CAE 463/524
Building Enclosure Design
Spring 2015

Lecture 13: April 28, 2015
Some last application notes
Enclosure research
Course wrap-up

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Last time: Guest lecture

- Bruce Kaskel, Principal, WJE (Wiss, Janney, Elstner Assoc. Inc.)
  - 30 years at WJE
  - B.S. Architectural Studies, UIUC
  - MArch, Structures, UIC
  - Practice areas:
    - Curtain walls and windows
    - Exterior wall systems
    - Glass performance
    - Leakage investigation
  - Registered Architect and Engineer
  - ASTM Fellow
  - Past president of SEAOI
  - Board of Governors, Insulating Glass Certification Council
- **Thoughts??**

Catch-up from 2 weeks ago

- Codes and standards in building enclosure design
  - City, state, and national energy codes
  - ASHRAE 90.1, 189.1, AEDG30, AEDG50
    - Various pathways to compliance
  - USGBC LEED (points back to ASHRAE)
  - ASTM test standards (incl. commissioning)

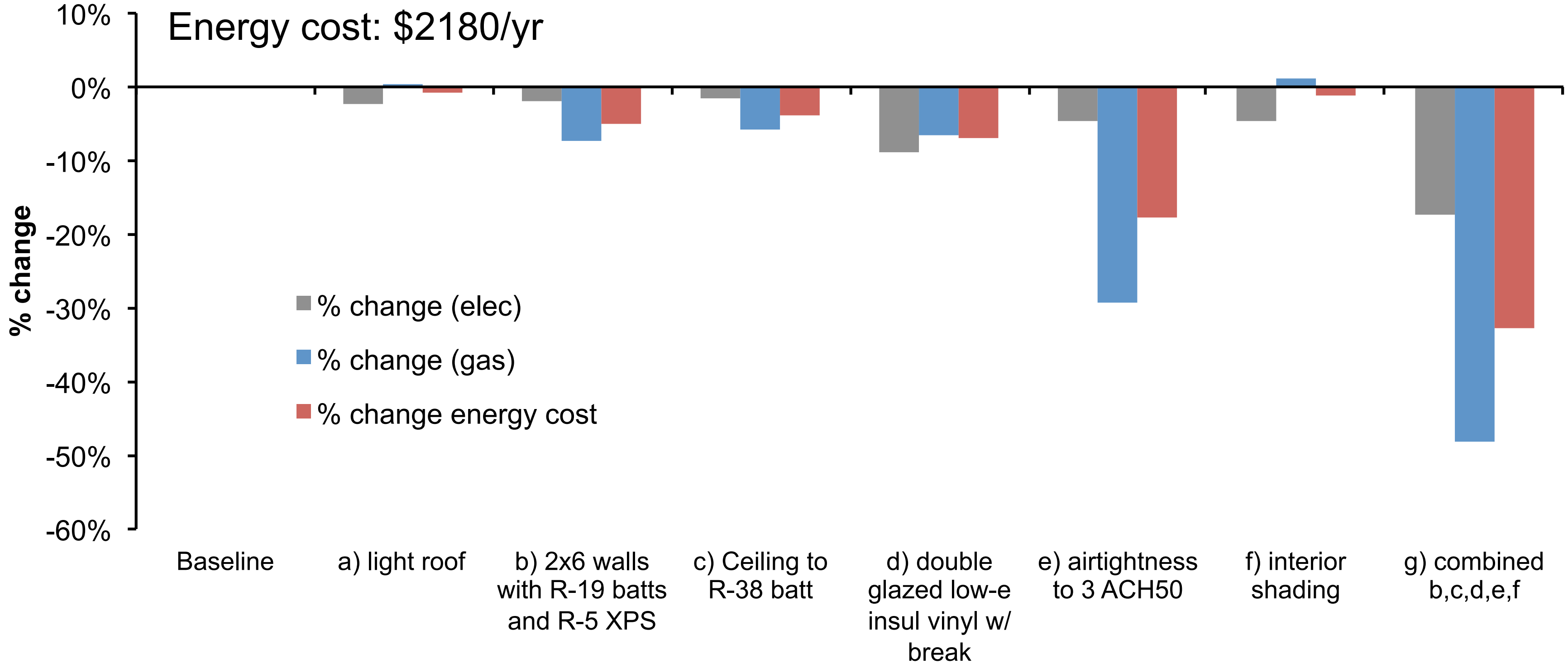
- HW5: Energy simulation in enclosure design (residential)

- Final project reports due to me (PDF via email)
  - Tuesday May 5 @ 11:59 PM

HW 5 solutions

- HW #5 using BEopt and EnergyPlus

Baseline home:
Electric 9800 kWh
Gas: 150 MMBtu
Energy cost: $2180/yr



Objectives for today

- Some application notes for building enclosure design
- Thoughts on recent enclosure design research
- Course wrap-up and summary

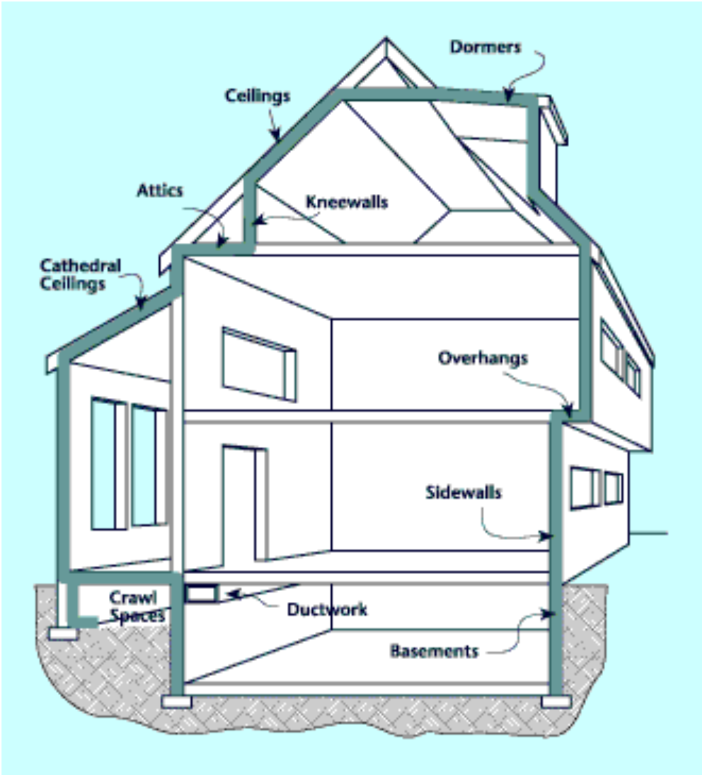
A FEW LAST APPLICATION NOTES FOR BUILDING ENCLOSURE DESIGN

INSULATION MATERIALS

Applications

Building insulation

- Insulation is necessary to control heat flow through enclosure
- All opaque external surfaces should have insulation
  - Walls
  - Ceilings
  - Roof
  - Basements
- We've discussed insulation in terms of thermal conductivity, U-values, and R-values
  - ***A lot***



Important properties of insulation

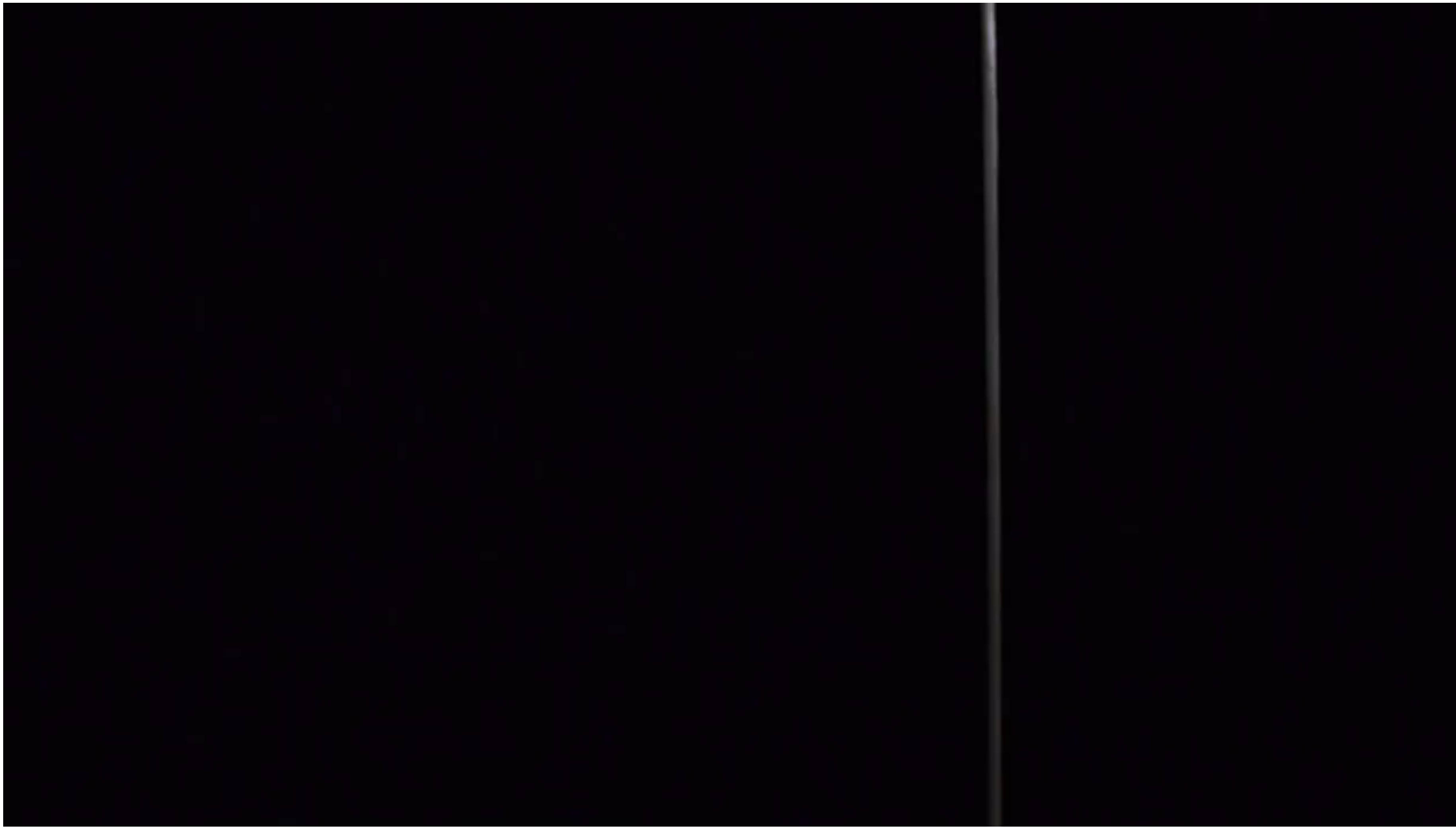
- Thermal resistance
  - Important for controlling heat flow and condensation
- Vapor resistance
  - Important for controlling water vapor transmission
- Fire/smoke resistance
  - Important for fire and life safety considerations
- Sound absorption
  - Important for noise control
- Structural integrity
  - Important for use in certain applications (e.g., roofing)
- Chemical composition
  - Important for knowledge of environmental considerations
- Costs

Thermal resistance measures (IP units)

- R = R-Value [(h ft^2 °F)/Btu]
  - Thermal resistance per unit area
  - Larger R-Value is better
- U = U Value [Btu/(h ft^2 °F)]
  - $U = 1/R$ = Thermal conductance per unit area
  - Often used for doors and windows
- r = thermal resistivity [(h ft^2 °F)/Btu in]
  - $r = R/L$ = also **R per inch** of thickness
  - Larger r value is better
- k = thermal conductivity [Btu/(hr ft^2 °F in)]
  - $k = 1/r = L/R$
  - Smaller k value is better

- How do we measure thermal resistance?

Measuring thermal resistance of materials



ASTM C1114-00 Heat flow apparatus (small sample) & ASTM C1363-05 Hot box (full sample)
https://www.youtube.com/watch?v=PjfznDPOeDA

Hot box apparatus

Thermal transmittance measurements with the hot box method: Calibration, experimental procedures, and uncertainty analyses of three different approaches

F. Asdrubali*, G. Baldinelli

Energy and Buildings 43 (2011) 1618–1626

Contents lists available at ScienceDirect

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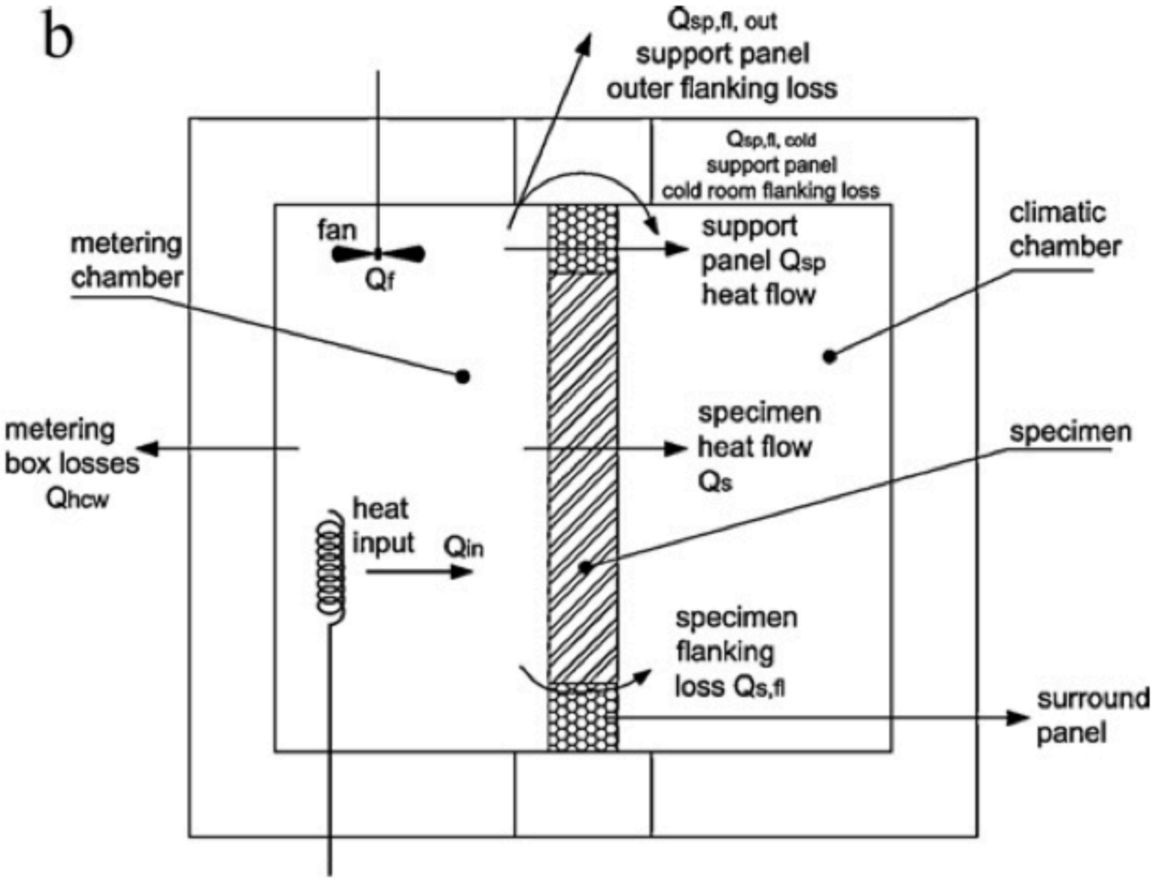

