Thermal Mass and Its Effect on The Whole Building Energy Performance

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ORNL BTC

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Part 1, Whole Building Energy

- Introduction - Thermal Mass in Buildings
- History of application of thermal mass in residential buildings
- Passive solar techniques and systems
- DOE and ASHRAE past research studies on thermal mass
- ORNL theoretical energy performance data

Thermal Mass in Buildings

- Parts of the building structure
  - exterior walls
  - interior walls
  - floors, and ceilings
  - fireplaces, stairs, etc...
- Furniture
- Finish materials
- Passive solar heat storage containers

How Thermal Mass Works in Buildings ?

- Thermal mass stabilizes the interior room temperature
  - lower summer cooling energy demands
  - lower winter heating energy demands
- Reduces energy demands in peak hours
- Improves thermal comfort

History of Thermal Mass Application in Buildings

- First Home for Human Beings; A Cave

- flat temperature profile year around
- uniform radiation temperature fields
- uniform humidity
- no drafts
- fresh air ???

Our Predecessors Knew How to Live in Hot Climates Without Air-Conditioning

Native Americans Preferred to Use Adobe Constructions

Up North, They Also Used Thermal Mass - Logs

Later They Used More Sophisticated Technology

Log Buildings are Still Very Attractive

Thermal Mass Was Often Used in Heating and Cooking Equipment

Today, Most of North American Residential Buildings are Made of Light Framing

Massive Buildings are Claimed to be More Expensive and Labor-Consuming

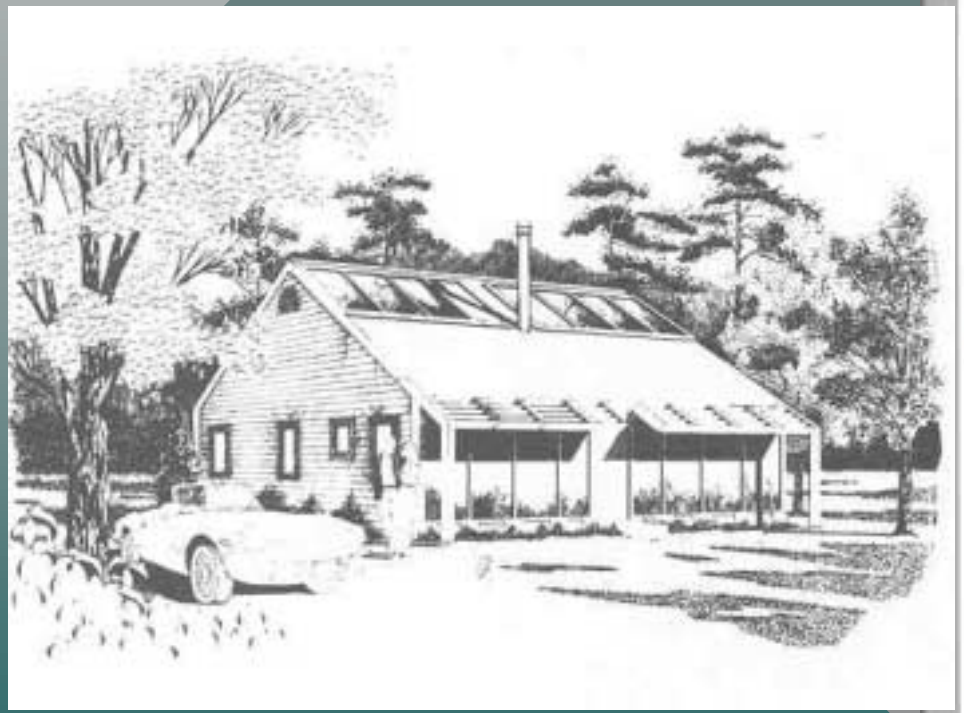
Using Light Framing is not Always a Right Choice

