Calculation of Energy Benefits of Application of Thermal Mass in Residential Buildings - Methodology

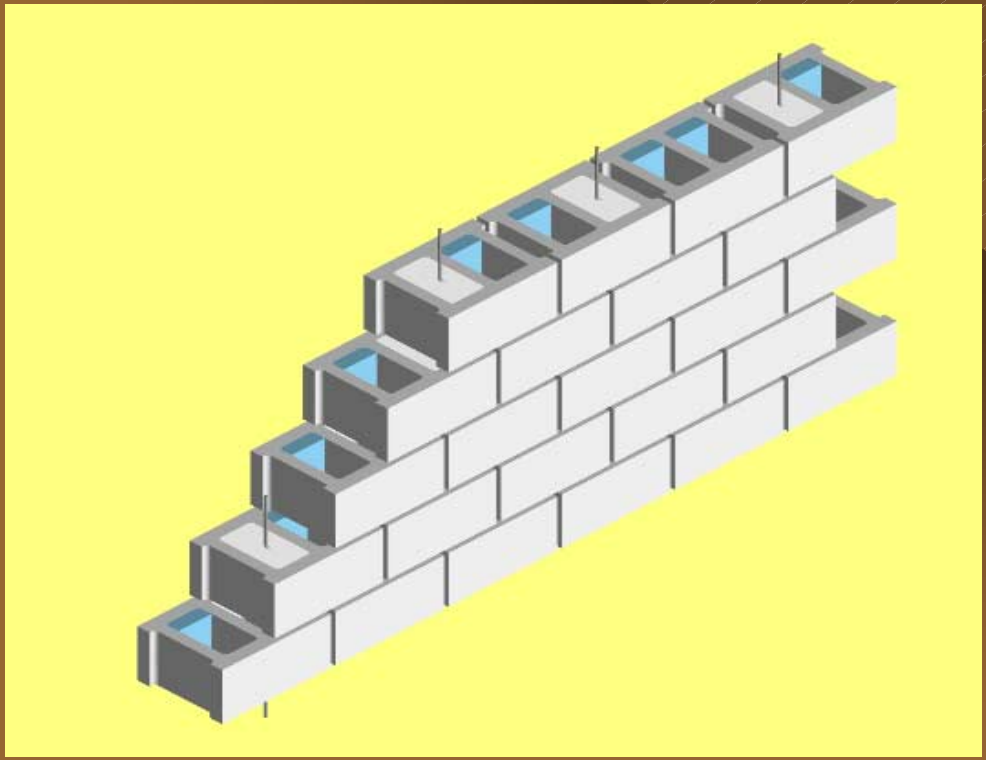
Energy Performance of Different Massive Exterior Walls - Effect of Material Sequence

Thermal Performance of Exterior Envelopes of Buildings VIII
Dec. 2-7, 2001

Thermal Mass and Its Effect on The Whole Building Energy Performance

Jan Kosny Ph.D.

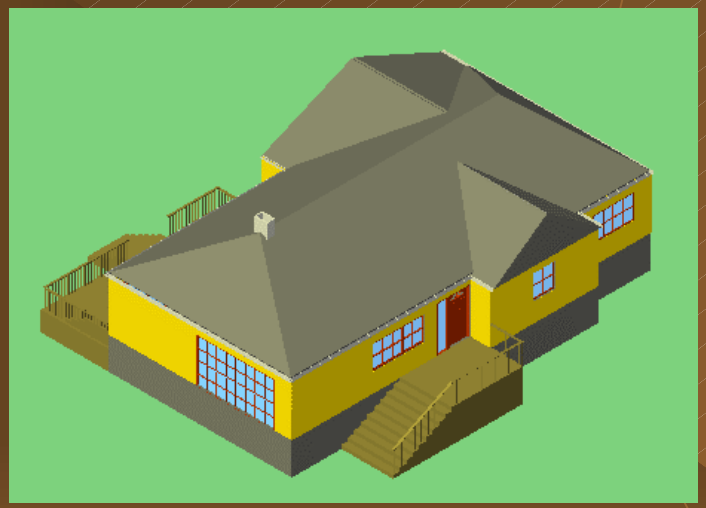
Calculation of Energy Benefits of Application of Thermal Mass in Residential Buildings - Methodology



- Methodology
- Field Demonstration Projects
- Lab. Experimental Procedures
- Thermal Mass Benefits Standards
- Sizing of HVAC Equipment
- Calculation of Potential Energy Savings

Calculation of Energy Benefits of Application of Thermal Mass in Residential Buildings - Methodology

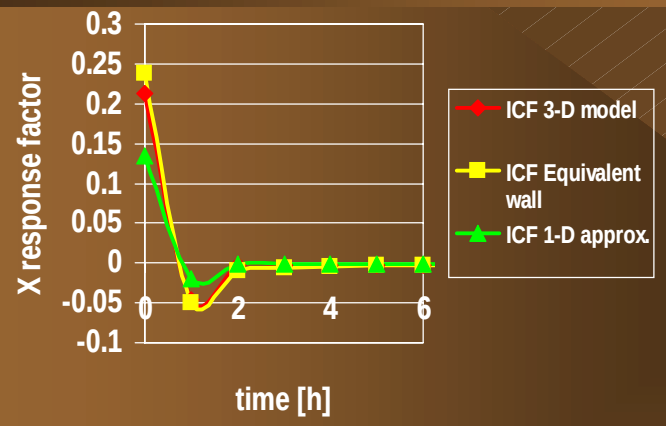
Dynamic thermal characteristics of building envelope components

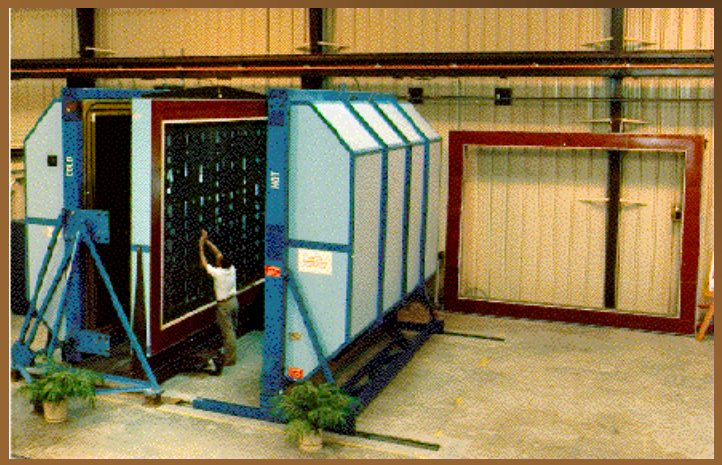


Dynamic energy benefits of building envelope systems

Dynamic loads

Dynamic Thermal Characteristics of Building Envelope Components





- Dynamic Hot-Box Testing
- 3-Dimensional Dynamic Computer Simulations
- Calculation Procedures for:
  - structure factors
  - series of response factors
  - transfer function coefficients

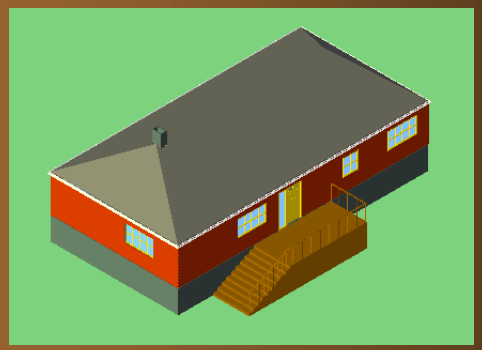
Dynamic Loads

- Solar radiation
- Exterior temperature fluctuations
- Interior temperature fluctuations
- Air-in and out-filtration
  - temperature difference
  - air pressure difference
  - frequency of air pressure changes
- Interior energy sources
- etc...