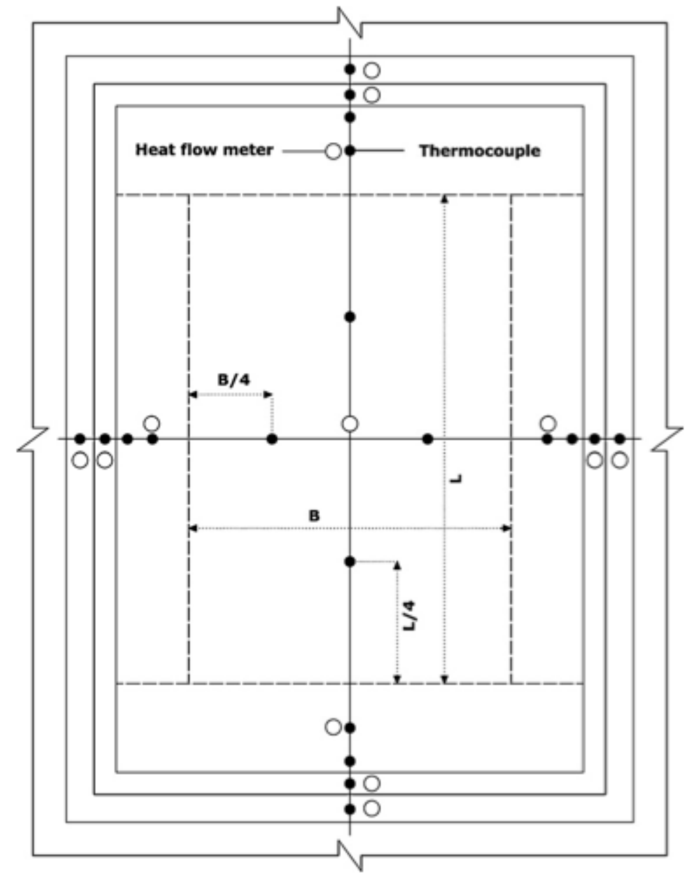

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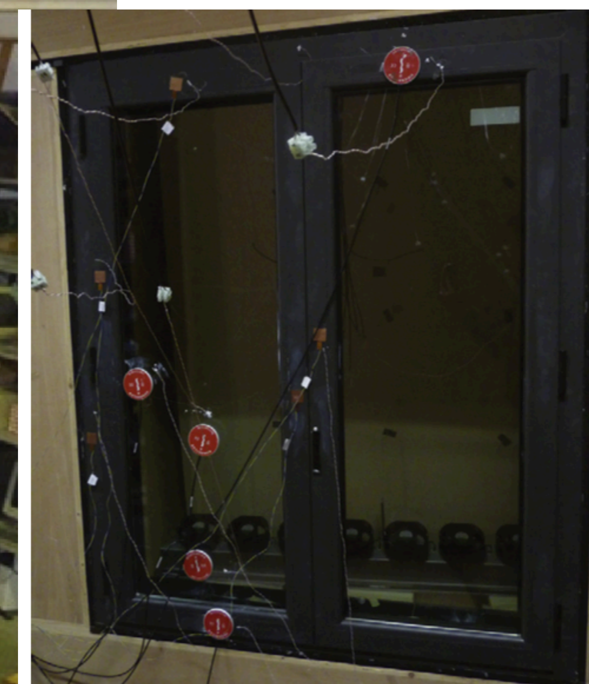


Notes for construction documents

- Conductivity of types of insulations can change from manufacturer to manufacturer
  - It is best to denote a required R value on the building drawings and in the specifications
  - Ensures that the required insulating value is installed

- When comparing insulations, it is better to compare R *per inch* or k values because they are basic material properties
  - Not dependent on thickness

Flame and smoke ratings

- **Flame spread index** is a relative measure of the speed of flame spread
  - 100 is the speed at which flames spread on red oak wood
    - 0 is asbestos-cement board
  - A flame spread rating of 20 means the flame spread speed is 20/100 = 1/5 (20%) that of red oak
  - Class A fire ratings (the best) have flame spreads of 0-25
  - Class B is 26-75
  - Class C is 76-200
  - Flame spread ratings are not the same as fire resistance ratings

- **Smoke-developed index** is a relative measure smoke emissions of a material as it burns
  - 100 is the amount of smoke developed by red oak when burned
    - 0 is asbestos-cement board

Flame and smoke ratings of some materials

Material	Flame Spread Index	Class
Brick	0	A
Plywood • Fire-retardant-treated	0-25	A
Gypsum wallboard	10-20	A
Cedar	69	B
Spruce	55	B
Plywood	120-180	C
OSB	150	C
Particle board	116-178	C

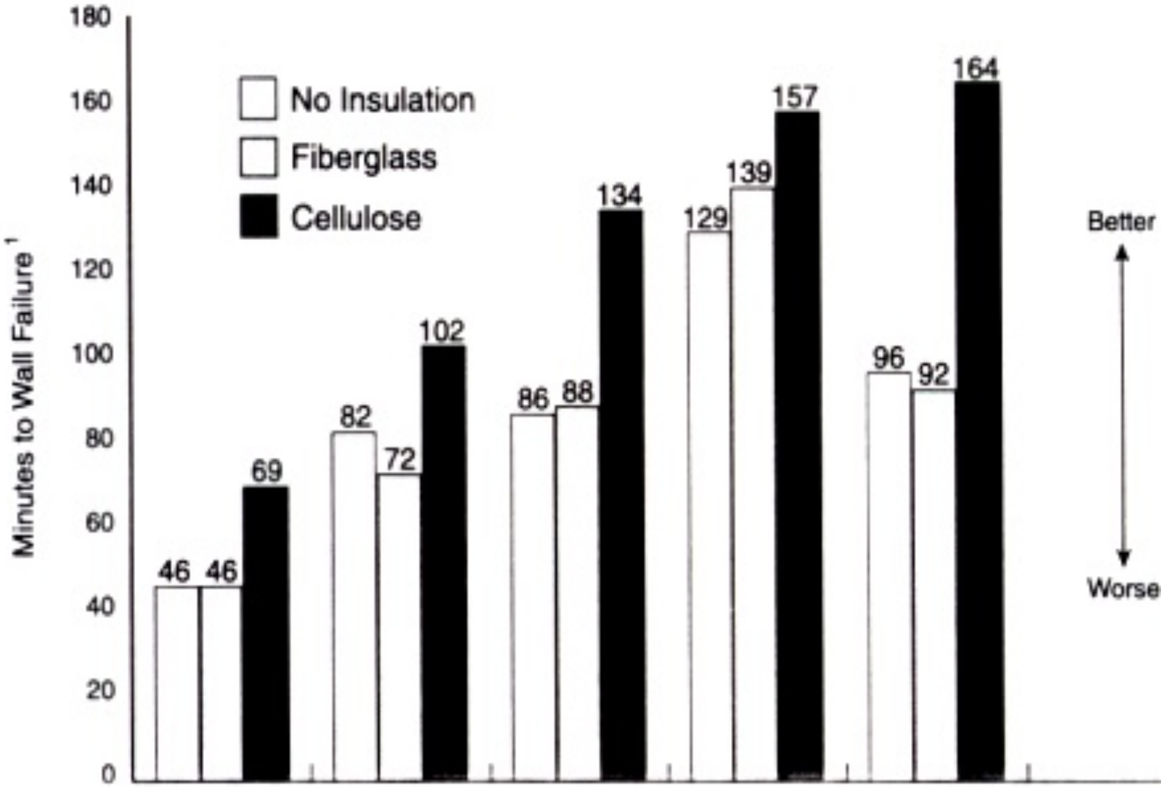
http://sfm.dps.louisiana.gov/doc_flamespread.html

Fire-resistance ratings

- Determined by ASTM E 119 and/or UL 72
- Duration of time for which a passive fire protection system can withstand a standard fire resistance test
  - "Passive fire protection" just means without active measures (e.g., water spraying)
  - Strategies include fire stops, fire doors, and particular wall and floor assemblies that utilize fire-resistant materials to prevent fire from spreading
    - Or at least increase the time it takes to spread)
    - Compartmentalization is often utilized

Fire-resistance ratings of assemblies

Figure 2. Wood and Steel Framed Wall Tests



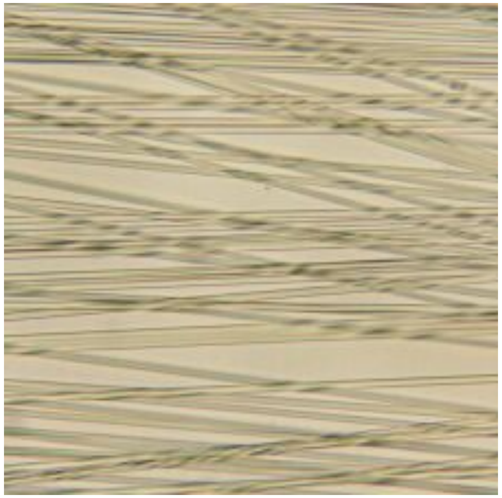
Stud type	Steel	Steel	Steel	Steel	Wood
Stud size	2" x 4"	2" x 4"	2" x 4"	2" x 4"	2" x 4"
Stud spacing	24" OC	24" OC	24" OC	24" OC	16" OC
Gypsum type	½" X	½" Reg.	½" X	½" X	½" X
Gypsum layers (exposed x unexposed)[2]	1 x 1	2 x 2	1 x 2	2 x 2	1 x 2
Resilient channel	no	no	no	no	yes

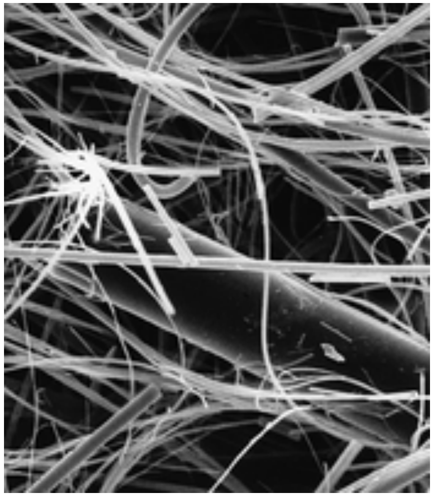
Primary types of insulation

- Fiberglass
- Mineral fibers
- Cellulose
- Natural fibers
  - Cotton
  - Wool
- Spray-on foams
- Rigid foams
- Structure-integrated insulations
  - EIFS, ICFS, SIPS

Fiberglass or glass wool insulation

- Fiberglass is made from thin filaments of glass
  - Also known as glass wool
- Fiberglass acts as an insulator by reducing internal convection and radiation
  - Glass fibers conduct heat better than still air, but the closely spaced fibers resist air motion and nearly eliminate convection
  - Radiation is absorbed and reradiated by fibers but each absorption and re-radiation reduces the energy transmission





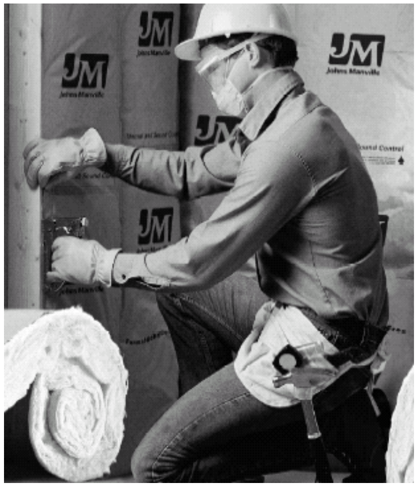
Forms of fiberglass insulation

- Blankets
  - Faced or Unfaced rolls and batts
    - Kraft paper facing provides some vapor resistance but reduces fire resistance
    - Foil facing provides vapor resistance, fire resistance, and a radiative reflective barrier
  - Encapsulated batts
    - Poly-encapsulation acts as a vapor barrier and makes it easier to install without contacting fibers

- Loose-fill
  - Blown-in to place
  - Fits into nooks and crannies in studs
- Rigid Boards
  - Used for acoustic panels and external insulation boards