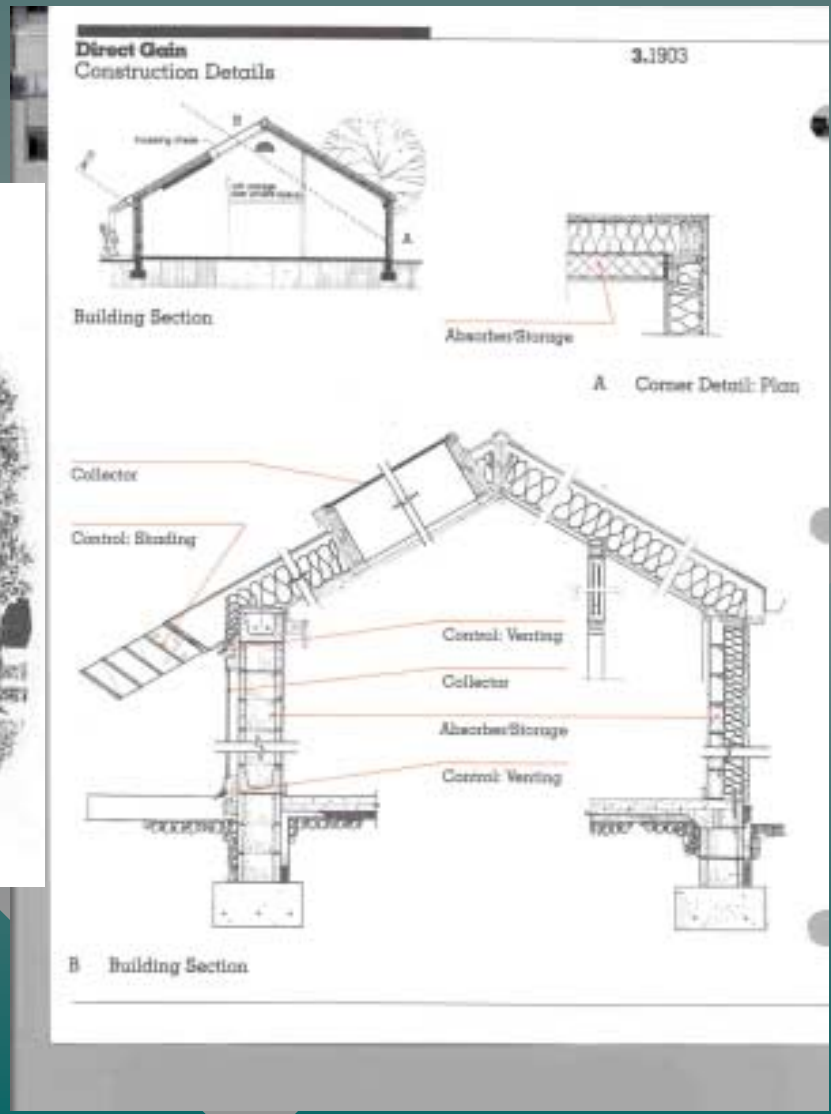
Passive Solar Architecture

Glassing + Thermal Mass = Energy Savings

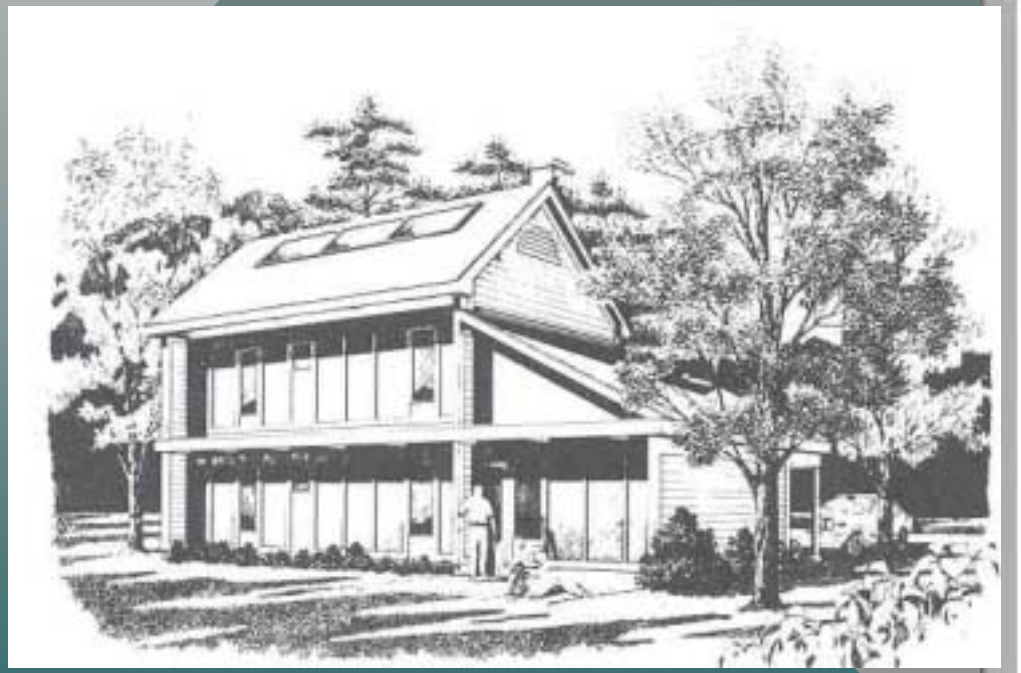
Three Basic Systems Used in Passive Solar Architecture

