CAE 463/524
Building Enclosure Design
Spring 2016

Week 12: March 29, 2016
Campus project presentations

Built
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Research
@ IIT

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Dr. Brent Stephens, Ph.D.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
brent@iit.edu

Today's schedule

1. Announce internship opportunities

2. Campus enclosure assessment project presentations

3. Introduce final individual project expectations and examples

4. Release take-home exam

5. *Roofing lecture?*

Internship opening: BTC

BTC

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Contact:
Kami Farahmandpour
Building Technology Consultants, Inc.
1845 East Rand Road, Suite L-100
Arlington Heights, Illinois 60004
Direct: (847) 454-8814
Main: (847) 454-8800
www.btc.expert
kamif@btc.expert

Building Technology Consultants,

Internship opening: ICL Architecture

- ICL Architecture | Engineering | Construction Management
  - David Fleener (IIT)

- Looking for 1-2 summer interns for both architecture and engineering drafting
  - Knowledge of Revit is a plus

- Email me your resume if interested

ICL [ARCHITECTURE]
architecture | planning | interior design | engineering

Campus enclosure assessment presentations

Team #	Members	Building
1	Naveen, Julia, Xu, Luanzhizi, Steve	Alumni
2	Bianca, Al, Taylor, David	SSV
3	Nina, Dina, Lindsey, Salvatore, JiWan	Vandercook
4	Andrea, Ben, Keonho, Kevin	Crown
5	Afshin, Ali, Mehdi, Jose, Kamal	Siegel

Project 2: High performance enclosure research

- Objective
  - Extend what you will learn about HAM and building enclosures and research a relatively “high performance” enclosure construction
    - Literature review, product review, and examples
    - Advantages and disadvantages
    - HAM analysis
    - Energy analysis
    - Cost considerations
    - Practical design considerations
    - Environmental and sustainability impacts

Project 2: High performance enclosure research

- Deliverable
  - Final report of findings, similar to a conference proceeding
    - Maximum 8 pages single spaced
  - No presentation required

- Expectations
  - Assignment/expectations document is on BB now
    - Two example reports are also provided on BB

Project 2: High performance enclosure research

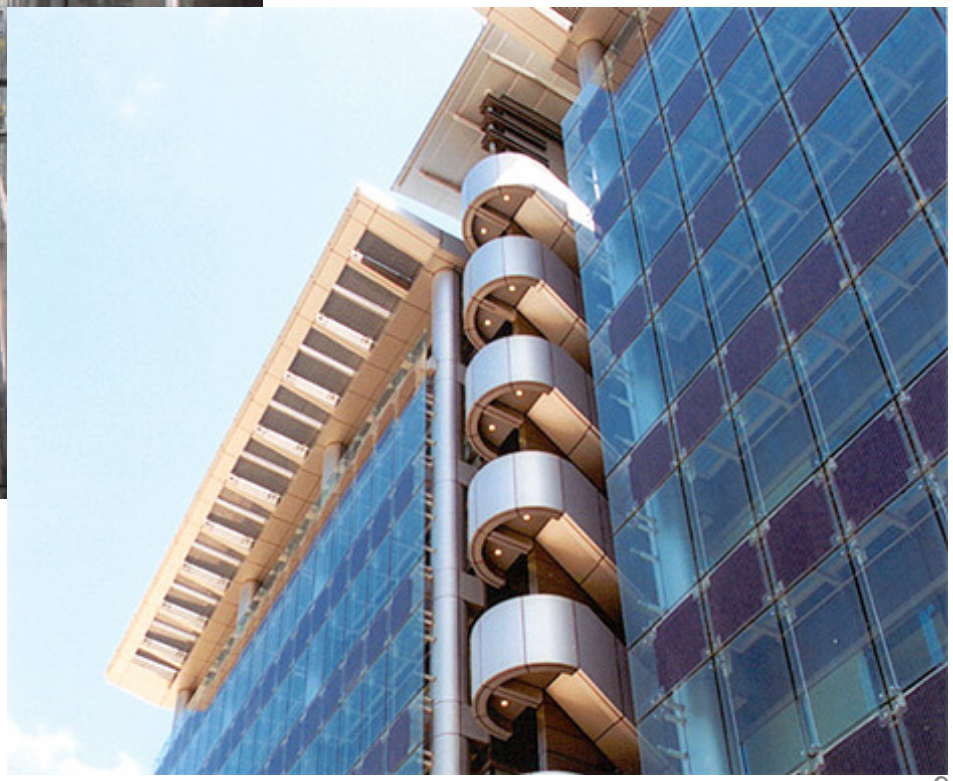
- Many new enclosure products/technologies/designs exist
  - How do they actually perform?
  - What are their advantages/disadvantages?

Green roofs

Green walls

Project 2: High performance enclosure research

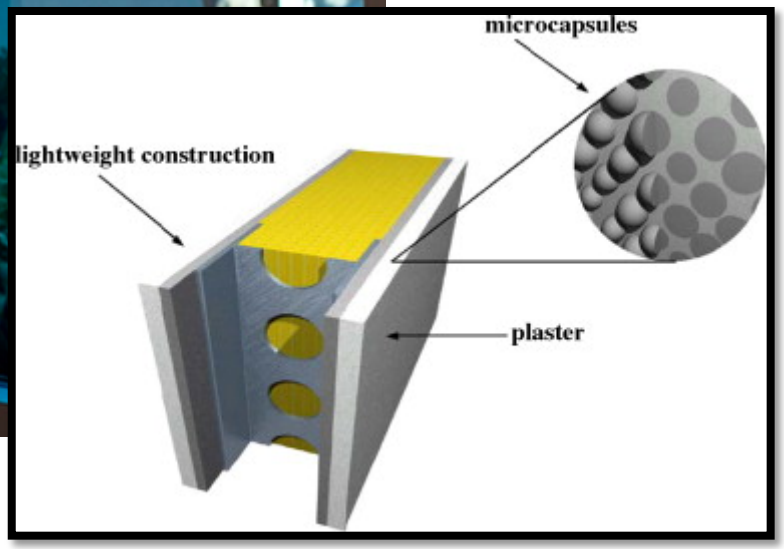
Double skin facades



Building integrated photovoltaics

Project 2: High performance enclosure research

Electrochromic windows (“smart glass”)



