Water Intrusion

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FORENSIC ENGINEERING & FIRE INVESTIGATION

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DONAN.COM • 800.482.5611

Presenter: Mr. Rob Orwig, P.E.
Senior Forensic Engineer/Heartland Regional Manager

CV Highlights:

- Lots of years of engineering experience
- 2-1/2 years with Donan Engineering

Goals

- Identify the source of water intrusion.
- Understand the effects of short term and long term water intrusion.
- Know how a properly constructed building envelope performs.

Where does the water come from?

- Improper construction
- Lack of preventative maintenance
- Accident
- Storm damage
- Flooding

Roof sources

Deteriorated vent boot. Typically wear out before roof shingles.

No plumbing boot installed.

Roof sources

Improperly installed vent boot. Flashing on upslope should be under roofing. Nails used with sealant covering the heads.

Boot must be compatible with commercial roof type.

Roof sources

Deteriorated mortar – No wash – Movement from freeze-thaw action.

Chimney flashing is improperly installed.

Roof sources

Inset the step flashing but did not grout the flashing in place.

Chimney flashing is improperly installed. Flashing is adhered to the brick face.

Roof sources

Really bad design. A valley for three slopes ends at a transition from brick to siding.

And there is no continuous flashing around the corner.

Roof sources

Modified bitumen roof improperly installed at the roof edge.

Caulk used to seal gaps at poor installation.

Roof sources

Sliding shingles. Improper installation.

Wind damaged shingles

Roof sources

No flashing or drip edge.

Skylights

Roof sources

No cricket behind the chimney.
Improperly fastened shingle.
Improperly flashed.

Fiberglass mat shingles installed over deteriorated organic mat shingles.

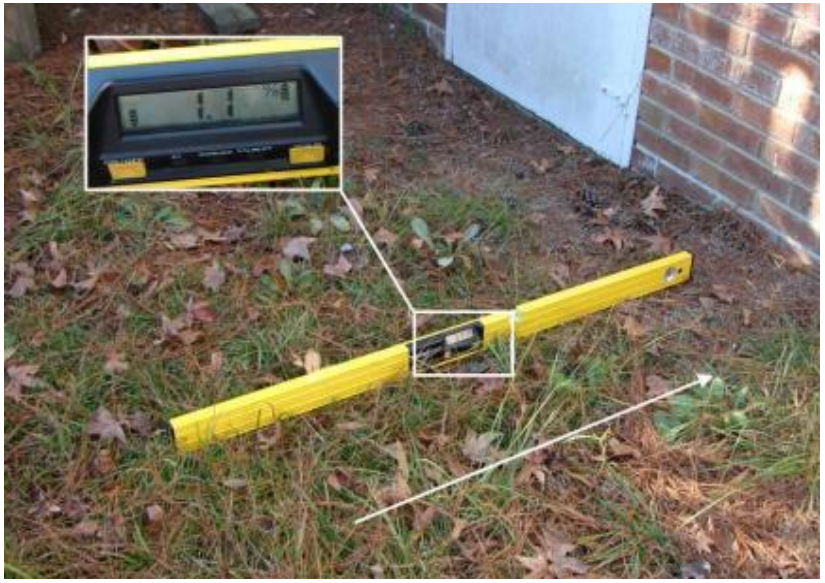
Surface runoff

Downspouts

- Discharge adjacent to the foundation

Ground slopes

- Ground slopes toward the foundation



Surface runoff

Efflorescence on the walls and wet soil because of poor exterior grade.

Water is entering a crawlspace vent and scouring the soil.

Common Problems

- Ground slope
  - In order to prevent water from damaging the foundation system, there should be no reverse or negative grading around the perimeter of the structure. The *International Residential Code (IRC)*, as well as good construction practices, requires a minimum of a 6-inch vertical drop in 10 feet of horizontal length around building foundations. This equates to a 5 percent slope away from the structure.
  - The IRC also states, “Where lot lines, walls, slopes or other physical barriers prohibit 6 inches of fall within 10 feet, drains or swales shall be provided to ensure drainage away from the structure.”

Common Problems

- Site grading
  - The IRC states, “Surface drainage shall be diverted to a storm sewer conveyance or other approved point of collection so as to not create a hazard. Lots shall be graded so as to drain surface water away from foundation walls.”