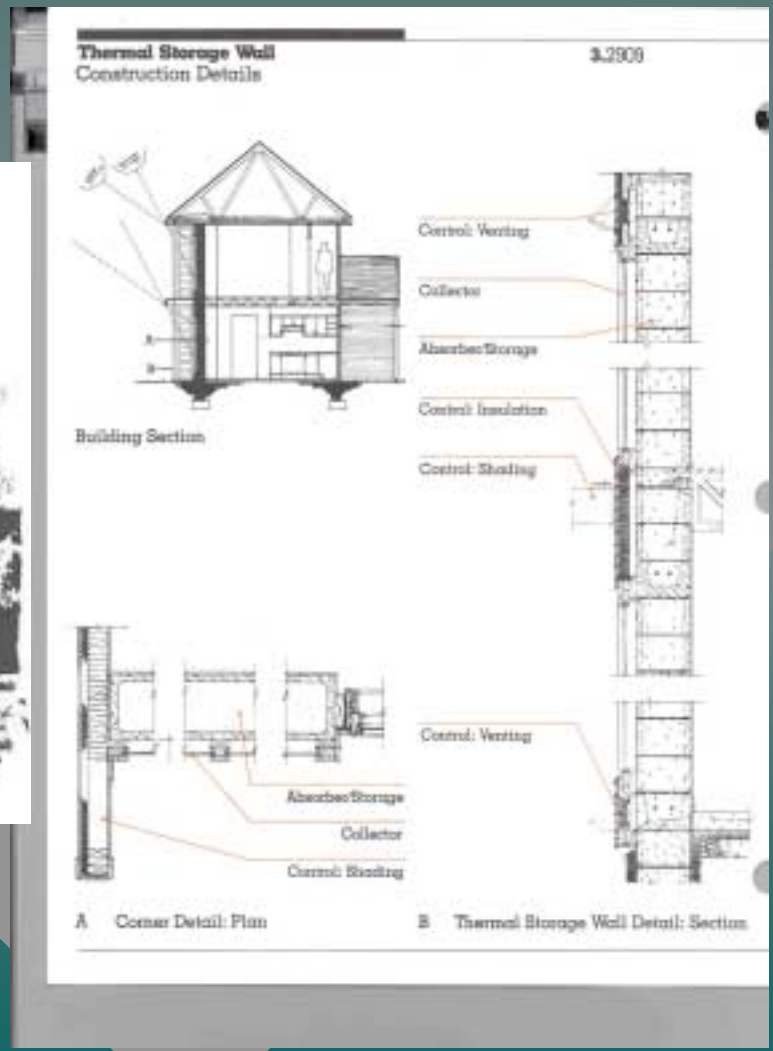
Direct Gain System



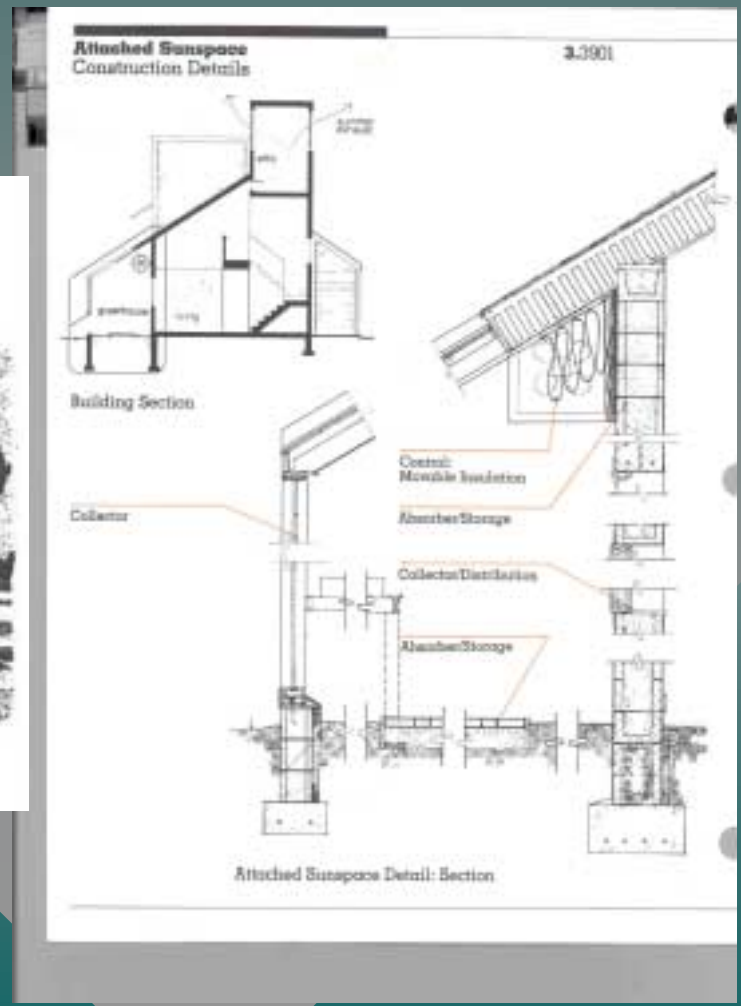


Thermal Storage Wall System





Attached Sun-Space System



History of DOE Research on Thermal Mass

Los Alamos National Lab. Late 1970s

- 18 different passive solar systems were tested
- Significant potential for energy savings in solar houses was predicted based on collected experimental results
- Guidelines for designing of passive solar buildings were developed

NIST Thermal Mass Studies Gaithersburg 1982

- Six 20x20-ft. buildings were tested (lightweight and massive)
- Massive buildings consumed considerably less energy
- Recorded results served for calibration of computer models
- Little impact of thermostat set-back on energy savings

Northern New Mexico Study Tesuque Pueblo - 1985

- Eight 20x20-ft. buildings were tested (lightweight and massive)
- Massive buildings consumed about 5% less energy than light weight.
- Recorded results served for calibration of computer models
- Four computer models (DOE-2.1A, DOE-2.1C BLAST, DEROB) were used for energy analysis

Oak Ridge National Lab. Massive Earth-Covered Building, 1982 - 1984

- 4000-sq ft. occupied dormitory was tested (lightweight and massive)
- Recorded results served for calibration of DOE-2.1B computer model
- Computer simulations yielded approximately 10 -13% energy savings for that type of buildings vs. light-weight constructions

NAHB Massive Building Study 1999

- Three side-by-side 1100-sq ft homes were tested (lightweight and massive)
- 20% difference in energy consumption was recorded between massive and light-weight house
- Computer simulations yielded approximately 9% energy savings after taking into account the difference in wall R-value (ORNL calculations)