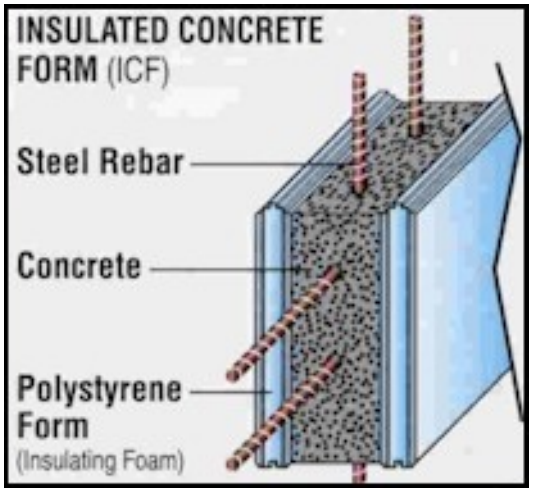
Phase change insulation materials

Project 2: High performance enclosure research

Bio-based insulation materials (mushrooms)

Structural insulated panels (SIPS)

Project 2: High performance enclosure research



Insulated concrete forms (ICFs)

Vacuum insulated panels

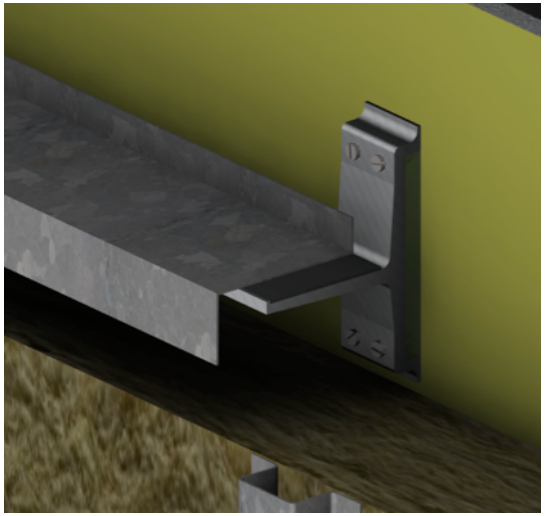
Nano-porous aerogels

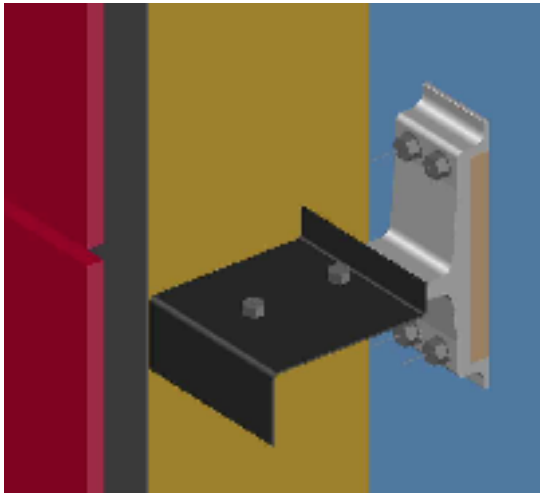
Project 2: High performance enclosure research

“Cool” roofs (e.g., white roofs)

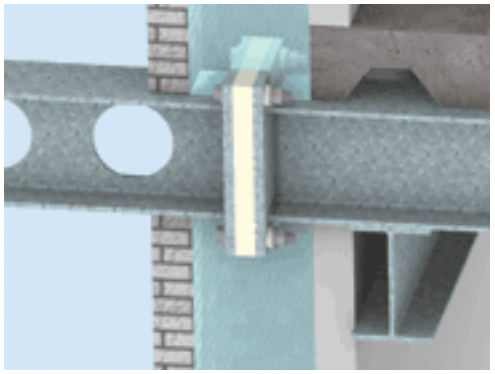
Straw bale construction

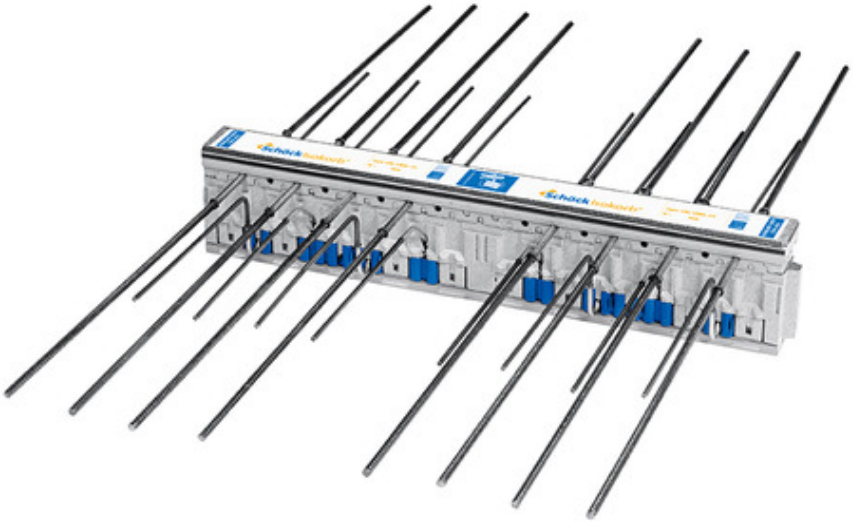
Project 2: High performance enclosure research