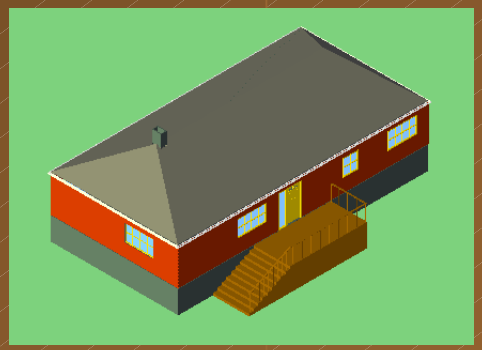
Calculation of Energy Benefits of Application of Massive Wall Systems in Residential Buildings

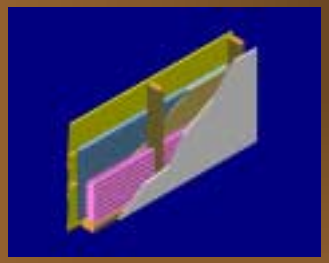
- Dynamic wall R-value equivalent (**DRE**) is calculated by comparisons of light weight wall building energy demands versus energy demands for building containing massive walls.
- Energy demands are calculated using DOE-2.1E computer simulation results
- Dynamic R-value equivalent (**DRE**) =
  = Steady-State R-value x **DBMS**.
  DBMS - Dynamic Benefits for Massive Systems

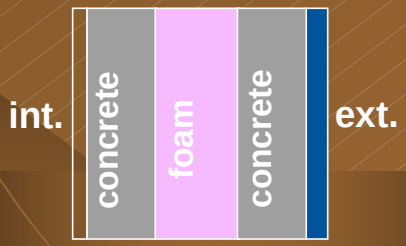
Building Loads Comparisons Generated by DOE 2.1E Simulations



vs.

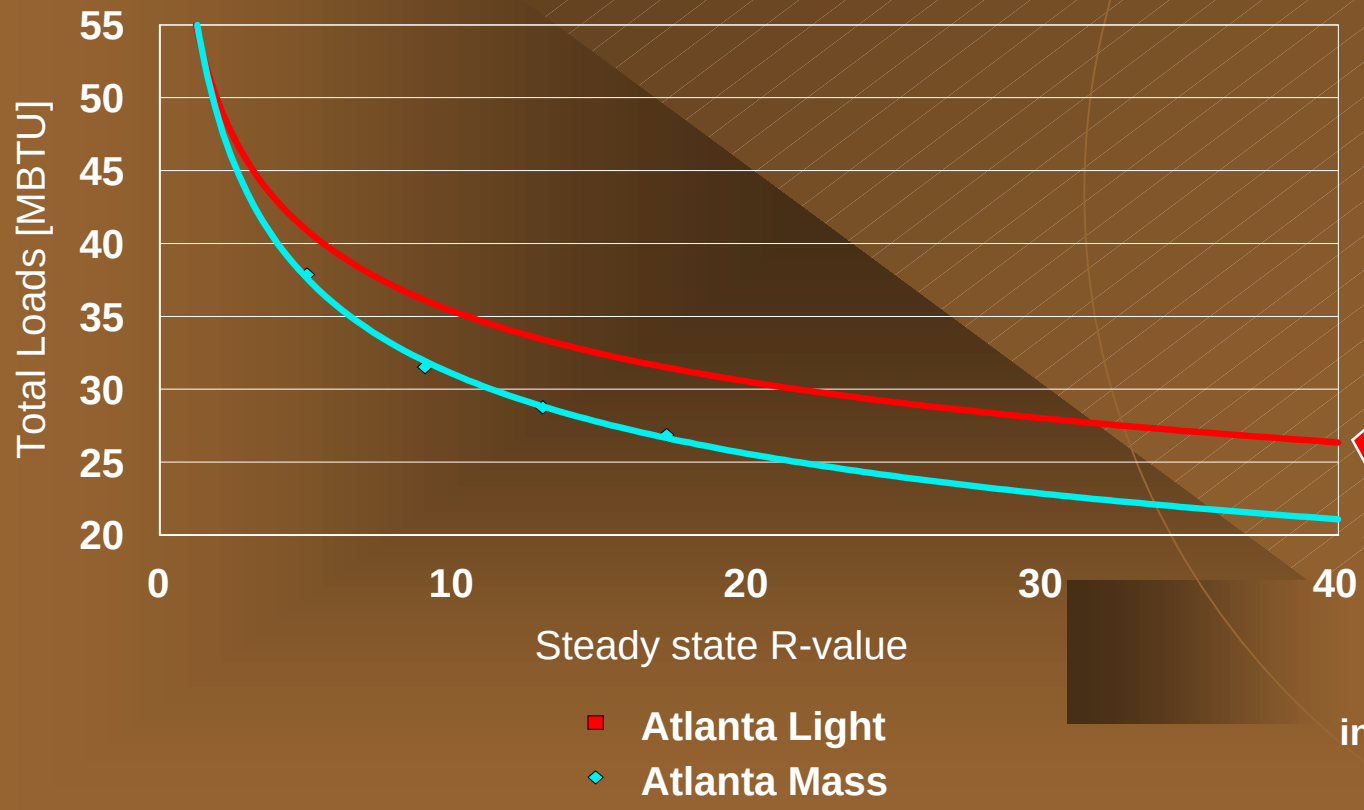


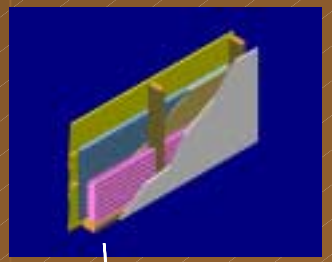


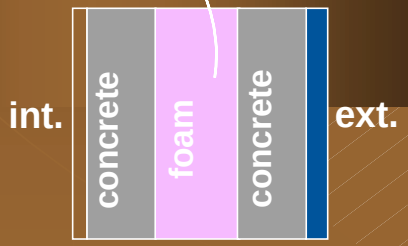


Only dynamic thermal characteristics of exterior walls are taken into account. Other buildings characteristics are the same for both type of buildings.

