BERMUDA ROOF IN HARTFORD, CONNECTICUT

BY REMO CAPOLINO, RRC, PE

Cityplace I is a Class-A, high-rise office tower in the heart of downtown Hartford, Connecticut. This polished, granite-clad, 530-ft.+, 38-story building was designed and completed in the 1980s by Skidmore, Owings, and Merrill. Atop the building is an aesthetically pleasing and functional bermuda seam copper roofing and wall cladding system. Around the year 2000, building manager Jones Lang LaSalle (JLL) identified areas of the copper roof assembly on the north facing exposure that were exhibiting out-of-plane movement, suggesting the initial attachment to the receiving substrate had been compromised. After a few repairs by local roofing contractors, JLL turned to an RCI professional for an opinion regarding the condition of the roof assembly. The Connecticut office of Wiss, Janney, Elstner Associates was then retained to conduct an investigation and report upon the existing conditions and any recommendations for repairs.

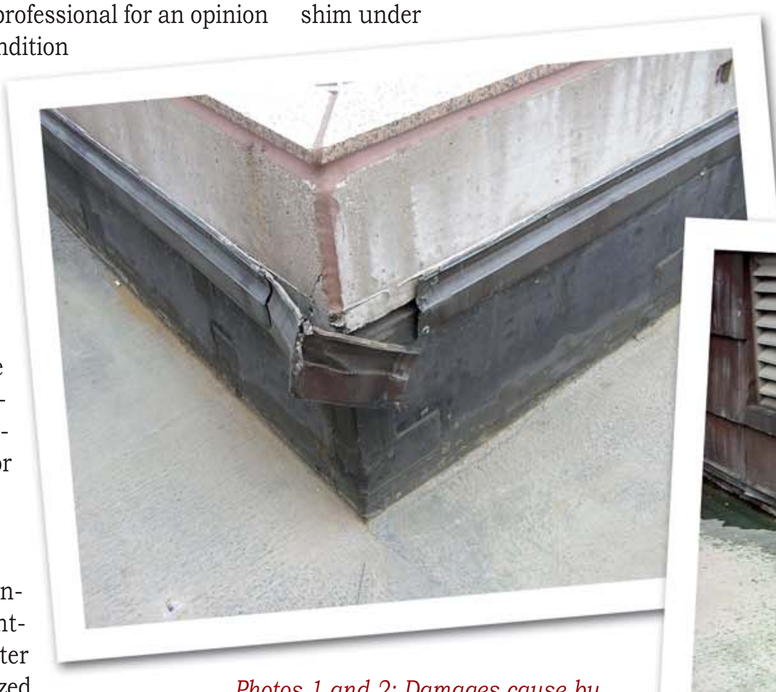
Overview

The roof consists of an eight-foot-wide perimeter "ring" of rubberized asphalt waterproofing with a concrete topping slab. Within this outer ring rises a seven-foot vertical wall and steep-sloped copper bermuda seam roof. There are 16 different roof areas with slopes ranging from a very walkable 6:12 to a near vertical 60:12, with a combined area of approximately 30,000 square feet. These roof areas serve as mansards. Above them all is a small flat roof with rubberized asphalt in a gravel-ballasted IRMA assembly.

The originally installed steep-slope roofing assembly consisted of a metal deck with horizontal 2x6s installed at 20-5/8 inches on center and extruded polystyrene (XPS) placed between the 2x6s. Over this, 24-inch by 8-ft. sheets of 3/4-inch plywood were installed with the long dimension laid perpendicular to the roof slope. A 3/4-inch shim under the lower edge of each plywood panel combined with a 3-3/8-inch shingle overlap created the 20-5/8-inch-exposure, Bermuda-shaped substrate, which was then clad with 16-oz. copper. The copper panels covered the 20-5/8-inch exposure plywood sheets and were installed in 10-foot long panels. Between each 10-foot panel, a gap was left to allow the installation of a "drive" or a "slip." This drive was installed similarly to the cap of an expansion joint and performed a similar function: to allow the adjacent copper to move while still preventing water entry.

