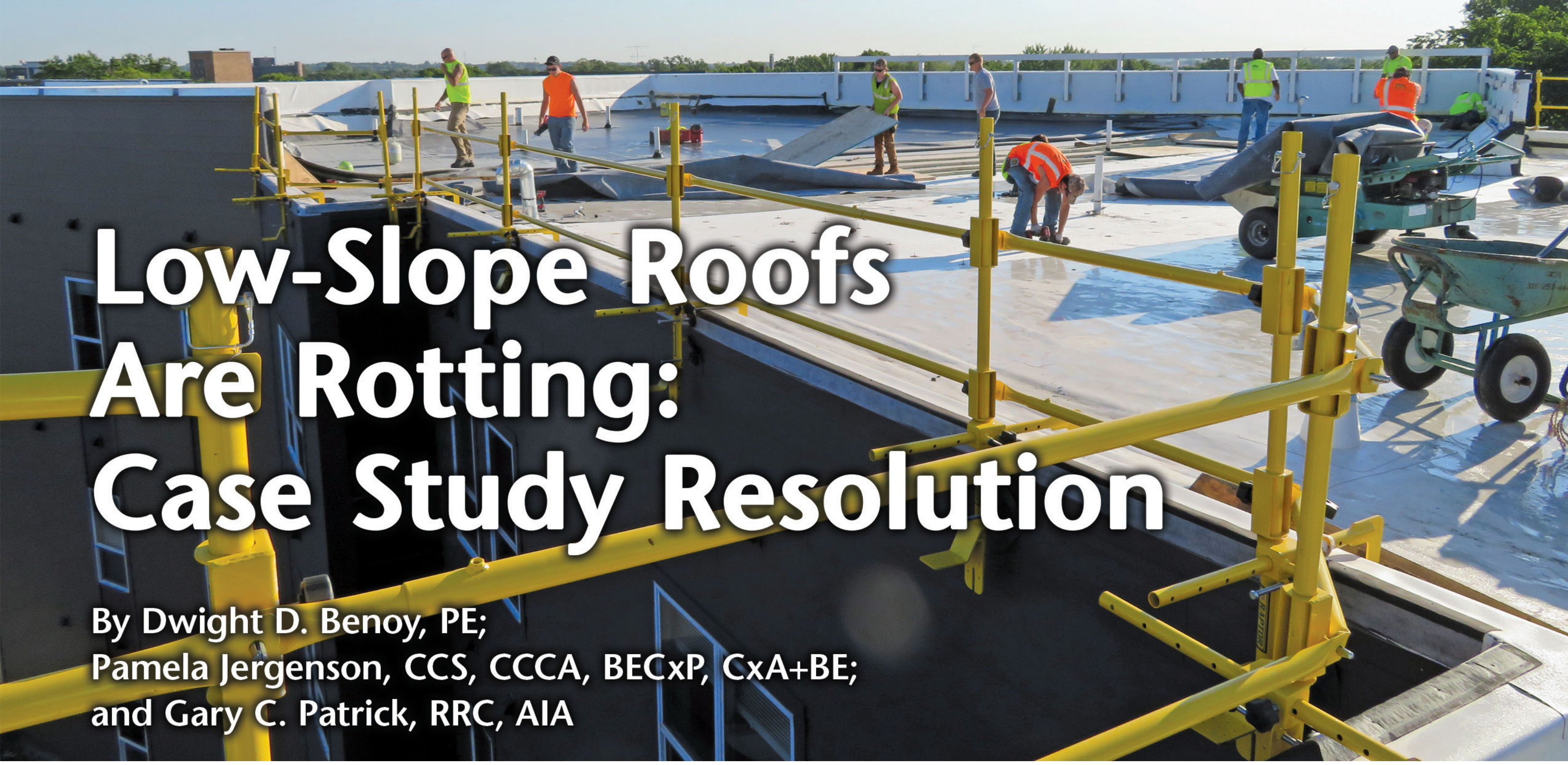

Low-Slope Roofs Are Rotting: Case Study Resolution

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"Low-Slope Roofs Are Rotting" was an article published in July 2016 in *Interface* journal about three buildings in a northern United States climate experiencing premature deterioration of their roofs due to moisture condensation within the roof assembly. The full paper can be found on IIBEC's website here: https://iibec.org/wp-content/uploads/2016-07-benoy-jergenson.pdf. The following article is a description of the challenges faced to design and construct the repair at one of the buildings that was the basis for the original article.

