Build a Better House
The Foundation

Maine Indoor Air Quality Council

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Maine *Uniform* Building and Energy Code

IRC...Int' l Residential Code 2015
IBC...Int' l Building Code 2015
IECC...Int' l Energy Conservation Code, 2015 or...
ASHRAE 90.1 2007
ASHRAE 62.1 and ASHRAE 62.2 2013
ASTM E-1465-08



Building Science Basics

Bulk Water Management

Heat Flow Management

Vapor Management

Air Flow Management

Workshop Topics

Construction Issues...
- Dealing with water, heat, vapor and air
- Common sense approaches

Health Issues...
- Mold and respiratory problems
- Radon and lung cancer
- Other soil contaminants

Code interactions...
- 2015 IECC basics

Some Terms...

Foundation... a structural element transferring building loads to the ground

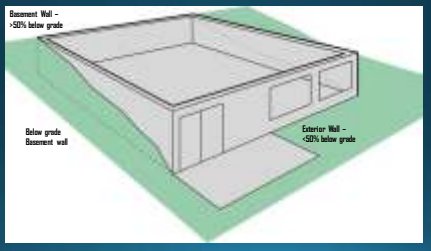
Basement... a floor of a building beneath the ground or first floor, at least partially below grade

Frost depths in Zones 5, 6, and 7 brought about "Basement Foundations"

Crawlspace versus Basement

For our discussion today, a crawlspace should differ from a full basement only in height

Defining Below-Grade Walls



There are only 2 ways to successfully construct basement foundations in our climate

Warm and Dry
or
Cold and Dry

Warm and Dry

Energy savings offset minor extra construction cost

Reduces the need for dehumidification

Provides useable space

Minimizes callbacks relating to moisture and mold

Cold and Dry

Provides no energy savings, especially if boiler is located in unheated space

Requires dehumidification during summer months

Increases callbacks regarding mold and moisture

Dry, Energy Efficient, Radon Resistant, and *Easily Built*



Basement Foundation Types

Poured Concrete



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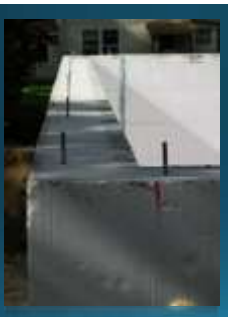

Insulated Concrete Forms

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Concrete Block

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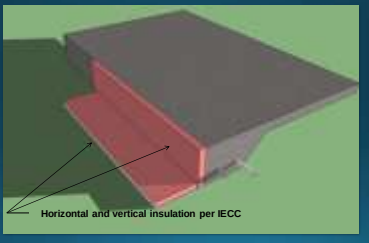
Slab on Grade



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Pier or Pile Foundation





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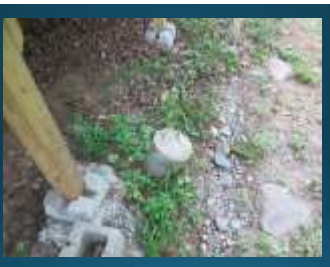

Freeze/thaw effects on concrete pier

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Prevent Frost Damage



Water freezes and expands, (not the soil particles)

Poor drainage is the primary cause

Freezing "saturated" soils causes frost damage

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Preferred pier foundations



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The effects of "scour"

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Redundancy

"the inclusion of extra components that are not strictly necessary, in case of the failure of main components"

An example would be crushed stone, drainage piping, foam insulation, vapor barrier, 6" WWRM, saw cuts

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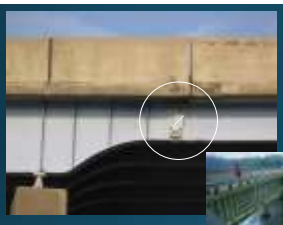

Mianus River, CT 1983



For lack of redundancy…

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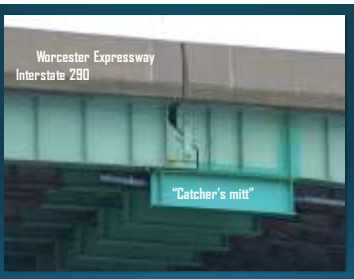

Redundancy… and safety

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Bulk Water Management

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Rules of Moisture Movement

Moisture flow is from warm to cold
Moisture moves from more to less
Air carries moisture from high pressure to low pressure
Gravity pulls water down
Water wicks up
Drainage is critical

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How will I move site water <u>away</u> from the building? (½ foot drop per 10 feet run = 5% pitch)



Site Opportunities & Constraints

Courtesy HLTurner, Inc.