Investigation

A visual observation of the roof showed many areas of impact damage on the vertical rising walls. This was caused by the window-washing rig that travels the perimeter ring accidentally hitting the wall at corners and other areas with limited clearances (see *Photos 1* and *2*). A significant number of



Photos 1 and 2: Damages cause by window-washing rig.

Photo 3: Cracks in copper at drive cleats.

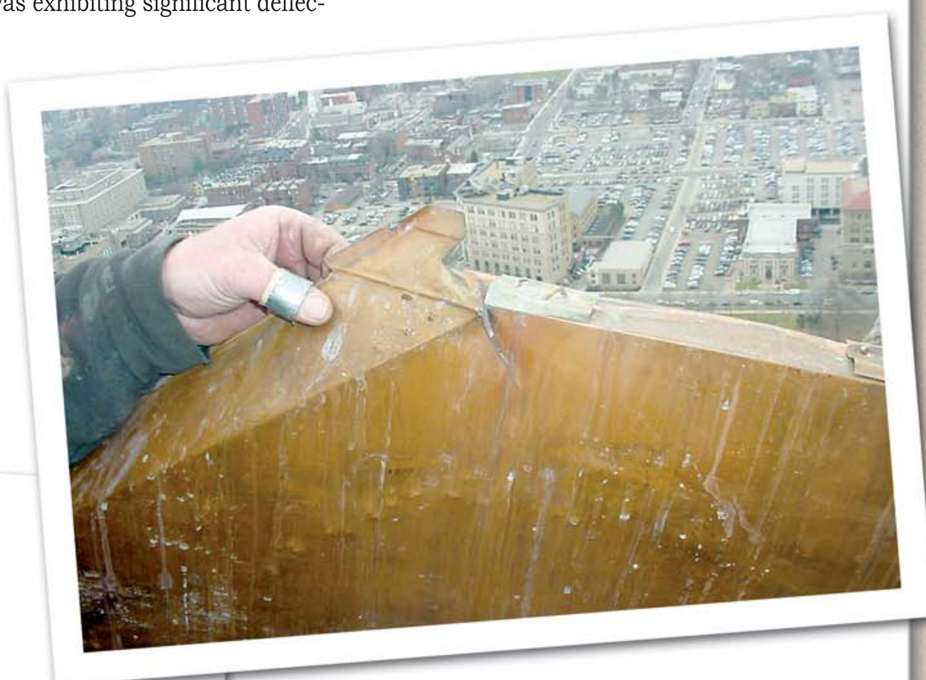
cracks were also noted in the copper at the intersections of the Bermuda panels where the drives are installed between the panels (see *Photo 3*). Inspection openings in the copper cladding yielded multiple reasons for the cracked and deformed copper. At the drives between Bermuda panels, no cleats were present to prevent the wind pressure from repeatedly lifting the copper off the substrate. Over the course of 20+ years, the repetitive action caused the copper to fatigue, which allowed a crack to form and propagate. At the hips, the convergence of multiple planes of flat copper intersecting in one location and the lack of any provision to accommodate for thermal expansion and contraction, caused the unsoldered cuts (required to form the copper into the corner configuration at the time of initial construction) to tear. (See *Photos 4* and *5*.)

Some time after installation, the felt and rosin paper underlayments beneath the copper panels slipped from their original positions and gathered at the bottom leading edge of many Bermuda panels. This accumulation of materials pushed the copper panels outward from their original position and created the curved or bowed shape that was noted by the building management (see *Photo 6*).

Upon opening one location of copper that was exhibiting significant deflection, the underlying plywood substrate was brittle, and the nails used to secure the copper cleats to the plywood were heavily corroded. The combination of fastener corrosion and plywood degradation resulted in significant sections of the copper panels detaching from the building (see *Photos 7* and *8*). The only attachment to the building was indirectly through 3/4-inch locks to the adjacent copper panels in the Bermuda courses above and below.

When the investigative opening was enlarged, it was discovered that an area of approximately 100 square feet was not attached to the building and was only locked to adjacent panels. To make matters worse, mechanical attachment of these adjacent panels was compromised to varying degrees, based upon the condition of the plywood and the extent of corrosion to the copper nails.