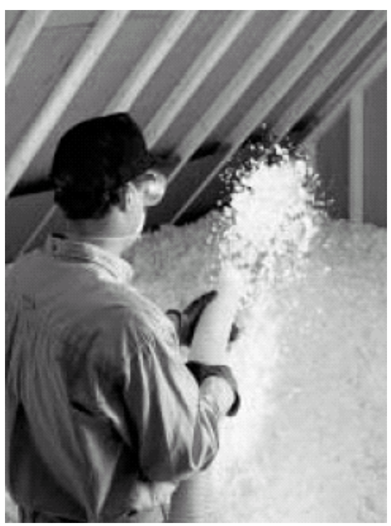
Types of fiberglass insulation

Kraft Faced

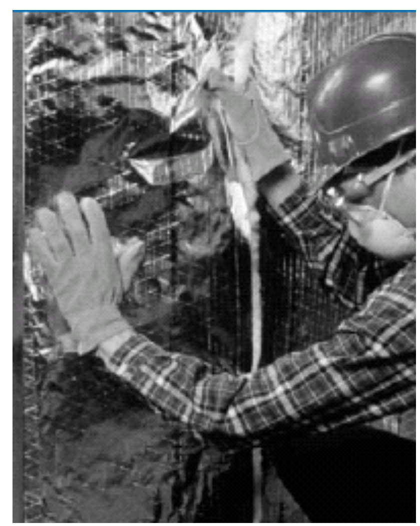


Poly Encapsulated

Rigid



Blown In



Foil Backed

Properties of fiberglass insulation

- $R \approx 3$ hr·ft$^{2}\cdot{}^{\circ}$F/Btu per inch with $2 < R < 3.7$ per inch
  - Starts a bit higher but usually drops as fiberglass settles
  - Must avoid compression to keep R-value high
    - A 6 inch fiberglass batt compressed to fit in a 2x6 stud has a lower R value than a 5 inch fiberglass batt undisturbed
- Usually sold according to its R-value
  - R-11, R-13, R-19, etc. (or R per inch)
- Vapor Resistance (IP)
  - 0.001 rep (bare), ~0.1-5 rep (Kraft faced), 20 rep (foil faced)
- Relatively low cost

Advantages and disadvantages of fiberglass

- Advantages
  - Low density
    - Easy storage and transport
  - Inexpensive (both material and installation costs)
  - Inorganic – fiberglass itself is fire and mold/bacteria growth resistant
- Disadvantages
  - Low density means surprisingly poor fire resistance
    - Material very difficult to ignite, but flame travels through air space fairly well
  - Fiberglass is a carcinogen
    - Very hazardous installation - must wear gloves, masks and goggles
    - Must keep fibers from getting airborne after installation
  - Can absorb moisture since there are no closed cells
    - R-value can drop when wet

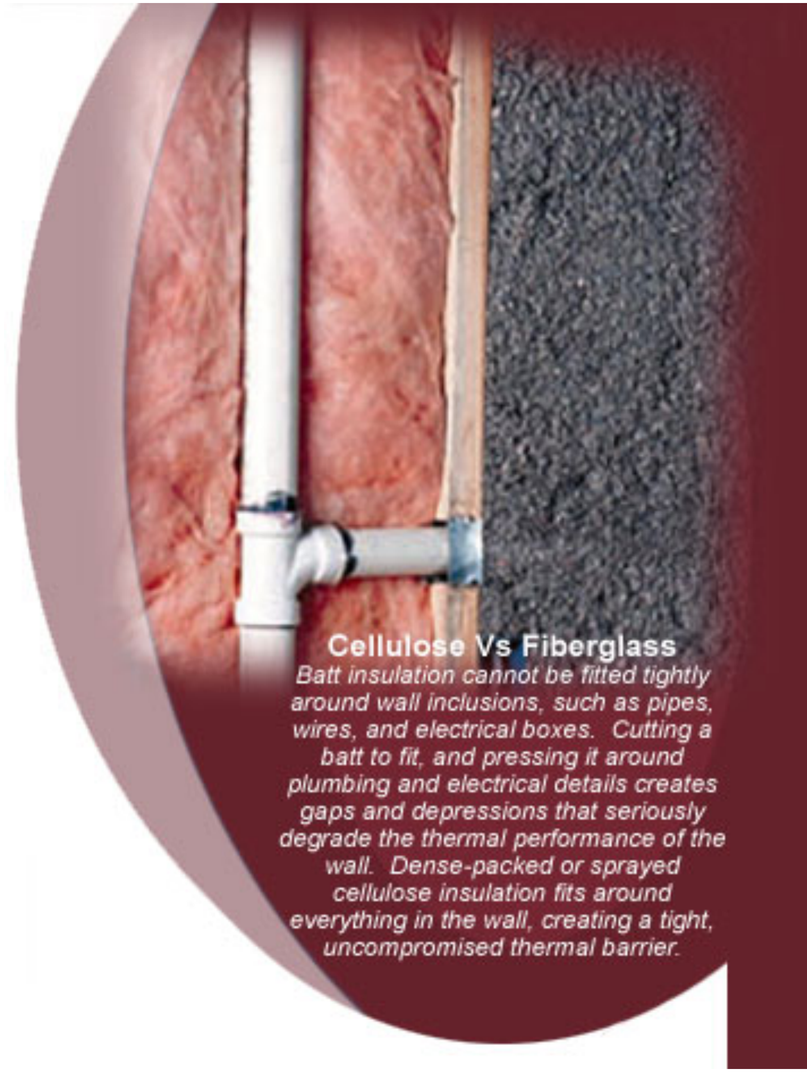
Rock and slag wool insulation (aka mineral wool)

- Rockwool
  - Made from basalt (a volcanic rock) and limestone
- Slagwool
  - Made from recycled blast furnace slag (byproduct of iron/steel)
- r usually a bit higher than fiberglass
  - R is 3.7 $hr \cdot ft^2 \cdot {}^\circ F/Btu$ per inch for 2.5 pcf rock wool
  - R is 3.9 $hr \cdot ft^2 \cdot {}^\circ F/Btu$ per inch for 4 pcf rock wool
- Higher fire resistance than fiberglass
- Does not absorb moisture well
- Installed costs a bit higher than fiberglass

Mineral wool insulation

Cellulose insulation

- Made from shredded newspaper and wood pulp
  - Chemically treated to increase fire resistance
  - Noncarcinogenic
- $r \approx 3.6$ hr·ft^2·°F/Btu per inch
- Cellulose is applied wet and sticks to wall and fills gaps
- Installed costs a bit higher than blanket fiberglass



Advantages and disadvantages of cellulose

- Advantages
  - Low embodied energy
    - 6x less energy than fiberglass to manufacture
    - 25 to 50x less embodied energy than other mineral fibers
  - Higher density than fiberglass can reduce air flow
    - May reduce heat transfer even with a lower R value
    - Less air space means flame spread characteristics can be better than fiberglass
- Disadvantages
  - Absorbs and retains moisture, which reduces R-Value
  - More susceptible to mold/fungus growth than mineral fibers
  - Lower innate fire resistance than mineral fibers
    - Wet applied clings to walls which means quicker ignition
  - Wet Applied Cellulose must dry before walls are closed – slows down construction time

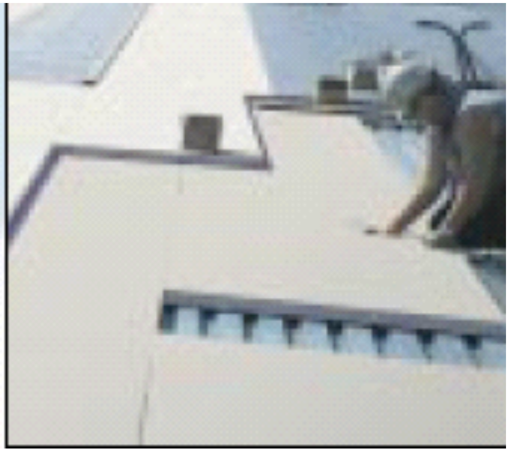
Cotton fiber insulation

- Made mostly from recycled cotton fibers
- r value ≈ 3-4 $hr \cdot ft^2 \cdot {}^\circ F/Btu$ per inch
- Organic
  - Possible problems with mold/fire
  - Fire ratings are pretty good
- No problems with chemical emissions
  - Possible problems with allergies
- Low embodied energy
  - 100% recyclable
  - Low energy to manufacture
- Installed cost is comparable to mineral fibers and cellulose

Insulation made from recycled denim

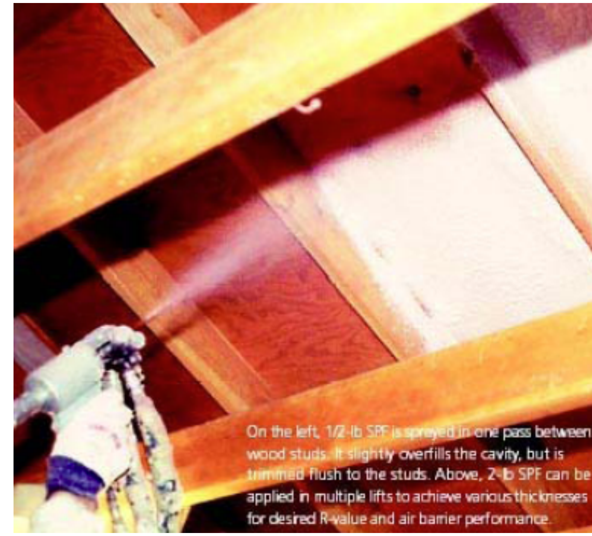
Foam insulations

- Foam building insulations offer an alternative to fibrous materials
- Liquid foams are sprayed in and expand to fill cavities
  - Use in place of spray in fiberglass or cellulose
- Foam board is rigid and self supporting
  - Use in place of blanket, batt or rigid fiberglass insulation
  - Very useful for external and roof insulation



Spray-on expanding foam

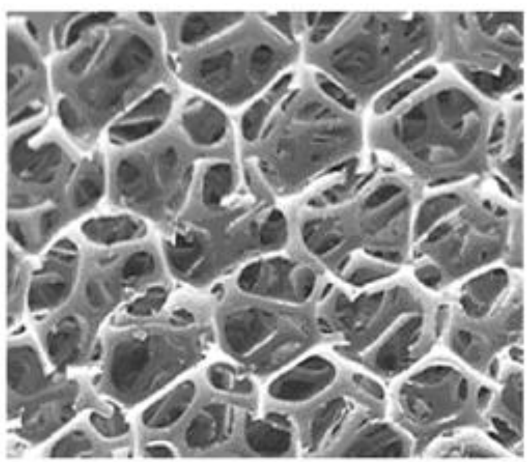
- Spray-on polyurethane material
- r ≈ 3-7 hr·ft^{2}·°F/Btu per inch
- Spray in expanding foam fills cracks and gaps
- Closed cell completely eliminates the need for taping/sealing and air barrier material
  - This is great for trying to insulate existing construction where it is hard to cut around framing and piping
    - Spray in foam can be sprayed around it
- Installed costs are higher
  - But you eliminate the cost to install an air barrier for closed cell foam

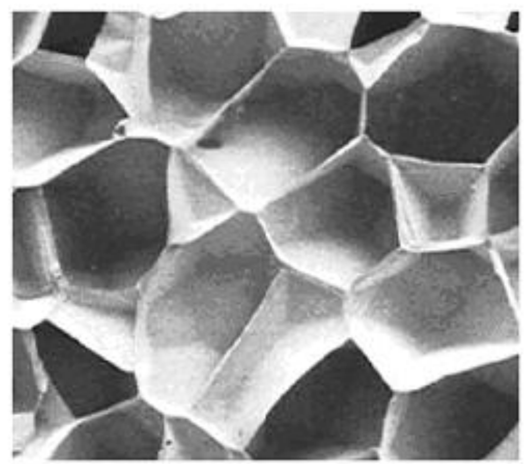


Open-cell:
r ~ 3.6 per inch

Closed-cell:
r ~ 6.5 per inch

Open-cell and closed-cell foams





Expanded polystyrene (EPS)

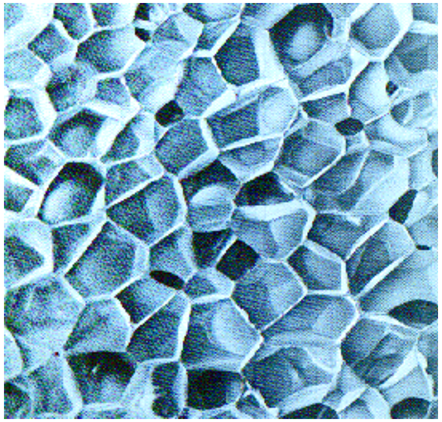
- Also called styrofoam
- Polystyrene beads are heated in molds
  - Expands a gas (pentane) within
  - Resulting structure is touching spheres with gaps in between
- More easily molded to different thicknesses than XPS

EPS properties

- r ≈ 4 $hr \cdot ft^{2} \cdot {}^{\circ}F/Btu$ per inch
- Density ≈ 1 - 5 lb/ft^3
- Vapor Resistance ≈ 0.3-3 rep/in
- Compressive strength
  - Much higher than non-rigid fiberglass
- Up to 4% or 5% water absorption
- Flame Spread: 20
- Smoke Developed: 150-300

Extruded-expanded polystyrene

- XEPS or **XPS**
- Polystyrene is melted and injected with a blowing agent forming gas bubbles
- Resulting structure is more like a honeycomb with closed or open cells
- Often used as structural insulating panels (SIPs) or insulating concrete forms (ICF)
- Because the cells are closed, it stores less moisture and is suitable for foundation insulation



XPS properties

- $r \approx 5.5$ hr·ft^2·°F/Btu per inch
  - A bit higher than EPS
- Density ≈ 1.5-5 lb/ft^3
- Vapor Resistance ≈ 0.4–2.2 rep/in
  - Compressive Strength: 20–100 PSI
- Flame Spread: 5
  - Closed cells reduce flame spread
- Smoke Developed: 175

Polyisocyanurate (“polyiso”)

- Low conductivity gas is injected to form bubbles
  - Decreases thermal conductivity
  - Increases thermal resistance
- Available in rigid board or as a spray on foam
- Foil backed boards repel water and reflect radiant energy

http://www.polyiso.org/

Polyiso insulation properties

- $r \approx$ 8-10 hr·ft^2·°F/Btu per inch
  - Highest of all common building materials
- Vapor Resistance ≈ 0.5 reps/in
- Density ≈ 1.5 – 2 lb/ft^3
- Compressive Strength: 16 – 40 PSI
- Flame Spread: 5
- Smoke Development: 165

