Understanding Green Homes & Durability

The Building America Systems Integration Approach

Betsy Pettit, AIA

Building Science Consortium

Green = Sustainability = Durability

People (personal environment) →	**Buildings** (indoor environment) →	**Environment** (exterior environment)
Short-Term Concerns →	**Mid-Term Concerns** →	**Long-Term Concerns**
Local Concerns →	**Regional Concerns** →	**Global Concerns**

Systems Integration is the way to get there

Building America Homes Durability = Systems Integration

- Indoor Environmental Quality
  - Durability of Occupants
    - Comfort
    - Indoor air quality
- Materials and Resources
  - Durability of Building
    - Moisture control
- Energy and Atmosphere
  - Durability of Planet
    - Energy efficiency

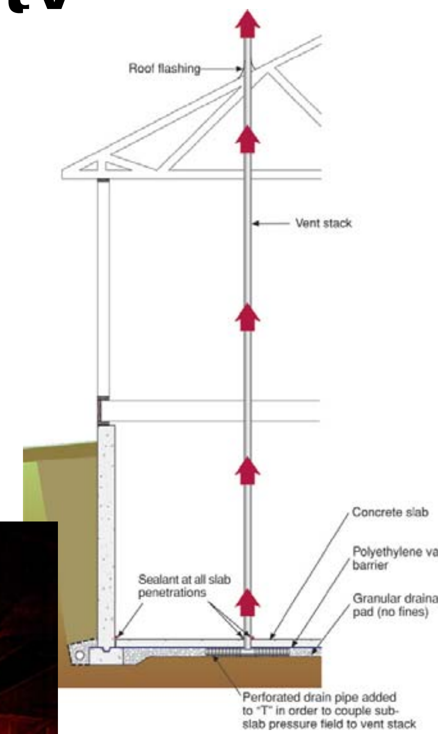
The link is clear - USGBC LEED for Homes

For Certification: First 30 points REQUIRED

- Indoor Environmental Quality (IAQ)
- Materials and Resources (MR)
- Energy and Atmosphere (EA)
- Homeowner Awareness(HA)

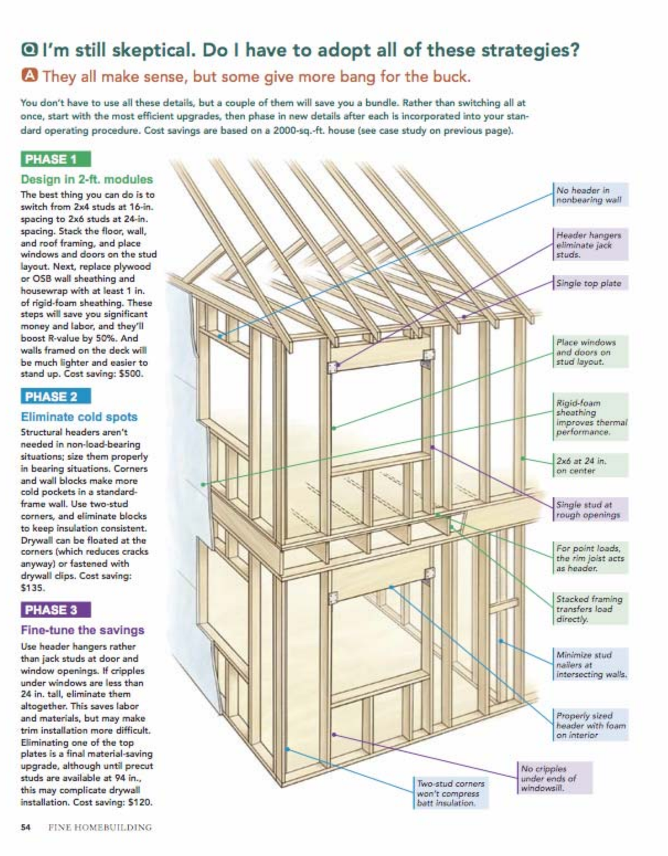
Indoor Environmental Quality (Durability of Occupants)

- Combustion safety
- Outdoor air change according to ASHRAE 62-2
- Air distribution sizing through manual D
- > MERV 8 filtration
- Radon control (EPA region 1)
- Garage/house separation



Materials and Resources (Durability of Building)

- Efficient use of framing lumber
  - Advanced framing concepts
- Detailed durability plan
  - Taken from BA durability research



Q I'm still skeptical. Do I have to adopt all of these strategies?

A They all make sense, but some give more bang for the buck.

You don't have to use all these details, but a couple of them will save you a bundle. Rather than switching all at once, start with the most efficient upgrades, then phase in new details after each is incorporated into your standard operating procedure. Cost savings are based on a 2000-sq.-ft. house (see case study on previous page).

PHASE 1

Design in 2-ft. modules

The best thing you can do is to switch from 2x4 studs at 16-in. spacing to 2x6 studs at 24-in. spacing. Stack the floor, wall, and roof framing, and place windows and doors on the stud layout. Next, replace plywood or OSB wall sheathing and housewrap with at least 1 in. of rigid-foam sheathing. These steps will save you significant money and labor, and they'll boost R-value by 50%. And walls framed on the deck will be much lighter and easier to stand up. Cost saving: $500.

PHASE 2

Eliminate cold spots

Structural headers aren't needed in non-load-bearing situations; size them properly in bearing situations. Corners and wall blocks make more cold pockets in a standard-frame wall. Use two-stud corners, and eliminate blocks to keep insulation consistent. Drywall can be floated at the corners (which reduces cracks anyway) or fastened with drywall clips. Cost saving: $135.

PHASE 3

Fine-tune the savings

Use header hangers rather than jack studs at door and window openings. If cripples under windows are less than 24 in. tall, eliminate them altogether. This saves labor and materials, but may make trim installation more difficult. Eliminating one of the top plates is a final material-saving upgrade, although until precut studs are available at 94 in., this may complicate drywall installation. Cost saving: $120.