Additional openings were made and eventually, printed labels on the wood verified the suspicion that the dimensional 2x6 blocking and plywood sheathing were all Fire Retardant Treated (FRT) lumber. The document review done prior to the destructive investigation gave no indication that



Photos 4 and 5: Tear in copper at hips.

Photo 6: Bowed copper due to accumulation of underlayments (felt and rosin).

FRT lumber was used in the construction of the roof assembly.

It is widely accepted that FRT wood of the age of this building experiences significant degradation as a result of the combination of the fire retardant treatments and elevated temperatures. The age of this roof is such that most of the copper has a dark brown patina that can easily reach 140°F in the summer months. This particular wood degradation phenomenon as a result of FRT has been written about extensively. For more information on this issue, consult the excellent literature available from RCI, ASTM, and many wood building associations.

The condition of plywood in many areas on this roof was such that if the copper cladding were not there to spread the load, the foot pressure of an individual on the roof could punch through to the underlying XPS insulation. These FRT issues created a situation that significantly impaired the ability of roof cladding to withstand high winds.

Temporary Protection

Timing of the investigation and design development and acquisition of budgets for repair or replacement were such that hurricane season had arrived before any repair or replacement of the existing roof assembly could be implemented. In August 2003, a hurricane came up the east coast and threatened high winds in the Hartford area. Knowing the condition of the roof, two methods of tem-

Photo 7 (above): Corroded copper fastener.

Photo 8 (left): Brittle plywood substrate.

Photo 9: Debris netting on north elevation.

porary securement for the existing assembly were proposed. The first was the installation of screws and plates into each copper panel to directly engage the metal decking. This work would have been difficult due to the extremely steep slopes and the need to be "face to face" with every panel in order to install the screws. The second method was the installation of a dual-purpose safety and debris netting assembly. The netting assembly was designed to be secured into the concrete topping slab of the perimeter ring roof, extend up the sloped roof areas, and be secured to a railing connected to the building's steel frame at the small upper roof area (see *Photo 9*). With the bid process unable to outpace the oncoming storm, the building management made the decision to directly contract with the netting installer on an emergency basis. This direct action by the building management in installing the netting protected the building, its occupants, and innocent passers-by from harm. After the storm passed, areas of the installed netting were noted to have been stressed; however, no failure of the roof or netting was observed.

Repair/Replace Design Options

Based upon the roof's condition, it was decided that it could not be repaired. As a result, the entire roof assembly, including all wood blocking and insulation, would have to be removed and replaced.

The design of the new roof was opened up to include anything the building owners wanted and could afford. Many re-roofing options were explored, including standing seam copper; batten seam copper; fully adhered patina green-colored PVC with standing seam and batten seam applied elements; fully adhered PVC to replicate the Bermuda seam profile; and removal and replacement in kind.

In order to facilitate a decision, renderings of batten and standing seam profile PVC roof assemblies were provided for the owner's review and comments (see *photos 10, 11,* and *12*).

After many iterations and life-cycle cost analyses, it was decided that the most environmentally friendly, cost-effective, and longest life expectancy would be realized with the installation of a new, Bermuda-style copper roof assembly to replicate the

Photo 10: Photo of existing copper roofing.

Photo 11: Rendering with Sarnafil Pacific Turquiose.

Photo 12: Rendering with Sarnafil Patina Green.

original. Many small changes from the initial construction were made to the design to improve the assemblies' constructability and ability to protect the building and its interior while simultaneously minimizing and facilitating its maintenance by management.

The design of the new roof assembly was done with the knowledge that the building currently is not FM insured; however, in the volatile real estate market, everything is subject to change. It was decided to design and install a roof assembly that, while it was not submitted, reviewed, tested, and approved by FM, it could be if necessary.