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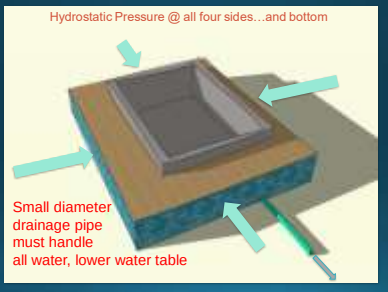

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Site Situations

Building over broken rock…

Good drainage

High radon potential



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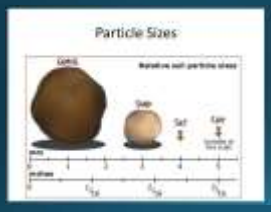

> 2mm… Gravel

0.06mm – 2mm… Sand

0.002mm – 0.06mm..Silt

< 0.002mm… Clay

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Dry Basements

Drain, drain, drain, drain……

Create continuous capillary breaks… no paper or wood materials in contact with concrete foundation

Keep summer air away from any chilled surfaces… warm the surfaces, dehumidify as needed

Carefully planned plumbing arrangements

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Prevent fines from clogging system



Courtesy P&K

This will be inaccessible later

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Drain interior sub-slab

Install granular porous material prior to insulation, VDR, and concrete



Rigid pipe preferred, flexible tubing acceptable

Courtesy P&K

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Interior and Exterior Sub- Surface Drainage



Connecting interior and exterior drainage systems helps drainage

Confuses radon depressurization system

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Drainage lines to daylight



Courtesy P&K

©2021

Cross sectional area = πr^2

Area = 9π = 28.27 in^2

6" pipe

Area = $4\pi 2$ = 25.13 in^2

4" pipe

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Footer Drain Outfall Location

Locate outfall pipe where it emerges to daylight

Put in Owners Manual?



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Insulation at outer end of outfall pipe, if needed

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Capillary diffusion



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Capillary Breaks

Reduce Wicking From Footer



Courtesy Camroden Associates

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Delta®-Footing Barrier



Capillary Break

Always prevent wicking to wood



Courtesy Camroden Associates

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No capillary break

Non treated sill

Poor flashing details

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Damp Proof to reduce *water vapor diffusion*

Largely ineffective against *bulk water intrusion*



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Water Proof



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Waterproof membrane

IRC R406.2
minimum 6 mil
polyethylene

Ensure compatibility with emulsion

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Dimpled drainage mat



Courtesy Platon™

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Clean sand



Drainage Mat

Supervise backfill operations

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Effective low cost bulk water management



Pitch away from foundation 5% slope on <u>all</u> sides *IRC 401.3*

Provide porches and deep overhangs

Minimize excavation depth

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Prevent surface water from recharging sub-surface drainage system



Create swale if necessary

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The +5% slope built into the project can easily become -5% over time

Overfill to allow for subsidence, or compact backfill during placement, or regrade after a year or two?

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Overcompensating for subsidence

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Surface Drainage Retrofit Needed?



Courtesy P&K

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Outside conditions can sometimes be improved



Turner Building Science & Design

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Avoid at all costs



Roof water added to sub-surface water

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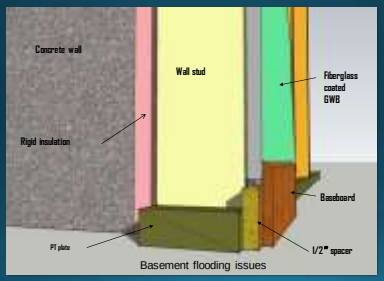
Baseboard detail



Basement flooding issues

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Stud wall rigid foam hybrid

PT plate

XPS behind studs

Cavity insulation?