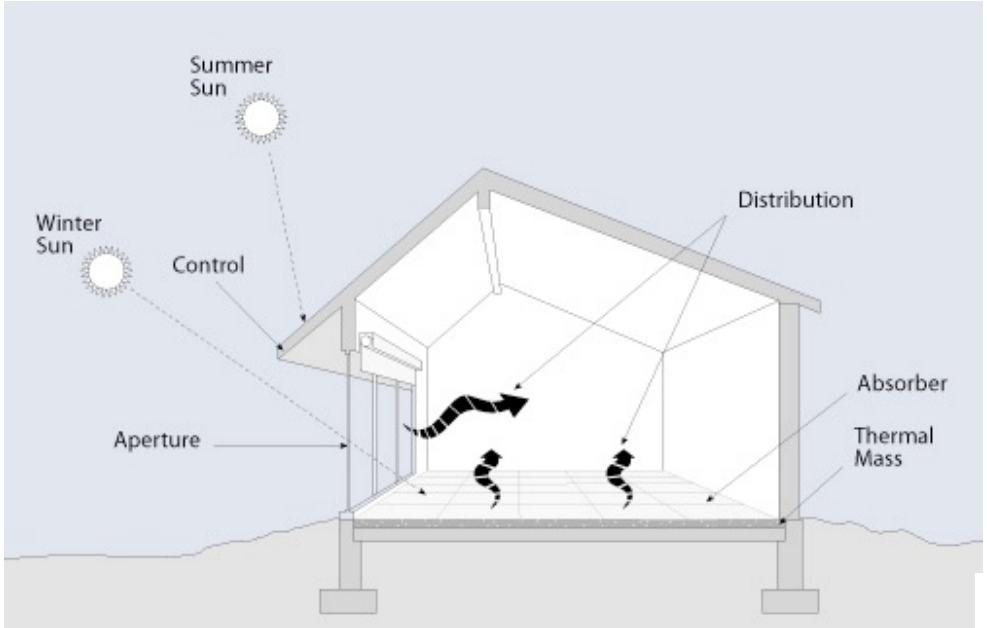
Thermal break systems for cladding





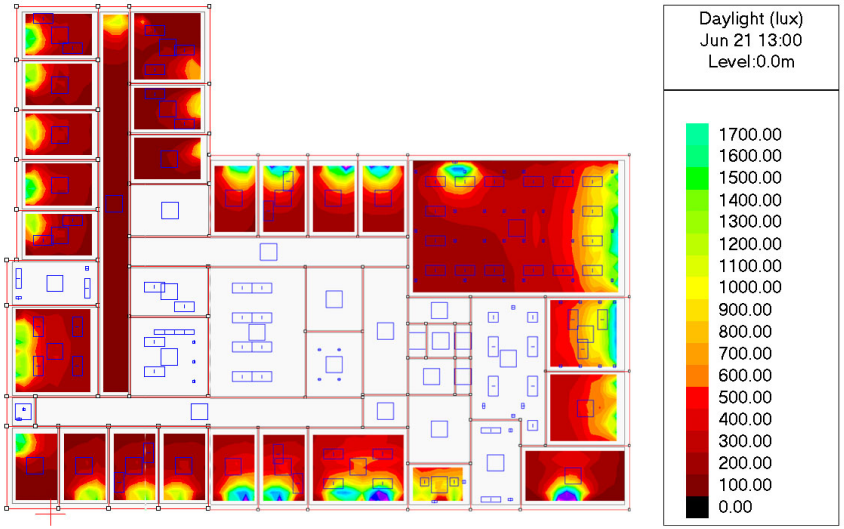
Thermal break systems for balconies

Project 2: High performance enclosure research



Passive solar and thermal mass

Daylighting and energy trade-offs



Project 2: Topic selection

- **Email me** your topics by **Friday April 8, 2016**

Name	Project topic
Blat Tatay, Andrea	
Curioni, Dina P.	
Jarma, David A.	
Jordan, Taylor L.	
Kane, Benjamin M.	
Lim, Keonho	
Mitchell, Alexander R.	
Panczak, Bianca J.	
Rice, Lindsey E.	
Townley, Nina V.	
Ashayeri Jahan Khanemloo, Mehdi	
Babaei Sonbolabadi, Kamal	
Cueto, Patrick Kevin M.	
Del Pino Torres, Julia Del Rosario	
Faramarzi, Afshin	
Foss, Stephen M.	
Qiu, Luanzhizi	
Sharghi, Ali	
Sudhakaran, Naveen	
Zhang, Xu	
Castro, Jose L.	
Dipietro, Salvatore D.	
Lee, JiWan	

Take-home exam

- Your take-home exam is released today
  - Open notes
  - Open book
  - Work individually (do not compare or share answers)
  - Due in 1 week (April 5th @ 5 PM)
  - Email me with any questions or clarification issues