Advantages and disadvantages of foams

- Advantages
  - Highest R-values = best insulating capabilities
  - Easy storage, transport, and installation
  - Easily shaped and tapered
    - Important for designing drainage in roofs
- Disadvantages
  - Least environmentally friendly to manufacture
    - Made from plastics (oil and natural gas inputs)
    - Blowing agents in XPS and polyiso are still usually HCFCs or HFCs
  - Foams generally have lower fire resistances and are toxic when ignited
  - Does have some water absorption properties (especially EPS)
  - Possible VOC off-gassing problems

Structural requirements of insulations

- On rooftops, the insulation must be able to support some load
  - Rain, snow, occasional people
- Fibrous materials need a supporting shell or need to be used on the interior only
- Rigid fiberglass is strong but more expensive
- Foam insulations are self supporting and are used almost ubiquitously for external roofing insulation

Acoustic concerns

- For acoustic concerns, the insulation must allow sound into the porous structure and have minimal contact with walls
  - Fibrous materials like fiberglass, rockwool, cotton, and wool are good
  - Blown-in materials like cellulose are okay, but they have contact with both sides of walls

- Rigid foams are usually closed cell and do not provide any acoustic benefit
  - Rigid foams (either open or closed) in touch with two walls transmits vibration directly which will decrease sound isolation
  - Properly installed (i.e., only touching one wall) open cell foams can act similarly to a fiberglass batt

Applicability of insulations

- Fibrous, cellulose, and expanding foams are really only useful as cavity insulation

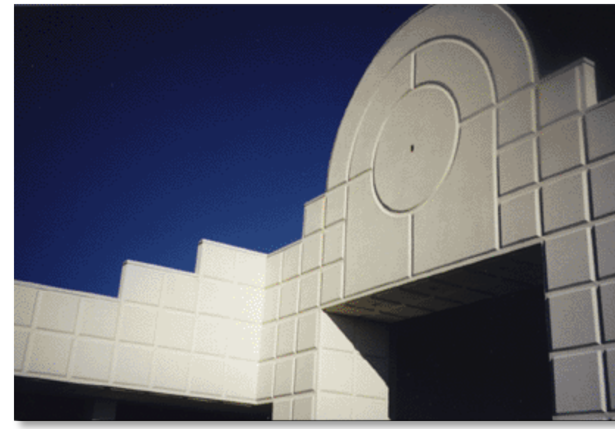
- Rigid foams are mostly used as exterior insulations
  - Even thin pieces of external insulation can reduce thermal bridging of structural elements

Structure-integrated insulation systems

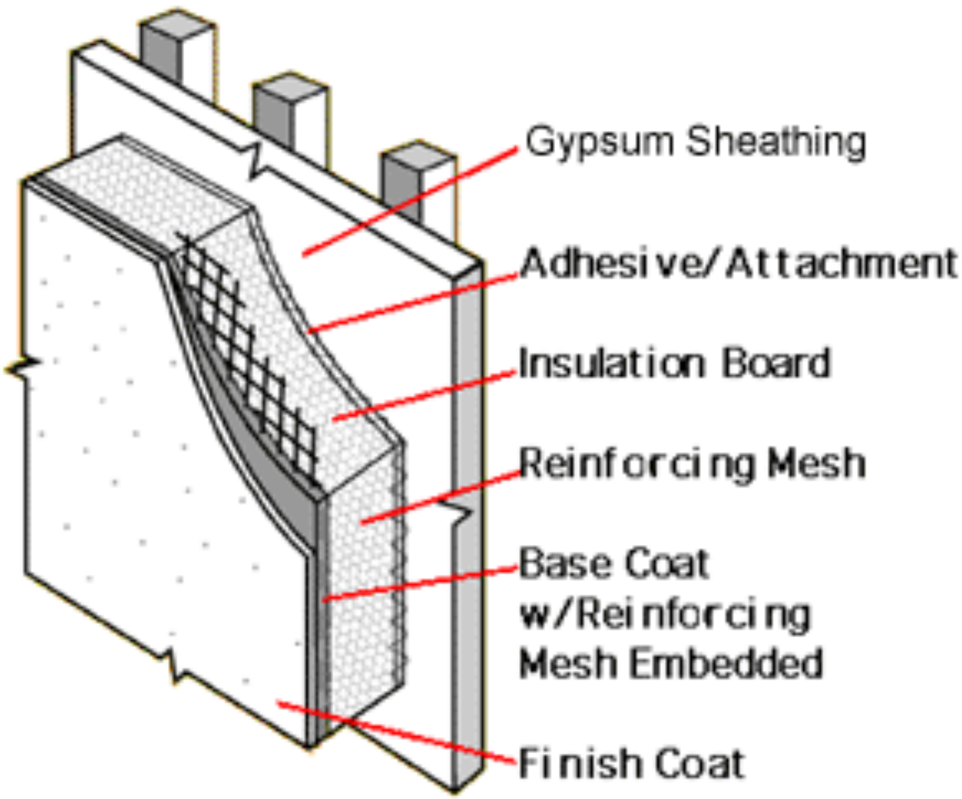
- EIFS
  - Externally Insulated Finish Systems
- ICFs
  - Insulated Concrete Forms
- SIPs
  - Structural Insulated Panels

EIFS

- Exterior Insulation and Finish Systems (EIFS) are insulated, multilayered exterior wall systems
  - Essentially this is “synthetic stucco”
  - Introduced into US in the 1970s to improve energy efficiency
  - First used on commercial buildings
    - Then used in homes as well
  - Large share of the commercial building exterior wall market



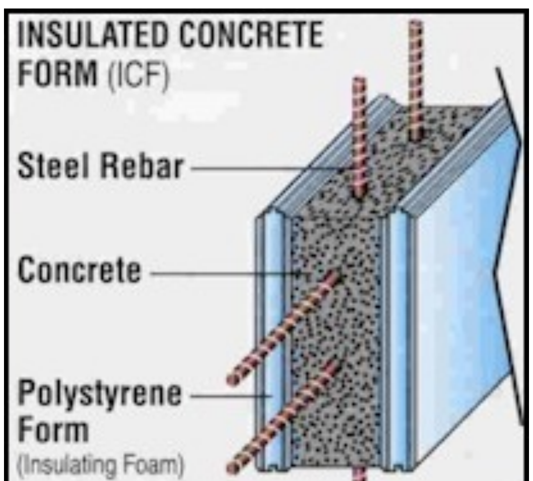
EIFS construction



- OSB, plywood, or gypsum board substrate
- Polystyrene or polyisocyanurate insulation
- Multi-coat acrylic polymer with fiberglass reinforcement for finish
  - Synthetic stucco

ICFs: Insulated Concrete Forms

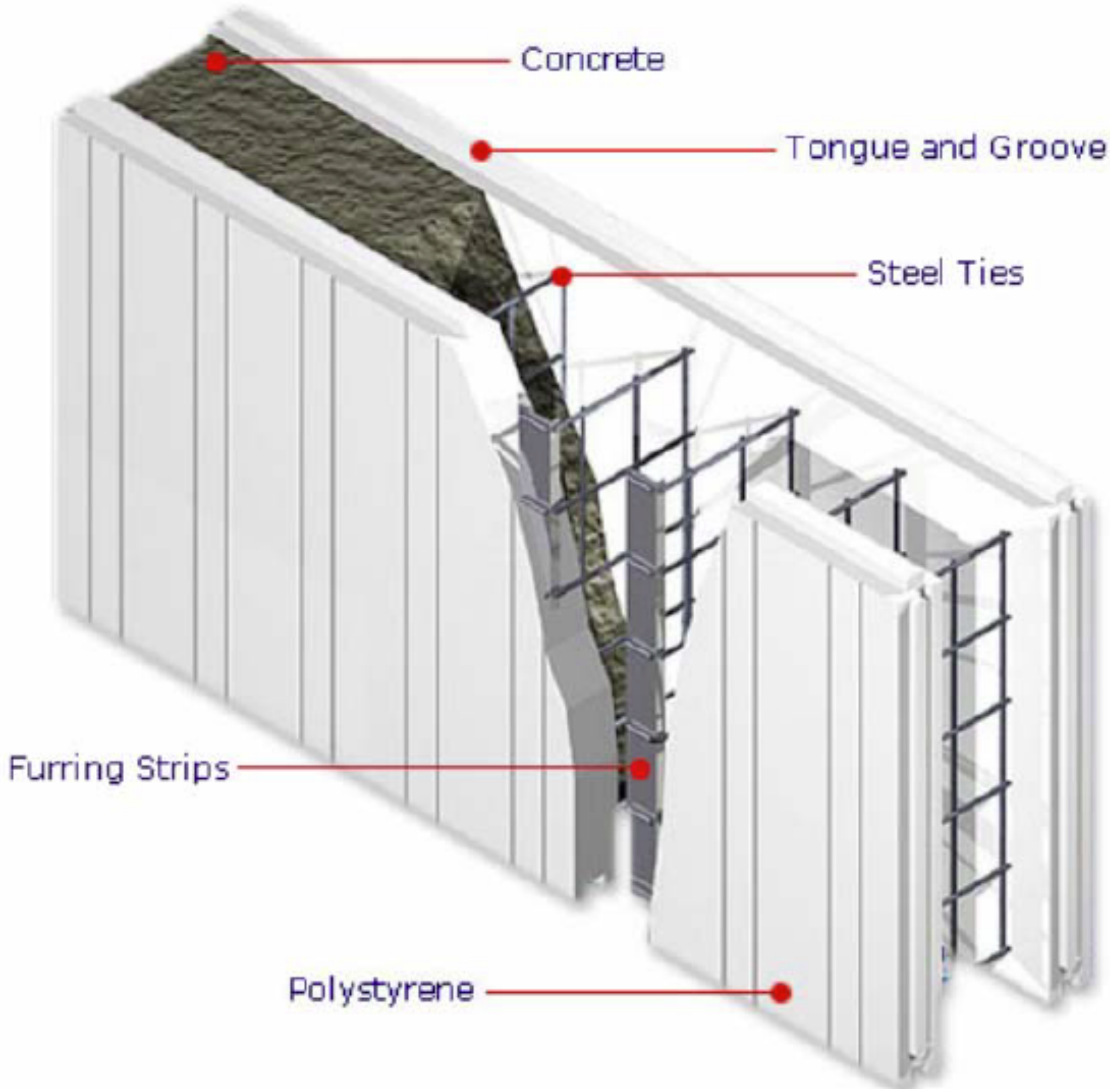
- Forms or molds that have made insulation for accepting reinforced concrete
- These forms are stacked and tied together, rebar is added, then filled with concrete
- Forms remain in place after concrete cures
  - It's like formwork you don't remove



Components:

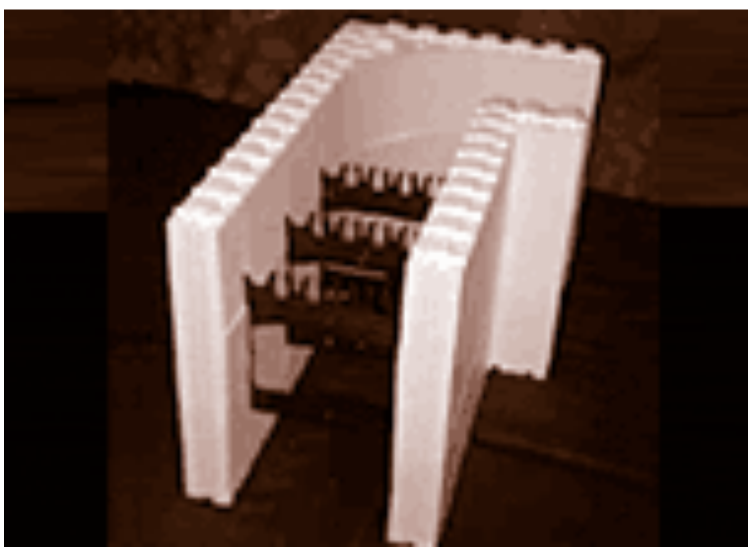
- 2 Pieces of EPS or XPS 2-4 inches thick
- 4, 6, 8, or 12 inch thick concrete fill
- Steel rebar

ICFs



Concrete
Tongue and Groove
Steel Ties
Furring Strips
Polystyrene

ICFs

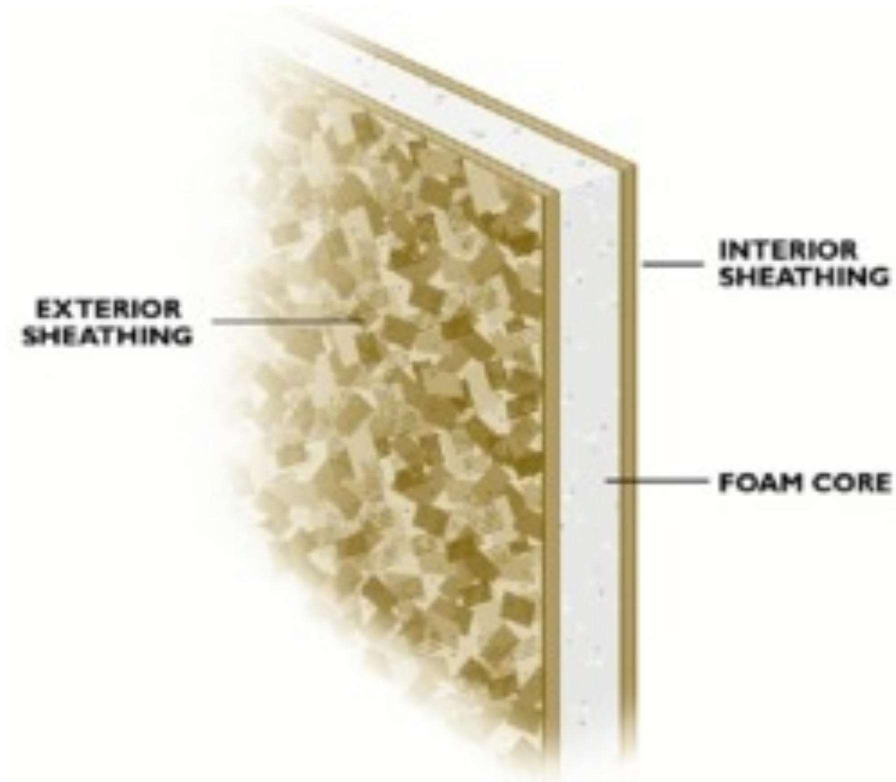


Advantages of ICFs

- Benefits of both thermal mass and high R value
  - R-20 to R-40 (IP) are commonly available
- ICFs create a structural concrete wall that is up to 10 times stronger than wood framed structures
- High sound isolation
- Good protection against fire, water, insects
- Construction methods are easy to learn
- Flexibility in design
  - Can be externally cladded with EIFS to make virtually any shape