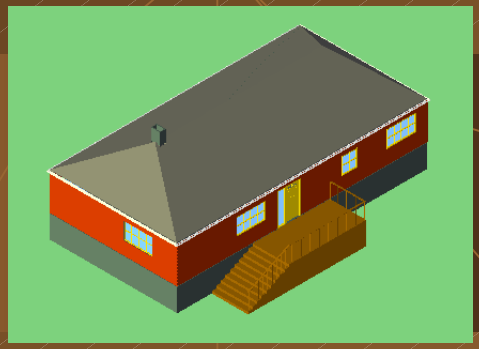
Building Loads Comparisons Generated by DOE 2.1E Simulations



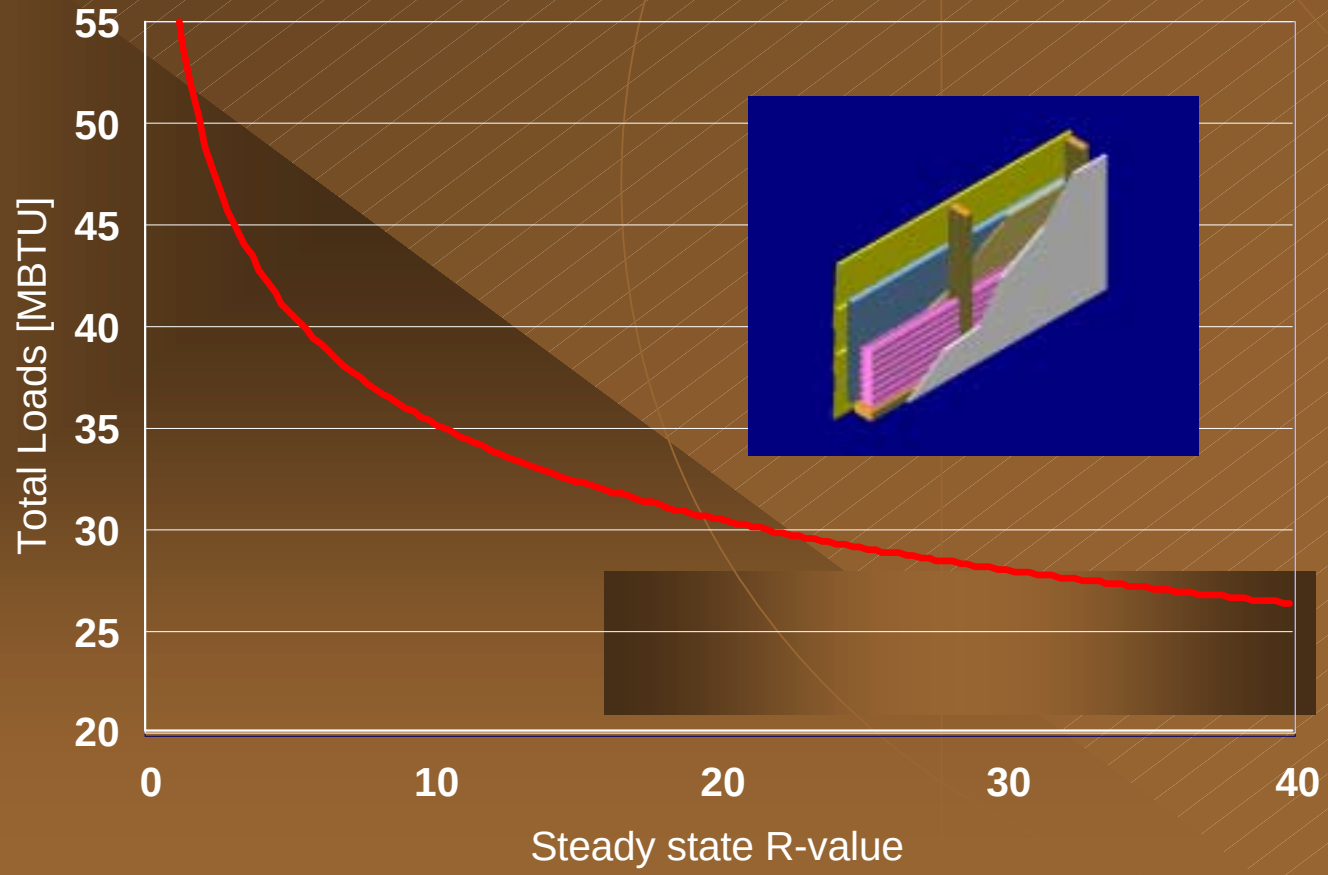




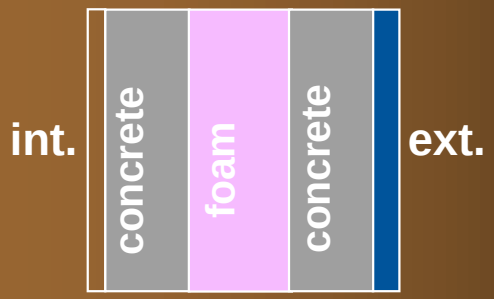
Calculation of DRE (Dynamic R-value Equivalent)

