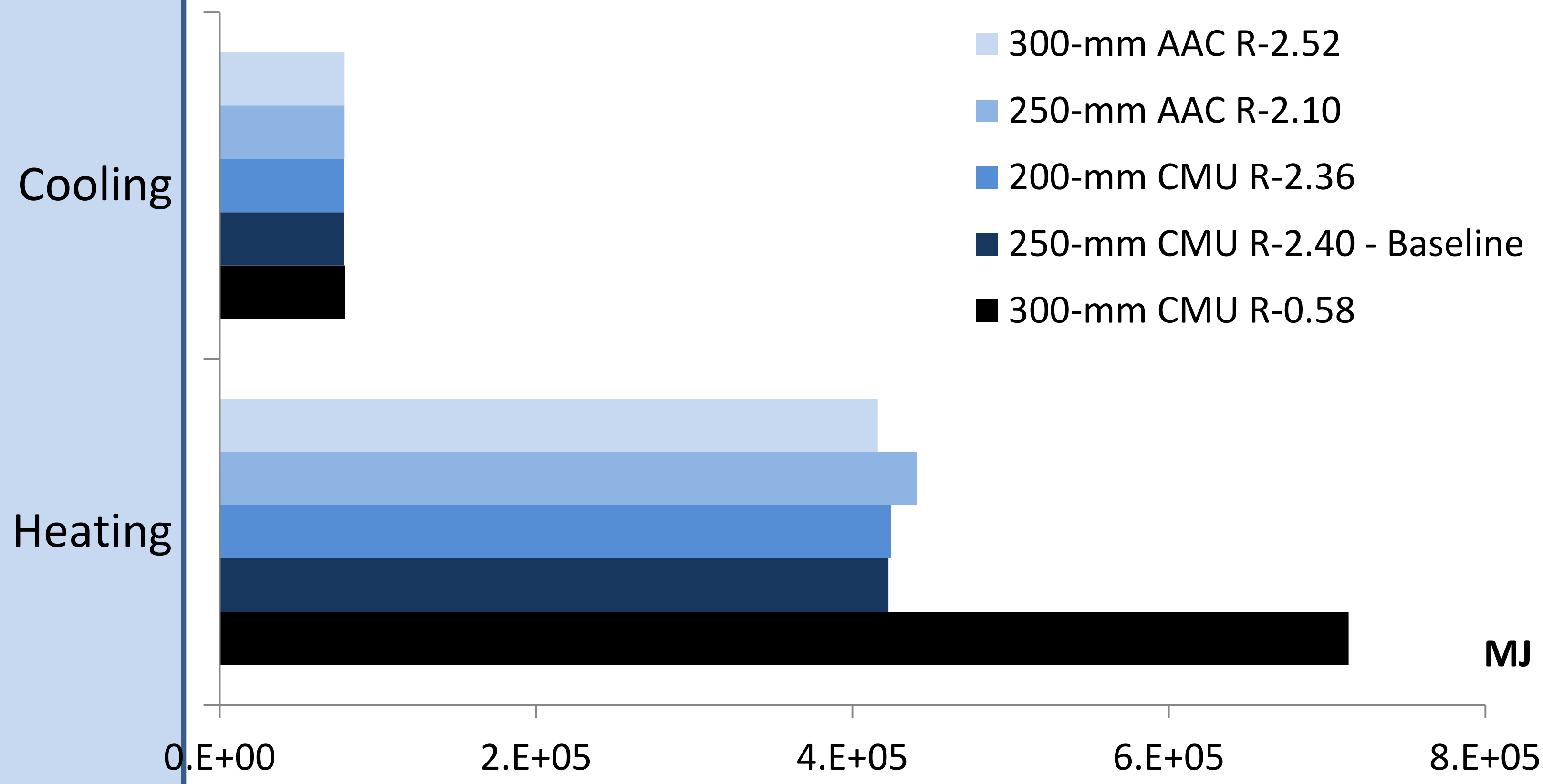
Interior South Wall Surface Heat Flux on a Winter Day



Interior South Wall Surface Heat Flux on a Summer Day



Annual Cooling Loads



Conclusions

- Data gaps in the thermal conductivity of AAC were identified
- This resulted in lack of acceptance of lightweight AAC in thermal mass credits
- We measured thermal conductivity of concrete samples to fill the data gap. Results matched theoretical expectation fairly well.
- We used the data to simulate thermal performance of AAC and CMU wall cases in several climates.
- AAC wall systems performed comparably to insulated CMUs, suggesting that thermal mass credit may be appropriate for lightweight AAC-4 blocks.

Thanks!

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