ROOFING

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

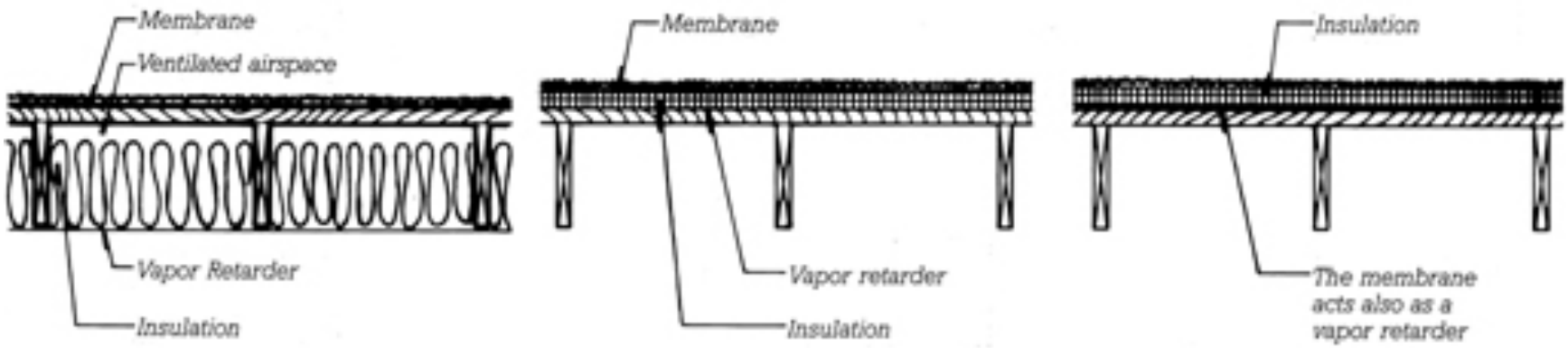
- Ballast material
  - Stone aggregate
  - Precast concrete blocks or Pavers

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

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

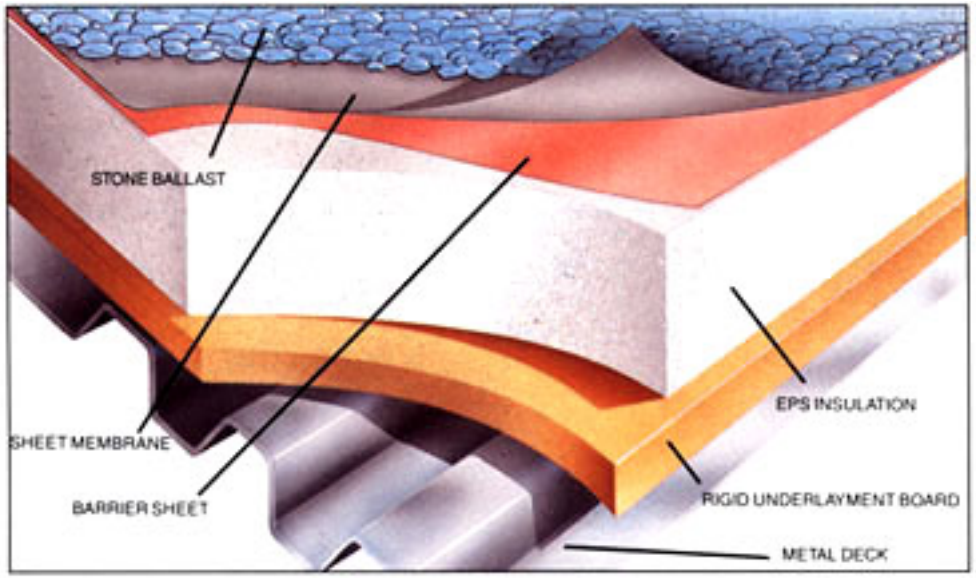
Roof thermal insulation

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



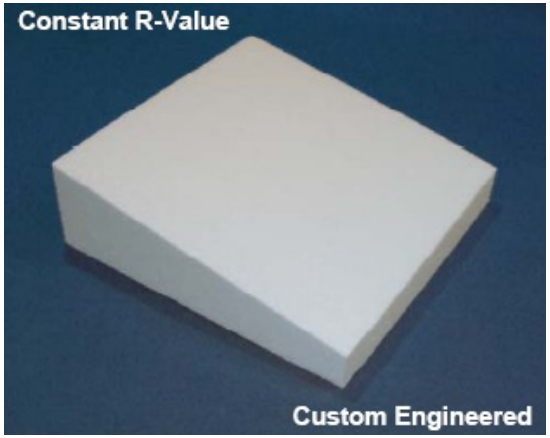
Typical roof insulation

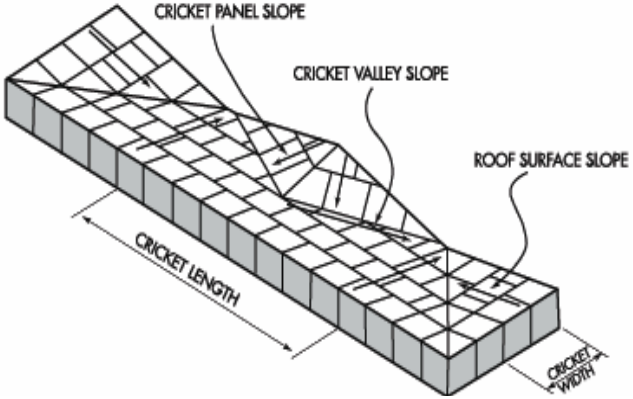
- Over-deck insulation is usually EPS, XPS, polyiso, or rigid fiberglass
  - These are the only insulation materials that can handle the wind/ snow/roofing loads and still provide high insulating capabilities
  - High inherent R values of EPS and polyiso gives good insulating capabilities with only a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