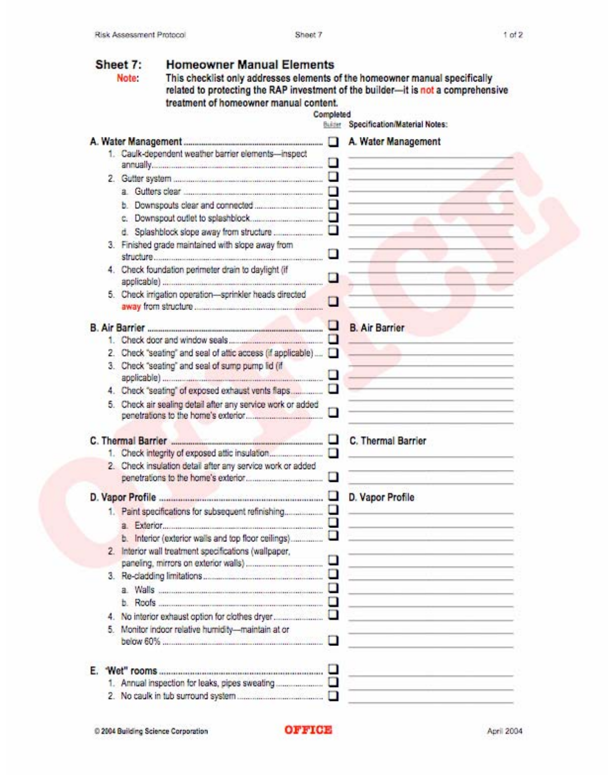
54 FINE HOMEBUILDING

Energy and Atmosphere (Durability of Planet)

- Meets Energy Star
- Third party inspected and tested
  - Insulation, duct leakage, overall air leakage
- Energy Star windows
- Manual J design and refrigerant charge test

Homeowner's Manual (Encouraging Durability)

- Basic manual
  - Building Science Consortium developed a homeowners manual for high performance homes (Building America Homes) that has been shared with the homebuilding industry



Risk Assessment Protocol — Sheet 7 — 1 of 2

Sheet 7: Homeowner Manual Elements

Note: This checklist only addresses elements of the homeowner manual specifically related to protecting the RAP investment of the builder—it is not a comprehensive treatment of homeowner manual content.

	Completed Builder	Specification/Material Notes:
A. Water Management	❑	**A. Water Management**
1. Caulk-dependent weather barrier elements—inspect annually	❑	
2. Gutter system	❑	
a. Gutters clear	❑	
b. Downspouts clear and connected	❑	
c. Downspout outlet to splashblock	❑	
d. Splashblock slope away from structure	❑	
3. Finished grade maintained with slope away from structure	❑	
4. Check foundation perimeter drain to daylight (if applicable)	❑	
5. Check irrigation operation—sprinkler heads directed away from structure	❑	
B. Air Barrier	❑	**B. Air Barrier**
1. Check door and window seals	❑	
2. Check "seating" and seal of attic access (if applicable)	❑	
3. Check "seating" and seal of sump pump lid (if applicable)	❑	
4. Check "seating" of exposed exhaust vents flaps	❑	
5. Check air sealing detail after any service work or added penetrations to the home's exterior	❑	
C. Thermal Barrier	❑	**C. Thermal Barrier**
1. Check integrity of exposed attic insulation	❑	
2. Check insulation detail after any service work or added penetrations to the home's exterior	❑	
D. Vapor Profile	❑	**D. Vapor Profile**
1. Paint specifications for subsequent refinishing	❑	
a. Exterior	❑	
b. Interior (exterior walls and top floor ceilings)	❑	
2. Interior wall treatment specifications (wallpaper, paneling, mirrors on exterior walls)	❑	
3. Re-cladding limitations	❑	
a. Walls	❑	
b. Roofs	❑	
4. No interior exhaust option for clothes dryer	❑	
5. Monitor indoor relative humidity—maintain at or below 60%	❑	
E. "Wet" rooms	❑	
1. Annual inspection for leaks, pipes sweating	❑	
2. No caulk in tub surround system	❑	

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EcoVillage Homeowner Handbook
2

YOUR DETROIT SHOREWAY COMMUNITY DEVELOPMENT HOME AND THE BUILDING AMERICA DIFFERENCE

Congratulations! Your high performance home is built to stringent Building America* criteria. It has been designed and constructed to deliver superior

- energy-efficiency,
- comfort,
- indoor air quality,
- environmental responsibility, and
- durability.

This has been achieved by treating your home as an integrated system with building materials, equipment and their installation tuned for performance and value.

But every home requires operation and maintenance. Just how well you operate and maintain your new home can determine just how superior its performance will be. **A little maintenance on a regular basis may prevent some big problems or headaches in the future.**

But fear not, this is a **short** manual. With attention to some key components, key systems, and periodic inspections, you will be spending most of your time at home **without** this manual, but be glad that Detroit Shoreway Community Development put just the right amount and type of information in **your** hands.

Continuous rigid insulation for thermal break

Cellulose insulation

Slab-on-grade insulation

Photovoltaic panels on garage roof

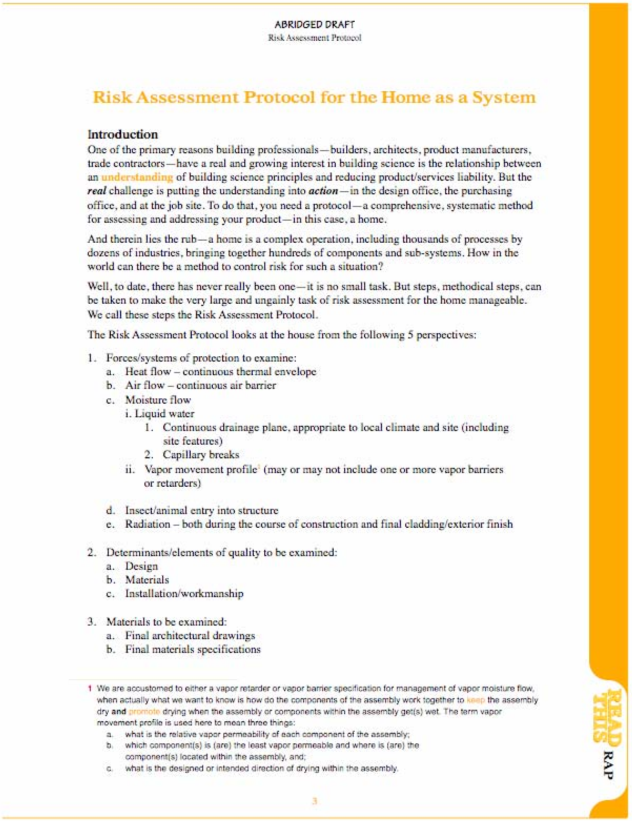
Groundbreaking ceremony

* Building America is a Department of Energy housing initiative for innovative production home builders. For more information, see http://www.eren.doe.gov/building_america/index.html.

