Basements are Changing

- Increasingly used as living space
  - Not a root/coal cellar anymore!
  - High quality space expected - new and retrofit
  - Owner can finish herself
  - Low cost for high density sites (cities)
  - Can now locate laundry, heating, hot water elsewhere
- Modern basements are different – they need different approaches!
- Commercial basements are similar

Basements - Part of the Enclosure

This presentation

- Basement functions
- Basement Performance
  - Problems
  - Causes
- Solutions
- Crawlspace & Slabs next session
Basements

- Below grade enclosure
  - Includes floor slabs,
  - practically need to include transition
  - Separates exterior (soil/air) and interior
- Functions of all parts of the enclosure
  - Support
  - Control
  - Finish (usually)

Building Enclosure Functions

- Support
  - Structure: wind, gravity, earthquake
  - Below grade – Soil pressure, hydrostatic?
- Control
  - Heat (less extreme than above grade)
  - Air (less air pressure, but it stinks, Radon?)
  - Moisture (vapor, free and bound liquid)
- Finish – usually, but optional
- Distribute (sometimes)

Moisture: Old ideas

- CBD#161 - 1974
- Drainage layer
- Moisture barrier
- Exterior insulation
- Air barrier

Control: Moisture

- Moisture causes most failures
  - Mold (musty basement smell)
  - Decay (especially rim joist)
  - Staining /Paint peeling
  - Floods and leaks, eventually causing the above
  - Salt damage to masonry – old basements
- Where does moisture come from?
  - 1. Exterior
  - 2. Built in
  - 3. Interior

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Appendix V
1. **Controlling Exterior Moisture Sources**

- Same approach as above-grade rain control
  - **Deflection**
    - Overhangs, slopes, gutters
  - **Drainage/Exclusion/Storage**
    - Three strategies for the enclosure
  - **Drying**
    - Remove built-in incidental moisture

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**Surface Drainage**

- **First step**
  - Common problem
- **Overhang**
- **Gutters**
- **Downspouts**
- **Sloped grade**
- **Perimeter drain**
Solution

Problem

Basement Enclosure Strategies

- Classification of Groundwater control
  - 1. Drained
    - Needs capillary break and gap/drain space
  - 2. Perfect Barrier ("waterproofing")
    - One layer of perfect water resistance
    - Beware hydrostatic forces
  - 3. Storage (mass)
    - Safe storage capacity and drying
    - Don't use vapor barriers, do insulate (carefully)
Basement Ground Water Control

Wall System

- Joints
- Elements

Imperfect Barrier
- Mass or Storage Types
  - Less mass and lower permeability
  - More mass and more permeability
- Cavity
- No Cavity
- Face Sealed
- Concealed Barrier

Perfect Barrier
- Drained or Screened Types

Screened(1) Below-Grade Enclosure Wall System

Drained type:
- drainage system with drainage plane, and
- capillary break

Above Grade Level
- A. Screen (similar to cladding—shed and screen surface moisture—rain)
- B. Drainage—crushed stone

Below Grade Level
- C. Drainage plane and Capillary break
- D. Interface with undisturbed below grade environment
- E. Concrete or concrete masonry
- F. Insulation (int.
  - option)
- G. Interior finish

Screened(2) Below-Grade Enclosure Wall System

Drained type:
- drainage system with drainage layer & plane,
- capillary break

Above Grade Level
- A. Screen—optional (similar to cladding—shed and screen liquid moisture—rain and groundwater)

Below Grade Level
- B. Backfill—not necessarily free draining

C. Drainage plane and Capillary break
- D. Interface with undisturbed below-grade environment
- E. Concrete or concrete masonry
- F. Insulation (int.
  - option)
- G. Interior finish

Screened(3) Below-Grade Enclosure Wall System

Drained type:
- drainage system with drainage plane, and
- capillary break

Above Grade Level
- A. Screen—optional (similar to cladding—shed and screen liquid moisture—rain and groundwater)

Below Grade Level
- B. Backfill—not necessarily free draining

C. Drainage plane and Capillary break
- D. Interface with undisturbed below grade environment
- E. Concrete or concrete masonry
- F. Insulation (int.
  - option)
- G. Interior finish

Drain can be gutter or new drain tile

Collection and Exit Drain

Interface with undisturbed below-grade environment

Non-soil drainage layer

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Appendix V
Barrier (1) Below-Grade Enclosure Wall System

Perfect barrier:
- drainage system can be used to reduce hydrostatic pressure
- waterproofing layer resists significant head of water

Above Grade Level
- A. Screen – optional
  (similar to cladding—shed and screen surface moisture-rain)
- B. Drainage (opt) – crushed stone

Below Grade Level
- A. Positive side Waterproofing
- B. Concrete or masonry
- C. Insulation—heat flow control (int. option)
- D. Interior finish

Must use waterproofing below water table!
Slab? Connection?