The new roof design included a fire barrier gypsum board installed directly on the metal deck. Over this fire barrier, a continuous layer of insulation was installed with vertically oriented 2x4s at 16 inches on center to act as spacers and create a vent channel within the roof assembly. The vertical 2x4 vent spacers were crossed with horizontal 2x6s at a spacing to match the exposure of the Bermuda panels. These 2x6s were screwed through all new materials and into the metal deck. Plywood was used for the final sheathing and 3/4-inch kickers at the bottom of each panel created the step required for a Bermuda system (*Figure 1*).

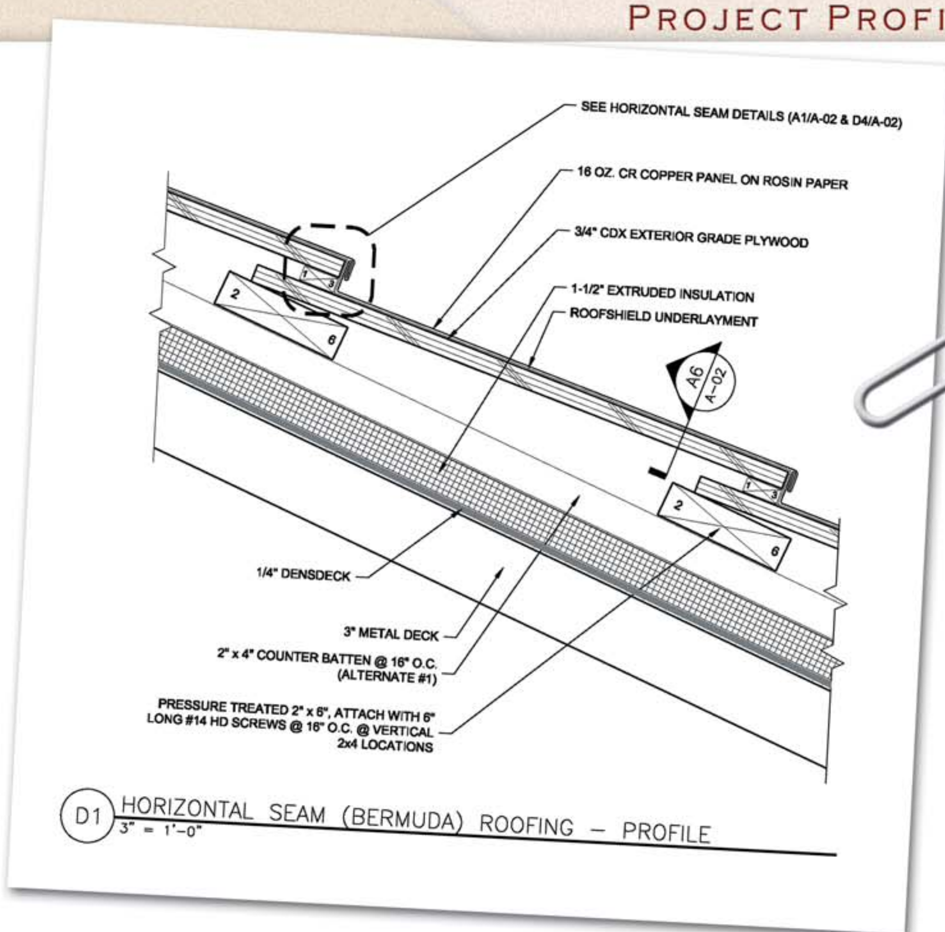
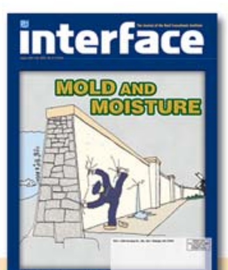


Figure 1

Interface Wins Award

Chamblee Graphics, the Raleigh, North Carolina printer that has been printing RCI's technical magazine since 1997, recently received an industry award for the journal. The May, August, and October issues of 2005 were entered into the "PICA Awards" as examples of a "sheet-fed magazine series of four or more colors." PICA, the Printing Industry of the Carolinas, granted the printing of *Interface* its "Best of Category" designation. The magazine is now eligible to be submitted on the national level for awards judged and presented by the Printing Industries of America (PIA).

Nicole Leech, contract designer for *Interface*; and Kristen Ammerman, executive editor, were presented by Chamblee Graphics with framed certificates of the honor.