The buildings that were repaired were actually two four-story, wood-framed buildings called Coborn Plaza Apartments in St. Cloud, MN. Each building has retail space on the first floor with student housing for nearby Minnesota State University on the upper three floors. J.A. Wedum Foundation is the owner of the complex. Granite City Roofing, Inc. of St. Cloud was the reroofing contractor. Inspec was the architectural/engineering firm. This reroofing project proved to be one of the most challenging in Inspec's 45-year history from a design and constructability standpoint.

BACKGROUND

The three buildings from the original article had similar nonventilated roof assemblies comprised—from interior to exterior—of gypsum board ceiling, vapor/air barrier (polyethylene sheeting), wood structural trusses, blown-in fiberglass insulation to fill the truss cavity, oriented strand board (OSB) structural roof decks, rigid board insulation, and a roof membrane. Coborn Plaza differed from the other two buildings in that it had a tapered polystyrene board insulation system over the structural deck and a plate-bonded thermoplastic olefin (TPO) single-ply roof membrane. All three buildings are multistory wood-framed structures housing retail on the first floor with apartments on the upper floors.

The essence of the problem in all three buildings was that moisture-laden air migrated into the truss space and condensed in the upper reaches of the roof assembly. This resulted in excessive moisture buildup, mold, and rot of the OSB structural roof deck and structural trusses in a substantial portion of the roof area. Discontinuities in the vapor/air barrier (polyethylene sheeting), which allowed moisture to migrate into the roof assembly, occurred at interior partition and demising walls and at penetrations through the ceiling, such as sprinkler heads and electrical boxes for light fixtures.

The problem was discovered approximately five years after the buildings were constructed when tenants of the top-floor apartments on the Coborn Plaza Building observed mold on the gypsum ceiling and complained of musty odors. A mold remediation project was undertaken that included removing the gypsum ceiling, vapor/air barrier, and blown-in insulation. It was discovered that the exhaust ducts for the bathroom and dryer vents were poorly installed in some of the units. These ducts ran through the structural trusses and exited the exterior walls through the rim area. This duct layout also bypassed the ceiling vapor/air barrier, contributing excessive moisture to the truss space.

The remediation work included cleaning and sealing these ducts, which were thought at the time to be the only cause of the problem. The moldy framing and structural roof deck were cleaned and painted with an antimicrobial paint. Some of the rotted deck was reinforced from below with additional OSB sheathing and framing.

After the remediation project, inspection openings from the interior were made to verify whether the remediation was effective. It was discovered that excessive moisture was present, having redeveloped in a matter of months following the remediation. Another source for the moisture was investigated. Hygrothermal modeling was conducted as part of the investigation to provide information to confirm or deny the theory that the vapor/air barrier was inadequate. Results indicated a propensity for moisture to accumulate.

DESIGNING THE REPAIRS

Due to the damages already experienced and the potential for more to develop, it was determined that Coborn Plaza needed to have a complete roof replacement. The