Space left for removable baseboard

Easy wiring



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Remember…

A foundation can never be warm unless it is dry

No insulation method will work if the foundation leaks

A foundation will leak if it is surrounded by water

Drainage and water proofing are critical to a healthy energy efficient house

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Remember…

An uninsulated foundation can contribute 30% or more to the building's total heat loss

Insulating the foundation is an important step towards an energy efficient and healthy home

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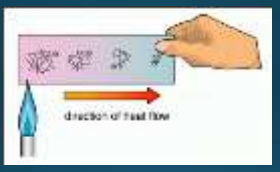
Heat Flow Management

The Rules of Heat Movement



Heat will always flow from warmer to cooler, or more to less

Minimum Thermal Standards for Foundations and Floor Slabs

IECC 2015 Table 402.1.1

Basement wall R-value… 15/19 *(Continuous/cavity)*
Crawl space wall R-value… 15/19 *(Continuous/cavity)*
Slab R-value and depth… 10, 4 feet
Ceiling… R-30

Basement ceilings can be insulated to R-30 if space is unconditioned, i.e., unheated
** R-19 allowed*

*(*Really a poor option in a cold climate)*

IECC 2009

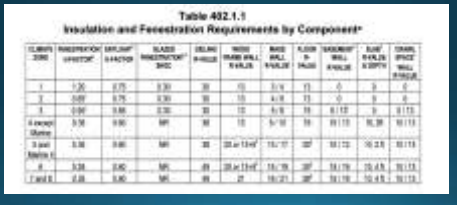
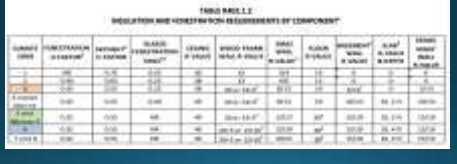


Table 402.1.1
Insulation and Fenestration Requirements by Component*

IECC 2015



Resistivity (ρ)

$R=\rho L$ *(Length, or thickness)*

Material	*Resistivity*
Concrete…	*0.15*
Softwood…	*0.9*
Fiberglass…	*3.5*
XPS…	*5.0*
Isocyanurate…	*5.6*
Dead air…	*5.6*
Vacuum…	*40.0*
Water…	*0.24*

Heat Loss Calculation

Surface Heat Loss =AΔT/R

A = Surface Area
ΔT = Temperature Difference
R = Resistance

One can change one or all three of these parameters

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Heat transfer mechanisms

Conduction… molecular excitation without molecular movement

Convection… fluid movement of excited molecules

Radiation… electromagnetic motion of charged particles



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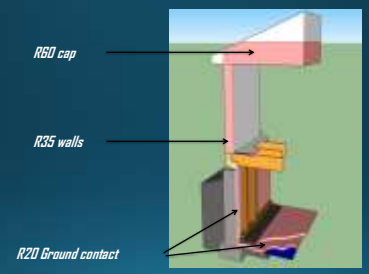

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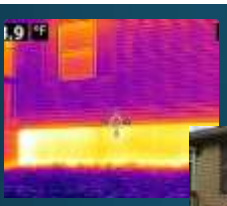

It pays…



…to insulate the basement

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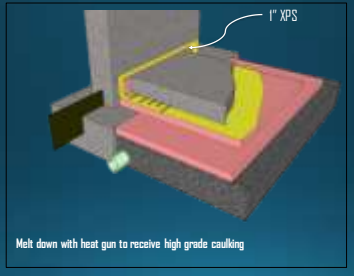

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Carefully insulate all concrete walls

Exterior or Interior

Code: (If Habitable or useable space, conditioned space)

IRC N1102.1.5
"insulate from the top of the basement wall to depth of 10 feet below grade or the top of basement floor, whichever is less"

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Exterior or Interior Insulation



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Fine Homebuilding

Exterior foam infested with ants

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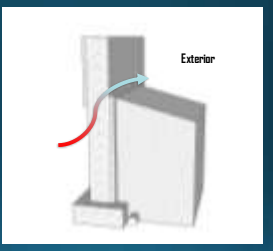
Not a great solution...



