SCIENTIFIC EVALUATION OF EXISTING ROOFING SYSTEMS

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The scientific method is that of comparing two terms: "cause" and "effect." We study cause and predict effect; from effect we can determine cause.

In roof failure analyses we must remember that the roof starts to wear out the moment it's completed. The cause of failure of a 25 year old roof may simply be age, and may be simply deduced. The study of a 5 year old roof, prematurely failed, is much more complex. To get the right answers we must ask the right questions. These questions are derived from our study of effects (defects) noted in the examination of the entire building system. The proper identification of causal factors of premature roof failures is vital if we wish to avoid recurring failure. Simply put, we must identify the problem and the cause of that problem for lasting results.

Plans & Specifications

The identification of causes starts with an examination of the building plans and specifications, if available. Unfortunately, few owners realize the importance of preserving these documents. Our task is to assemble information on how the roof was contrcuted, and not how it was meant to be constructed. Use "as built" information, checking job records, job logs and addenda. (A check of the job log and weather information, for example, may reveal why the east wing has roof blisters, when they reveal that an inch of rain fell on an uncompleted roof.) By gathering all available data, we simplify our study of effect to determine cause.

Our first stop in the plans is the structural drawings which diagram the supporting "skeleton" of our building. Note deck type and placement and the relation of the underlying structure. Note all possible stress points such as change of direction of the deck, different adjoining deck types, etc. A brief sketch on tracing paper of these structural points can be superimposed over roof plans to give us stress locations on the roof.

Mechanical and electrical drawings might yield further information. Note the type of openings and flashing provisions for projections. Is the ceiling space a plenum or duct return? Was conduit laid into the roofing system? You can predict this by previously noting the deck type, especially with wood or precast concrete. The answers are found in these drawings.

Next check the architectural drawings. Start with the floor plan to learn the use of the rooms. If the roof is over a kitchen, steam room, or shower, it will be pertinent when we're on the roof. Check the roof plan for general locations of penetrations and projections. Check the roof details, roof edge, flashing and penetration details. Examine the wall sections, noting spandrel and wall flashings, especially over windows and ledges. Many "roof leaks" are really wall leaks. Check location and type of expansion joints. Superimpose your sketch of the structural stress points over the roof plan and note the expansion joint locations. Prepare a roof sketch on tracing paper for later use.

Now turn to the specifications where we note the roof system components. Were the components suitable for their intended purpose? Are they compatible with each other? Have you noted, from previous investigations, problems with this combination of components? The answers to these questions may be all we need to determine the problem.

Interior

It's hard to convince owners, anxious to get to the roof, that you must start in the interior. We are looking for effects here: stain, wet ceilings, rust, cracks, etc., which can yield clues to the causes. Note room usages and use your senes to estimate relative humidity, temperature and air movements. Each can be important in your final summation of effect and determination of cause.

Plot leak locations on your sketches, noting whether the stain or wet spot is circular or straight line. By noting the type of stain you can predict whether the problem is puncture (circular stain), or a roof split (straight line stain). Measure the leak locations from known points easily identified when you're on the roof. Probably the hardest part of this work is to locate the precise point on the roof directly above the leak in the interior. Use your tape measure.

Interrogate the occupants of the building, particularly those who know the building history. You want to know when it leaked last, (don't chase old leaks already repaired) and these peeple have short memories. When does it leak? Does it leak only in the spring? (Ice backup or condensaion?) Did it leak in the last rain? When was the last rain? (How good is their memory?) How hard did it rain? (Drain backup) Was the wind blowing the rain? (wall leaks) Did it quit leaking shortly after the rain, (flashing leak) or did it drip for days (main roof split or puncture)? How long has it leaked at this location? (How much insulation is damaged?) Try to confirm your answers with more than one occupant. A roof investigator is a detective, and he must listen carefully for clues to determine cause.

One of the most troublesome examinations concerns condensation problems, especially in northern climates. Understand water vapor, vapor pressure, dew point, and resultant condensation effects. Owners often "can't believe" that whole ceilings may fall in, simply from condensation. The author has seen 12" of frost clinging to the underside of the roof deck. When this frost starts to melt it is the equivalent of a 1" rainfall – inside the building.

The temperature at a point in an insulated system can be approximated by the following formula:

$$T_p = T_i - \frac{r}{R}(T_i - T_o) \text{ where}$$

T_p = temperature at the point
T_i = temperature inside
T_o = temperature outside
r = insulative resistance to the point
R = total insulative resistance

Heat Flow Out

If you suspect condensation, apply the formula to determine the temperature at the point (usually the roof deck). Determine the relative humidity and air temperature of the room. Dewpoint charts will give you the dewpoint at different air temperatures. Keep in mind that the building is affected by interior vapor pressures from within, which can be more insidious than external moisture. Don't get caught in the condensation trap!

