Second Chances: The New Roof is Still Leaking?

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Building envelope upgrades and repairs are commonly done reactively, such as in response to apparent issues. Performing repairs and/or system replacements in reaction to building symptoms without properly diagnosing the issues can lead to significant costs to the owner. This article examines a proposed roof replacement intended to address recurring moisture problems in a commercial building in the Chicago-area. Following an inspection and further analysis, alternate remediation was ultimately prescribed to address the actual source.

Patterns of frost-melt on roof surface.

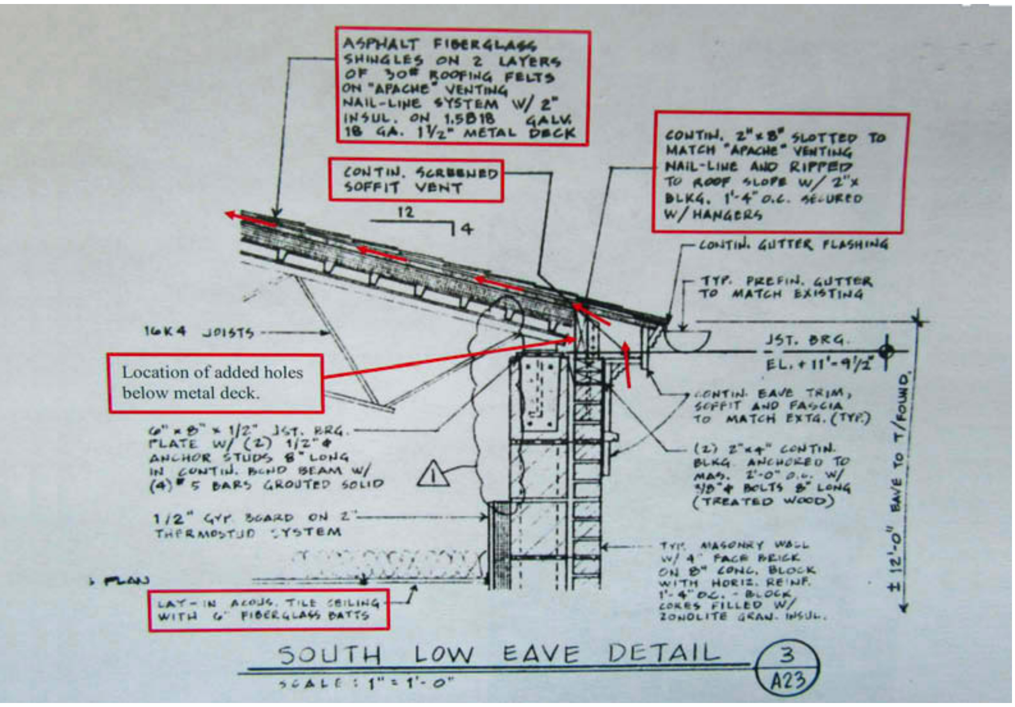
Inspection

The building in question is a 1996 addition to a structure originally constructed in 1900. The addition has load-bearing masonry walls supporting a steel-trussed roof, with open web bar joists and metal decking. The roof included vented nail-board sheathing (OSB over 2x4 spacers atop 2-inch polyisocyanurate rigid insulation) over the metal deck with two layers of #30 felt and asphalt shingles. This roof was vented through slotted soffits up the sheathing to the ridge. Wall insulation was not continuous to the roof and stopped at batt insulation located at the ceiling.

The asphalt shingle roofing, which was only 16 years old, had been replaced in 2012, about two years prior to our inspection. The replacement work included new flashing, underlayment, ice-and-water shield, and roof-vent modifications to supplement original. The repairs retained the ventilated panels and a continuous ridge vent. The contractor also added vents along the bottom of the soffit and drilled holes through blocking along the top of the wall to ventilate the attic beneath the metal decking. Photos from the 2012 construction also revealed gaps between the panels which remained.

Moisture issues persisted after the roof replacement work during colder months and were attributed to ice-dam problems by previous consultants. Contemplating yet another repair project, the owner asked us to evaluate the roof system. We visually examined the roof from the exterior and interior and reviewed available documents. Temperature and relative humidity values were also documented.

Our inspection revealed that the new shingles were in good condition. However, melted frost observed on the roof surface demonstrated active heat loss through the building envelope, telegraphing joints between the underlying sheathing panels. The owner mentioned that ice accumulated near roof edges after some snow events. Ice accumulation within these areas was present during our visit. The observed heat loss and ice accumulation is consistent with ice damming.



Original roof with theoretical venting illustrated by red arrows.

Water staining was visible on ceiling tiles and interior wall surfaces. The owner stated that numerous ceiling tiles were replaced after the previous year's snows and were again damaged over the recent season when snow melted away. Damaged tiles and water stains did not correspond with locations of ice accumulation, indicating an alternate moisture source(s) likely existed. From the attic, numerous gaps and voids in the batt insulation were observed and no continuous vapor barrier was provided at the ceiling. Insulated ductwork also ran through the attic that fed into the space below. The attic temperatures were warm near the middle of the roof and cooler above storage areas near the roof edge. See Table below for temperature and relative humidity values taken during the inspection.