The Building America Program

- Has been building homes using these principals for many years
  - These certification requirements describe the minimum Building America Home requirements of the Building Science Consortium (BSC) over the past ten years
  - **BSC developed the first durability plan concept**

The Building America Program
First Draft - Risk Assessment Protocol



ABRIDGED DRAFT
Risk Assessment Protocol

Risk Assessment Protocol for the Home as a System

Introduction
One of the primary reasons building professionals—builders, architects, product manufacturers, trade contractors—have a real and growing interest in building science is the relationship between an understanding of building science principles and reducing product/services liability. But the ***real*** challenge is putting the understanding into ***action***—in the design office, the purchasing office, and at the job site. To do that, you need a protocol—a comprehensive, systematic method for assessing and addressing your product—in this case, a home.

And therein lies the rub—a home is a complex operation, including thousands of processes by dozens of industries, bringing together hundreds of components and sub-systems. How in the world can there be a method to control risk for such a situation?

Well, to date, there has never really been one—it is no small task. But steps, methodical steps, can be taken to make the very large and ungainly task of risk assessment for the home manageable. We call these steps the Risk Assessment Protocol.

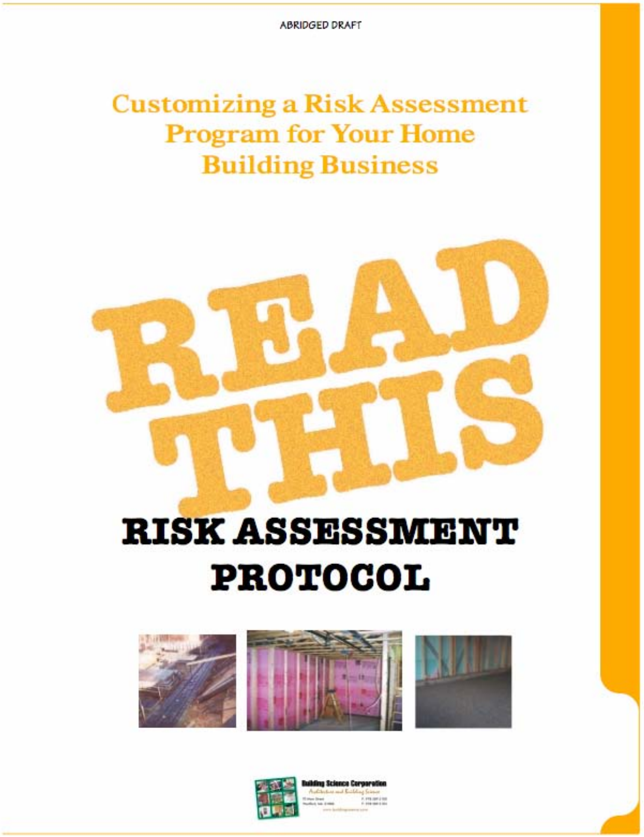
The Risk Assessment Protocol looks at the house from the following 5 perspectives:

1. Forces/systems of protection to examine:
   a. Heat flow – continuous thermal envelope
   b. Air flow – continuous air barrier
   c. Moisture flow
      i. Liquid water
         1. Continuous drainage plane, appropriate to local climate and site (including site features)
         2. Capillary breaks
      ii. Vapor movement profile[1] (may or may not include one or more vapor barriers or retarders)
   d. Insect/animal entry into structure
   e. Radiation – both during the course of construction and final cladding/exterior finish
2. Determinants/elements of quality to be examined:
   a. Design
   b. Materials
   c. Installation/workmanship
3. Materials to be examined:
   a. Final architectural drawings
   b. Final materials specifications

1 We are accustomed to either a vapor retarder or vapor barrier specification for management of vapor moisture flow, when actually what we want to know is how do the components of the assembly work together to keep the assembly dry **and** promote drying when the assembly or components within the assembly get(s) wet. The term vapor movement profile is used here to mean three things:
   a. what is the relative vapor permeability of each component of the assembly;
   b. which component(s) is (are) the least vapor permeable and where is (are) the component(s) located within the assembly, and;
   c. what is the designed or intended direction of drying within the assembly.

3

READ THIS RAP

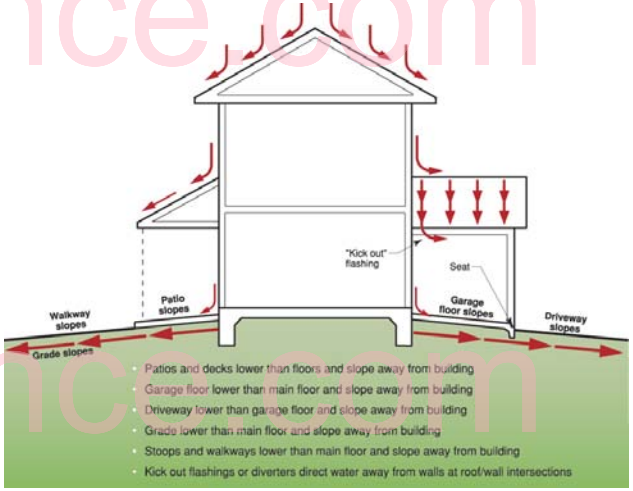


Steps for a Durability Plan

- Pre-design
  - Decisions on useful service life
  - Collection of environmental conditions
  - Design intent of internal environmental conditions
  - Identifying/prioritizing damage functions
- Design and specification
  - Enclosure, mechanical systems, interiors
  - Drawings and specifications required to communicate intent
- Installation
  - Pre-work checklists
  - Post-work checklists