Common Problems

- Gutters and downspouts
  - Good construction practice dictates that gutters be installed on the roof and that downspouts should discharge at least 10 feet from the foundation. If the downspouts discharge near the foundation, the water run-off from the roof can result in excessive moisture in the soils around the foundation.

New gutters…new problems

Notice the depression in the grade around the downspout.

The concentration of water at the downspout caused the soil to compact.

Problems with the veneer

The weep holes in the brick veneer have been caulked causing elevated moisture content of the interior flooring

The water proof backing to the faux stone is improperly installed and the windows were not properly taped causing damage to the interior walls.

Crawlspace moisture

Subsurface water in a sump pit.

Long term plumbing leak.

Crawlspace moisture

Condensation on the uninsulated ducts and the cooled floor framing adjacent to the ducts.

Floor structure adjacent to the ducts is deteriorated.

Crawlspace moisture

Water entering the crawlspace at the sewer lateral.

Why are roots in the crawlspace? It was very wet.

Crawlspace moisture

A condensation line that is leaking or not extended to the exterior of the house.

Dryer vent not exhausting outside of the crawlspace.

Common Problems

- Subsurface water
  - Moisture in the soil can rise as much as 11 feet above the water table.
  - Depending on ground water tables, soil characteristics, and surface water drainage around the foundation, large amounts of moisture can be introduced into the crawlspace by evaporation from the ground.
  - Water vapor from the crawlspace can also enter walls, move upward within stud spaces, and even reach the roof.

Localized versus General

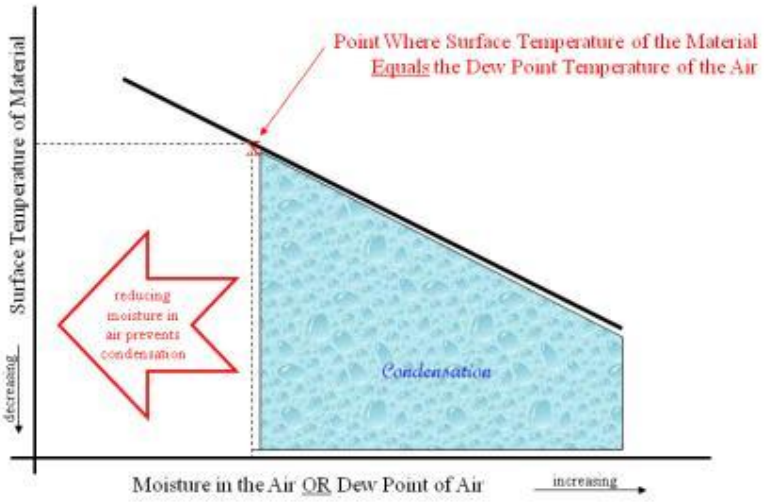
- Localized
  - Damage is concentrated at water source (plumbing).
  - Damage lessens as you move away from the source.
- General
  - Widespread and not focused at a potential water source.
  - More severe in areas of poor ventilation.
  - Can be concentrated around HVAC equipment and duct work.

Common Problems

Condensation

Condensation occurs when moist air contacts a cold surface (surface at or below the dew point of the air). The dew point is the specific temperature for the ambient relative humidity and temperature of the air and can be found on a psychometric chart.

Condensation most commonly occurs in improperly ventilated attics during winter months and in crawlspaces which contain active moisture sources (broken water pipe, leaking HVAC supply duct, dryer vent not routed to exterior, leaking drain pipe, etc.).



How Moisture Condenses on a Cold Surface

Common Problems

Crawlspace Condensation Example

Temperature (° F)	Relative Humidity (%)	Dew Point Temp. (° F)
Summer		
68	70	58
68	80	62
68	90	65
Winter		
50	60	37
50	70	41
50	80	45

Uncommon Problem

- Washout
  - Typically found in conjunction with a negative ground slope.
  - Soil is removed during heavy rains.
  - Unstable footing/ foundation.
  - Very dangerous.

How is the house being conditioned?

- Are they using a kerosene heater to heat the house?
  - The combustion process produces water vapor and if the unit is not properly ventilated can cause elevated moisture levels throughout the house.
- Is the air conditioning unit new? Was the size (tonnage) increased?
  - Short cycling can cause the moisture in the house to not be removed because the air conditioner does not run long enough. This can cause moisture in the air to condense on surfaces in the house.