While you're in the interior get into the attic or plenum area. Look for stains, rust, etc. In these energy-conscious days watch for added attic insulation which may induce condensation. Check the perimeter insulation at the spandrel area. Recall your plan examination of details. Is the spandrel insulation on the **inside** of the spandrel instead of the outside as shown on the plans? Never assume that what you saw in the plans was installed that way! An isolated spandrel can result in thermally induced structural movements.

Exterior

Again, we're looking for effects. Don't start on the roof. We must correlate our examination of the assembled data and verify them. Start at the foundations, looking for cracks and settling. Examine exterior walls for points of water entry. Keep in mind that a narrow (hairline) crack can often suck in more from capillary action than a wide crack where only the water that is blown in, or flows in, is present. Note the color and shading difference in brick or siding materials. Moisture in a wall can create all kinds of effects, from spalling of bricks to subtle color changes, especially in freezing climates. Note the wall condition above the spandrel (the parapet) where unheated from the interior. Check windows and penetrations for cracks, joints, caulking condition and flashing.

Roof

If we have done our previous work well, this part is the easiest. We'll want to walk over the main part of the roof, noting deformities, e.g., blisters, buckles and wrinkles. Our foot pressure can tell us a great deal. What type of insulation? Wet or dry insulation? Deck condition? Structural integrity? We can get indications simply from foot pressure. Note surfacing material and defects. Look for "stress lines." A roof is constantly moving in response to temperature change. The results of this movement can often be seen in the surface of the roof either through ridging, or the phenomenom of "gravel turnover." Gravel surfacing tends to darken on the bottom and bleach out on the top. When a roof moves at a point, the gravel at that point will "roll" or "turnover," creating an almost imperceptible line of color change. Nevertheless, with experience, the lines are readily visible and can point our stress and possible split locations.

Remember a roof will not age uniformly. Some areas are placed under higher weathering stress than others. Examine corners carefully. Is the roof uniform in color? Dark areas indicate water ponding. Watch for leaf and seed debris around roof drain bells and flashings. Elm seeds attached to the drain bell 6" above roof line indicate how effective the drainage system is when heavy rains occur. An inspection during or after a rain can be helpful and every roof investigator should conduct one inspection in a heavy rain. We are seldom on roofs during these ultimate tests of water integrity and we can learn a great deal from this experience. If you are in snow country, examine a roof during a snow storm and note that water (in the form of snow) can move in any direction with great speed and force. You'll gain a better understanding of roofing problems viewing the roof in these extremes.

Flashings

We're looking here for attachment. We want to note stress point pulling, both laterally and longitudinally. Flashings might be pulled from the wall by roof movement, or diagonally deformed by wall movements. Note the nailing pattern, lap treatment and heights, especially in snow areas. Watch for water-filled blisters which can be tested with the fingers. A "gurgling" indicates water behind the flashing. A firm resistance to finger pressure, with no gurgling, indicates an air blister only. Note the surface of the flashing and watch for an air blister only. Note the surface of the flashing and watch for small, 1/8" to 1/4" blisters in the surfacing of the flashing. These blisters are an indication of moisture behind the flashing which is vaporized and punches out from within through the flashing membrane and "pops" the surfacing material. Looking higher on the flashing or wall will often give you the source of the initial moisture entry.

Edge Details

Check the parapet or gravel stop detail to see how it's attached. Look for thermal movement points here, especially with gravel stops. Note the interior and exterior condition of the parapet wall and watch for entry points for moisture into the wall. Check reglets for hairline cracks at the mortar joint. Most metal flashing reglets are installed by bricklayers who do not seal the metal joint. Leaks occurring at 8 or 10 foot spacing along a wall can often be traced directly to reglet laps.

Expansion Joints

Take a cover off the expansion joint and examine the "as built" construction compared to the plan detail. Many expansion joints are constructed by overenthusiastic carpenters and have no freedom of movement. Have air spaces been filled with loose insulation material to prevent condensation? Check the cover joints which are the weak points of the installation. You've noted the type of cover from the specs. Is the cover that what was specified? Check the bellows on integral covers for ultraviolet deterioration, especially on PVC bellows.

Penetrations

Check pitch pockets or boxes. Although not recommended, they are often used as a last resort. Remove the cover from vent pipe flashing. Architects design "frost-proof" vent covers by allowing air up into the pipe chase which only aggravates condensation. The pipe should be sealed at the roof level and the chase packed with soft insulation. Check hoods and clamp rings around pipe projections for sealant at the point of connection.