...but not uncommon

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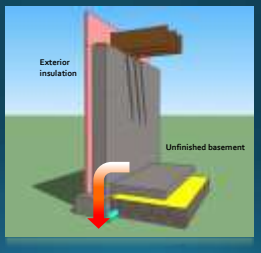
What's happening here?

Where is heat likely to flow?

Add interior insulation...



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Insulate below the load?



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How much load is on the foam beneath a footing?

Assume 275 pounds per square foot of footprint...
A 28x36 two story house would weigh 277,200pounds

A clear span floor and roof system puts all the weight on the footing
The perimeter of the building is 128 lineal feet

277,200 pounds divided by 128 lineal feet equals 2,165 pounds per lineal foot or
1,429 pounds per square foot or just under 10 pounds per square inch

Normal XPS is capable of dealing with 25 pounds per square inch!

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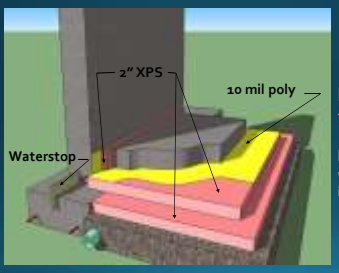

Isolating the footing

Basement interior wall will be insulated

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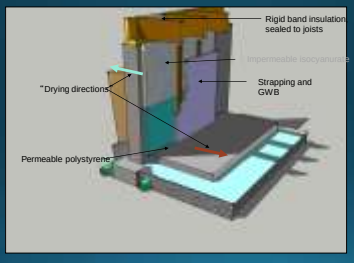
Full height insulation and finish



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Insulation anchor

Plastic anchor designed to attach insulation board to concrete

110 lb pullout

Eliminates curing time

Handles irregular concrete surface

Adhesive might work



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Attaching XPS with flat roof washers and and Tapcon™ screws

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Infrared Imagery



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Let us step away from "Basement Foundations"...



Insulating a frost wall and concrete slab

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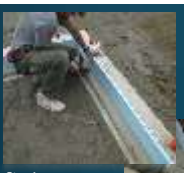
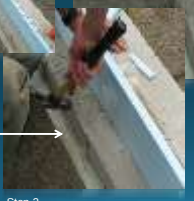


Step 1



Almost ready

Note vertical 2" XPS



Step 2

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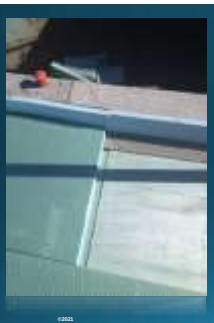

Two layers of 2" extruded polystyrene, joints staggered

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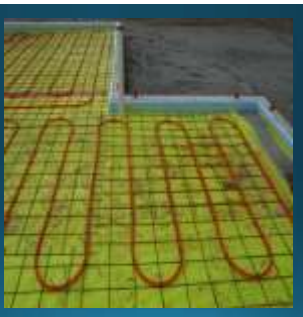
Ready for concrete placement



Snap ties will be cut prior to concrete

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Crete-Heat®

EPS polystyrene insulating panels for radiant floors

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End of Session One

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Upcoming at 4:30 today…

Paul Demers talks about changes to Maine's Building Codes

Begin Session Two

Vapor Management

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The Rules of Vapor Transport

Water vapor will always move from areas of higher concentration to areas of lower concentration

Drivers include…

Vapor pressure differential

Permeability of substrate

Air movement

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…will surely migrate to the spaces above



Water vapor in a damp crawlspace or basement…

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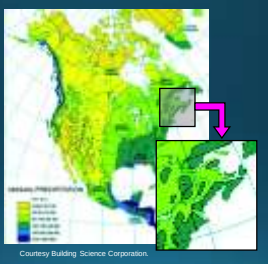
Maine is definitely <u>not</u> a dry climate

40-60 in/yr



Courtesy Building Science Corporation.