Unique Problem

- Manufactured home
  - Has a vapor barrier (insulation blanket or under belly) installed below the under-floor framing.
  - Tears or openings in the under belly can introduce moisture and result in condensation.
  - The under belly can act as a dam to trap water from plumbing leaks.

Unique Problem

Manufactured homes typically have a main HVAC trunk line that runs down the center of the unit.

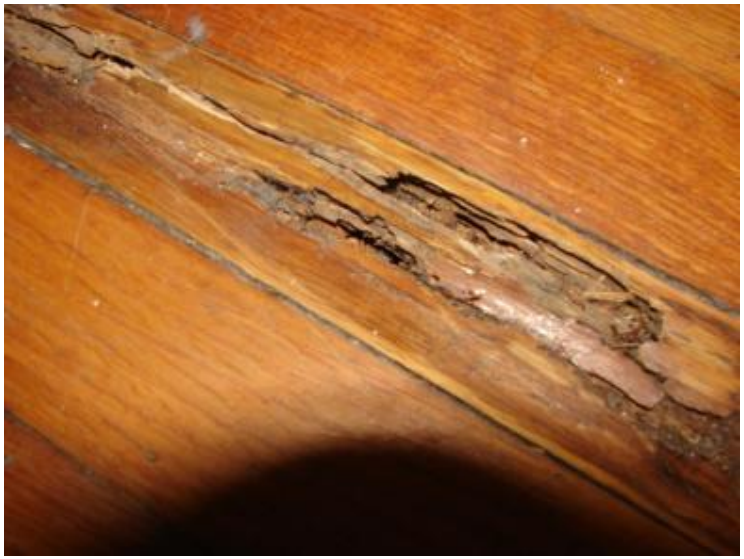
Evidence of crawlspace moisture - Interior

- Wood flooring
  - Buckling and cupping

- Carpet
  - Sagging floors

Evidence of crawlspace moisture - Interior

- Insect damage
  - Termites



- Floor registers
  - Moisture and deterioration

Evidence of crawlspace moisture - Interior

- Elevated moisture
  - Penetrating meter

- Elevated moisture
  - Contact meter

Common Problems

- Moisture in wood flooring
  - Hardwood flooring will expand (i.e. swell) as it picks up moisture.
  - Wood will move only very slightly lengthwise and mostly in the direction of cut or width.
  - The United States Department of Agriculture states that the average moisture content of in-service interior wood flooring should be 8 percent.
  - Cupping results when the top surface dries and shrinks faster than the bottom surface (or the bottom surface absorbs moisture and expands).
  - Buckling occurs when the flooring no longer has room to expand.

Evidence of crawlspace moisture - Exterior

- Soft and wet soil
  - Soil probe

- Wall settlement
  - Cracks in the veneer

Evidence of crawlspace moisture - Exterior

- Ventilation
  - Are there enough vents?
  - Does their location make sense?

- Vents below grade
  - Surface water intrusion
  - Are they blocked by decks, trees, etc.

Common Problems

- IRC requirements for crawlspace ventilation:
  - The minimum net area of ventilation openings shall not be less than 1 square foot for each 150 square feet of under-floor space area.
  - One such ventilating opening shall be within 3 feet (914 mm) of each corner of said building.
  - The total area of ventilation openings may be reduced to 1/1500 of the under-floor area where the ground surface is treated with an approved vapor retarder material and the required openings are placed so as to provide cross-ventilation of the space.
  - Just because there are enough vents doesn't guarantee there will be no moisture problems.

Evidence of crawlspace moisture - Crawlspace

- Ponded water
  - Along the exterior walls

- Foundation walls
  - Water stains and efflorescence

Evidence of crawlspace moisture - Crawlspace

- Deterioration occurs when the sill plate and rim joist are not treated lumber.

Evidence of crawlspace moisture - Crawlspace

- Wet soil
  - Partial vapor barrier or no vapor barrier

- Condensation
  - On decking

Common Problems

- Vapor barriers
  - Vapor barriers have been shown to reduce humidity in crawlspaces by 90 percent.
  - The barrier should be made of 6-mil plastic.
  - The barrier should cover the entire earthen floor and extend above the level of the exterior ground.
  - The barrier should extend 1 foot up all penetrations (such as pipes and piers).
  - All laps should be at least 1 foot wide.
  - The edges of the barrier along walls, penetrations, and laps should be sealed.