Findings

The 1996 design intended soffit-to-ridge venting of the roof above the metal deck, between the insulation and sheathing. This system ideally allows air to escape from beneath the shingles (during hot exterior temperatures) to prevent overheating the shingles. However, the air-flow through this cavity is not adequate to maintain cool temperatures (avoiding snow-melt) during colder months. The efficacy of the insulation was compromised, being separated between the ceiling and roof levels. In addition, the presence of ductwork (even insulated) separated from interior conditioned spaces with ceiling insulation, is not advisable, as warm air escaping ductwork joints can add unwanted heat and humidity into this space. These conditions lead to condensation and ice dam formation at the building.

Location	Temperature Dry Bulb (Degrees F)	Relative Humidity (%)	Dew-point Temperature (Degrees F)
Assembly area	69.0	25.0	31.8
Bathrooms	66.5	27.7	31.6
Storage	68.4	26.7	32.2
South Storage	66.6	25.5	30.0
Attic (central)	68.4	28.8	34.1
Attic (above storage)	64.0	32.0	33.6
Exterior Reference	26.6	93.0	24.8

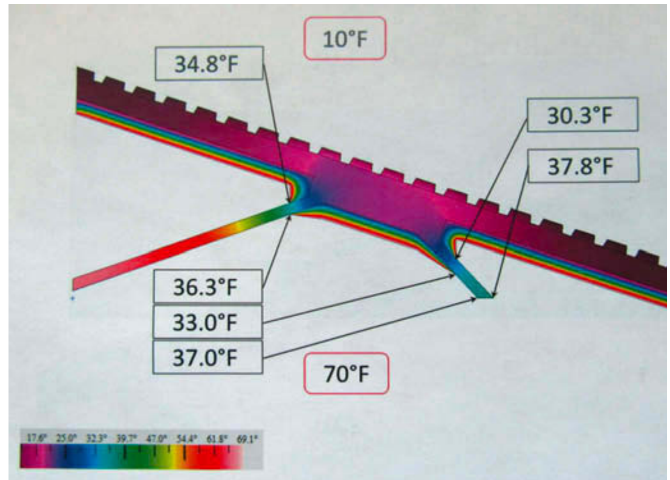
Condensation: Gaps between the sheathing panels and corresponding rigid insulation compromised the continuous layer of insulation and allowed exterior air to contact the metal deck. In addition, the segmental layer of batt insulation, separating the attic from conditioned spaces below, lacks a continuous air/vapor barrier and allows conditioned air from below to enter the attic. Warm air was also free to enter the attic through joints in the insulated ductwork above the ceiling. With colder exterior temperatures, the deck was cooled below the dew-point temperature of the interior air. As deck temperatures dip below this dew point, condensation occurs. When deck temperatures are below freezing, frost can built-up in areas where interior air flow is more stagnant and later melt during warmer periods. This melting resulted in observed water stains on interior finishes.

Ice Damming: Where interior air circulation within the attic was greater (near ducts), conditioned air could warm the roof deck, melting snow at upper roof portions which would then refreeze further down the roof. Adding holes in the soffit and into the attic was not consistent with the intended ventilation path, and allowed air to bypass the already un-insulated wall. This cooled the roof edges in colder weather exacerbating ice dam formation. Accumulated ice on lower roof portions can trap snow melt, allowing it to collect/pond up the roof, beneath the shingles and underlayment, and into the building.

Repairs

To prevent condensation and ice dams, a continuous layer of insulation and air and vapor barriers along the roof was recommended. The warm air seepage within the attic exacerbated these conditions, thus the ceiling insulation was removed and the attic was treated as a conditioned space. This included insulating and integrating the upper wall portions with the roof to create a continuous air and vapor barrier. Two options

Lose-fitting and displaced insulation in attic.



THERM model with temperature gradient across insulated truss.

were presented: (A) Install insulation beneath the metal deck and salvage the recently installed roofing, or (B) Install a new system of insulation, air and vapor barriers on the exterior, and replace the roofing. Since the work could be limited to the addition, Option A was selected so that the two-year old roof, which matched the remaining building, could be retained.

Option A utilized a closed-cell spray polyurethane foam (SPF) insulation on the interior face of the metal decking. An SPF product with an integral fire retardant that satisfied the ASTM E84 and UL 1715 testing criteria was used to satisfy IBC requirements for ignition and thermal barriers. This insulation was installed in two layers to encase the truss top chords and control potential thermal bridges. Using THERM software, two-dimensional computer models of the assembly were evaluated to identify temperature gradients and condensation potential while assessing insulation coverage. In addition, component additive methods were used in conjunction with THERM to demonstrate that the resulting R value satisfied the IECC requirements for the assembly. Available fire-test data for the SPF did not include configurations with continuous SPF installed with horizontal-to-vertical transitions. Consequently, an alternate materials (foil-faced mineral wool) insulation were used at wall transitions.

In summary, this building demonstrates how water damage initially attributed to moisture infiltration proved to be primarily from internal sources. A more complete understanding of the building systems is required when assessing issues and developing repair approaches. Reviewing building systems and repair needs should include seasonal monitoring. Moisture sources are not only from the exterior, and evaluating the efficacy of envelope control layers should be included with these assessments.

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SPF Installation partially completed.

Ceiling reinstallation without the fiberglass insulation.