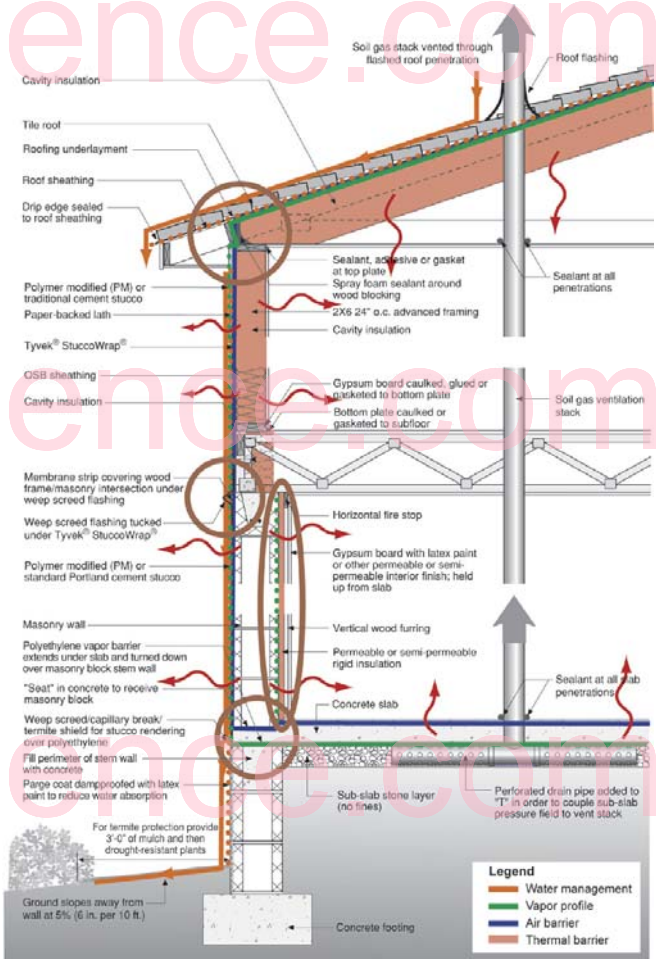
Durability Plan - Pre-design

- Useful Service Life
  - For house should be 100 years
- Collection of external environmental conditions
  - Temperatures, rainfall, wind, microclimate
- Design intent of internal environmental conditions
  - Want to keep interior below 60% RH in hot humid climates
- Identifying/prioritizing damage functions
  - High rainfall areas would be rainwater entry

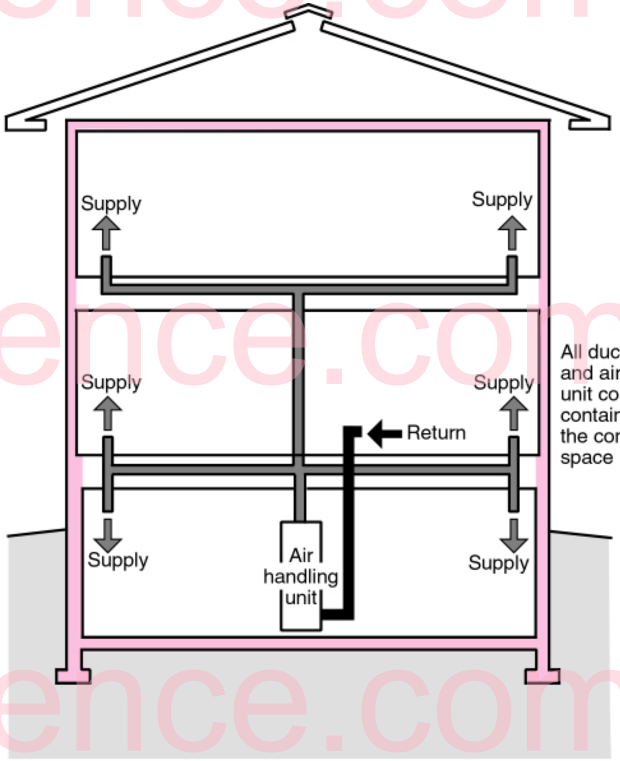


Durability Plan - Design and Specifications

- Design strategy to handle damage functions (moisture,heat, ultra violet radiation, ozone)
  - Drainage plane details and continuity
  - Air barrier details and continuity
  - Thermal barrier details and continuity
  - Vapor profile
  - Mechanical design strategies
  - Extreme Conditions - ie pests, fire, floods, hurricanes
  - Management of moisture in wet areas

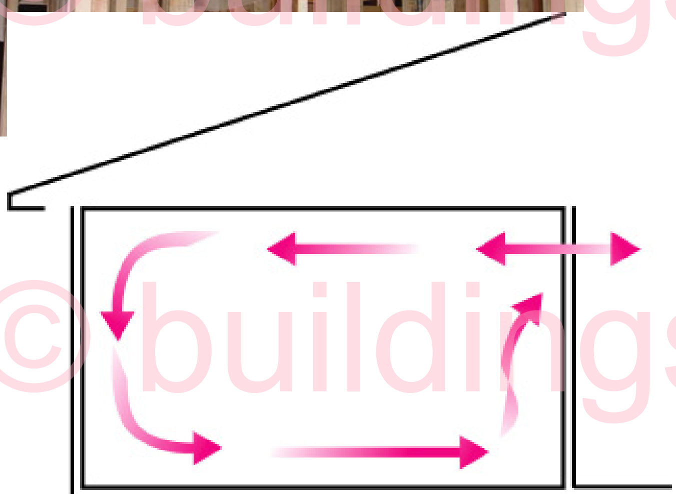


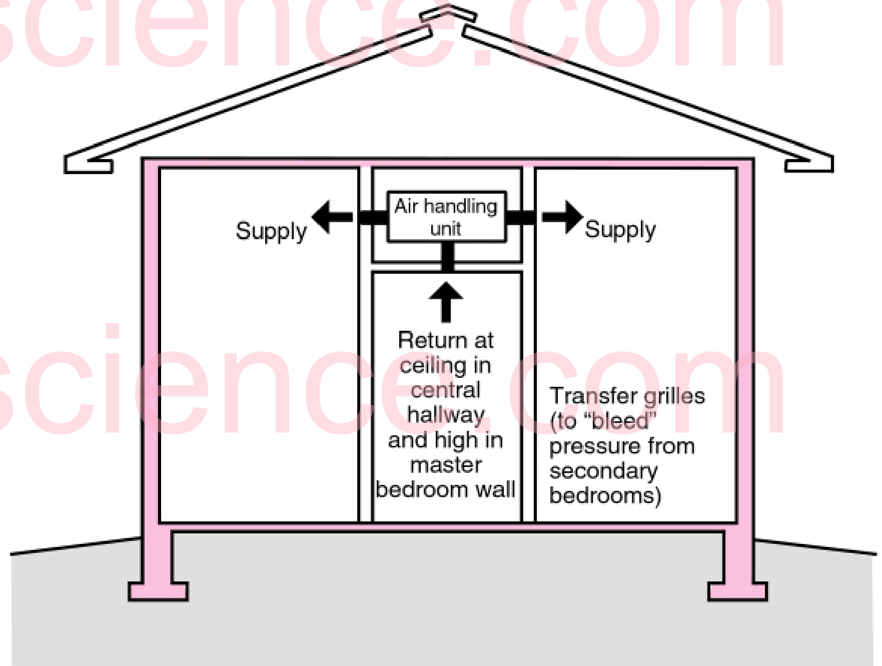
Durability Plan - Design and Specifications