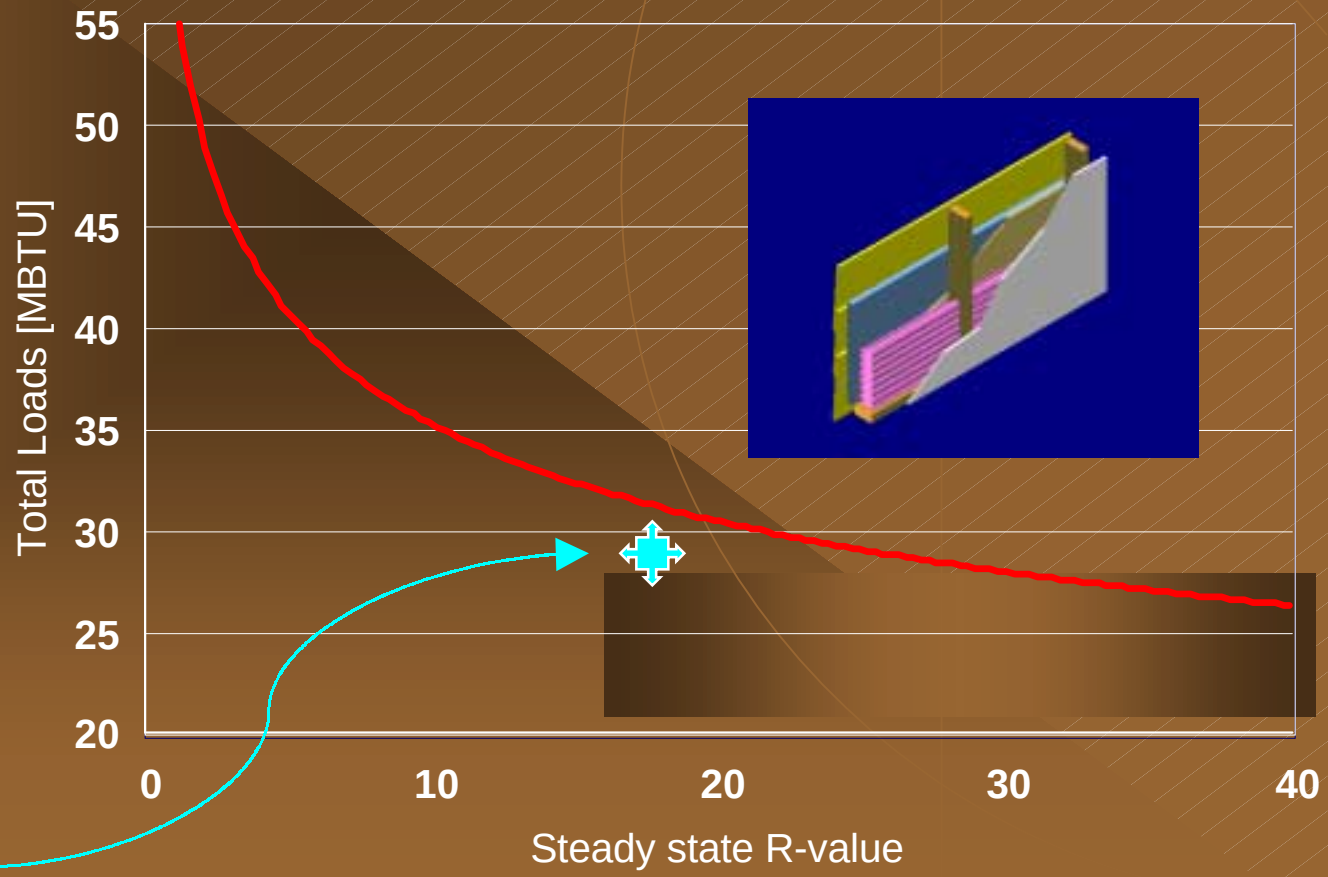


Relation between wood frame wall R-values and total building heating and cooling loads



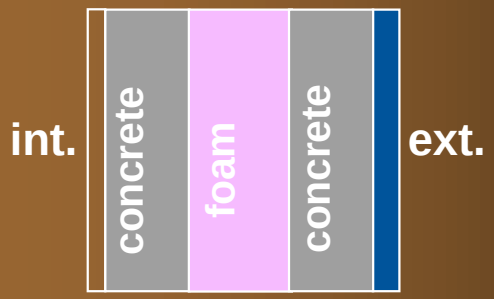
Calculation of DRE (Dynamic R-value Equivalent)





Total loads for house with R-18 massive walls

Calculation of DRE (Dynamic R-value Equivalent)



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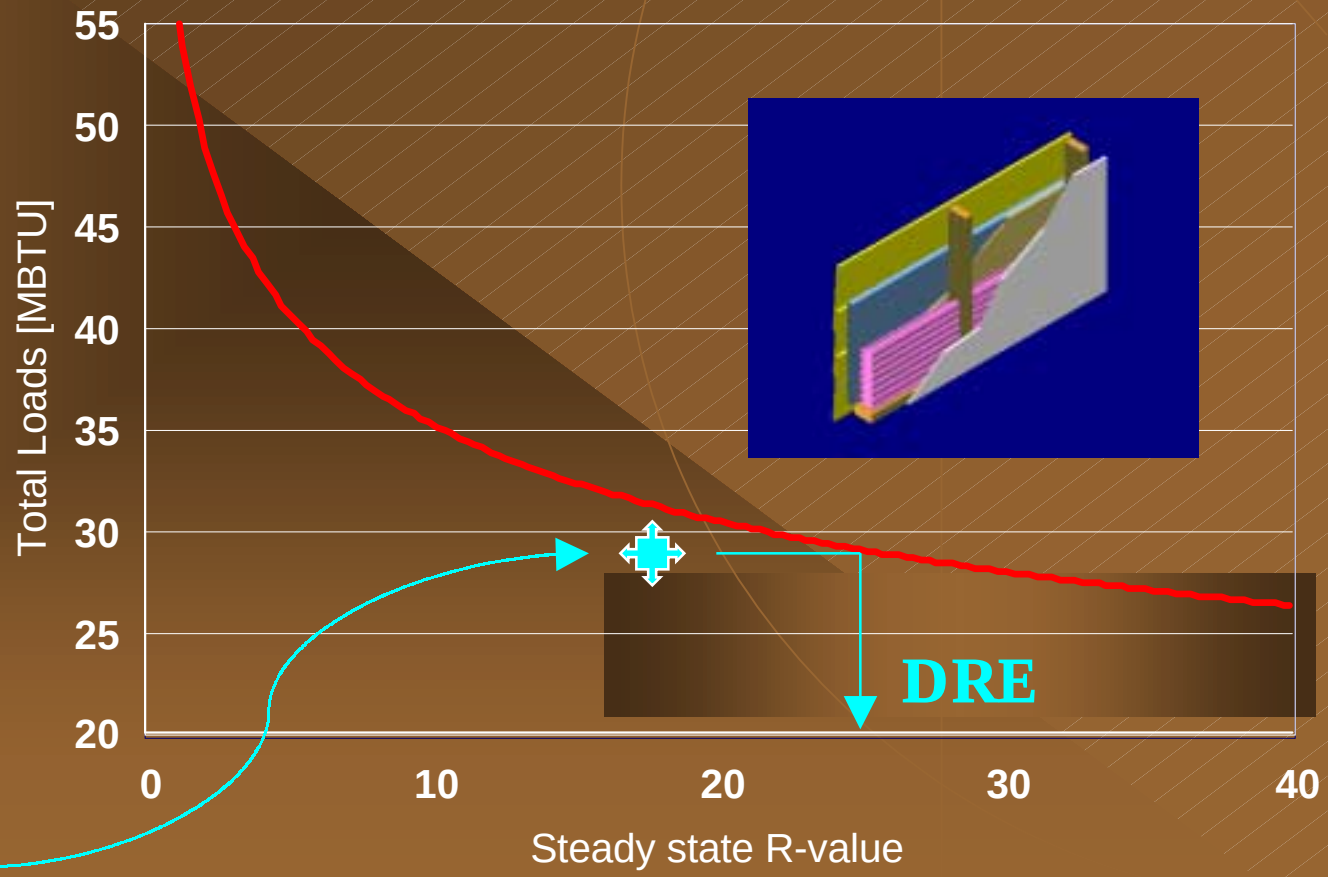
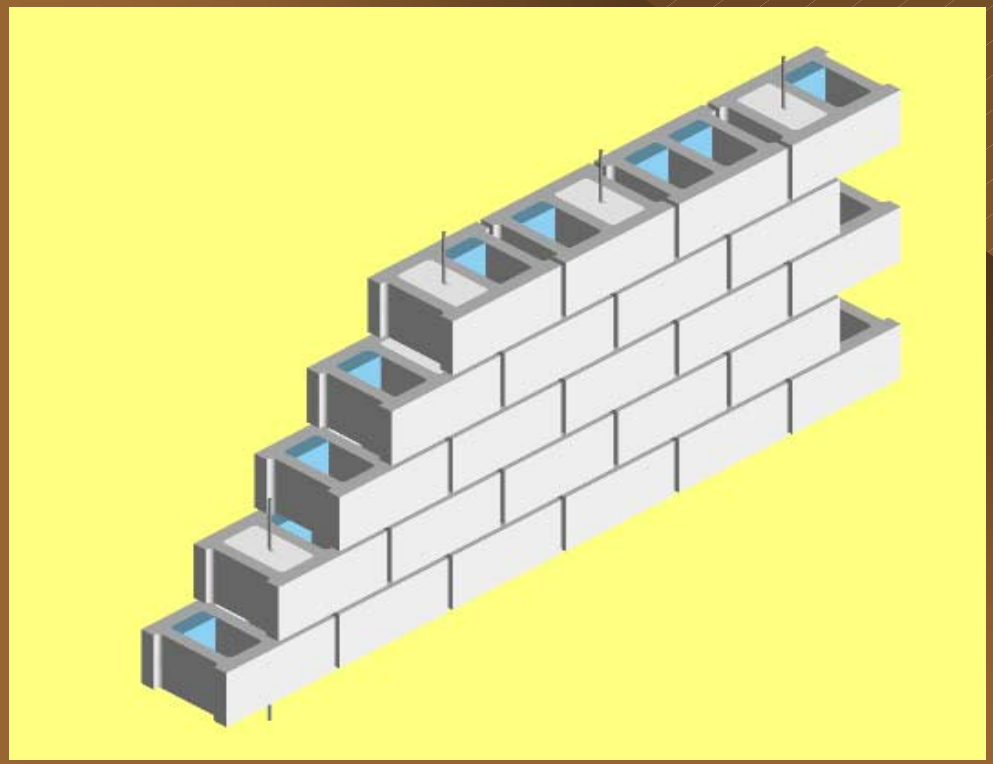