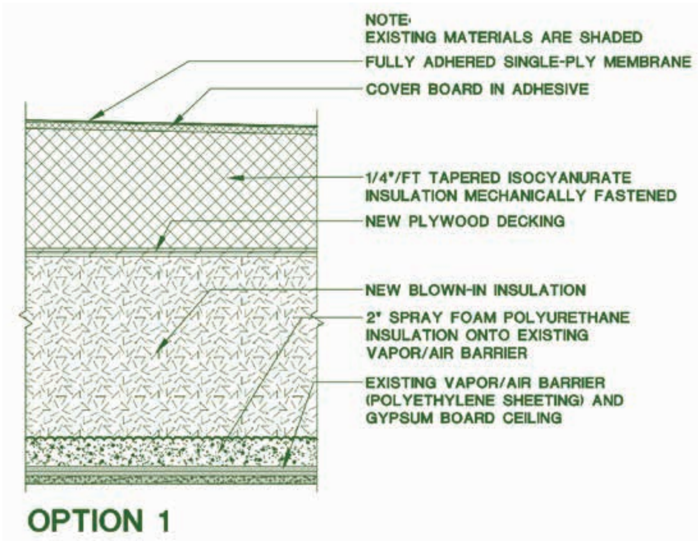

Figure 1

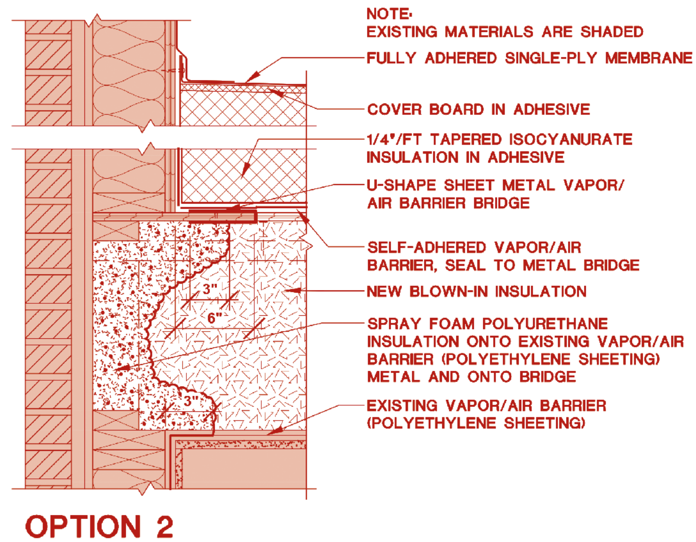

Figure 2

primary challenge was to develop a complete vapor/air barrier below the dew point temperature that also tied into the wall vapor/air barrier to envelop the building.

Repair options were developed, with hygrothermal modeling conducted for each. The owner required all work to be conducted from above the ceiling to minimize disruption to the tenants. The options included:

Option 1

This option (*Figure 1*) was intended to create a complete vapor/air barrier by installing spray foam over the existing polyethylene sheeting and bottom chord of the truss. This required the removal of the existing roof system down to the structural roof deck and removal of a significant portion of the roof deck to facilitate vacuuming the existing blown-in insulation out of the truss space, and installation of the spray foam insulation and new blown-in insulation. New tapered insulation and roof membrane above the structural roof deck were part of this solution.

Option 2

Option 2 (*Figure 2*) required removal of the existing roof system down to the structural roof deck, and replacement of any wet, rotted, and/or moldy deck and blown-in insulation. A roof vapor/air barrier would be applied on the structural roof deck.

Spray foam insulation of a minimum 3-in. thickness applied to the rim area was determined to be the most effective way in situ to transition the vapor/air barrier (polyethylene sheeting) from the exterior walls to the roof vapor/air barrier. The rim area is at the top of the exterior walls at the level of the 16-in.-deep roof trusses.

Sufficient insulation needed to be added above the structural roof deck to get the dew point temperature above the roof vapor/air barrier. This insulation also needed to be tapered to provide roof slope to the existing interior primary and secondary (overflow) roof drains. The hygrothermal analysis showed a minimum of 4 in. of isocyanurate insulation was required to keep the dew point temperature above the roof vapor/air barrier. This meant all roof drains would need to be raised to accommodate the increased insulation thickness.

Option 3

This option required removal of all the existing blown-in insulation in the truss space and installation of a sprinkler system to satisfy the fire code. A new roof assembly above the structural roof deck included a roof vapor/air barrier, tapered rigid board insulation, and membrane. This achieved the need to have the dew point temperature occur above the roof vapor/air barrier and minimize the amount of insulation required. This option also required the spray foam rim area described in Option 2.

This option was quickly eliminated from further consideration because the owner decided not to install a fire sprinkler system above the top floor ceiling due to the considerable disruption to the occupants and the cost. Therefore, the blown-in insulation in the truss space needed to be maintained by selecting Option 1 or 2.