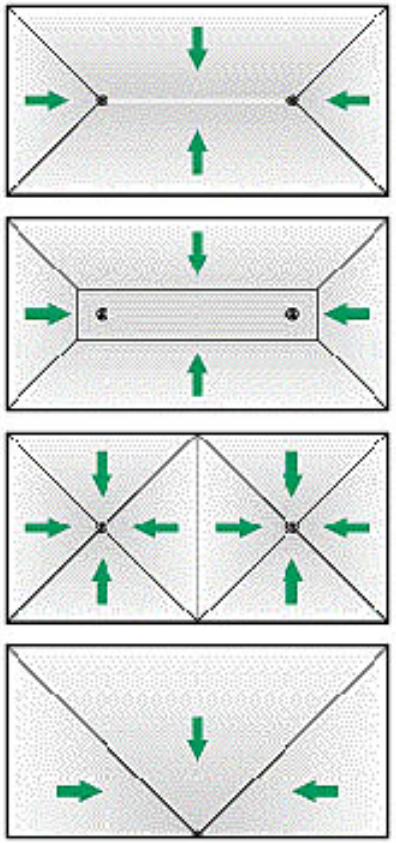


Tapered insulation

- 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

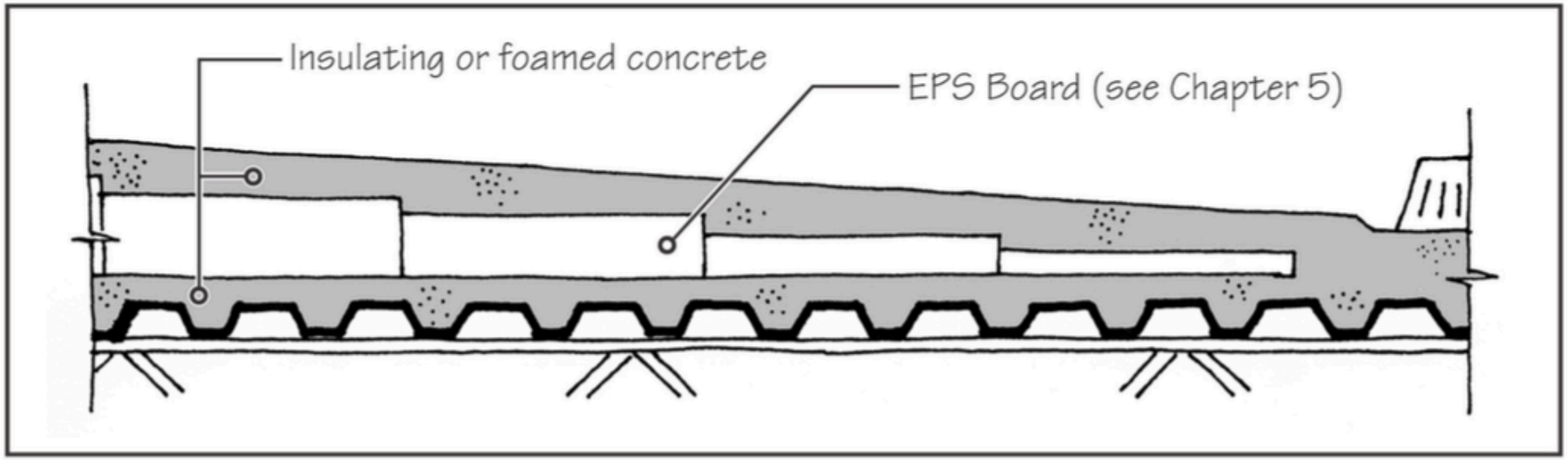
- **Insulating concrete** is a very lightweight concrete that with perlite or vermiculite as a high insulating granular additive
  - 0.8 < R per inch < 1.2 (normal concrete is about 0.2)