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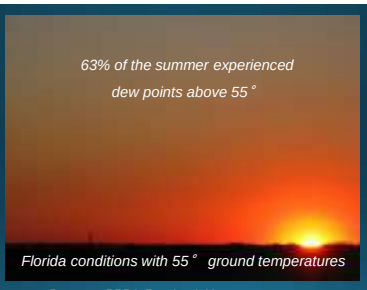

Summer 2004, Portland, Maine

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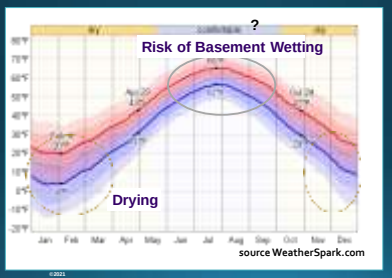
Portland Average Dew Point Weather Data



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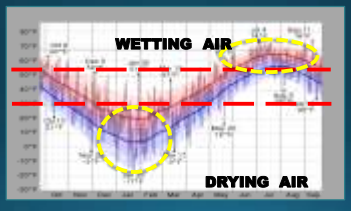
New England Dew Point Climate Graph









Ground water T° September 2012



Humid air
and
cold pipes

103

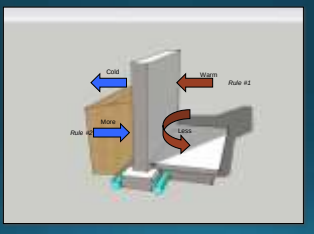


104



105

Foundation wall drying pathways



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Another example of new
concrete and dew point



108

Simple Approximation

In F° ... $T_{dp} \approx T_{db} - 9/25(100-RH)$

For example... $T_{db} = 60°$ RH = 50%

$T_{dp} \approx 60° - (9 \times 50/25) \approx 60° - 18° \approx 42°$

41.33° using Decatur.de calculator

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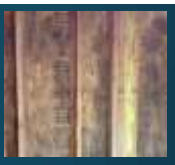
Using the previous slide...

What is the temperature of the inside surface of exterior sheathing on a walkout wall?



Determine total R-value

Determine ΔT

From outside... $T_{interface} = T_{ext} + (\%$ total R-value x ΔT)

Walk out wall with R-15 fiberglass, ½" CDX sheathing. T_{ext} 25°

Total R value = 15.5 ΔT = 35°

$T_{interface}$ = 25° + (.032 x 35°) = 26.12°

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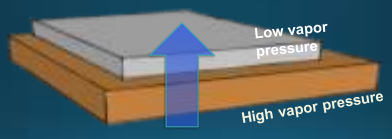
Existing Basement Floors

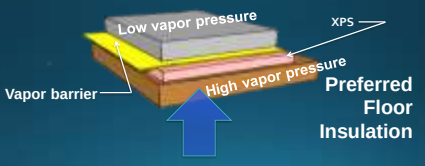
Most likely situation in older homes



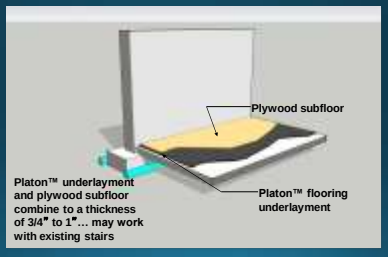
Water vapor diffuses through porous concrete... floor will never be quite dry, and always cold

Vapor diffusion is stopped... floor is warm and dry

Unlikely situation in older homes



Flooring underlayment without insulation



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Finish a basement floor ?

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Open windows, uninsulated floor

115

Don't open the vents



Winter cold defeats the purpose of insulating the crawlspace



Summer humidity will condense

Courtesy Foam-Tech

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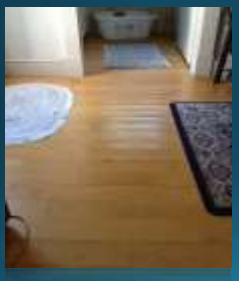
116



Constant high humidity below

117

In reality, this is not a dehumidifier



118



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119



Air temperature

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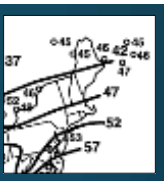