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

Durability Plan - Design and Specifications





Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

Durability Plan - Installation

- Pre-work checklists
- Post-work checklists

Risk Assessment Protocol Sheet 1.1a 1 of 3

Sheet 1.1a: Foundation/Basement — Turned Down Slab

Completed (Architect / Specifier) — Specification/Material Notes:

A. Water Management ☐ ☐ **A. Water Management**
1. Structure ☐ ☐
   a. Capillary break at footing & slab/soil interface ☐ ☐
   b. Wall – below grade ☐ ☐
      i. Dampproofing ☐ ☐
      ii. Waterproofing ☐ ☐
      iii. Drainage space/material ☐ ☐
   c. Wall – above grade ☐ ☐
      i. Finish/coating ☐ ☐
      ii. Material ☐ ☐
   d. Capillary break at slab/framing interface ☐ ☐
      i. Exterior walls ☐ ☐
      ii. Interior walls ☐ ☐
2. Site ☐ ☐
   a. Free-draining backfill ☐ ☐
      i. Height / Width ☐ ☐
   b. Impermeable Cap ☐ ☐
      i. Depth ☐ ☐
   c. Ground slope away from foundation ☐ ☐
      i. Slope % ☐ ☐
      ii. Distance ☐ ☐
   d. Landscaping ☐ ☐
   e. Irrigation ☐ ☐

B. Air Barrier ☐ ☐ **B. Air Barrier**
1. Concrete Slab ☐ ☐
   a. Thickness ☐ ☐
   b. Penetrations sealed ☐ ☐
   c. Joints sealed ☐ ☐
2. Mudsill ☐ ☐
   a. Sill gasket (see **Photo 1**) ☐ ☐

C. Thermal Barrier ☐ ☐ **C. Thermal Barrier**
1. Slab insulation ☐ ☐
   a. Perimeter edge ☐ ☐
      Type ☐ ☐
      Thickness (R-inch) ☐ ☐
   b. Partial perimeter under slab (see **Photo 2**) ☐ ☐
      Type ☐ ☐
      Thickness (R-inch) ☐ ☐
      Width ☐ ☐
   c. Under entire slab ☐ ☐
      Type ☐ ☐
      Thickness (R-inch) ☐ ☐
   d. On slab insulation ☐ ☐
      Type ☐ ☐
      Thickness (R-inch) ☐ ☐

D. Vapor Profile ☐ ☐ **D. Vapor Profile**
1. Slab vapor retarder (see **Photo 2**) ☐ ☐
   a. Material ☐ ☐
   b. Interior drying capability ☐ ☐

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Risk Assessment Protocol Sheet 9.1 1 of 1

Sheet 9.1: RAP Summary — Design Changes

- Example: Change Item Framing — Example: RAP reference[1] 2.1a (office)/C.4a
  Example: Pre-RAP Practice: No detail, framers prerogative — Example: Pre-RAP Practice: Two-stud corner architectural detail for jobsite framing plans
- Change Item — RAP reference
  Pre-RAP Practice — Post-RAP Practice
- Change Item — RAP reference
  Pre-RAP Practice — Post-RAP Practice
- Change Item — RAP reference
  Pre-RAP Practice — Post-RAP Practice
- Change Item — RAP reference
  Pre-RAP Practice — Post-RAP Practice

See attached supporting photos.

[1] The reference should follow this format: Sheet Number (Sheet Type)/Line Item. For example: 1.2 (Office), B.2b [Conditioned crawlspace, Air Barrier, Concrete wall, masonry block].

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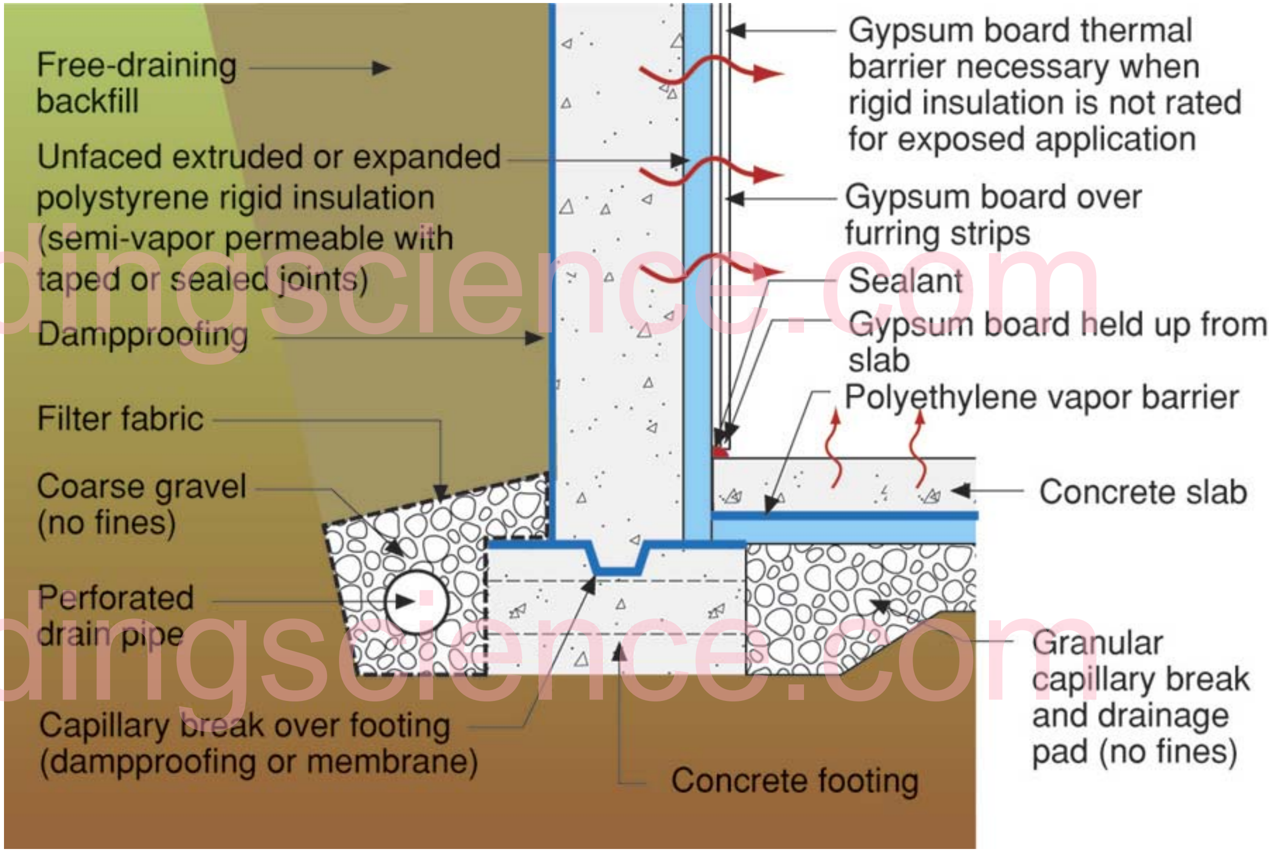
The Building America Program