- **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

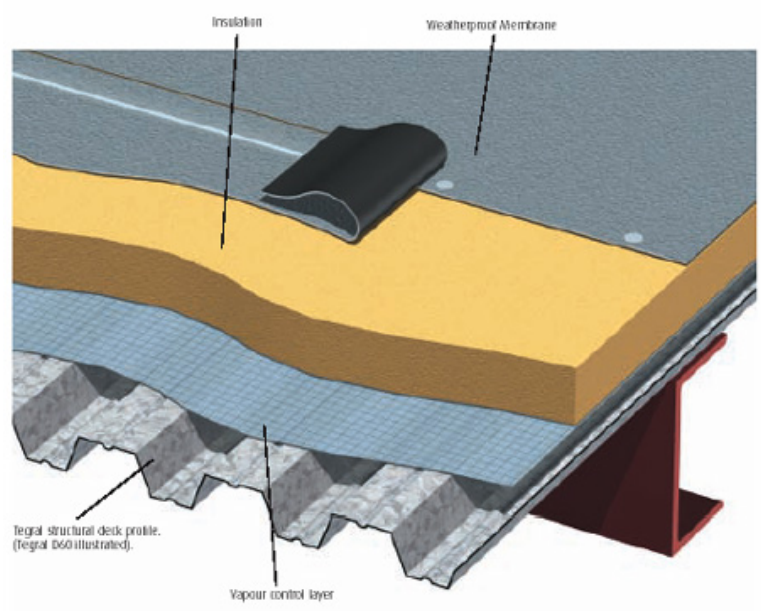
Embedded insulation

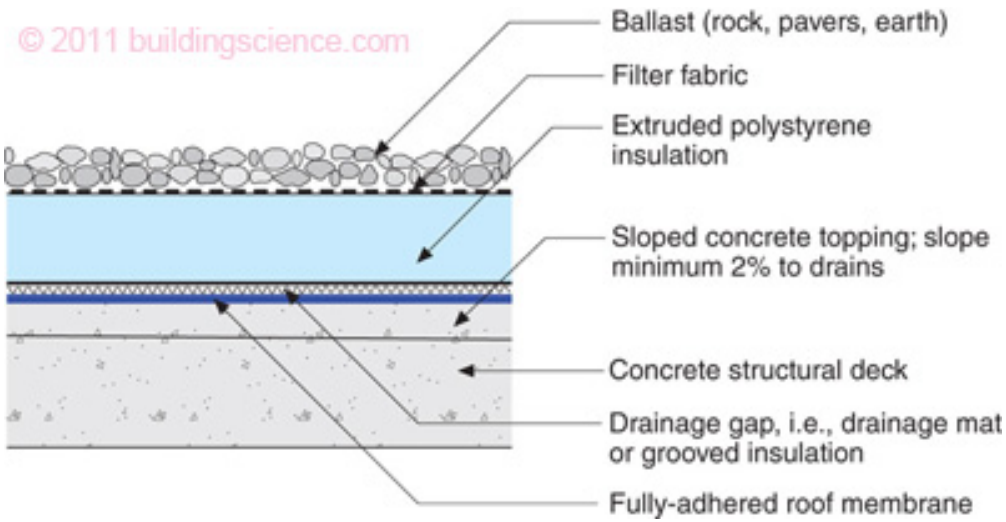
- EPS or polyiso insulation can be embedded within the concrete itself
- This is commonly done with foamed or insulating concrete



Roof membranes

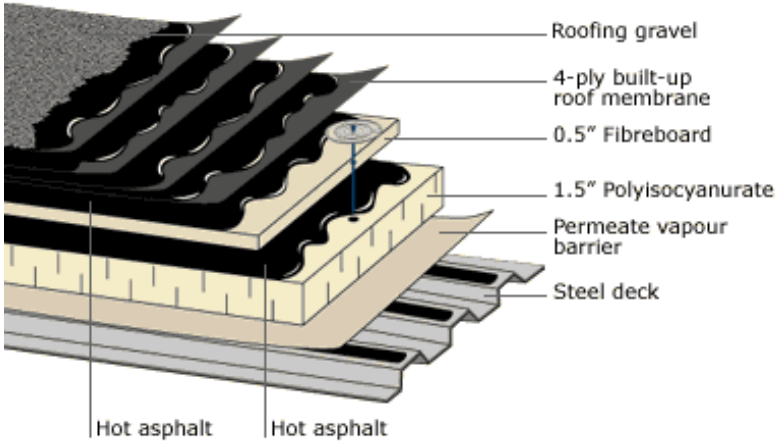
- Membrane roofing systems are used to prevent leaks and move water off of roofs
- Three main categories:
  - Built-up roof membrane
  - Single-ply roof membrane
  - Fluid-applied roof membrane



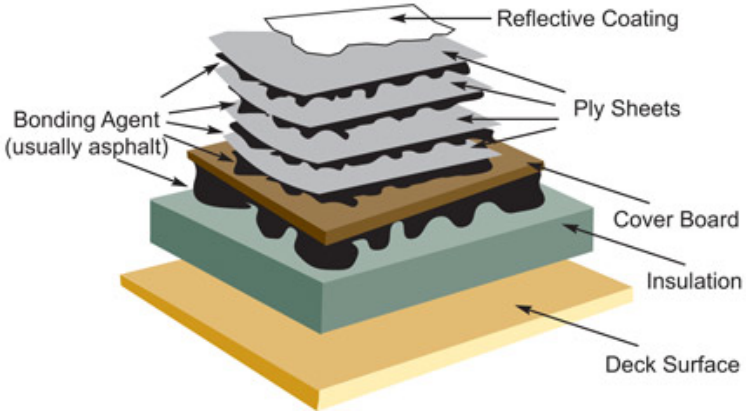


Built-up roof membranes

- 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

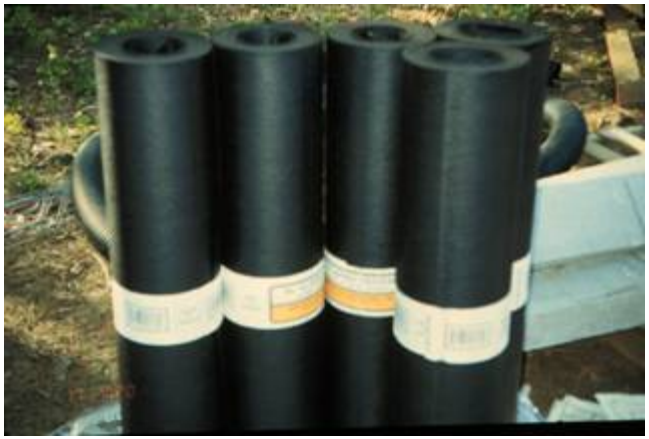


- Modified bitumen sheets
  - Bitumen has polymers added to improve the UV protection and make it more cold resistant
  - Felt or fiberglass sheets are embedded with modified bitumen
    - 2 to 3 layers of the sheets are installed with more modified bitumen between