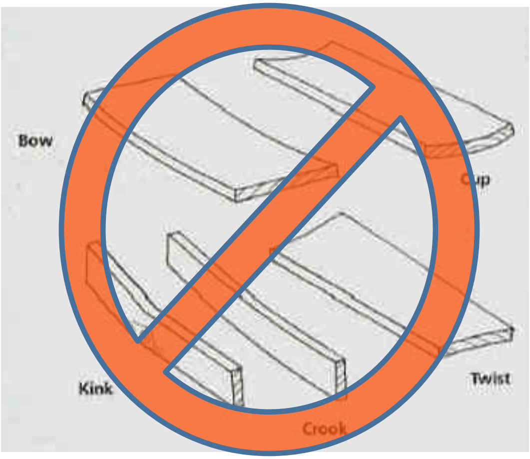
Structural Insulated Panels (SIPs)

- SIPs are a manufactured wall panel system usually constructed of two wood panels that sandwich a foam core
  - Usually OSB around EPS
  - Sometimes foam is XPS or polyiso



SIP construction benefits

- Panels can be pre-cut at the factory
- No framing = fewer workers
  - Retains very high structural strength
- Easier to hang drywall
  - No studs to mark and find
- Walls will be straighter
  - No cups, warps, etc., as found in most lumber
- Results
  - Faster construction
  - Big reduction in labor costs



Disadvantages of SIPs

- Less flexibility for wires and pipes
  - Locations must be set before manufacture
  - Conduit challenging
- On the job design changes are difficult
- Cranes are needed for large panels

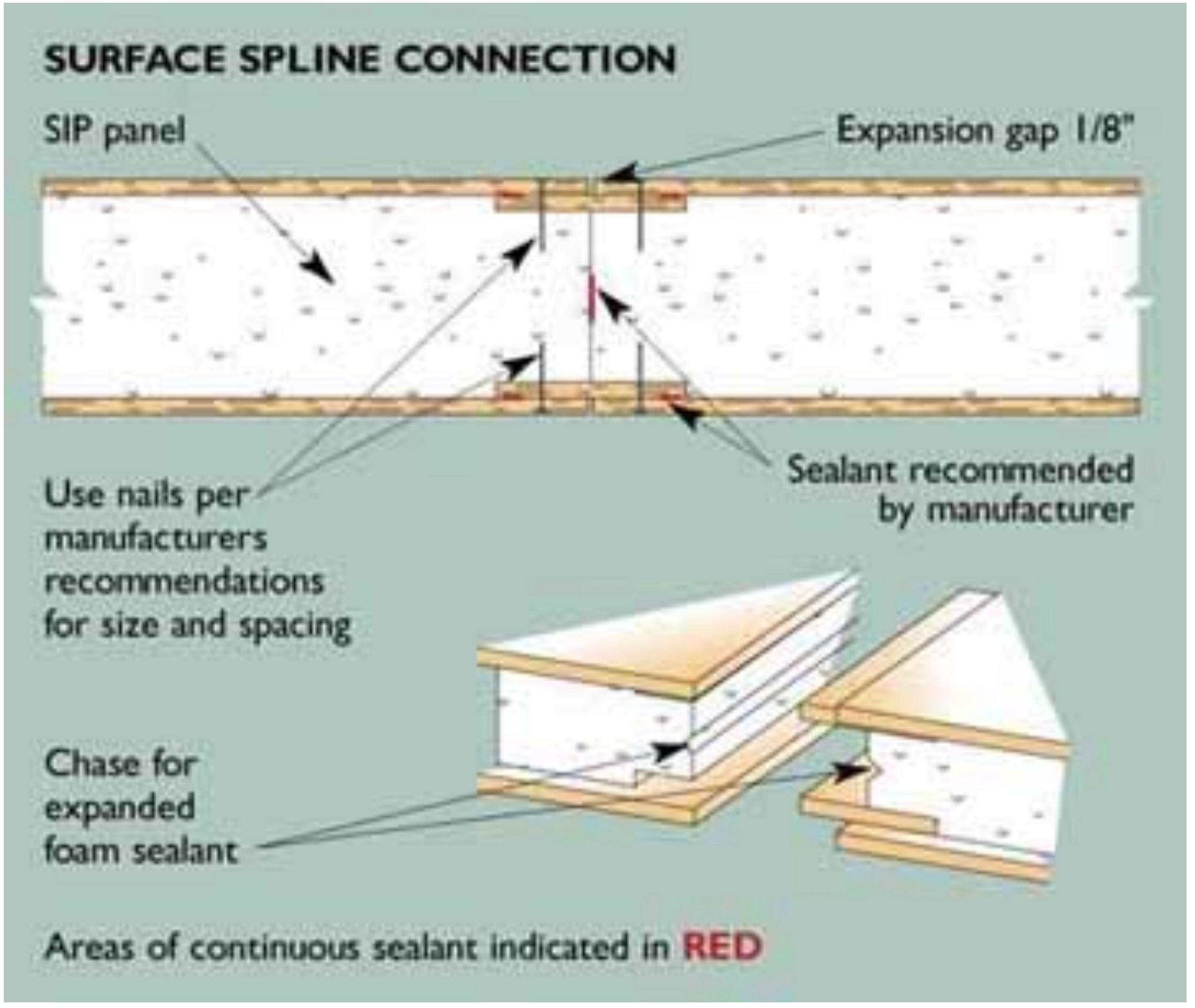
Thermal benefits of SIPs

- Little framing means few thermal bridges
- Use of EPS/XPS/Polyiso foam insulation provides high inherent R-Value
- Lack of air gaps reduces air leakage considerably
  - Less chance for moisture to get to insulation
- Inherently high vapor resistance
  - Vapor barrier not needed in most climates
- Result: installed R-Value is near theoretical R-Value

SIP connection details

- Surface spline connection eliminates thermal bridging

- Put together like puzzle pieces



SIPs

ROOFING

Applications

Roofing

- First line of weather defense
  - Precipitation (rain, snow)
  - Sun
  - Thermal Transmission
- Subjected to extreme heat and cold
  - Surface can have wide temperature swings

Roofing

- The roof receives the most severe physical and chemical degradation of any building component
  - Extreme temperature swings
  - Extreme UV exposure
  - High wind and rain exposure

- Good roofing is hard to design
  - Roofing the subject of nearly 65% of the lawsuits against architects and builders[1]
  - Low-slope roofing has the shortest lifespan of any component – typically 12-15 years[1]

[1]Mehta, *Building Construction,* Pearson, 2008

Two main types of roofs

- Steep Roofs
  - Used primarily on small buildings

- Low-Slope Roofs
  - Used on larger buildings

Principal elements of a roof system

- Substrate – support for roofing
  - Framing
  - Framing + Deck
  - Framing + Deck + Insulation or Concrete fill
- Roofing
  - Barrier formed to protect substrate from elements
  - Continuous membrane or overlapping units

Low-slope roofs

- Advantages
  - Can cover large horizontal surfaces
  - Simpler geometry, often less expensive
  - Roof can have other functions
    - patio, decks, parking, etc.

- Disadvantages
  - Water drains slowly
  - Slight structural movements can tear the membrane
  - Water vapor pressure can blister & rupture the membrane
  - Increased structural load from wind and accumulation

Low-slope roof components

- Structural Support: Deck on frame
- Thermal Insulation
- Roof Membrane
- Roof Ballast
- Drainage
- Flashing

Ballast and traffic decks

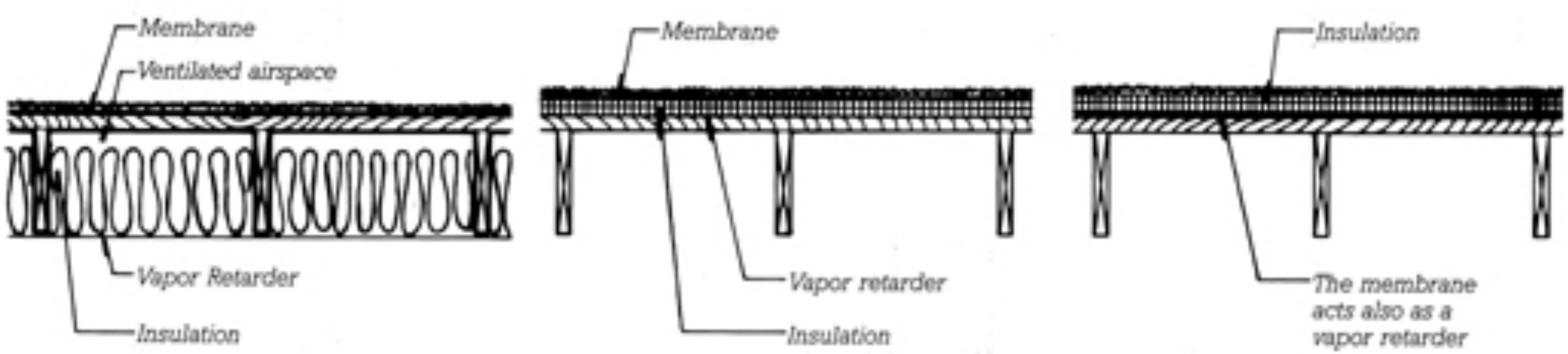
- Ballast material
  - Stone aggregate
  - Precast concrete blocks or Pavers

- Purpose
  - Hold down membrane
  - Protect membrane from ultraviolet light
  - Protect membrane from physical wear

- Traffic decks – installed over membranes for walks, terraces, drives, etc.

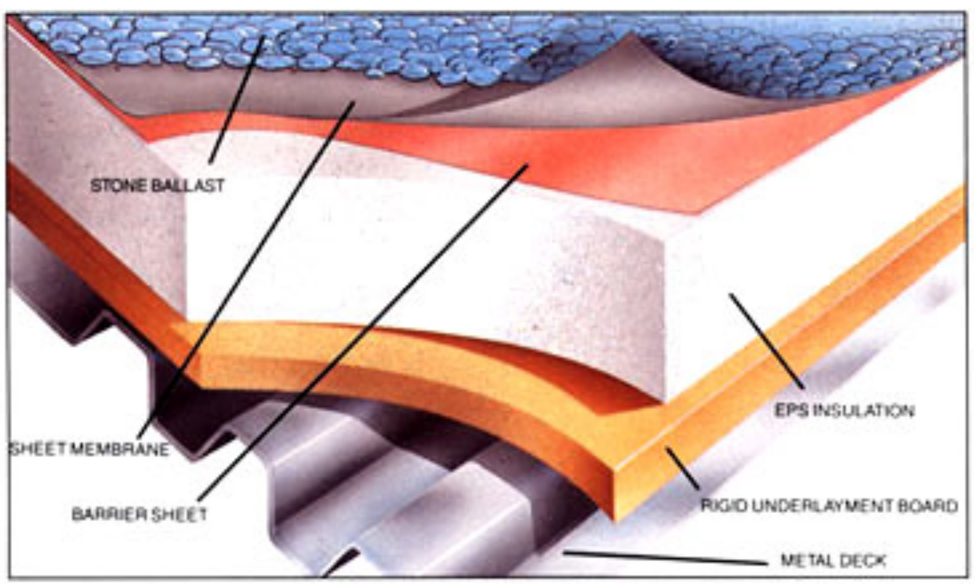
Roof thermal insulation

- Insulation is required to meet ASHRAE 90.1
- Location and placement:
  - Below the deck: Thermal bridging is a problem
  - Between the deck and membrane: membrane exposed
  - Above the membrane: helps protect membrane
- Rigid insulation attachment
  - Adhered or mechanically attached



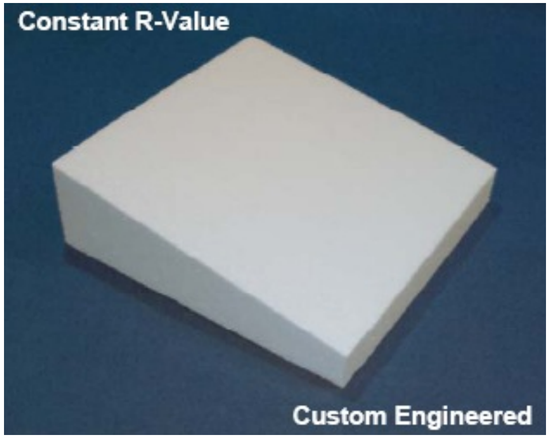
Typical roof insulation

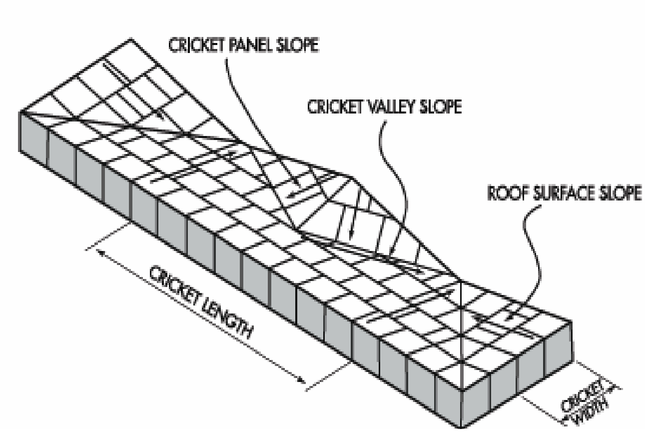
- Over-deck insulation is usually EPS, XPS, polyiso, or rigid fiberglass
  - These are the only insulation materials that can handle the wind/snow/roofing loads and still provide high insulating capabilities
  - High inherent R values of EPS and polyiso gives good insulating capabilities with only a few inches of insulation