Mean Annual Earth Temperature
Source: Virginia Tech website

120



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Health and Mold

Health studies in North America and Europe show that damp houses and basements contribute to respiratory problems



Courtesy Fox

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Chronic moisture leads to mold

All moldy basements have at least one type of pathogenic or toxigenic mold

Mold is a known allergen and asthma trigger

Maine has one of the highest childhood and adult asthma rates in the Northeast



©2021

Mold spore growth is limited by moisture alone

Liquid water needed to initiate growth
50°-80° F preferred (ACGIH)





©2021

Mold Remediation

USEPA suggests...
- Containment if affected area is greater than 10sf
- Personal protective equipment
- Professional judgment

Common sense suggests...
- *Hiring a licensed remediator for large areas*

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If things get wet during construction...
Clean water damage

Remove very wet materials ASAP

Dry quickly (easier in winter, harder in summer)

Ventilate and dry all cavities

Monitor drying



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Crawlspace Guidance

Keep water out

Drain perimeter to keep out surface and ground water

Use a vapor barrier to prevent water vapor entry from the soil

Anticipate plumbing leaks

Courtesy Camroden Associates

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Crawlspace Guidance

If crawlspace is dry - seal vents R408.3

In cold climates (Maine) insulate the crawlspace walls (typically inside) IECC402.2.9

Exhaust air from beneath polyethylene groundcover to prevent entry of soil air laden with radon and other stuff, (or insulate floor and pour mud slab and keep wood above dew point.)

Courtesy Camroden Associates

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Active moisture control in a sand floor crawl space *1465 6.1.3.3*



Mud Slab with VDR under it preferred in new construction

Better Solution?

Don't build a crawlspace!

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You can have a very dry basement with excellent drainage and still have a moisture and mold problem... Why?



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The average year round earth temp in Maine: "Cold"

IRC N1102



Courtesy Building Science Corporation

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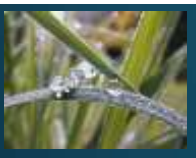

Dew Point

The temperature at which water vapor condenses into liquid water

Dew point temperature is easily calculated knowing relative humidity and surface temperature

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Relative humidity is the ratio of the current absolute humidity to the highest possible absolute humidity

Relative Humidity

A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more

Example dew points

How about a spring day of 77°F and 80% RH?
Dew point for that air is 70°F
Uninsulated basement wall, or poorly insulated basement wall, is significantly colder than 70°F

How about a summer day at 87°F & 60% RH?
Dewpoint is still around 70°F

Summer ventilation air wets the basement!!

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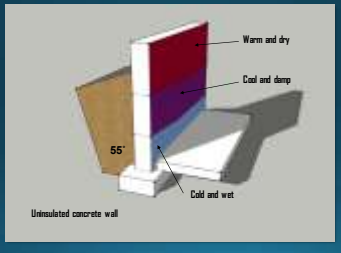
Temperature gradient
Summer conditions



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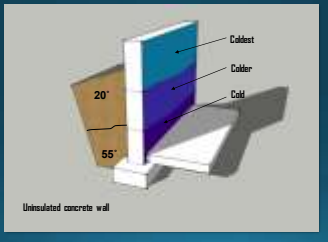
Temperature gradient
Winter conditions



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Summer Solution
dry air

Air humidity control
Monitor with hygrometers (60%RH or less)

Ventilate basement only on days with low outside RH *Requires owner involvement*

Dehumidify with a drain in place, eliminating batch system

Courtesy Camroden Associates

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Less serious moisture problem?
Lots of hot water use?
Use a heat pump water heater.