- Moves beyond the goals of these first 30 points described by LEED Home Certification
- Intends to reduce energy by more than twice the goal of Energy Star
- Requires long term durability for success of program
  - Durability Plan and Durability Standard

Building America Homes
Comfort, Indoor Air Quality, Energy Efficiency

All rely on:

- Leak-free homes with high R-value enclosures



Building Physics

- Energy moves from higher state to lower state
  - (the second law of thermodynamics)
- Heat moves from warm to cold (thermal gradient)
- Moisture moves from more to less (concentration gradient)
- This is the thermodynamic potential
  - The psychrometric chart is a visual representation of the thermodynamic potential of water vapor
- It takes even more energy to counteract this phenomena

What are the consequences of this paradigm shift?

- Less heat loss into the enclosure
- Less Drying Potential
- Things stay wet for longer

Verifying Durability

- LEED Homes will give 1 to 5 extra points for third party verification
  - Probably not enough points
- A standard must be created before verification can occur
  - BSC working on a Durability Standard
    - Quality Assurance
    - Quality Control

Building America Homes

Different Designs for Different Climates

- Houses in all climate zones have interior moisture generation relating to the number of people per square foot
  - BSC work with ASHRAE 62-2 committee to promote appropriate air change rates
- Houses in cold climates generally need to dilute the moisture pollutant with (dryer) outside air
  - BSC work to provide aircycling with furnaces and determine if, when, and where to use HRV's and ERV's
- Outside air is generally a moisture pollutant in hot humid climates
  - BSC work to provide customized rates of air change and supplemental dehumidification in an energy efficient manner

Building America Homes

Different Designs for Different Climates

Subarctic/Arctic
A subarctic and arctic climate is defined as a region with approximately 12,600 heating degree days (65°F basis) or greater.

Very Cold
A very cold climate is defined as a region with approximately 9,000 heating degree days (65°F basis) or greater and less than approximately 12,60 heating degree days (65°F basis).

Cold
A cold climate is defined as a region with approximately 5,400 heating degree days (65°F basis) or greater and less than approximately 9,000 heating degree days (65°F basis) .

Mixed-Humid
A mixed-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

Hot-Humid
A hot-humid climate is defined as a region that receives more than 20 inches (50 cm) of annual precipitation and where one or both of the following occur:

- a 67°F (19.5°C) or higher wet bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- a 73°F (23°C) or higher wet bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year. †

† These last two criteria are identical to those used in the ASHRAE definition of warm-humid climates and are very closely aligned with a region where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

Hot-Dry
A hot-dry climate is defined as a region that receives less than 20 inches (50 cm) of annual precipitation and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year.

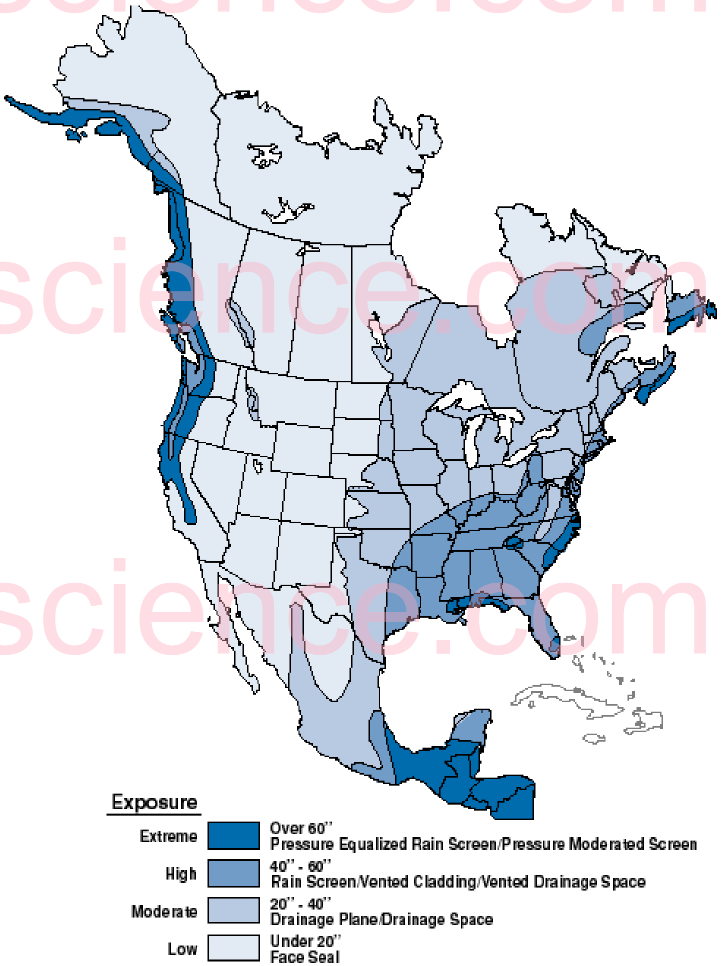
Mixed-Dry
A mixed-dry climate is defined as a region that receives less than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (50° F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.