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



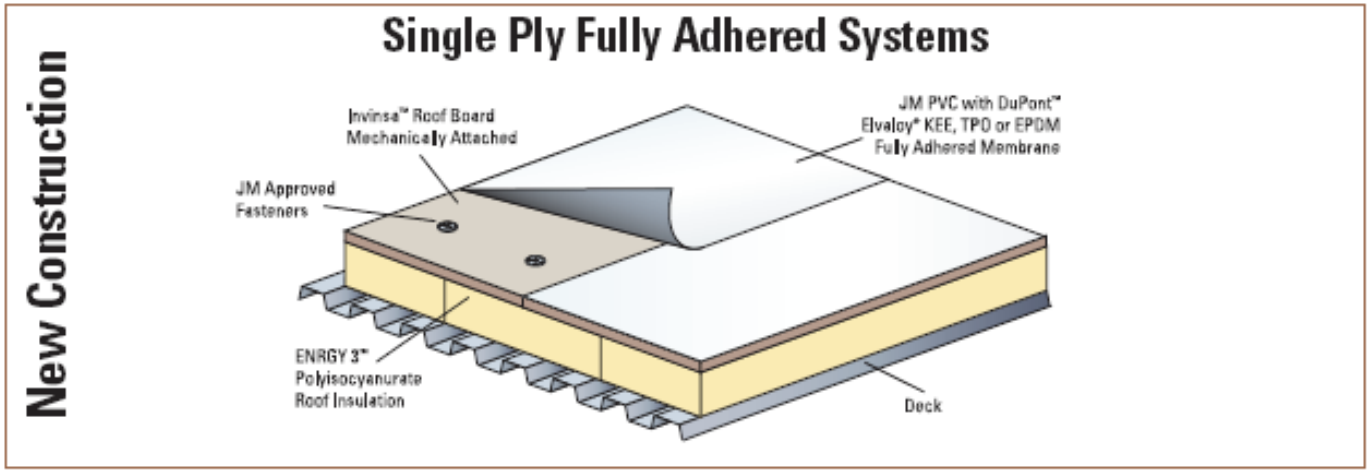
Advantages and disadvantages of BUR

- 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

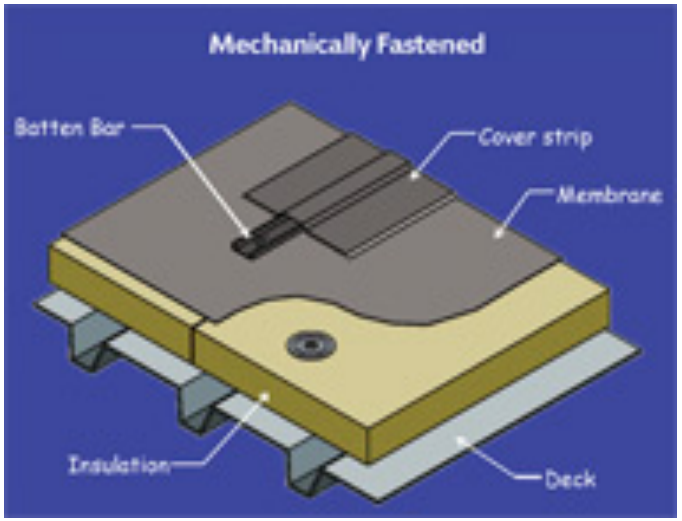
Single-ply roof membrane

- 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 absoprtivity)

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

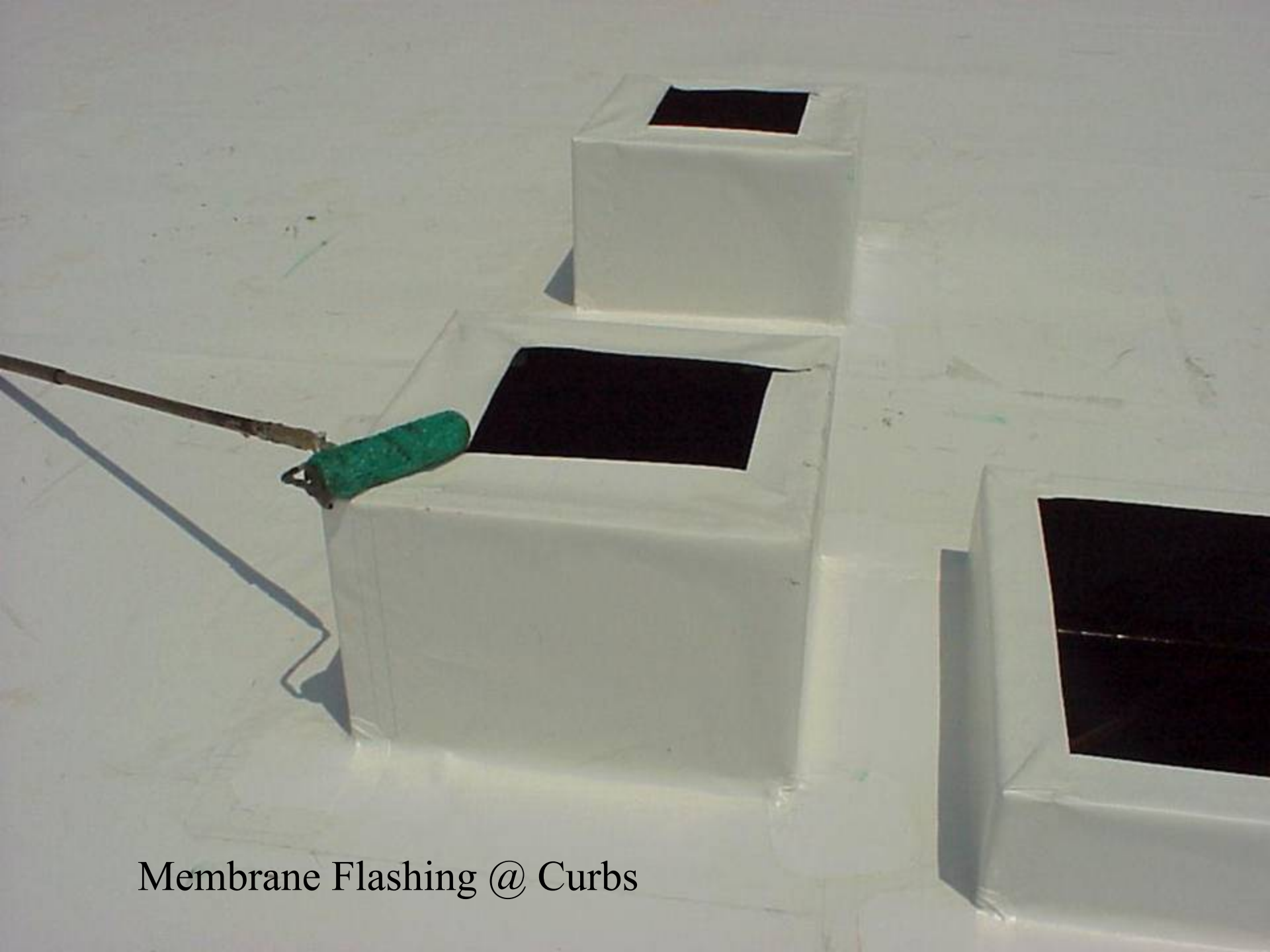
- TPO (thermoplastic polyolefin) is also a thermoplastic
  - TPO is more flexible and stretchable than PVC but less than EPDM
  - TPO does not lose its flexibility over time like PVC