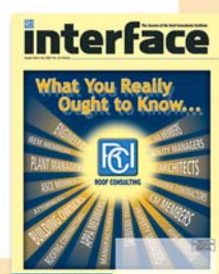


Photo 14: Roll-up door soffit damage.

Photo 13: Stainless steel bumper.

Photo 15: Roll-up door with protective gutter/bumper.

The wood used in this project was untreated due to the failure of the original FRT and concerns about the long-term viability of the new preservative treatments, particularly Alkaline Copper Quaternary (ACQ), and its corrosive effects on mechanical fasteners. As pointed out to the building owner, copper roofs have been installed for over a hundred years with many achieving useful service lives in excess of 70 years without the use of preservative treated wood. [Editor's note: see David Hunt's article starting on page 132 of this issue.] That being said, every effort was made to protect the untreated wood from moisture in the event of localized water penetration, and to prevent long-term moisture accumulation within the roof assembly. The venting system described above – in conjunction with an extremely vapor-permeable, spun-bonded polypropylene underlayment – protects the wood from getting wet. The breathable attributes of the construction would accommodate a drying cycle in the unlikely event a leak does occur, allowing the wood to dry quickly.

Another advantage of the spun-bonded polypropylene is that being 500+ feet in the air with nothing around to buffer the high winds, the high tear resistance of the material makes it much more likely to withstand construction traffic and high winds during the course of construction.

Other subtle changes to the original design include the addition of a stainless steel "bumper" system at all inside and outside corners to protect the copper-clad vertical walls. Protection is required from the window-washing rig as it goes around the building. It included the incorporation of a gutter made from bent and welded stainless steel plates that acts not only as a water collection device above the roll up door that provides the only access to the ring roof, but also serves to protect the copper soffit from damage by the washing rig. See *Photos 13, 14,* and *15.*

Both the original and new copper cladding terminate no more than four inches above the concrete topping slab and will not allow the installation of an eight-inch-high base flashing when the time comes to replace the waterproofing membrane beneath the concrete topping slab.

One more change from the original design was to incorporate a watertight stainless steel apron flashing behind the vertical wall cladding that begins at the concrete topping slab and extends up the wall and behind the copper cladding, providing a minimum protection height of eight inches. This flashing can be used to extend any waterproofing base flashings that are installed in the future so that they extend up beyond the bottom of the copper cladding and will not require any removal of the newly installed copper.

Construction

Once the investigation and design were complete, the project was let to four prequalified local bidders. Silktown Roofing, a local Connecticut contractor, was the successful low bidder at $1.7 million when all alternates were included. A contract was signed, and work began in early 2005.

The challenges of working atop a high-rise building were significant and worth mentioning. The building was fully operational, and construction could not be allowed to interrupt normal business activities of any of its tenants. As a result, material handling was limited to between 11 p.m. and 6 a.m. The one bit of good news was that during these hours, the contractor would have exclusive use of the freight elevator. This becomes critical when it is recognized that over 1,000 cubic yards of debris were removed from the building, with a similar amount of new materials being brought in, moved up, and installed. In total, approximately 58,000 linear feet of wood blocking, 1,300 sheets of 3/4-inch plywood, 60,000 square feet of insulation boards, and approximately 50,000 pounds of copper were brought into the building and up to the roof – primarily during "off" hours.

The limitations and timing of material handling were only the tip of the iceberg. With "Murphy's Law" in full force, a major law firm with high-end finishes was located directly below the work area as construction began. This limited the amount of noise that could be made in the work zone during regular business hours. With all these limitations being presented at the time of the bid, the contractor as well as the entire project team did an excellent job in coordinating and working around the building's occupants and staff.

Safety was the highest priority of both the contractor and building management. Local OSHA inspectors were invited to the site prior to the start of construction to review and discuss the contractor's proposed means and methods. Weekly job meetings included a time at which the contractor's safety officer inspected the site and made sure all local, state, federal, and company safety regulations were being implemented. If issues were found, they were dealt with immediately. As a result, there were no on-site injuries and no OSHA violations for the duration of the project.