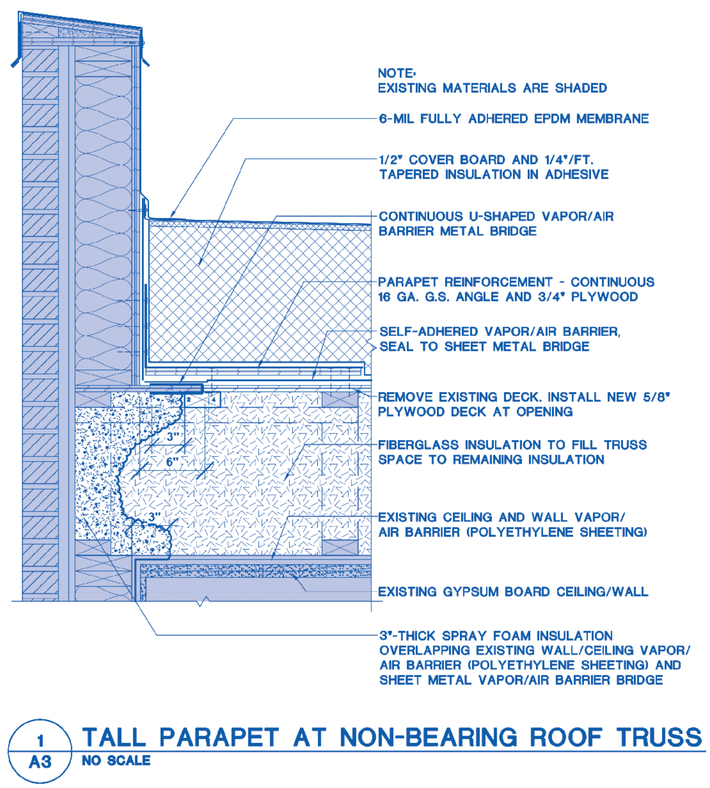

Figure 3 – Detail from winning Option 2.

Figure 4 – Typical invasive inspection opening above trusses.

Figure 5 – Typical invasive inspection opening below roof deck sheathing.

THE SOLUTION

Option 2 is the solution that was ultimately selected and developed into construction documents for bidding and construction (*Figure 3*). This was the best solution to achieve the goal of a complete vapor/air barrier. It also exposed all the existing roof assembly to allow for the removal and remediation of wet, deteriorated, and moldy roof components. This option also maximized the reuse of the structural roof deck and blown-in insulation that was still in acceptable condition.

Vapor/Air Barrier Continuity

Vapor/air barrier continuity from the wall to the roof was the key consideration and the toughest challenge for the repair design. Installing the roof vapor/air barrier on top of the structural roof deck required transitioning the vapor/air barrier through the structural roof deck to the rim area to complete the envelope. This was solved by designing a U-shaped sheet metal to wrap around the structural roof deck edge, which provides a surface on the bottom to receive the spray foam insulation applied to the rim area, and a surface on top to which the self-adhering membrane roof vapor/air barrier could be bonded.

Other Considerations

In addition to selecting Option 2, other considerations included:

- The rim area had to be accessed from above, which required the removal of some of the structural roof deck and blown-in insulation along the roof edge parapet.
- The parapet varies in height, with some of the low parapet design being challenged by the additional insulation thickness.
- The trusses run parallel and perpendicular to the parapets, which causes variations in the rim area conditions.
- The structural roof deck removal along the parapets compromised the structural integrity of the roof perimeter at some conditions, so an engineered solution was required that included continuous steel angles and plywood sheathing being added to reinforce the structure (*Figure 3*).
- An allowance was included in the base bid for deck and blown-in insulation replacement. The allowance amount was an educated estimate of how much replacement would be required based on the previous investigation work. Unit prices were requested to be used to charge against this allowance.
- During the design process, input was provided by Horizon Roofing Company. Collaboration amongst Horizon, the owner, and the A/E worked to develop a construct-

ible design that achieved the goals and minimized costs and delays.

CONSTRUCTION CHALLENGES

Preconstruction

Three contractors were invited to bid the project, and they provided input during the bidding process. One key, high-risk factor in constructing Option 2 was that doing all the work from the top side left the roof open and vulnerable to the weather for a substantial portion of time each day. Some days had greater exposure than others, depending upon how much deck and blown-in insulation needed to be replaced.

