Basements are Changing

- Increasingly used as living space
  - Not a root 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, hotwater elsewhere
  - Slabs growing (old people) unlikely to make a major dent
- Modern basements are different – they need different approaches!
Basements – Part of the Enclosure

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

Functions of the building enclosure

- 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)

Support (Structural performance)

- Structural system
  - Does not work based on rational analysis
  - Don’t ask for an engineer’s stamp
- Failure modes
  - Poorly compacted subsoil
  - Top-edge Bracing
    - Raised bungalows
    - Stairwells parallel to wall
Basement Structural System

- Similar for most basements
  - Foundation Wall
  - Floor slab
  - Footing

- Above Grade
- Below Grade

Basement Structural System

- Raised Bungalows
- Stairs

- Above Grade
- Below Grade

Floor slab

Control: Moisture

- Moisture causes most failures (less spectacular)
  - Mold (musty 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?
  - Exterior
  - Interior
  - Built in

- Recent studies – Minn, Chicago, CMHC, IRC
Exterior surface water

Surface Drainage

- First step
  - Common problem
- Overhang
- Eavestrough
- Downspouts
- Sloped grade
- Perimeter drain

Moisture Sources:

- Built into the Assembly
  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

Exterior surface water
- Drainage won’t help here
- Damage recovery

From: Lstiburek 2002
Initial Drying

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

Moisture Sources:

1. Precipitation
2. Rainwater shedding
3. Surface water Run-off
4. Water vapor
5. Sub-surface Moisture
   - Groundwater
   - Vapor

Minimize Rain loads
Provide Good Shedding
Provide Good Drainage
Provide Capillary Breaks

A wet basement
- ground water

Basement in a Bag
- Tolerable north of Arctic Circle
Controlling ground/rain water

- Many different acceptable methods
- Classification of Groundwater control
  - 1. Drained
    - Needs capillary break and 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)

Screened(1) Below-Grade Enclosure Wall System

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

A. Screen (similar to cladding—shed and screen surface moisture-rain)
B. Drainage—draining backfill
C. Drainage plane and capillary break
D. Concrete or concrete masonry
E. Insulation (int. option)
F. Interior finish

Screened(2) Below-Grade Enclosure Wall System

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

A. Screen (optional) (similar to cladding—shades and screen surface moisture-rain)
B. Drainage—crushed stone
C. Drainage plane and capillary break
D. Concrete or concrete masonry
E. Insulation (int. option)
F. Interior finish

Screened(3) Below-Grade Enclosure Wall System

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

A. Screen (optional) (similar to cladding—shades and screen liquid moisture-rain and groundwater)
B. Drainage—crushed stone
C. Drainage plane and capillary break
D. Concrete or concrete masonry
E. Insulation (int. option)
F. Interior finish

Non-soil drainage layer

Collection and Exit Drain

Collection and Removal Drain

Interface with undisturbed below-grade environment
Barrier (1) Below-Grade Enclosure Wall System

Perfect barrier:
- drainage system needed to reduce hydrostatic pressure
- waterproofing layer resists 300-600 mm head of water

A. Positive side waterproofing
B. Concrete or masonry
C. Insulation—heat flow control (int. option)
D. Interior finish

No Drainage – hydrostatic pressure developed

Above Grade Level

A. Screen – optional (similar to cladding—shed and screen surface moisture-rain)

Collector and Removal Drain

Lowers water table, reduces hydrostatic pressure

Interface with undisturbed below grade environment

Barrier (2) Below-Grade Enclosure Wall System

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

A. Negative side waterproofing
B. Concrete or concrete masonry
C. Insulation—heat flow retarder (int. option)
D. Interior finish

No Drainage – hydrostatic pressure developed

Above Grade Level

A. Screen – optional (similar to cladding—shed and screen surface moisture-rain)

Collector and Exit Drain

Interface with undisturbed below grade environment

Storage (1) Below-Grade Enclosure Wall System

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

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

Limited ability to resist moisture loads

Above Grade Level

A. Screen – optional (similar to cladding—shed and screen surface moisture-rain)

Collector and Removal Drain

Dampcourse (opt) – crushed stone

Interface with undisturbed below grade environment

Storage (2) Below-Grade Enclosure Wall System

Collector and Exit Drain

Interface with undisturbed below grade environment

Dampcourse (opt) – crushed stone

Collector and Exit Drain

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

No Drainage – hydrostatic pressure developed

A. Screen – optional (similar to cladding—shed and screen surface moisture-rain)
Dimple Sheets

- Drainage gap
- act as vapor barrier
- So little water = maybe no capillary break needed