Marine
A marine climate meets all of the following criteria:

- A mean temperature of coldest month between 27°F (–3°C) and 65°F (18°C)
- A warmest month mean of less than 72°F (22°C)
- At least four months with mean temperatures over 50°F (10°C)
- A dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Building America Homes

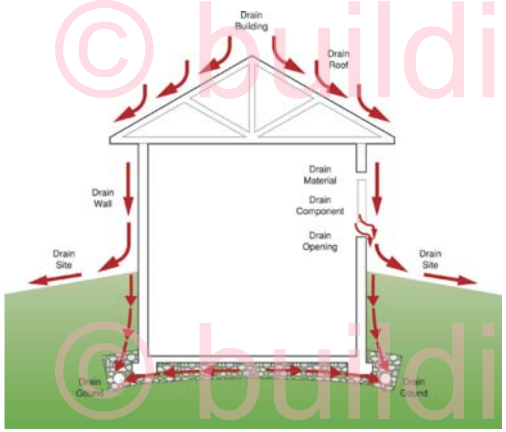
Different Designs for Different Climates

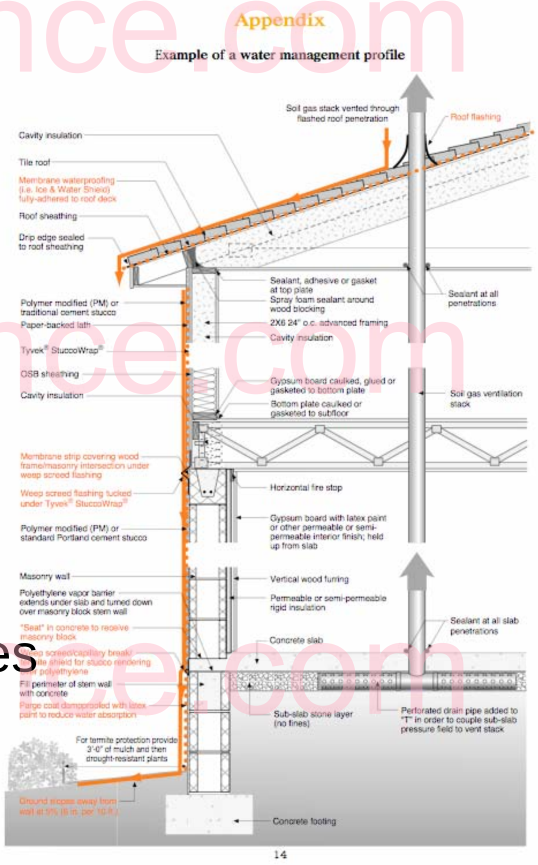


Understand Building Science Concepts

- Damage Functions
  - Moisture flow, heat flow, ultraviolet radiation, ozone
- Moisture degradation is the largest factor limiting the service life of a building
- Durability is a function of moisture control (the most important of the damage functions)
  - Enclosure design
  - Mechanical system design

Water Drainage/Storage/Protection



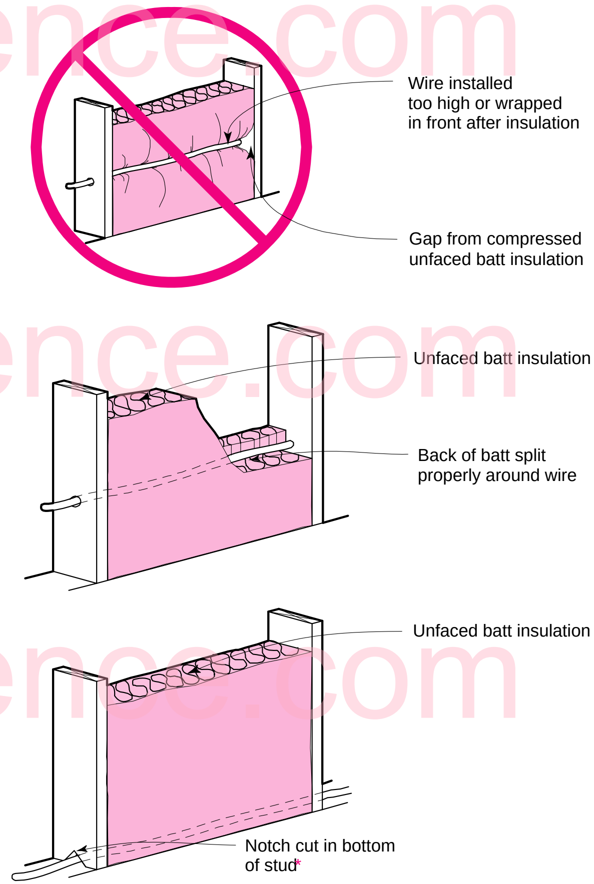


BSC research includes:
- Manual on Moisture Management
- Research on wetting and drying of assemblies
- Window flashings research
- Insulating sheathing as drainage plane