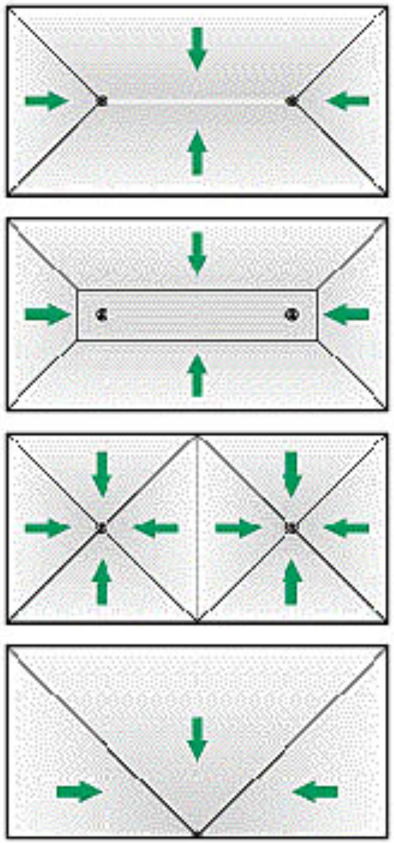


Tapered insulation

- To promote proper drainage roof should have a ¼" slope for every 12"
- This can be achieved through the use of tapered roof insulation







Typical Drainage Pattern

Insulating and foamed concrete

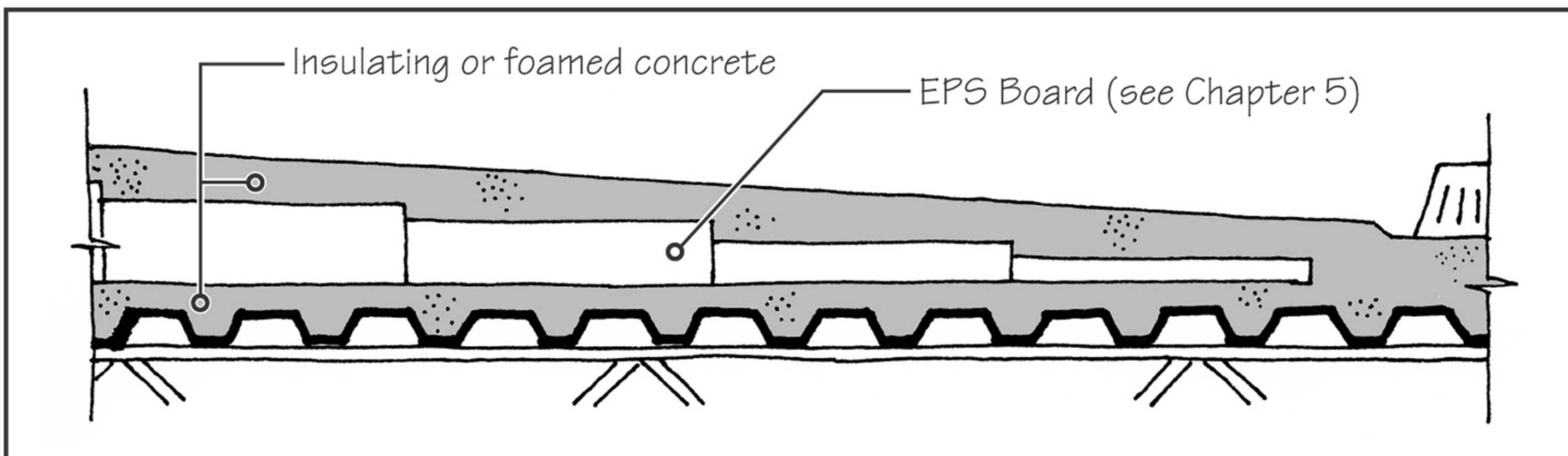
- **Insulating concrete** is a very lightweight concrete that with perlite or vermiculite as a high insulating granular additive
  - 0.8 < R per inch < 1.2 (normal concrete is about 0.2)

- **Foamed concrete** (also called cellular or aerated concrete) has a foaming concentrate that creates tiny air bubbles within the concrete
  - Increases thermal resistance
  - 0.5 < R per inch < 2

- Both of these are popular for use on roofs where the strength requirements are lower than for floors or walls

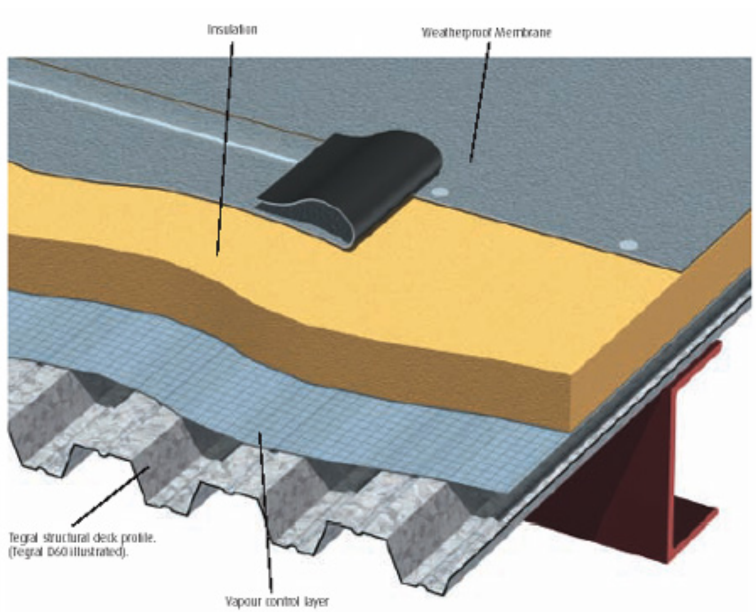
Embedded insulation

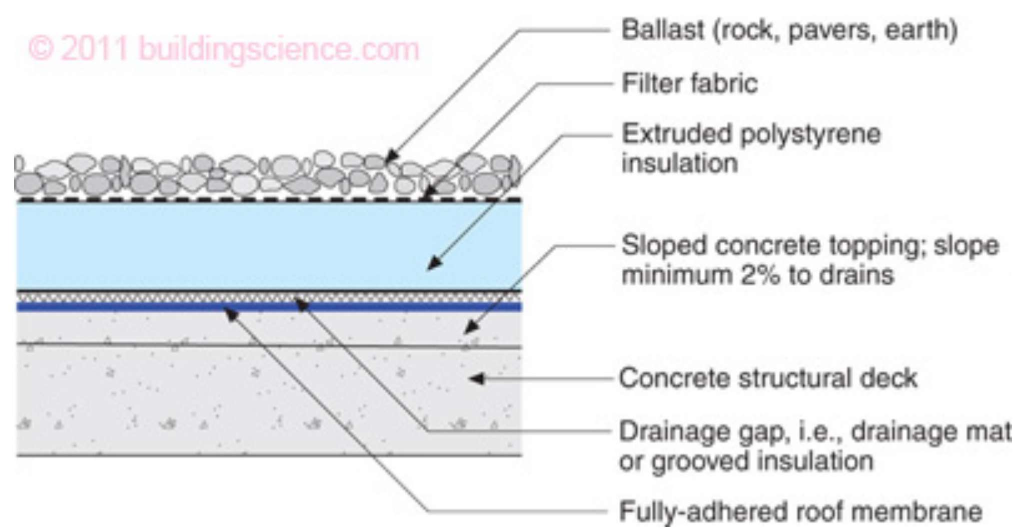
- EPS or polyiso insulation can be embedded within the concrete itself
- This is commonly done with foamed or insulating concrete



Roof membranes

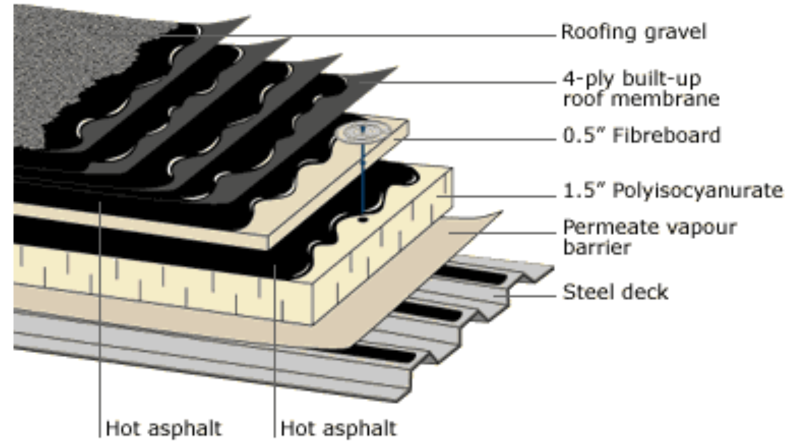
- Membrane roofing systems are used to prevent leaks and move water off of roofs
- Three main categories:
  - Built-up roof membrane
  - Single-ply roof membrane
  - Fluid-applied roof membrane



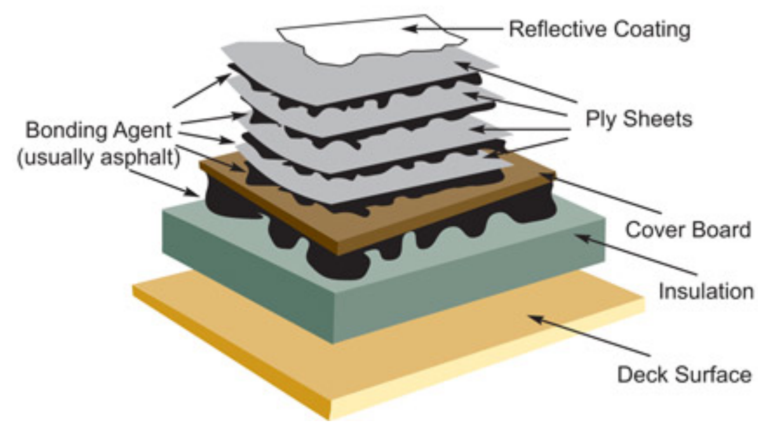


Built-up roof membranes

- Standard built-up roof membrane
  - 3-5 layers of felts + bitumen (asphalt)
  - Bitumen provides waterproofing
    - Semi-solid crude oil product
  - Felt provides the structural support needed
    - Because bitumen will soften (and can even melt) at high temperatures

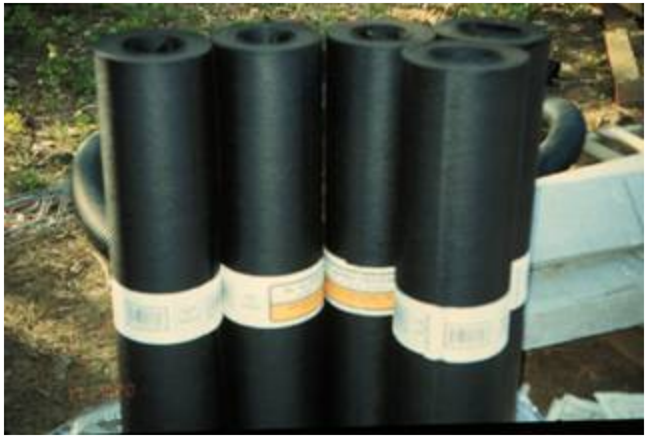


- Modified bitumen sheets
  - Bitumen has polymers added to improve the UV protection and make it more cold resistant
  - Felt or fiberglass sheets are embedded with modified bitumen
    - 2 to 3 layers of the sheets are installed with more modified bitumen between



Built-up roof membranes

- Multiple plies of asphalt-impregnated felt bedded in bitumen (hot asphalt or coal tar)
- Forms a “laminated” membrane typically 2-4 plies thick
- Stinks during install



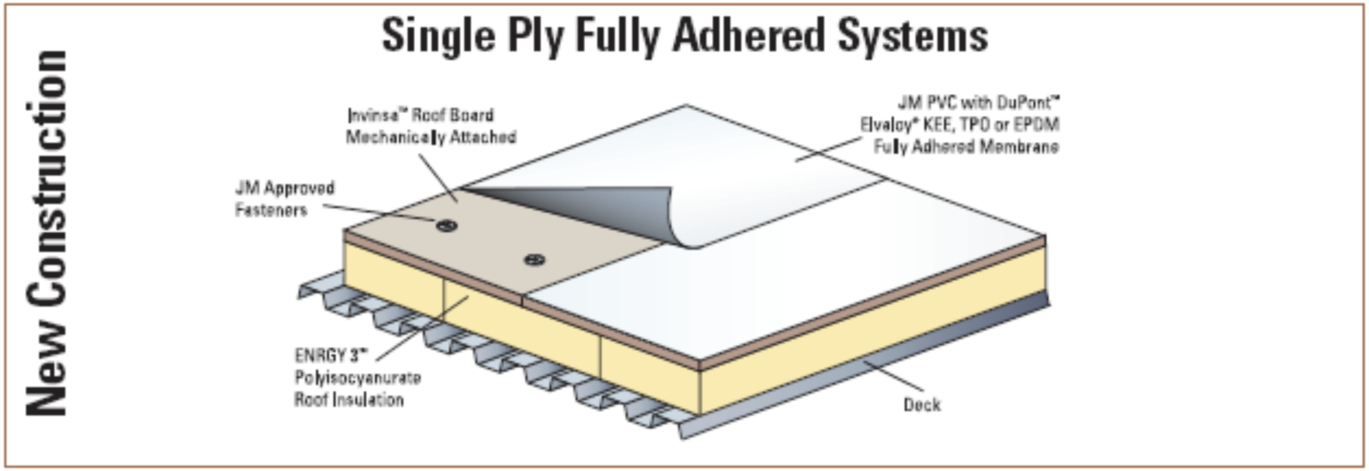
Advantages and disadvantages of BUR

- Advantages
  - Can be easily repaired/patched in case of leaks
  - Can last longer than a single ply membrane roof
  - High tensile strength limits movement and reduces chances for fracturing
  - If structure does move, BUR can move with it

- Disadvantages
  - Not seamless, more locations for possible leaks
  - Higher cost (more materials, time and labor)
  - Less sustainable (uses much more raw materials and energy to install)
  - Fumes during installation

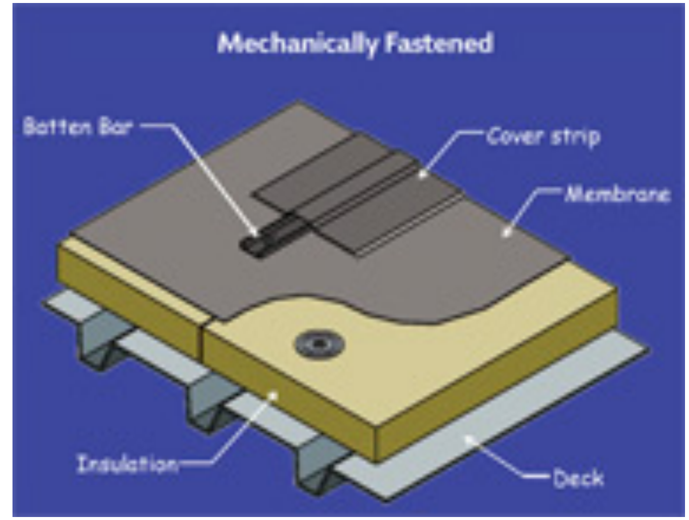
Single-ply roof membrane

- Sheet materials that are applied to the roof in a single layer
- Attached to the roof:
  - Adhesives
  - Ballast weight
  - Concealed fasteners



Single-ply materials

- Thermosetting
  - Compounded rubber polymer
  - Cannot be softened
  - Must be joined by adhesives or pressure sensitive tapes
  - EPDM
    - Ethylene propylene diene monomer
      - Most widely used
    - Also Neoprene, CPE, etc.