Controlling ground/rain water

- 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)

Perimeter Drains

Exterior Moisture
Moisture Sources:

1. Water Vapor
2. Localized Flooding (abnormal - Water & Vapor)
3. Localized Flooding (Abnormal)

Moisture Sources:

from Interior

Control interior vapor levels by:
- winter ventilation
- summer dehumidication

Control flooding:
- floor drains
- disaster pans at appliances

Air and vapor

- Surface condensation
- Interstitial condensation
- Solar driven summer condensation
- Drying retarders
- Psychrometric Chart

Special Exterior 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

Moisture – not ground water

- 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
Measured Soil Temperatures

Note: open field values. No house to add heat.

Waterloo Measured Soil Temperatures

Soil Temperatures at University of Waterloo Weather Station (1999)

Exterior Temperature and Moisture Conditions

Soil Relative Humidity almost always ~100%
- Liquid water may be present
**Psych Chart: Air Vapour Content vs Temperature**

- **Temperature**
- **Saturation**
- **100% RH**
- **75% RH**
- **50% RH**
- **25% RH**

**Below Grade Basement Psychrometrics**

*Since soil is at nearly 100%RH, the vapor drive is almost always inward except at very top during winter in humid houses.*

- **Flow in**
- **Flow out**

**Basement Vapour Movement**

- Vapor moves by Diffusion & Air movement **Diffusion**
- Water vapor moves from more to less
- Common rule:
  - place vapor retarding layers on moist (i.e. high vapor pressure) side to control vapor diffusion **Air Leakage**
- Vapor moves with air flow (high to low pressure)
  - Stop air flow or flow from dry side
Basement Vapour Diffusion

- Water vapor is moving from soil to interior
  - for almost the entire year
  - over all but the top foot of basement
- Hence, place vapor barrier on outside
- But we put it on the inside!
- Moisture moving by diffusion from drying concrete and soil is trapped by interior vapor barriers

Basement Air Movement

- Water vapor moves along with airflow
- If moist air touches a cold surface, condensation occurs
- Control?
  - Include an air barrier
  - Avoid air loops
  - Avoid pressures

Condensation: Cool air contains less vapor

Cool air – increase RH
Heat air – decrease RH
Air leakage

Internal Stack Effect & Insulation

• Gaps in batt insulation on both sides
• Wrinkles inevitable

Hot air = light
Cold air = heavy

Common basement problem

Internal Stack Effect

• Gaps in batt insulation on both sides
• closed circuit
• energy cost
• cold surfaces

Cold air = heavy

Air movement (Stack Effect)

Cold concrete = summer & winter

Hot air = light
Cold air = heavy

Result: Air Flow

Result: Air Flow
Wall w/ only Batt Insulation

Air leakage
Air permeable insulation
Crack

Winter
Cold
Condensation

Wall w/ Insulated Sheathing

Air leakage
Air permeable insulation
Crack

Warmer

Materials to use?

- Foam Board: EPS, XPS, PIC
  - water tolerant
  - vapour barriers to vapour retarders
- Spray foam
  - Semi-rigid (Icynene) and rigid (Spray polyurethane)
  - airtight
  - May allow some drainage
  - R values of 4 to 4.4/inch
  - vapour semi-permeable (Icynene much more)

ICFs

- If you afford it, use them – cap break, insulation, vapor retarder
Better

- Add layer of:
  - foam or
  - spray foam

Best?

- Foam only
- Vertical strapping
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 of cold and impermeable

Inward Diffusion @ grade

1. Temperature and solar heating warms wet material
2. Vapour drives inward (& out)
3. Vapour dries to inside

Wetting
If impermeable

Drying
If permeable

Condensation on “cold” surfaces

Rim joists

- Scenario
  - Wood generally on exterior
  - 38 mm 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 Floors

- Basement floors
  - Part of enclosure
- Concrete alone fine but when you finish…
  - Comfort (cold and hard)
  - Water under finish flooring
  - Water condensing on top (summer)
- Solutions
  - Install finish over small amount of insulation
  - Install vapor barrier

Slabs

Summary

- Tolerable
- Risky
- Be perfect ..& lucky
Summary

- good

- From: Lstiburek 2002
  This is theoretically best, but thermal mass of walls requires good summer humidity control and floor should be insulated

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

Addition

- Repair – Wall leaks groundwater
- Retrofit/Reno – Risk reduction