Collector and Removal Drain

Lowers water table, reduces hydrostatic pressure

Backfill – not necessarily free draining

Barrier (2) Below-Grade Enclosure Wall System

Perfect barrier:
- drainage system to reduce hydrostatic pressure
- waterproofing

Above Grade Level
- A. Screen – optional
  (similar to cladding—shed and screen surface moisture-rain)
- B. Concrete or concrete masonry
- C. Insulation—heat flow retarder (int. option)
- D. Interior finish

D. Interior finish

Collector and Exit Drain

No Drainage – hydrostatic pressure developed

Storage (1) Below-Grade Enclosure Wall System

Limited ability to resist moisture loads

Above Grade Level
- A. Screen – optional
  (similar to cladding—shed and screen surface moisture-rain)
- B. Drainage (opt) – crushed stone

Below Grade Level
- A. Rubble or concrete masonry (storage)
- B. Usually no insulation to allow drying
- C. Usually no interior finish (limewash)

Interface with undisturbed below grade environment

Collector and Removal Drain

Limited ability to resist moisture loads

Storage (mass) system:
- usually no intentional drainage
- often no capillary break

Damproofing
- Capillary break = drainage plane, but needs gap
- vapour barrier?
- NOT waterproofing

Waterproofing resists standing head of water

Appendix V
Air gap membranes aka Dimple Sheets

- provide drainage gap
- act as vapor barrier

Glassfiber Drainage Gap

(contained in glassfiber material)

Rockwool Drainage Gap

(contained in the rockwool material)

Controlling ground/rain water

- Deflection: Roof and Surface Drainage
- Classification of Groundwater control
  - 1. Drained
    - Needs capillary break & gap/drain space
  - 2. Perfect Barrier
    - One layer of perfect water resistance
    - Beware hydrostatic forces
  - 3. Storage (mass)
    - Safe storage capacity and drying
    - Don't use vapor barriers, do insulate (carefully)
- Drying to Inside and Perimeter Drains

Review: Exterior Moisture
2. Built-in Moisture

1. Built-in Moisture (from water in concrete, mortar, wood, etc.)
2. Construction moisture accumulated during construction (ice, snow, rain, etc.)

- Minimize by:
  - Delay finishing internally
  - Reduce water in concrete

1. & 2.

3. Interior Moisture Sources

2. Localized Flooding

1. Water Vapor in contact with cold surfaces: air movement, and diffusion
2. Localized Flooding (abnormal - Water & Vapor)

Vapor failure – not ground water

1. Control interior vapor levels by:
   - winter ventilation
   - summer dehumidification
2. Avoid contact with cold surfaces
   - keep surfaces warm
   - stop water vapor moving
3. Control flooding
   - floor drains
   - disaster pans at appliances

Solutions

Initial Drying

- Soil cold for first yr
- Excavation collects water
- Concrete is wet
  - to 1 gal/ft²
  - 25-50 liters/m²
- Cannot dry to wet exterior
- Solutions = dry in
  - No low perm interior
  - Semi-permeable insulation
  - Smart vapor barrier

Finished Basement

- Drying continues to the interior
- Drying to the exterior
Managing Air and vapor

• Need to solve
  – Surface condensation
    • Sol’n: Keep surface warm & air dry
  – Interstitial condensation
    • Control air/vapor flow to cold surfaces & dry air
  – Solar driven summer condensation
    • Allow vapor flow in, slow rate of flow

Context: Below-grade Conditions

• Exterior soil is almost always at 100%RH
  – Plus liquid water can press against wall
• Never gets as cold or as hot as above grade
• Significant vertical temperature gradients
  – Top is different than bottom

Typical Soil Temperatures

For 7500 F HDD climate

Note: open field values. No house to add heat

Soil Temperatures
**Waterloo Measured Soil / Air Temperatures**

### Exterior Temperature & Moisture Conditions
- Soil Relative Humidity almost always ~100%
- Liquid water may be present

### Basement Psychrometrics
Since soil is at nearly 100% RH, the vapor drive is almost always inward except at very top (& rim) during winter in humid houses