House Wrap Benchtop Testing

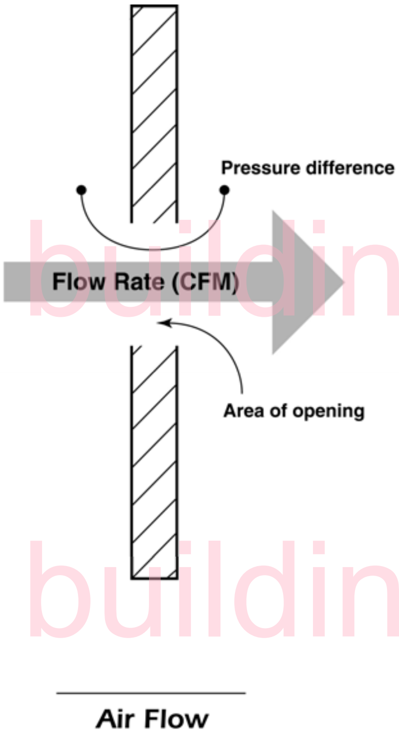


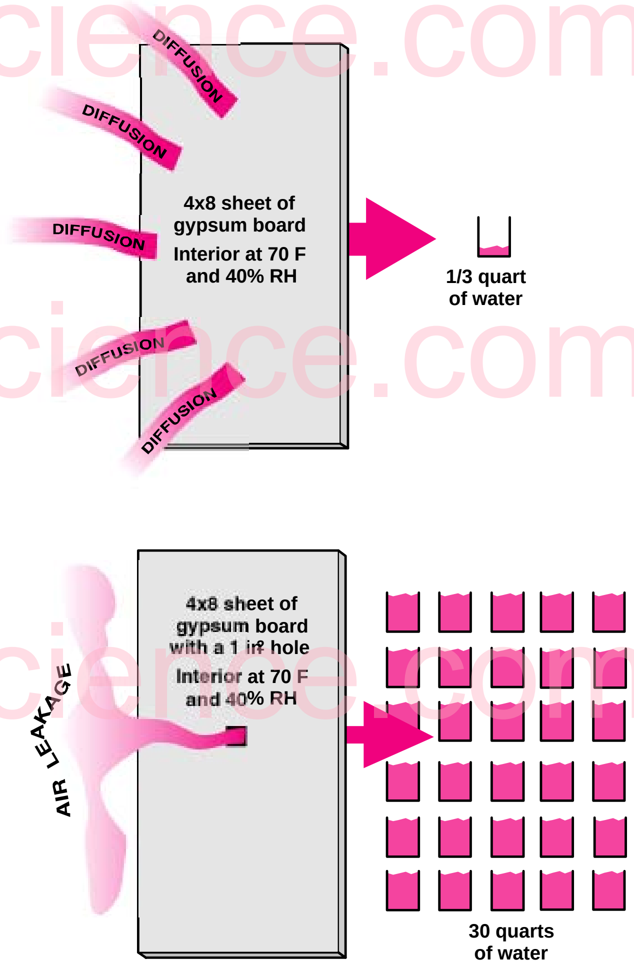

Thermal Enclosure Design



Alternate Wiring with Batt Insulation Detail

Air Leakage Control





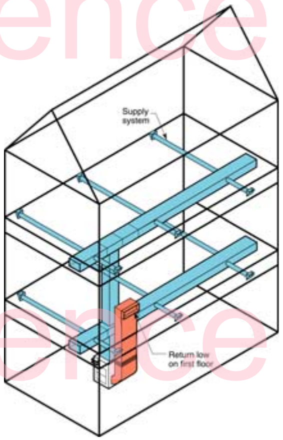
Water Vapor Control

- BSC Applied Research includes:
  - Code Work,
    - Vapor retarder, barrier, location, when needed
  - Test huts, various locations,
    - Is this a flow-through assembly,
    - Does it have unidirectional, bi-directional or no drying potential?
  - Training, What's a "perm?"
  - Interior humidity control

Space Conditioning Design

Provide dilution for the moisture pollutant:

- In cold climates, it is interior moisture generation
- In hot humid climates, it is exterior moisture



Extreme Enclosure Design

Hurricanes….Floods…..Mold

The next disaster: mold

After a water disaster, mold is everywhere. It's disgusting, a possible health hazard and costly to fix. The worst horror is that you're probably not covered by your insurance.

By Liz Pulliam Weston

Diane Beauchamp knows she's among the lucky ones. After Hurricane Katrina, her home in Ocean Springs, Miss., is still standing and apparently wasn't flooded.

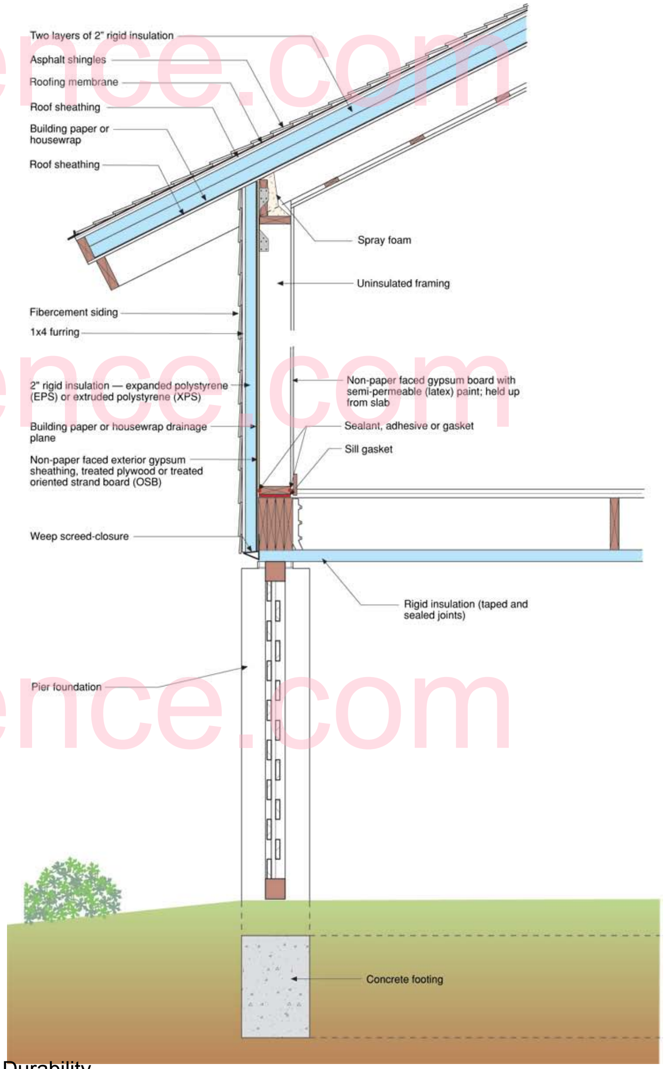
But it's covered in mold.

Rain seeped in through the wind-damaged roof and siding, Beauchamp said. Then the moisture sat and "cooked" in humid 100-degree heat for days, leading to mold growth in every room.

"It was really gross," Beauchamp said. "In the bedrooms, it was also on blankets on top of the beds, not just on stuff that was on the floor."

As bad as it was, Beauchamp said her mold growth couldn't hold a candle to the damage suffered by homeowners whose houses were actually flooded, where mold sprouted in a thick rug on nearly every surface.

Coverage limited, if available at all



Building Science Consortium

Extreme Enclosure Design

Earthquakes …..