Properly sealed vapor barrier

Evidence of crawlspace moisture - Crawlspace

- Condensation
  - On metal surfaces
  - On uninsulated ductwork
  - Leaking ductwork

- Condensation
  - At floor registers
  - Does the insulation continue to the flooring

Evidence of crawlspace moisture - Crawlspace

- Condensation
  - Rusting nails

- Condensation
  - Stains from dripping

Evidence of crawlspace moisture - Crawlspace

- Fungal Growth
  - Rot fungi occurs at 30% moisture content
  - Can a screwdriver penetrate the wood 1/8 inch? Yes, then rot has occurred.

- Fungal growth
  - Surface mold occurs at 18%-20% moisture content

Common Problems

- Fungal growth
  - Mold is a type of fungi.
  - Thousands of different fungi exist in the environment.
  - Fungi feed on organic material.
  - The key to controlling fungal growth is to control the moisture source.
  - Surface molds will grow when the wood moisture content is about 20 percent.
  - Wood moisture content must be about 30 percent for rot fungi to grow.
  - Relative humidity above 60 percent will support fungal growth.
  - Fungal growth can be seasonal.

Evidence of crawlspace moisture - Crawlspace

- Soft wood
  - Penetration with a knife
  - Structurally compromised

- Wood failure
  - Fractures

Evidence of crawlspace moisture - Crawlspace

- Insect damage
  - Tunnels
  - Mud tubes
  - “Saw dust” piles

- HVAC duct work
  - Loose insulation

Evidence of crawlspace moisture - Crawlspace

- Measurements
  - Moisture content in joists and beams

- Measurements
  - Moisture content in floor decking

Evidence of crawlspace moisture - Crawlspace

- Measurements
  - Relative humidity, air temperature, dew point temperature

- Measurements
  - Surface temperatures

Proper Moisture Contents of Building Materials

- Wood in the interior of a structure such as woodwork, flooring furniture, trim, and laminated timbers should have a moisture content between 4% and 13%. Most areas of the United States will be between 6% and 10%.
- Wood at the exterior such as siding, wood trim, framing, sheathing, and laminated timbers should have a moisture content between 7% and 14%. Most of the United States will be between 9% and 14%.

Moisture Control Strategies

- Keep building materials dry
- Keep water out of the building envelope
- Wall design should allow for materials between the exterior veneer and the interior finish to dry.
- Minimize air leakage
- Ventilate indoor air
- Use vapor retarders properly

What is the duration of the leak?

- Can a tool be inserted into the wood easily?
- Is the wood dark and discolored?
- If the wood member is constructed of plies or OSB are the layers delaminated?

OR

- Is the wood firm and difficult to indent with a pointed tool?
- Are there one or two concentric shapes around the leak origin?
- Is there little or no discoloration on the wood?

Equipment for Water Intrusion

- Penetrating moisture meter
- Nonpenetrating moisture meter
- Level
- Hygrometer
- Thermometer
- Psychrometric chart
- Soil probe
- Pointed tool

Site Study

- <u>Proper site study</u>

- Basics
  - Gather background information.
  - Study the general characteristics of the exterior.
  - Study the topography (slope) of the soil around the property.
  - Study the interior.
  - Study the crawlspace.

- Study the physical damage
  - Is the material wet or dry (one exposure event vs. continuous).
  - What is the extent (limit) of the damage.
  - Are water sources above, below, or nearby?
  - Does the damage appear to be long-term (e.g. black wood) or short-term (e.g. light brown wood).

- Investigate
  - Follow where the data takes you.

QUESTIONS???

Hold on…there's more!

Case Study

Insured reported that a kitchen cabinet began leaning one month ago. A contractor found cracked joists in the crawlspace.

What is the cause of damaged floor joists?

Front exterior elevation

No downspout extensions

Ground slopes toward the house

Not enough crawlspace vents

The crawlspace has a total of seven vents. Each vent provides 0.89 square feet of ventilation for a total area of 6.2 square feet. The crawlspace is approximately 1500 square feet. According to the current code, the required ventilation, without a vapor barrier, is 10.0 square feet.