### Basement Vapor Diffusion
- Water vapor is moving from soil to interior
  - for almost the entire year
  - over all but the top foot of basement
- Hence, should place vapor barrier on outside
- But we put it on the inside!
- Moisture from drying concrete, air leakage, wicking and soil also trapped by interior vapor barriers
Air & Vapor Wetting Sources

• Problems with fibrous insulation & vapor barrier

Diffusion of Construction Moisture
Air Leakage of Interior / Exterior Air
Capillary Wicking of Soil Moisture

Basement Wall Air Movement

• Water vapor moves along with airflow
• If moist air touches a cold surface, condensation occurs
  – Summer and winter problem
• Control?
  – Include an air barrier
  – Avoid air loops
  – Manage pressures

Typical basement ("normal practice")
1. Start dry
2. No leaks
3. No poly
4. Be lucky
Air leakage

Internal Stack Effect & Insulation

- Gaps in batt insulation on both sides
- Wrinkles inevitable

Cold air = heavy

Hot air = light

Inside

Batt

Outside

Air gaps

Common basement problem

Internal Stack Effect

- Gaps in batt insulation on both sides
- Closed circuit
- Energy cost
- Condensation

Cold Weather

Hot air = light

Result: Air Flow

Cold air = heavy

Problems w/ air permeable insulation

Cold Weather

Cold

Condensation

Air permeable insulation

Air leakage

Crack
Solution w/ Insulated Sheathing

- Air permeable insulation
- Air leakage
- Crack

How to insulate/finish basement wall?

- We need to:
  - Control exterior ground water
  - Insulate (energy, comfort and moisture)
  - Control air leakage and diffusion condensation
  - Provide (a little) inward drying
  - Accommodate different conditions over height

- How to do we all this?

Insulation Location Choices

- Builders like to insulate the interior

Internally Insulated Basement  Externally Insulated Basement  Basement Insulated in the Middle  Basement Insulated Both Externally and Internally
Hybrid

- Add layer of:
  - foam or
  - spray foam

To allow inward drying
- about 1 perm

Best?

- No summer thermal lag
- Sub-slab insulation a plus

- Foam only
- Vertical or horizontal furring
Spray foam basement insulation

- Open cell
  - Climate specific
- Closed cell

Materials to use?

- Foam Board: EPS, XPS, PIC
  - Water tolerant
  - Vapour barriers to vapour retarding
- Spray foam
  - Semi-rigid (Icynene) and rigid (Spray polyurethane)
  - Airtight
  - May allow some drainage
  - R values of 4 to 6/inch
  - Vapour semi-permeable (Icynene much more)

Insulated Concrete Forms (ICF)

- If you afford it, use them –
  - Cap break,
  - Insulation,
  - Vapor retarder,
  - Above grade
Inward Solar Drives at Grade

- Wet concrete from rain, grade, built-in
- Sun shines on wall and heats it
- Water evaporates and diffuses in & out
- Can condense inside if cold and impermeable

Inward Diffusion @ grade

1. Temperature and solar heating warms wet material
   - Drying If permeable
   - Wetting If impermeable
2. Vapour drives inward (& out)
3. Vapour dries to inside
   - Condensation on “cold” surfaces

Hot Wet materials

- 30-60 °C
- 90-100% RH
- VERY high vapour pressure
Rim joists

- Scenario
  - Wood generally on exterior
  - 1.5" wood is a vapor barrier
  - Practically difficult to stop air leakage

- Result
  - Condensation on rim joist in cold weather
  - Decay if it can’t dry in or out

- Solutions
  - Insulate on exterior

Basement

- New or retrofit
- Solves slab wetness & cold

Slabs

- Keep warm (comfort & condensation)
- Control wicking and diffusion
- Make softer
- Consider floods
Slabs

Retrofit Slab, drainage and sump before wall insulated

Retrofit

- Repair
  - Wall leaks groundwater
- Retrofit/Reno
  - Risk reduction
- Min 1” XPS
- Energy: 3”+EPS

Summary

- Control surface water by drainage
- Drainage layer on exterior of walls
- Poly interior stop drying and often result in problems
- Painted stud with foam OK
- Care needed at rim joist
- What happens if there is a flood, leak, etc.
Conclusions

• Building in a hole in the ground is hard
• Don’t forget about built-in moisture
  – and remember summer
• Moisture comes in liquid AND vapor
• Insulation and drainage are the best tools, not vapor barriers and waterproofing