Mechanical Equipment

Note type and placement. Note curb heights and flashing details. Watch for intakes and hood covers through which snow might blow. In snow areas a good rule is, "What you can see in, snow will blow in." Remember, it's difficult for water to move upward but easy for snow to do so. Many mechanical installations are not watertight. A simple lock seam could be your source for problems. One persistent roof leak was traced to a mushroom ventilator, the top of which had been hammered by a hail storm into a concave top surface. The neoprene washer on the attachment bolt of the concave mushroom cap had deteriorated. The "dish" created would fill with water and drip for days through the bolt hole.

Main Roof Failures

From your interior sketch of leak locations, measure leak points out on the roof surface to pinpoint the exact location on the roof. The source of entry sould be in this approximate location but may not be depending on deck type, vapor barrier, etc., information you obtained in your study of the plans and specs. Look for splitting stress lines. If no split is observed in the surface examination, remove the gravel surfacing to expose the roof felts and check for splitting. Once you note the direction the felts are run, additional clues are available. Almost all roofs will split in the direction in which the felts were run. Thus when you have determined the direction of the felts, the gravel removal paths should start across the felts as the most logical location of the split line.

Exploratory Testing

No roof should be reroofed without an evaluation of the substrate. Take 12 inch x 12 inch cuts down to the deck, especially in suspected locations of roof leaks. Examine the felt membrane as it is removed. Verify the number of felts. Approximate asphalt poundages may be estimated by micrometer or scale. Remove the insulation and note its condition and type. The salvaging of existing insulation may be possible depending on type and the extent of damaged material present in the existing roof. Be aware that certain so-called "inorganic" insulative materials contain organic matter and moisture deterioration may result. Additional substrate examination may be required either through additional test cuts, bracketing the roof into segments, or through non-destructive testing. Wet- or moisture-deteriorated insulations must be removed prior to reroofing. If leakage is extensive over concrete decks, grouted precast, or decks with vapor barriers, complete removal of insulation might be required.

Leak Simulation

If you can't determine where the leakage is occurring, simulate rain conditions in the area with a garden hose. Start at the low points of the area. Flood the roof with water, allowing sufficient time for water entry at each stage. The time element for leaks to occur can often be obtained in your interrogation of the occupants. After sufficient time, move the water stream up onto each of the suspected entry points. Keep the water stream pointing down to simulate rain. Do not force water in at odd angles that rain could not duplicate. Leak simulation is an important tool when all else fails.

Summation of Causes

You've studied all the effects. Now it's time to make judgments about possible causes. Is the roof simply aged, or is failure premature? If blisters are the problem, could they be occurring due to high relative humidity conditions below and the lack of a vapor barrier? Was the substrate wet to begin with? Were coated felts used in the construction of the roof? Do the blisters occur between felt plies or at the membrane-insulation interface? If splits are the problem, is the probable cause strucutral movement and lack of expansion/contraction provisions? What are the spans involved? Is the attachment sufficient? Is the membrane strong in tension? Are flashing details or installation the source of leakage? You're putting it all together now, comparing probable cause back to your effect list, eliminating the improbable. You have nailed down the causes.

Preparation of Specifications & Details

From the cause/effect study we can now prepare specs and details to correct defects. Our goal is to upgrade the original design without disrupting building operations. Adequate drainage may be our first consideration. Do we add additional drainage through scuppers or interior drains? Should we redesign for slope? Does the roof layout permit us to move water from one area to another? We must consider additional weights imposed upon the structure. We will certainly consider upgrading the roof system's insulating quality. How much additional insulation is required? What is the payback for these additional costs? Life cycle costing is a most important consideration at this point. Perhaps only a repair of the existing roof is required.

As we consider the various aspects, remember that each has an affect on the others. Upgrading of insulating quality may require upgrading of the roof membrane. Additional insulation thickness, or slope design, will require wood blocking and detail changes. We must consider all these factors in making our decisions.

SUMMARY

1. Define the problem.
2. Examine plans and specifications to determine existing system suitability and compatibility. Use "as-built" information.
3. Examine the interior looking for effects.
4. Prepare a plot of the problems discovered in the interior.
5. Examine entire exterior from foundations to roof looking for causes.
6. Prepare an exterior plot of possible causes, correlating it with the interior plot of effects.
7. Take exploratory cuts. Verify construction "as built."
8. Determine the most probable causal factors from your study of effects.
9. Prepare specs and details to upgrade the original design and correct defects.
10. Correlate each of the changes required with the total effect on the other components and building performance.