Calculation of Energy Benefits of Application of Massive Wall Systems in Residential Buildings

- A new measure of the wall thermal dynamic performance is introduced - Dynamic Benefit for Massive Systems (**DBMS**).
- The thermal mass benefit is a function of the material configuration and climate conditions.
- The product of **DBMS** and steady-state **R-value** is called Dynamic R-value Equivalent (**DRE**).
- **DRE** has not a physical meaning. It should be understood only as an answer to the question: *"What wall R-value should a house with wood frame walls have to obtain the same space heating and cooling loads as a similar house containing massive walls?"*

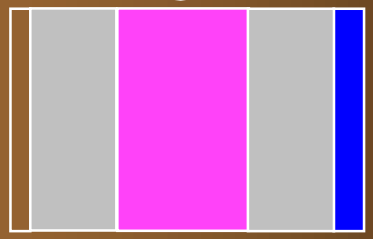
Energy Performance of Different Massive Exterior Walls: Effect of Material Sequence



- Steady state R-value
- Sequence of materials
- Ratio of thermal conductivities in neighboring layers

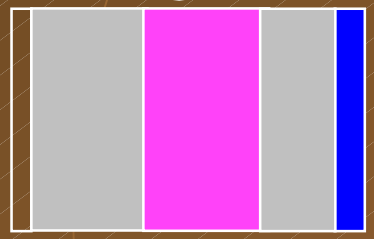
Dynamic Thermal Performance of Simple One-Dimensional Wall Assemblies

1



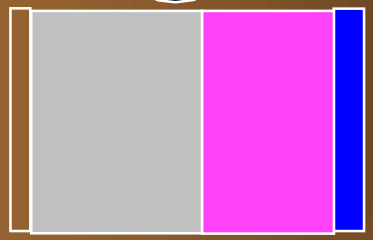
Gypsum-Board
Concrete
Insul. Foam-
Concrete
Stucco

2



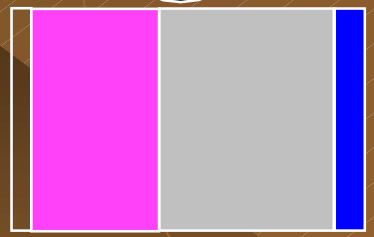
Gypsum-Board
Concrete
Insul. Foam
Concrete
Stucco

3



Gypsum-Board
Concrete
Insul. Foam
Stucco

4



Gypsum-Board
Insul. Foam
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5

Gypsum-Board
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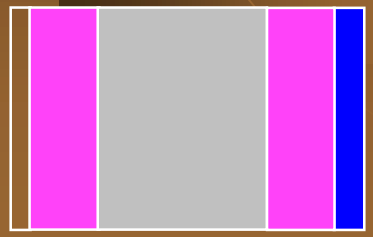
6