Courtesy Vaughn



Courtesy GE



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Air Flow Management

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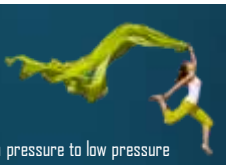
The Rules of Air Movement



Air always moves from high pressure to low pressure

Drivers include:
- Stack effect (hot air rises)
  - Important long-term
- Fans create high and low pressures
- Wind Effect
  - Can overpower both in the short term

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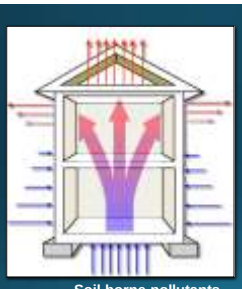

Stack effect draws pollutants into building

Courtesy Spruce Environmental Tech

Soil borne pollutants

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Health and Radon

Air Flow Management



Carcinogenic radioactive gas common in Maine soil and water

2nd leading cause of lung cancer

No predetermination possible

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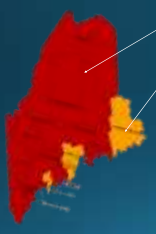
Radon in Maine



High radon potential
Likely 4 pci and above

Moderate radon potential
Likely 2-4 pci

The Maine Radon Section recommends that ALL homes be tested for radon Mitigation recommended if 4.0 or higher, and should be considered if between 2-4.

www.maineradiationcontrol.org for more information

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ASTM E-1465-08

Accommodations for active or passive system in all new homes *1465 1.1*

All new homes tested prior to occupancy by independent registered tester *1465 6.10.5*

All failed homes mitigated by registered mitigator

RRNC *(Radon resistant new construction)*

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1465 requires soil depressurization

Sub-slab installation of gas permeable layer	*Groundwater management (Bulkwater)*
Sub-slab installation of impermeable membrane	*Vapor diffusion retarder (Vapor control)*
Well sealed floor penetrations, cracks	*Radon Control (New concept)*
Alternate radon pathway	

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Override stack effect and redirect soil borne pollutants

Courtesy Spruce Environmental Tech

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Impermeable membrane

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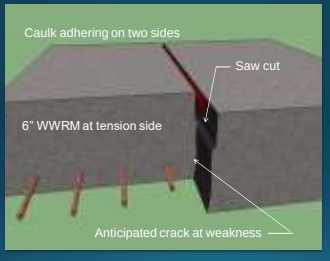

Creating manageable cracks

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Zip Strip

Use in lieu
of cutting
in the presence
of inflor tubing

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Sealing cracks



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Typical Passive Radon Mitigation System

1465 1.1.2

Pipe runs should be as straight as possible
Avoid 90 bends and horizontal runs

Driven by the "stack effect"
Routed within the thermal envelope *1465 6.5.5.2*

Provides radon reduction up to 50%

Can be easily converted to active system

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Documentation Package

6.12.4

Delivered to Owners or left in dust proof package near electrical panel...

Test results
System description
Installer's name and contact information
Fan information
Monitor operation

Principles of system operation
Actions
State radon agency information

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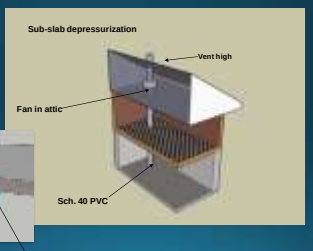
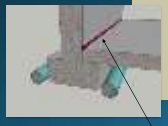
Radon mitigation

1465 1.1.1

Test for radon prior to renovation or finishing

Mitigate prior to renovation if test results are high





Don't forget! It can't be done after the walls are insulated

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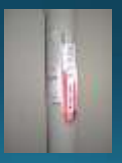
Typical Equipment

In line fan



Courtesy Spruce Environmental Tech

ASTM E 1465 governs placement, support, maintenance
Monitors, labeling required



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If Radon Activation Needed

Check valve prevents air leakage into gas permeable layer ***1465 6.4.4.2***

Must be accessible ***1465 6.4.4.1***





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Radon pipe taken out the side of the sump pit



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Radon Solutions

Radon resistant construction minimizes radon entry and increases success rate of sub-slab depressurization

Radiation Control Program

www.maineradiationcontrol.org

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Thank you, program sponsors...

Northeast Laboratory Services
TURNER GROUP
RenewAire
TC Hafford Basement Systems
MITSUBISHI ELECTRIC
Fresh Air
PERFORMANCE BUILDING SUPPLY
DUPONT

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Upcoming at 4:30 today...

Jeff Newman will answer your questions about radon diagnosis and mitigation in new and existing homes