- 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

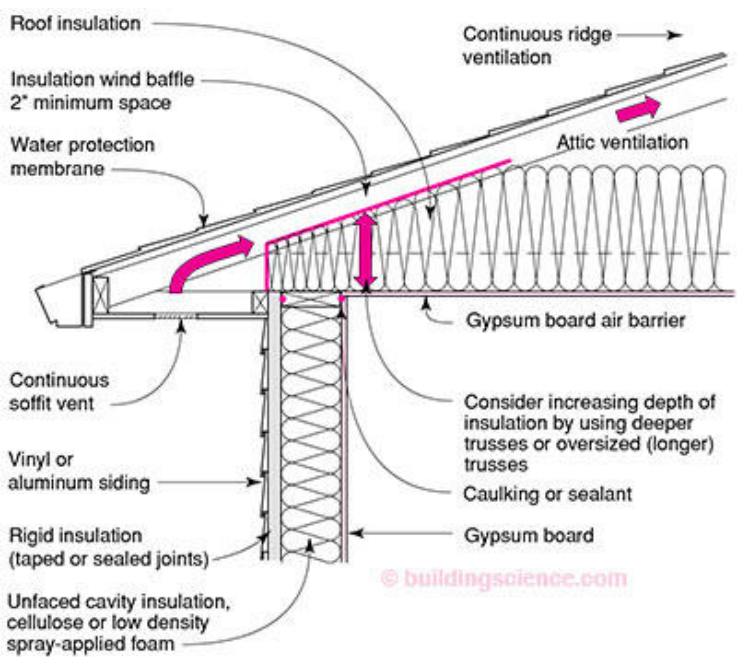
Advantages and disadvantages of membranes

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

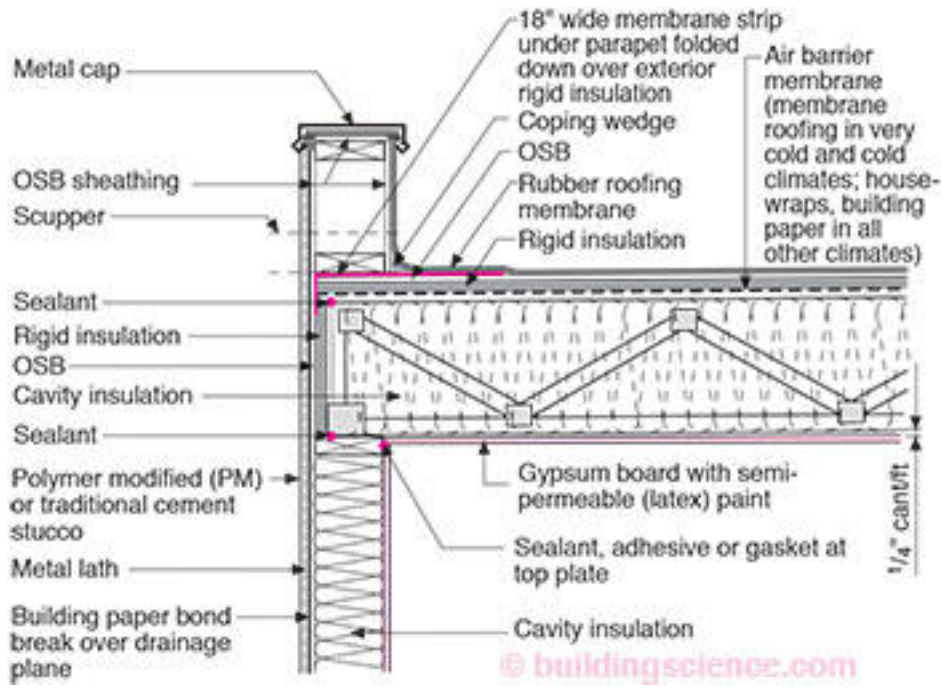
- Disadvantages
  - Any small puncture can cause leaks
  - Harder to repair small leaks
  - Must be completely (or near completely) replaced when repairs/ modifications are made
  - Shorter lifetime than BUR

For more information on roofing design

- http://buildingscience.com/documents/reports/rr-0404-roof-design/view



Vented roof assembly



Unvented flat roof w/ thermal control

- https://www.wbdg.org/design/env_roofing.php

WBDG a program of the National Institute of Building Sciences
WHOLE BUILDING DESIGN GUIDE