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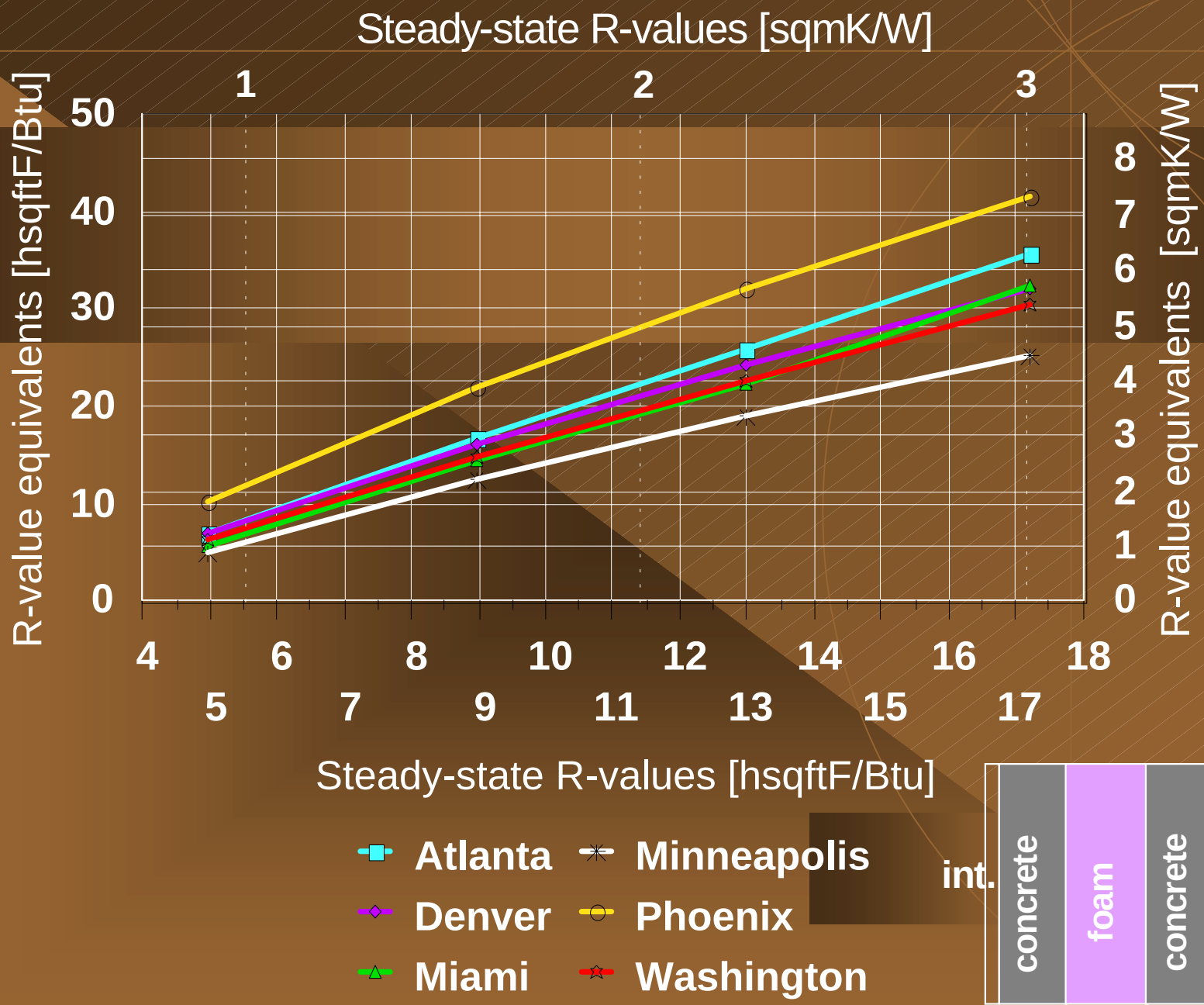
Steady-state R-values [sqmK/W]
1
2
3
R-value equivalents [hsqftF/Btu]
50
40
30
20
10
0
R-value equivalents [sqmK/W]
8
7
6
5
4
3
2
1
0
4
6
8
10
12
14
16
18
5
7
9
11
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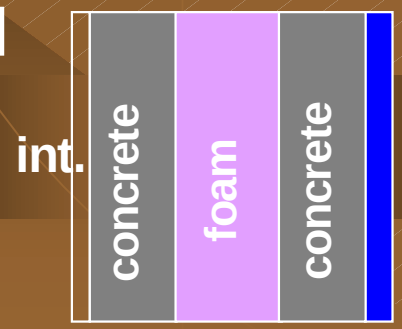
15
17
Steady-state R-values [hsqftF/Btu]
Atlanta
Minneapolis
Denver
Phoenix
Miami
Washington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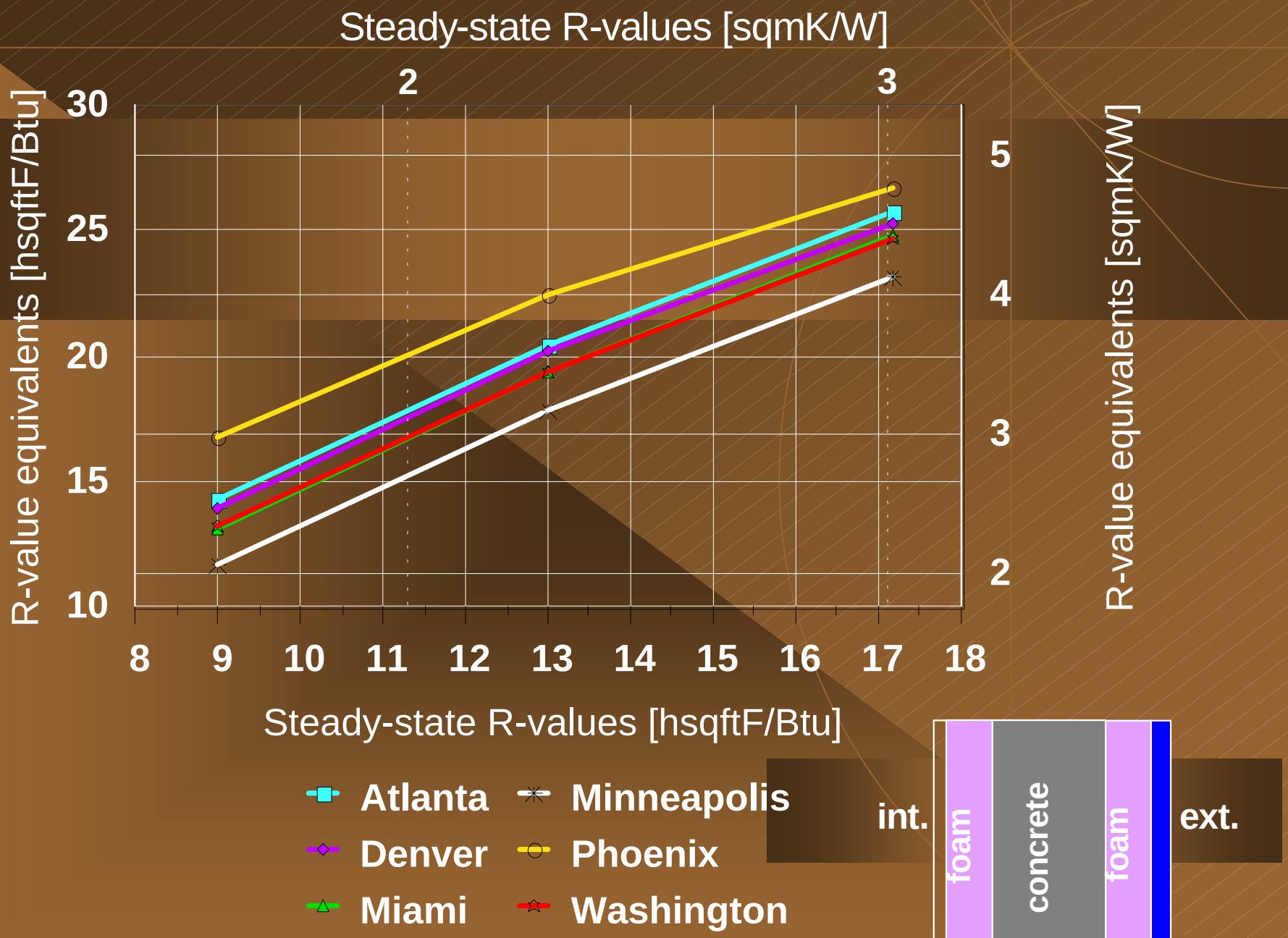
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R-value equivalents [hsqftF/Btu]