- Thermoplastics
  - May be softened and joined by heat or solvent welding
  - Polyvinyl Chloride (PVC) – widely used, polymer-modified bitumens, PVC alloys, etc.

EPDM

- EPDM (ethylene propylene diene monomer) is a thermosetting polymer (a synthetic rubber) that does not soften once it has cured
  - This material can stretch, but cannot be heat welded
  - It must be adhered or taped
- EPDM can stretch 300-500% of its original length before tearing
- Typical thicknesses are 45 to 60 mm
- EPDM has poor inherent fire resistance
- EPDM is black and must be covered for high solar reflectivity (low absorptance)

12 ft. wide EPDM membrane

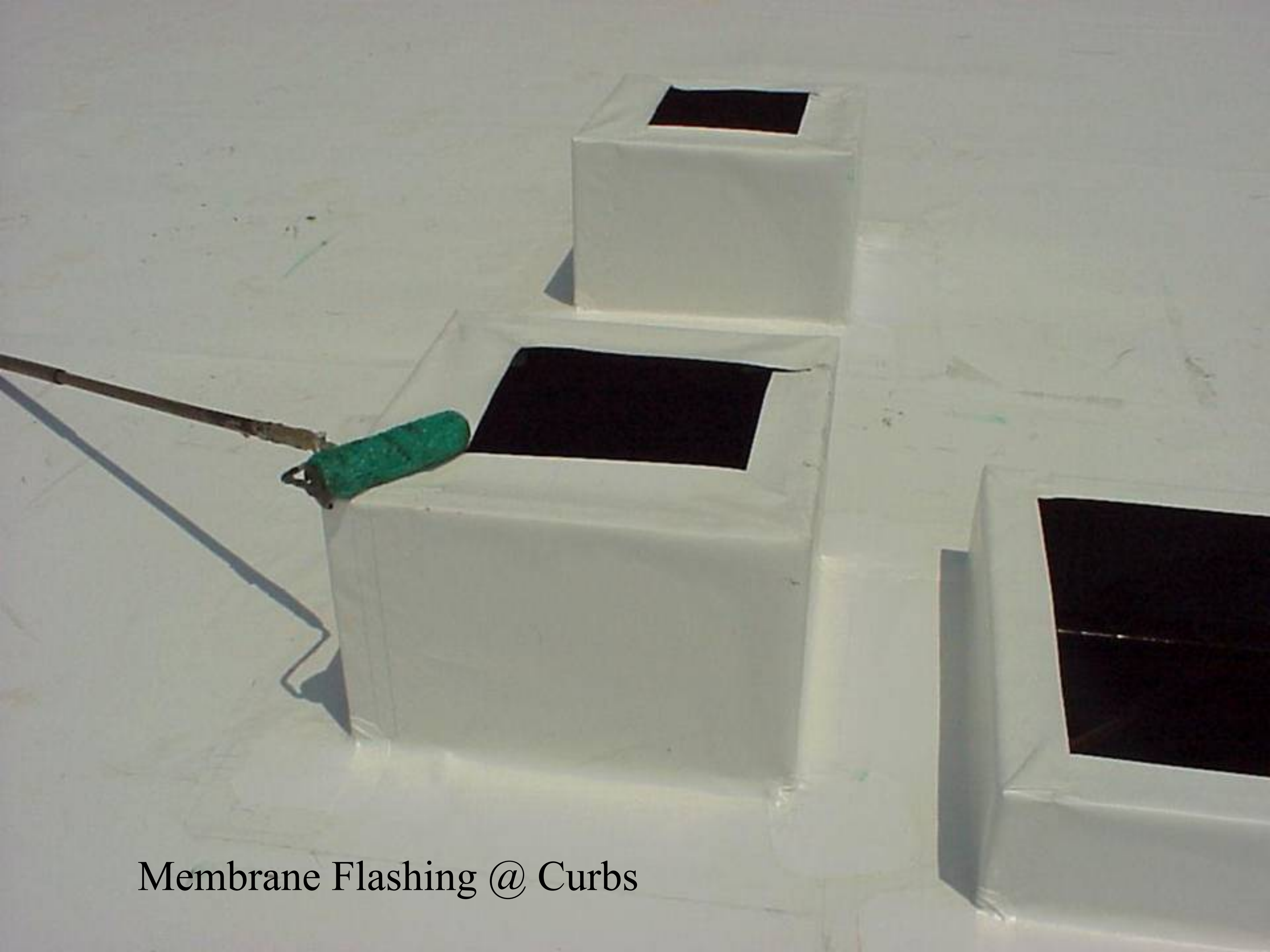
PVC and TPO

- PVC (polyvinyl chloride) is a soft and pliable form of the common plastic
  - PVC is very flexible, but is far less stretchable than EPDM
  - PVC membranes can be heat fused
- TPO (thermoplastic polyolefin) is also a thermoplastic
  - TPO is more flexible and stretchable than PVC but less than EPDM
  - TPO does not lose its flexibility over time like PVC
- These are easily used for cool roofing materials

Hand-held welding tool for PVC

Applying PVC or TPO

- Self-propelled hot air welding machine for PVC or TPO



Membrane Flashing @ Curbs

Fluid-applied membranes

- Fluids applied with a roller or spray gun and cure to form a rubbery membrane

Main Use: Complex shapes that are difficult to roof by conventional means such as domes and shells

Fluid applied membranes can also be installed fairly quickly so when speed is more important than cost, consider these

Advantages and disadvantages of membranes

- Advantages
  - Lower cost
  - No seams (if properly installed)
  - Lighter weight
  - Can expand/contract much better than BUR

- Disadvantages
  - Any small puncture can cause leaks
  - Harder to repair small leaks
  - Must be completely (or near completely) replaced when repairs/ modifications are made
  - Shorter lifetime than BUR

Building Envelope Design Guide (BEDG)

- The National Institute of Building Sciences has a program called Whole Building Design Guide, which also has a Building Envelope Design Guide
  - It's a great resource for all kinds of practical applications in enclosure design

Building Envelope Design Guide

The National Institute of Building Sciences (NIBS) under guidance from the Federal Envelope Advisory Committee has developed this comprehensive guide for exterior envelope design and construction for institutional / office buildings. The Envelope Design Guide (EDG) is continually being improved and updated through the Building Enclosure Councils (BECs). Any edits, revisions, updates or interest in adding new information should be directed to the BEDG Review Committee through the 'Comment' link on this page.

BEDG
BUILDING ENVELOPE DESIGN GUIDE

http://www.wbdg.org/design/envelope.php

Refer to Building Science Corp's website for more info

- "Enclosures that work"
  - http://www.buildingscience.com/doctypes/enclosures-that-work

- "Designs that work"
  - http://www.buildingscience.com/doctypes/designs-that-work

- "Understanding vapor barriers"
  - http://www.buildingscience.com/documents/digests/bsd-106-understanding-vapor-barriers

BUILDING ENCLOSURE RESEARCH

Recent advances and future needs

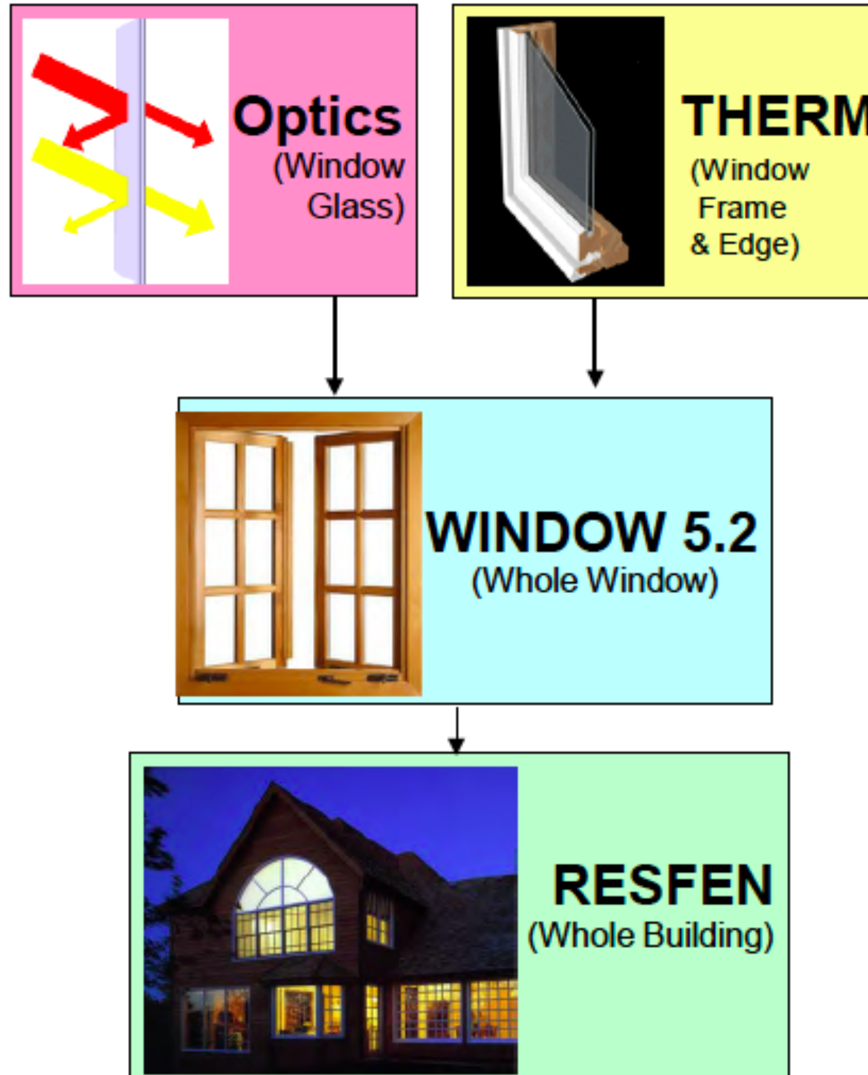
Recent advances in enclosure research

- Much of the recent building enclosure research I've seen relates to heat, air, and/or moisture transport
  - Measurements and modeling
- Research groups to watch out for:
  - Building Science Corporation
    - Research reports
  - Oak Ridge National Lab (ORNL)
    - Building Envelope Research Group
  - Argonne National Lab (ANL)
    - Building Efficiency Program
  - Lawrence Berkeley National Lab (LBNL)
    - Buildings Energy Efficiency program
  - National Renewable Energy Lab (NREL)
    - Buildings Research
  - Fraunhofer Center for Sustainable Energy Systems
    - Building Energy Efficiency R&D

Recent advances in enclosure research

DOE

Prototype – Concept Window
(Highly Insulating and Dynamic
R 5.6, SHGC 0.04 – 0.34)
Low cost unsealed center lite