Moisture on the foundation walls and a partial vapor barrier

Water in the sump pump

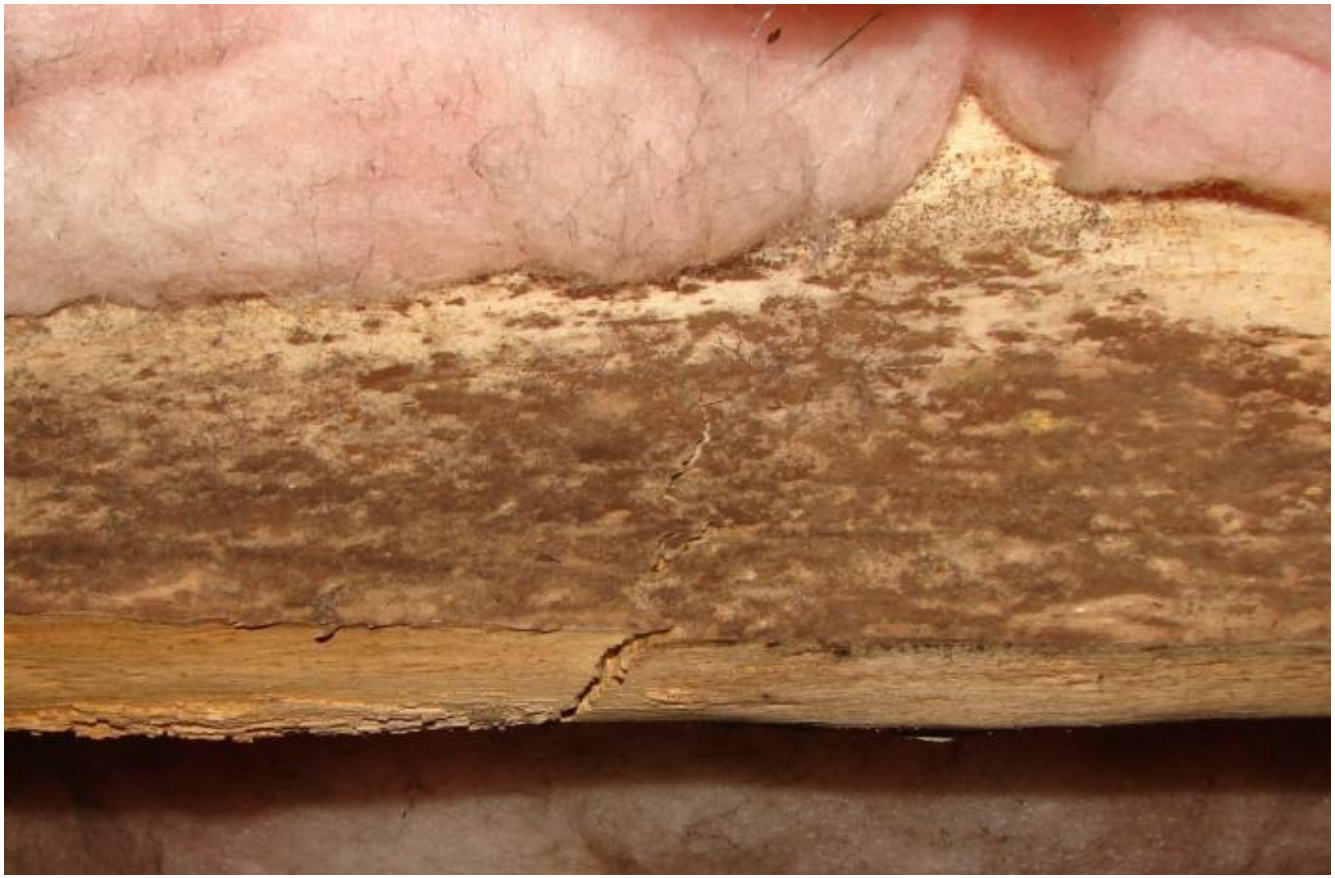
Rust on metal surfaces

Loose duct insulation and rusty metal

Air leak in the air handler unit

Fractured joist with fungal growth

Wood is soft on fractured joist



Maximum moisture content is 19%

Humidity, air temperature, and dew point

Surface temperature of the wood joists

What is going on….
Your thoughts????

CONCLUSIONS:

- The floor joists are fractured because of wood rot.
- The wood rot is the result of condensation on the floor joists.
- The condensation is the result of excessive moisture in the crawlspace.
- The excessive moisture in the crawlspace is the result of moisture evaporating from the soil in the crawlspace.
- The moisture in the soil is the result of inadequate surface water drainage.
- The cause of damage to the floor joists is inadequate surface water drainage.

Comments, questions, past studies, new projects for Donan Engineering, etc.???

Thank you!!