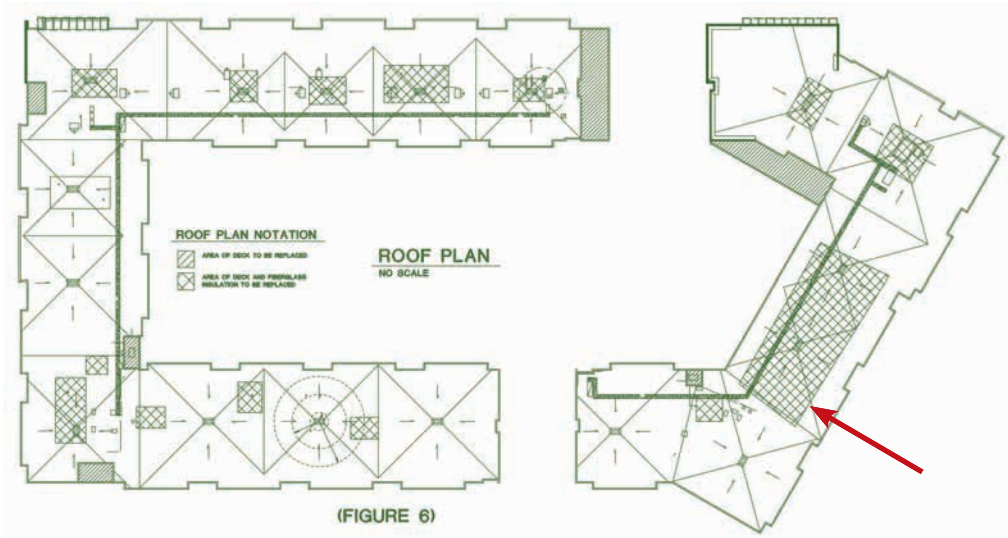

Figure 6 – Approximate areas of roof deck and insulation replacement.

During the design phase, based on investigation-generated test results and observations, it was decided to make 60 invasive inspection openings prior to the start of construction to provide an idea of where the deck and insulation would need to be replaced (*Figures 4* and *5*). This would help the contractor better plan the construction work. The contractor awarded the reroofing project would make and repair the inspection openings.

Because litigation had been initiated, parties involved with the original construction had an interest in observing the existing construction. To minimize the disruption to the contractor's operations during the roof replacement, all interested parties were allowed to observe and conduct moisture testing at each of the 60 invasive inspection openings. The owner hired IEA, an environmental consulting firm, to conduct moisture tests and sampling for fungal analysis on its behalf. This consultant provided a report, including a roof plan showing the results of their testing.

Moisture Content

Based on the 60 invasive inspection openings, test results, and observations, a roof plan was developed showing the approximate areas where roof deck sheathing and blown-in insulation would most likely require replacement (*Figure 6*). The final determination of what needed replacement would be made by the contractor when each area was opened daily. While on site, performing their periodic observations, the A/E assisted the contractor to determine what needed to be replaced. A hand-held moisture meter was utilized daily, which worked well in determining the moisture content of the OSB structural roof deck. Industry convention indicates that a 16% moisture content would be the threshold for requiring replacement.

The moisture meter did not provide useful readings for determining the need to replace the blown-in fiberglass insulation. Samples of insulation were taken to determine an oven-dried moisture content by weight to develop a correlation with moisture meter readings. A correlation could not be determined, so the decision to replace insulation was somewhat subjective. First, wherever mold was detected on the OSB deck, the underlying insulation was also replaced, because mold spores can migrate into the insulation. Second, the contractor determined whether excess moisture was present by sight and touch.

Construction

The contractor elected to do the perimeter work prior to the replacement work in the field of the roof (*Figure 7*). The perimeter work proved to be time-consuming and would have significantly reduced the size of the area that could be reroofed on a daily basis if it was done in conjunction with the field of the roof. The contractor could also schedule the perimeter work on days when

Figure 7 – Typical work at roof perimeter.

Figure 8 – Z-shaped vapor/air barrier transition metal.

Figure 9 – Two-piece U-shaped vapor/air barrier transition metal.

the weather forecast was a bit questionable, as the perimeter could be enclosed rapidly should precipitation be imminent.

The contractor fabricated a Z-shaped transition metal instead of a U-shaped transition metal that served the same purpose as a vapor/air barrier transition material (*Figure 8*). However, there were areas of the previous mold remediation where additional framing done as part of that work interfered with the installation of the Z-shaped metal. Therefore, a two-piece U-shaped metal was installed with the connection between the pieces accomplished with aluminum tape (*Figure 9*).