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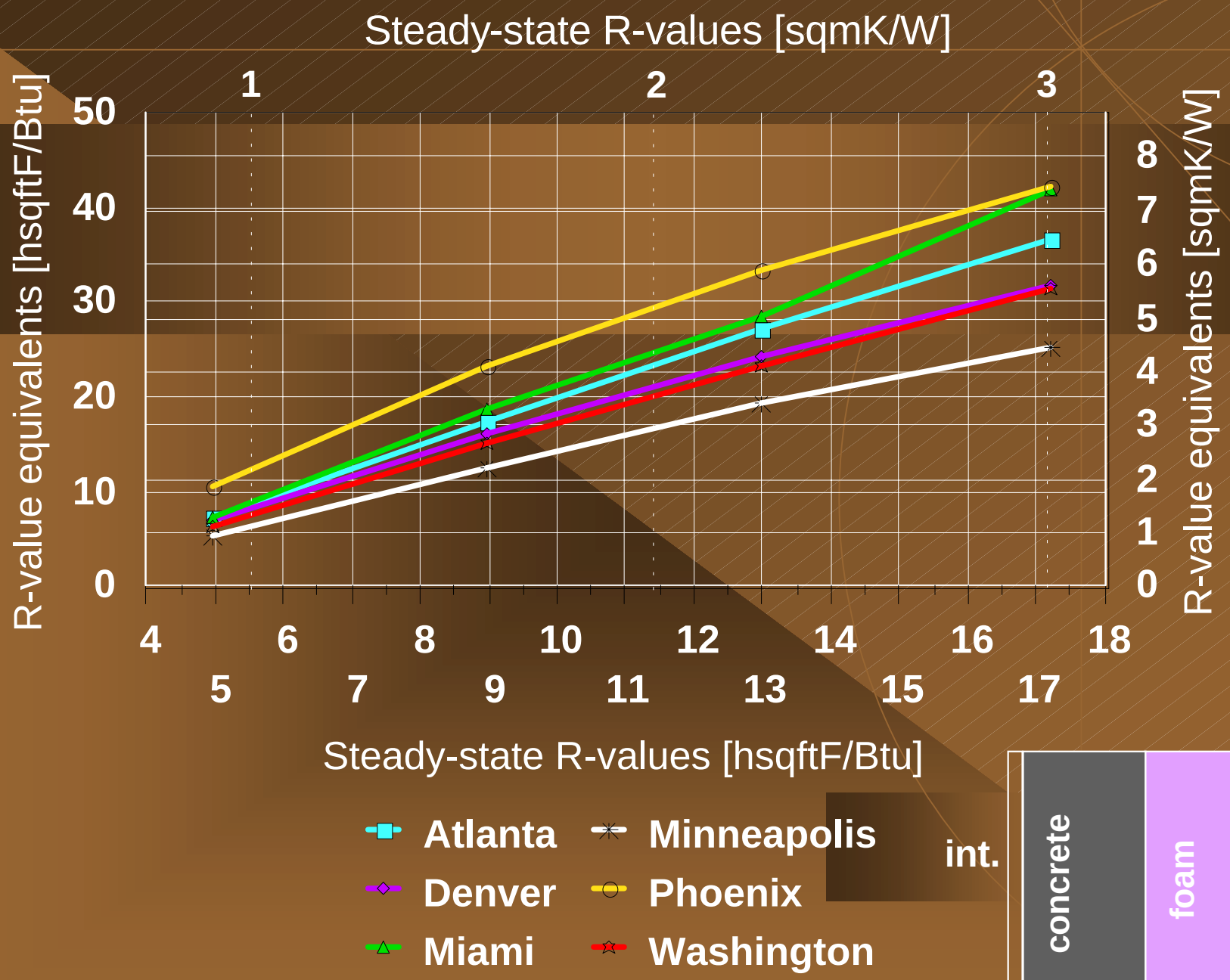
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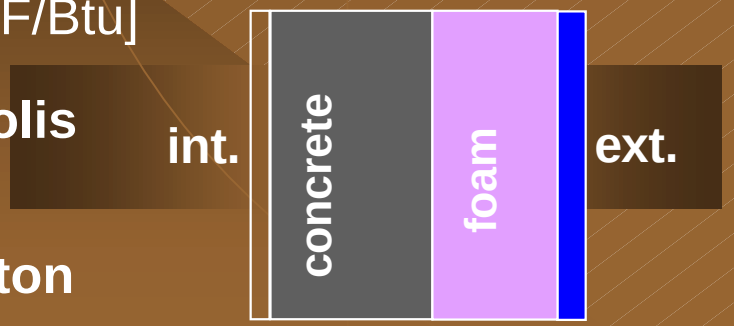
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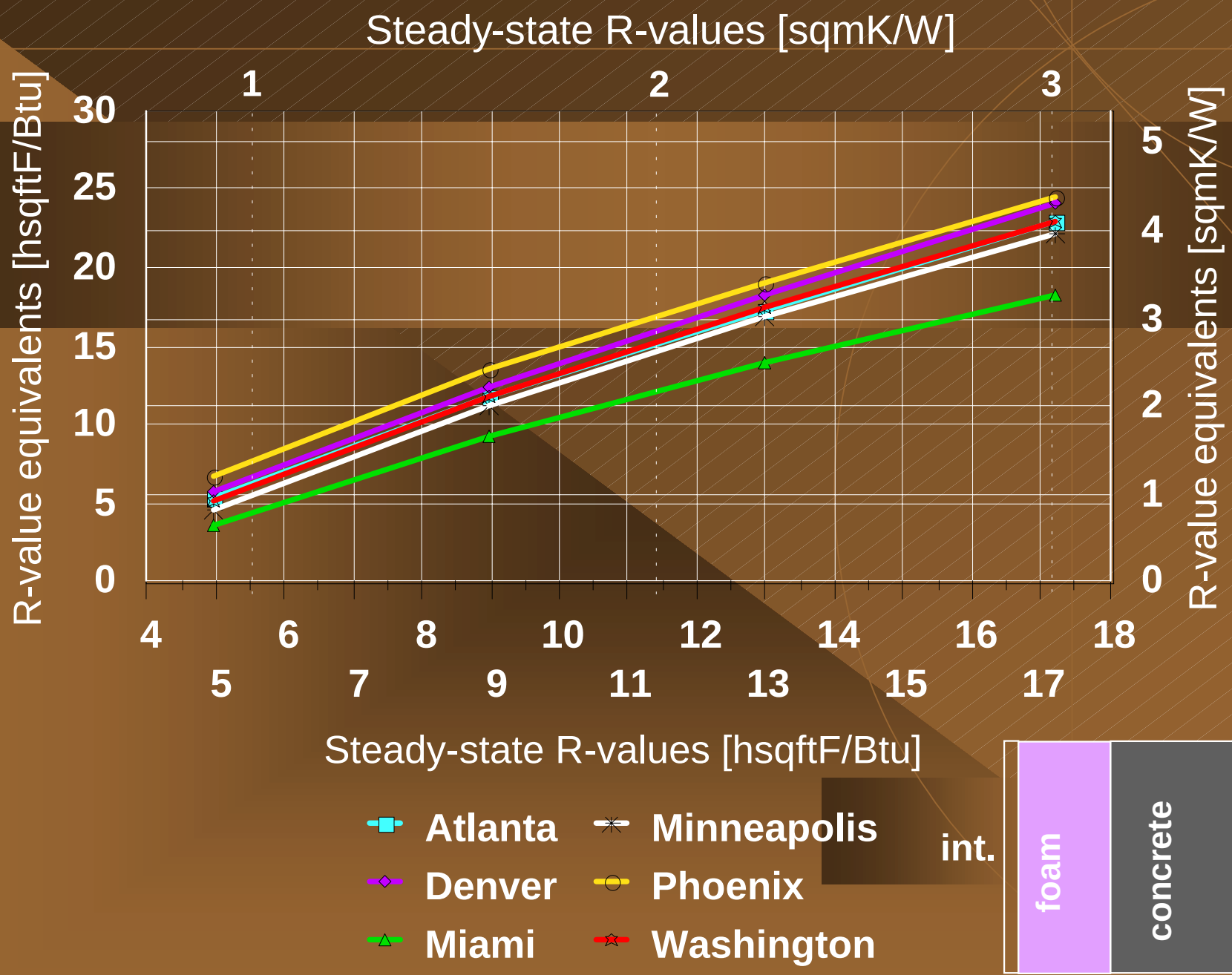
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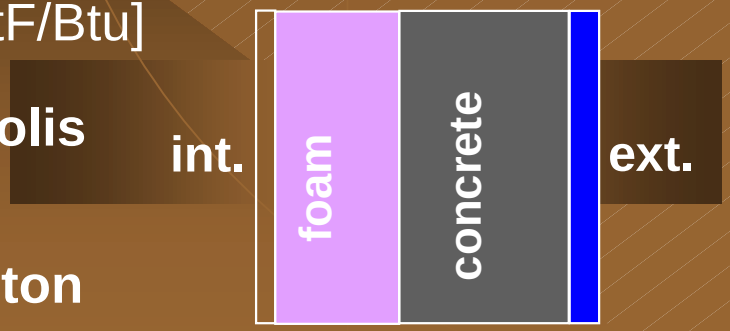
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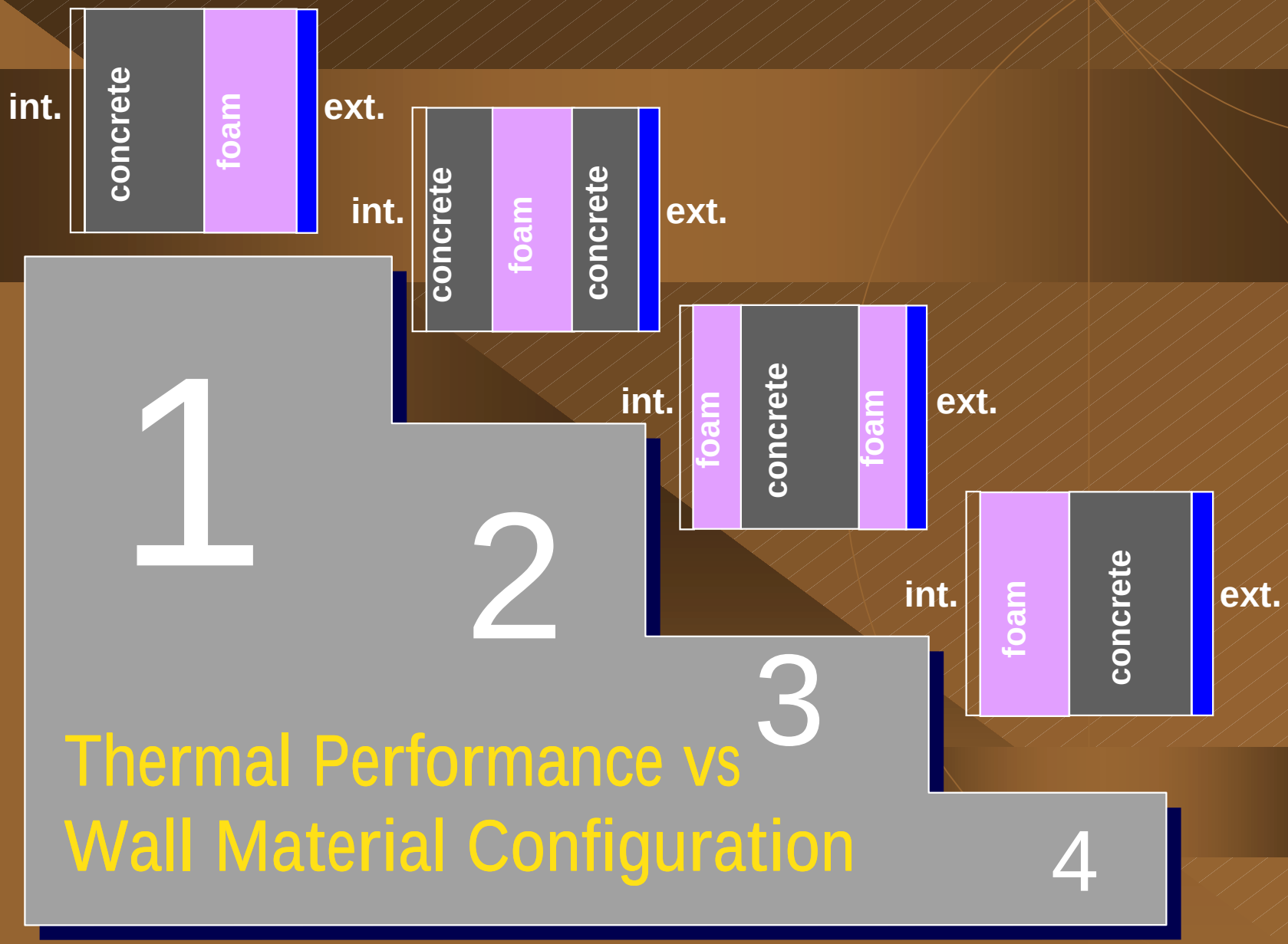
Thermal Performance vs Wall Material Configuration



Conclusions:

- Using thermal mass in buildings can significantly reduce annual energy demand.
- Efficiency of using thermal mass in buildings depends on:

  building configuration, type of building structure, amount of thermal mass in building, and internal heat sources,

  climate,

  steady-state wall R-value, and

  wall materials configuration.

Conclusions cont.:

- Massive wall configurations with thermal mass located on the interior side of the wall are most thermally effective.
- Estimated energy consumption savings generated by application of massive walls in residential buildings can reach 5 - 20%.
- A new measure of the wall thermal dynamic performance is introduced - Dynamic Benefit for Massive Systems (**DBMS**)
- The product of **DBMS** and steady-state **R-value** is called Dynamic R-value Equivalent (**DRE**).