DOE Research on Thermal Mass

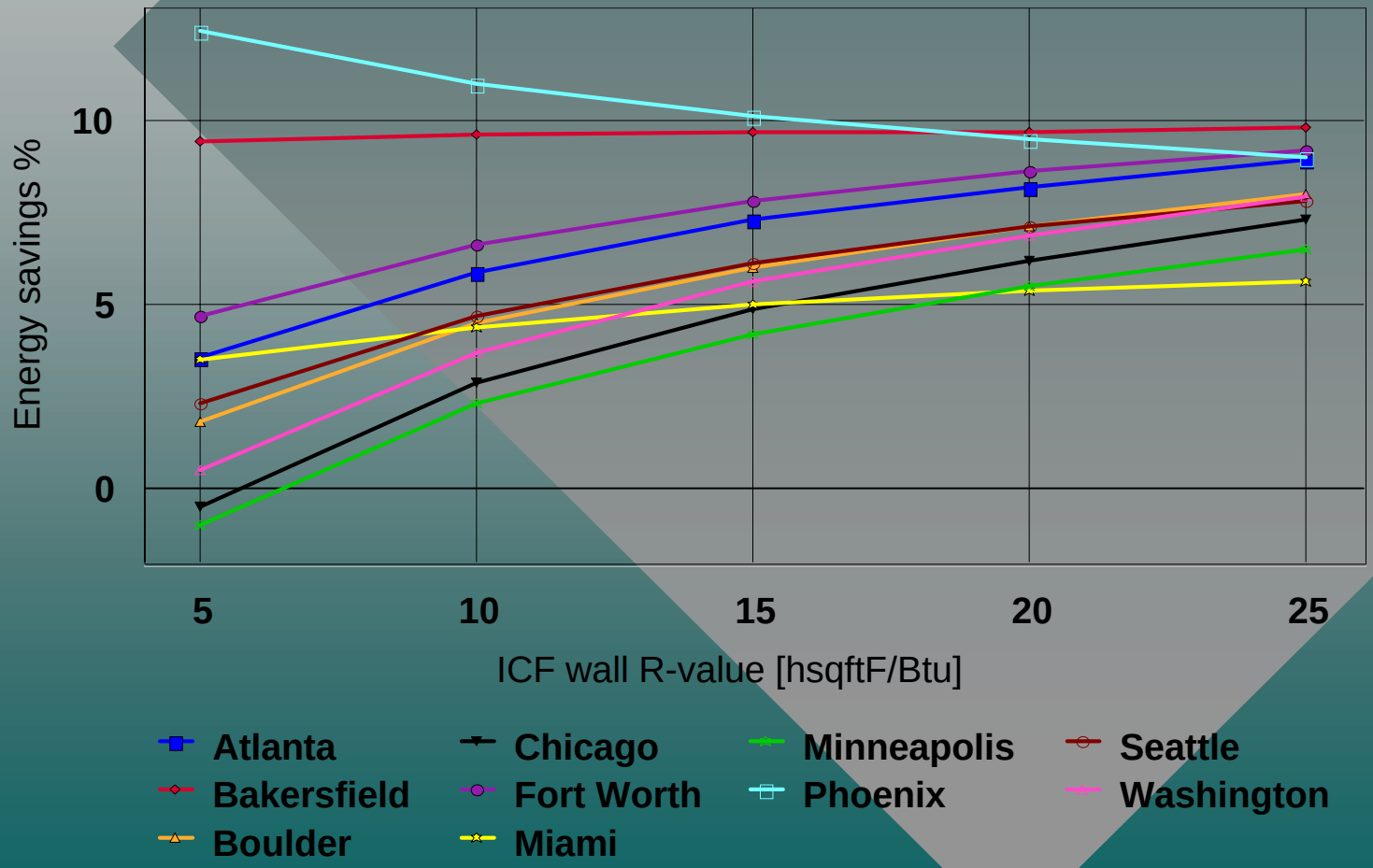
General conclusions:

- Several field demonstration projects has proved that using massive walls in residential buildings can significantly reduce total energy consumption
- NIST study demonstrated a little impact of thermostat set-back on energy savings