After the Z-shaped transition flashing was installed, a short width of vapor/air barrier was installed (*Figure 10*), and then a parapet reinforcing assembly of plywood and sheet metal angle was installed (*Figure 11*), followed by the field of the roof vapor/air barrier (*Figure 12*).

The contractor had on-call local insulation and plumbing subcontractors under contract and available to complete varying amounts of work, depending on what was uncovered and anticipated each day.

Figure 10 – Roof vapor/air barrier at roof perimeter.

Figure 11 – Plywood and sheet metal angle parapet reinforcement.

Figure 12 – Vapor/air barrier applied to field of roof.

Figure 13 – Blown-in insulation.

"The owner, the contractor, and the architect/engineer worked to develop a constructible design that achieved the goals and minimized costs and delays."

Figure 14 – Mold remediation paint.

Perimeter work required the insulation subcontractor to be on site to vacuum insulation, install the spray foam insulation in the rim area, and install new blown-in insulation on each day of perimeter work (*Figure 13*).

Mold remediation was handled by the contractor, alleviating the need for a specialty contractor. This eliminated coordination and delay issues. The contractor cleaned any discolored areas that were within moisture content limits, then painted these areas with an antimicrobial paint (*Figure 14*). Most of the parapet that was left in place was remediated when the perimeter work was constructed, which proved to be the most efficient.

The estimated amount of existing roof deck sheeting removal, based on the 60 invasive inspections openings, was 8,000 sq. ft. The actual amount of existing roof deck sheeting removal was 6,000 sq. ft.

While conducting the invasive inspection openings, and subsequently during the reroofing work, it was observed that the plate-bonded TPO roof membrane plates were severely corroded in much of the roof area. This significantly reduced the wind uplift resistance of the roof membrane. The contractor was conscious of the need to respond quickly, should a high wind event occur. Fortunately, the reroofing work was completed without incident.

The contractor removed tear-off debris from the site daily. The debris was lowered by crane into dump trucks. New materials were hoisted daily with only a one- to two-day stockpile on the roof. The crane and roofing materials were staged on the streets running adjacent to the building, but only at certain locations, which resulted in long travel distances across the existing roof in some areas. The city of St. Cloud allowed

Figure 15 – Perimeter safety rails.

Figure 16 – Completed roof.

the streets to be temporarily closed. Access to the retail establishments and egress from the buildings was continuously maintained but was an ongoing public safety challenge.

Perimeter safety was primarily accomplished with rails attached to the parapet (*Figure 15*). A safety monitor was also assigned to work with the crew applying the low-rise foam adhesive for the insulation attachment.

The fully adhered EPDM membrane over the tapered insulation system provided a fully draining roof with a finished appearance (*Figure 16*). Even with all of the construction challenges, the roof was completed in a timely manner.

REMARKS

The owner, the contractor, and the A/E worked together to achieve the goal of taking a sick building and making it well. All parties understood from the start that shortcuts couldn't be taken. As with most projects, some surprises were encountered, but these were quickly resolved with input from all parties. Cost efficiencies were considered and implemented only if they didn't compromise the design intent. The project was completed with minimal disruption to the operation of the building and its occupants.

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Dwight D. Benoy, PE, was employed at Inspec, a building enclosure consulting engineering and architectural firm in Minneapolis, for over four decades. He is a licensed professional engineer and has focused his practice in forensic engineering of the building enclosure. He received a BS in civil engineering from the University of Minnesota.

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Blast From IIBEC's Past: 1988

In 1988, Joe Hale agreed to chair RCI's (now IIBEC's) Asbestos-Containing Roofing Material Committee, the first new committee to have been formed by the association since its inception. Another new joint committee was formed with the National Roofing Contractors Association (NRCA) to explore mutually agreeable professional relationships between roof consultants and roofing contractors.

In November 1988, the association hired its first full-time paid employee, Paula Baker, as administrative assistant to the executive director (Bob Phillips) at the headquarters office in Raleigh.

Attendees at the Roof Consultants Institute's (now IIBEC's) board meeting in Washington, D.C., in August 1988. Seated, left to right: Second VP James E. Magowan, Treasurer Richard Horowitz, and First VP George F. Kanz. Standing, same order: Executive Director and Immediate Past President Bob Phillips, President D.B. Hales, and Secretary Donald E. Bush.