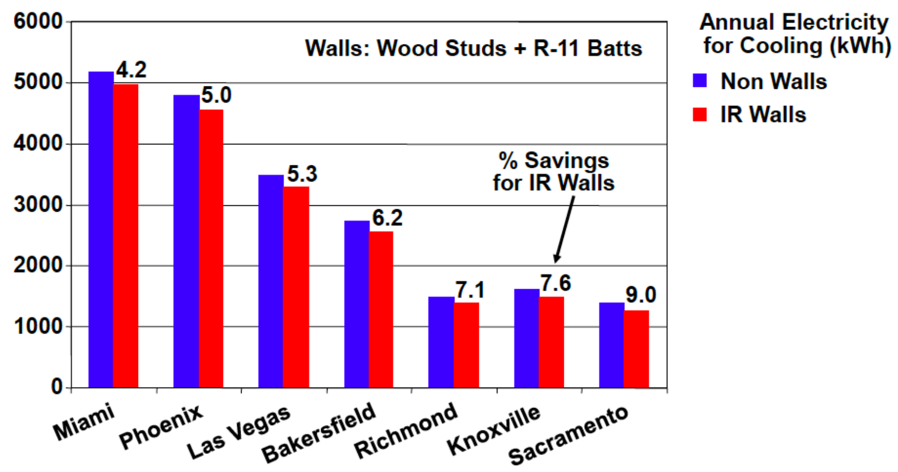
ORNL

Window technologies

Recent advances in enclosure research

DOE

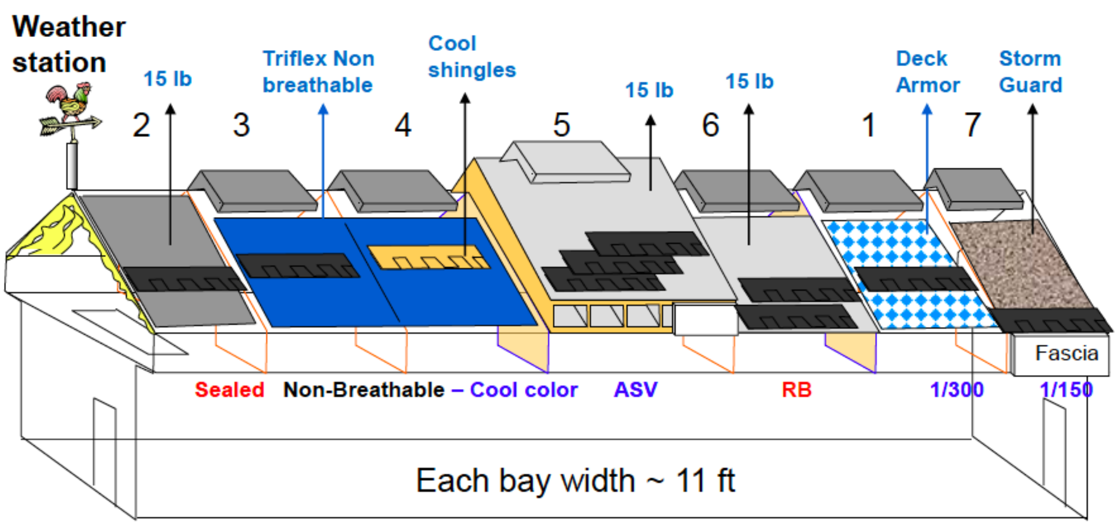
ORNL

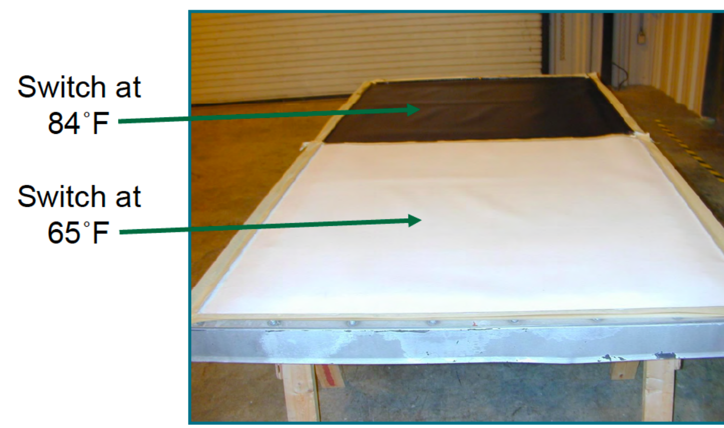


Wall technologies

Recent advances in enclosure research

ORNL





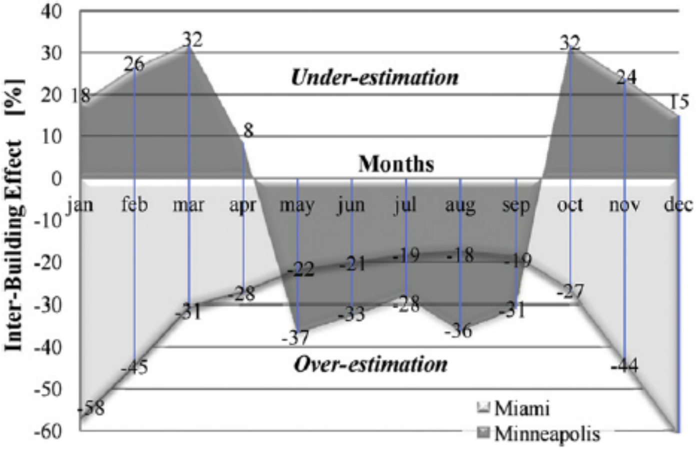
Roof technologies

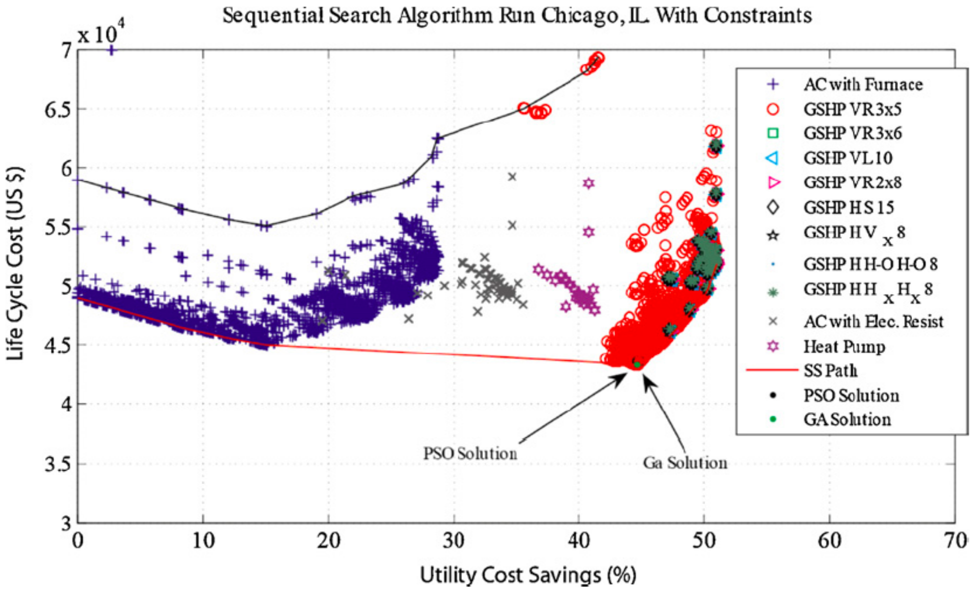
Recent advances in enclosure research

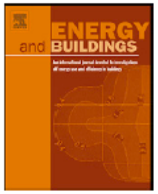
Inter-building effect: Simulating the impact of a network of buildings on the accuracy of building energy performance predictions

Anna Laura Pisello [a], John E. Taylor [b,*], Xiaoqi Xu [c], Franco Cotana [a]

[a] Dept. of Industrial Engineering, University of Perugia, Via Duranti 67, 06125 Perugia, Italy
[b] Charles E. Via, Jr. Department of Civil and Environmental Engineering, Virginia Tech, 113B Patton Hall, Blacksburg, VA 24061, USA
[c] Department of Civil Engineering and Engineering Mechanics, Columbia University, 618 S.W. Mudd Building, 500 West 120th Street, New York, NY 10027, USA







Optimization of envelope and HVAC systems selection for residential buildings

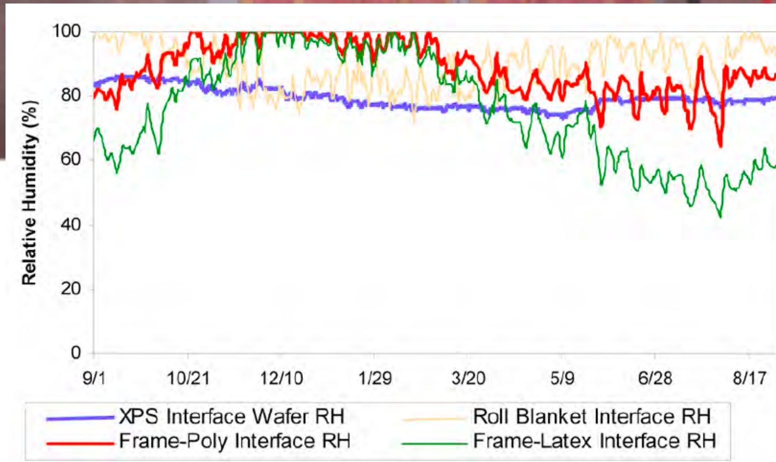
Youssef Bichiou [a], Moncef Krarti [b,*]

[a] Ecole Polytechnique de Tunisie, La Marsa, Tunisia
[b] Civil, Environmental, and Architectural Engineering Department, CB 428, University of Colorado at Boulder, USA

Simulations and optimization

Recent advances in enclosure research

BSC



Long-term moisture performance

Recent advances in enclosure research

Ozone Reductions Using Residential Building Envelopes

LBNL

Effect of ventilation strategies on residential ozone levels

Iain S. Walker*, Max H. Sherman

MS 90R-3083, Lawrence Berkeley National Laboratory, EETD, One Cyclotron Road, Berkeley, CA 94720, USA

Environmental Science & Technology

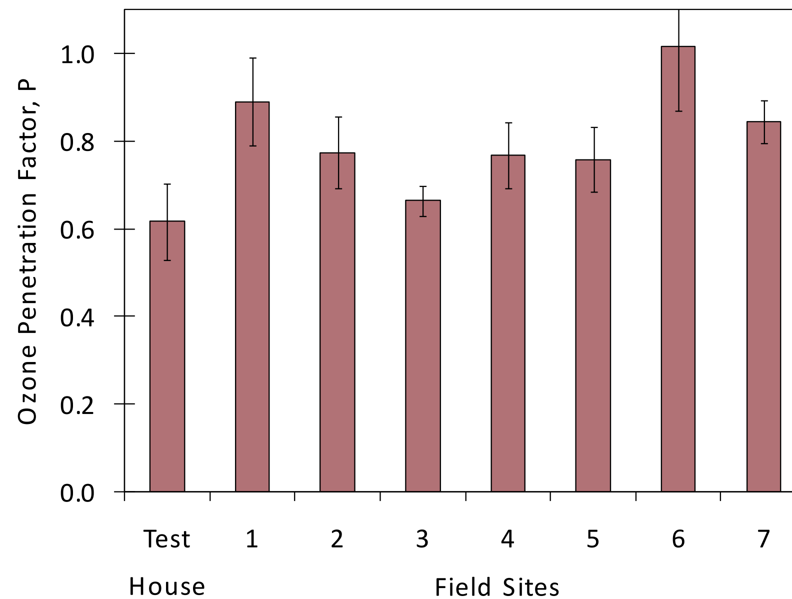
Article

pubs.acs.org/est

Measuring the Penetration of Ambient Ozone into Residential Buildings

Brent Stephens,* Elliott T. Gall, and Jeffrey A. Siegel

Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, Texas, United States



IAQ impacts

Recent advances in enclosure research

A model of vegetated exterior facades for evaluation of wall thermal performance

Irina Susorova [a,*], Melissa Angulo [b,c], Payam Bahrami [b], Brent Stephens [c]

[a] College of Architecture, Illinois Institute of Technology, 3300 S. Federal St., Chicago, IL 60616, USA
[b] Council on Tall Buildings and Urban Habitat (CTBUH), Illinois Institute of Technology, 3360 S. State St., Chicago, IL 60616, USA
[c] Department of Civil, Architectural and Environmental Engineering, Illinois Institute of Technology, 3201 S. Dearborn Street, Chicago, IL 60616, USA

Future enclosure research

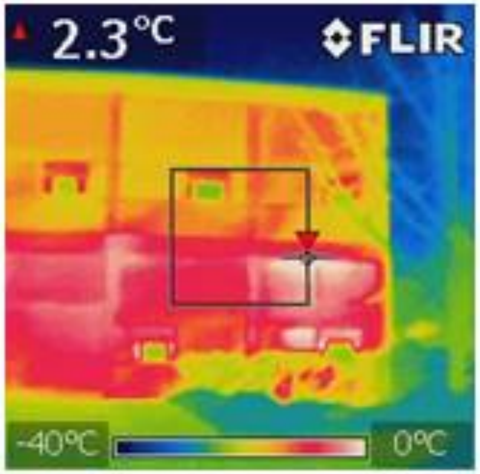
- Still room for improvement in:
  - Existing building retrofits
    - Measurement methods and retrofit optimization
  - New materials
    - Phase change materials
    - Recycled/natural materials
  - Advanced enclosure systems
    - Pre-fab and manufactured (lower embodied energy)
    - Better renewables integration
  - Optimal enclosure elements and orientation
  - Performance outside of design conditions
  - Long-term performance
  - Life cycle costs and environmental impacts
  - Impacts on indoor air quality (IAQ)

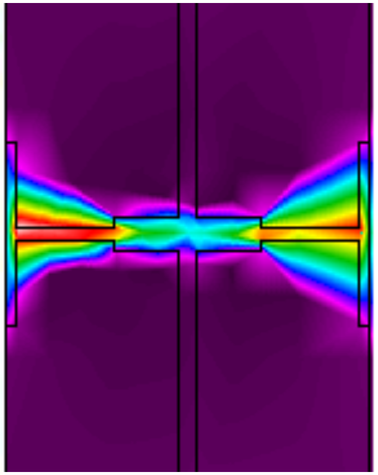
COURSE WRAP-UP

Course information

Course Catalog Description

- Design of building exteriors, including the control of heat flow, air and moisture penetration, building movements, and deterioration. Study of the principle of rain screen walls and of energy conserving designs. Analytical techniques and building codes are discussed through case studies and design projects.



Course objectives

To introduce students to the design of building enclosures (i.e., "building envelopes"), elements of which include walls, floors, roofs, and intentional openings. By taking this course students will be able to:

1. Design and assess building enclosure elements for heat transfer, airflow, and moisture control
2. Be proficient in current building codes as they pertain to building enclosure design
3. Critically analyze designs for advanced building enclosures for their impacts on energy use, airflow, and potential moisture issues
4. Be proficient with several software tools used in building enclosure design

Course re-cap

- Building science review
  - k, L, U, R, h_{conv}, α, ε, T
- Surface energy balances and energy exchanges
- Solar orientation
- Complex conduction
  - Thermal bridges, parallel path, 2-D (THERM), thermal mass, transient conduction
- Moisture flows
  - Hand calculations, WUFI
- Moisture management
- Air movements
  - Infiltration modeling, blower door testing
- Windows
- Energy simulation in enclosure design
  - eQUEST, BEopt + EnergyPlus
- Codes, standards, and applications
- High performance enclosure research reports

Course evaluations

- Available online now in MyIIT
- Very important that you complete the evaluation
  - It’s the only way I get graded
  - It’s the only way our courses get graded
  - It’s one of the best ways for us to improve courses/ teaching
  - It’s anonymous

- We usually only get about 50% response rate
  - Let’s try to do better than this
    - We’re at 55% now
  - If you have an internet connection you can do it right now

Thank you!

- Related upcoming courses for Fall 2015:
  - CAE 515 Building Energy Modeling (Julide Demirdoven)
  - ENVE 576 Indoor Air Pollution (Stephens)
  - CAE 513 Building Science (Stephens)