ORNL Theoretical Energy Performance Data for Massive Wall Systems

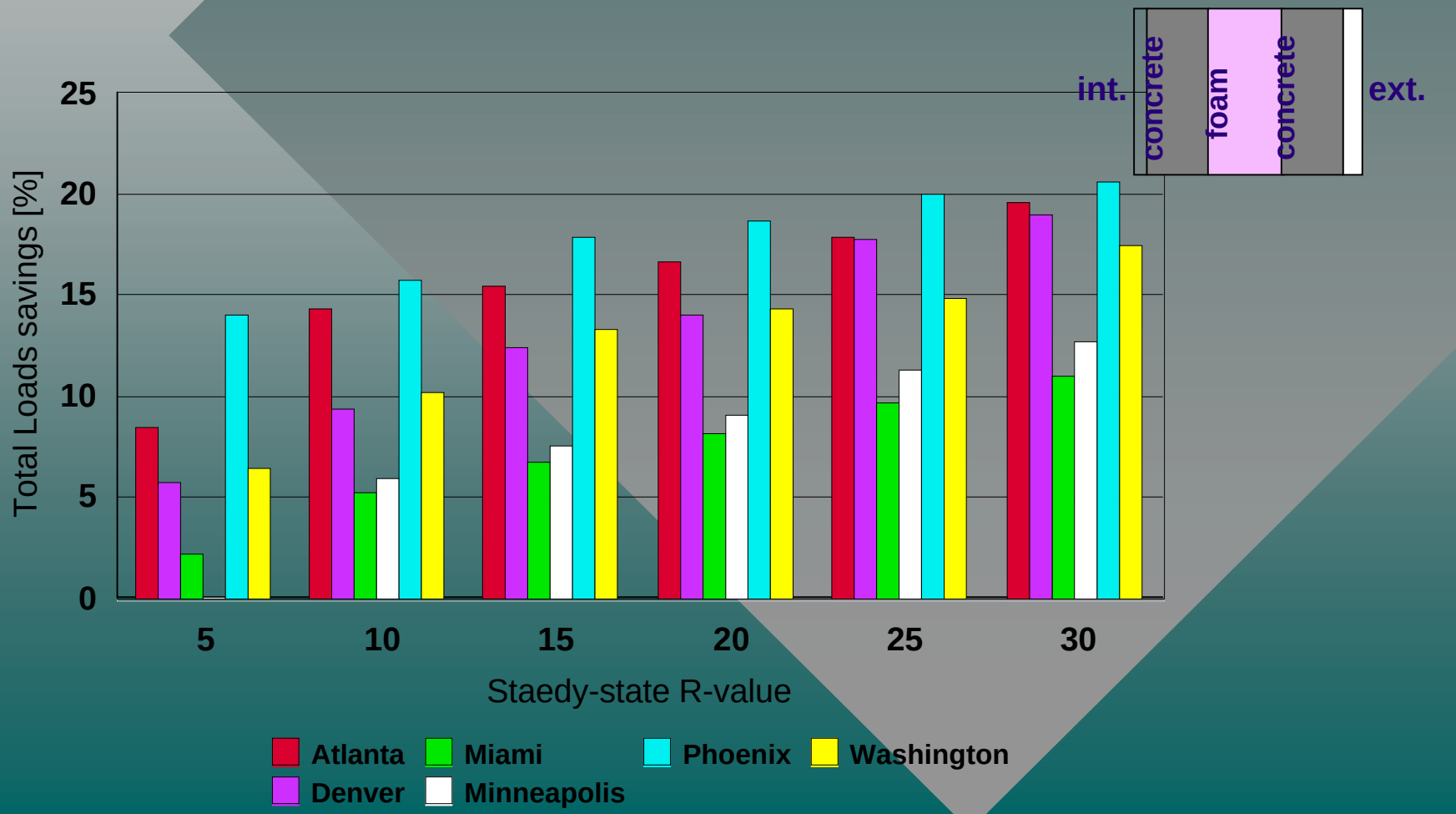
- Over 1000 DOE 2.1E parametric simulations
- Ten US climates
- Three types of residential buildings
- Four wall material configurations

ORNL Theoretical Energy Performance Data for ICF Wall Systems



ORNL Theoretical Energy Performance Data:

Potential Building Loads Savings Caused by the Use of Concrete Sandwich Panels in Residential Building



ORNL Theoretical Energy Performance Data:

General conclusions:

- Massive walls in residential buildings can significantly reduce total energy consumption
- More insulation used in the building, higher chance for energy savings when massive envelope systems are used
- Massive wall energy performance depends on the configuration of wall materials

Thermal Mass Energy Performance

Research data:

- Several experimental studies demonstrated that massive walls in residential buildings can significantly reduce building energy consumption
- ORNL theoretical calculations suggest that application of massive walls in residential buildings can significantly reduce building energy consumption

Thermal Mass Energy Performance

Current opinions:

- Research on Thermal Mass is concluded and no thermal mass effect on energy consumption was detected (one of the reviewers to the BUILDING VIII ENVELOPE CONFERENCE)

Thermal Mass Energy Performance

Situations:

- Standards for experimental estimation of dynamic thermal characteristics of building envelope assemblies are not available yet
- Energy codes providing energy credits for massive wall systems are not complete
- HVAC sizing directions for massive buildings are not available yet

Thermal Mass Energy Performance

Reality.:

- Several companies claim unrealistic energy performance data for their massive walls
- Oversized HVAC equipment is commonly installed in buildings with massive walls
- Designers and builders experience problems with code officials regarding the energy credits for massive wall technologies