Debris was of particular concern because the FRT plywood was so brittle that it literally crumbled in one's hands. There was great concern that absolutely no debris be allowed to leave the work zone uncontrolled. This criteria was brought to the attention of all bidders during the bid process and was driven not only for the concern of the general public, but also for the safety of another contractor that was simultaneously removing and replacing all of the approximately 26.5 miles of exterior building sealant during the reroofing project. At any one time, the sealant replacement contractor had at least three hanging scaffold rigs on the building. These rigs had wire rope climbers, safety tie backs, and personnel safety lines, all of which were in the area of the copper roof removal and replacement, and which could easily be damaged or cut by any uncontrolled debris (see *Photos 16* and *17).*

Photo 16 (above): Sealant replacement contractor sharing work space with roofing contractor.

Photo 17: Scaffolding used by roofing and sealant contractor in congested work zone.

Photos 18 and 19: System scaffold used to provide worker access.

The contractor decided to attack the re-roof in a "three phase" plan. First, removal of the existing roof would be done to expose the metal deck. Once removed, the exposed deck would be inspected and any voids or penetrations sealed to prevent water entry. This was an ingenious method of preventing water entry and offset any temporary protection while still allowing removals to proceed at the fastest pace worker efficiency would allow.

The second phase of work was carpentry and consisted of the installation of the gypsum fire barrier, XPS insulation, horizontal and vertical 2x4s, plywood, and ultimately the breathable polyester underlayment. The third and final phase was the actual installation of copper panels.

In order to access the work areas, the contractor provided both fixed and hanging scaffolds, depending upon the roof slope and the size of each roof area. The multiple phases of removals, carpentry, and sheet metal required that any method of access had to be extremely heavy duty, while still being flexible. The fixed scaffolding consisted of a "System scaffold," which is made up of two-inch-diameter vertical pipes with rings every 18 inches on center to which horizontal piping can be attached at intersection angles in increments of 12.5 degrees, allowing the entire system to closely mirror the contour of the building.

To the framing of the scaffold, work levels were installed where needed. A safety and debris netting was installed to the entire back of the scaffold, beginning from a minimum of 10 feet above the top work level and draping down to the base, to catch anything or anyone that might inadvertently try to "take the express" to the street below (see *Photos 18* and *19*).

Photo 20: Wood brackets used to provide worker access.

Even with the flexibility of the "System scaffold," as the height of the roof increased, the slope made the roof surface fade farther and farther away from the scaffolding to the point where outriggers could no longer reach the deck. After the third working level, located at approximately 18 feet above the perimeter ring roof, the fixed scaffold was abandoned and specially fabricated roof brackets were used to support planks upon which the workers stood to install the new work. These brackets and their fastening to the building were designed to withstand the load of not only the worker, but also the weight of any materials that needed to be installed. See *Photos 20* and *21*. At some

Photo 21: Specialty metal brackets used to provide worker access.

ROOF KNOWLEDGE ASSESSMENT

Test your knowledge of roofing with the following vapor retarder and skylight questions, developed by Donald E. Bush Sr., PE, RRC, FRCI, chairman of the RRC Examination Development Subcommittee.

This Month's Subject:
VAPOR RETARDERS/SKYLIGHTS

1. **The International Energy Conservation Code requires an approved vapor retarder be installed to prevent moisture from condensing within framed walls, roofs, or floors not otherwise ventilated to allow moisture to escape. What are the three exceptions to this requirement?**
2. **In other than hot-humid climates, the vapor retarder must be placed on which side of the insulation?**
3. **In situations where vinyl-faced insulation is being installed inside warehouse roofs and there is no ventilated air space above the roof insulation and no solid surface (such as gypsum board) immediately below the insulation, how should all vapor retarder seams be sealed?**
4. **The maximum skylight area that may be exempt from the code requirements is expressed as a percentage of the gross roof assembly area. Skylights located in the building envelope shall be limited to what maximum percentage of the gross roof assembly area?**
5. **Roof surfaces are those building envelope surfaces with a slope of less than ? degrees from the horizontal.**

Answers on page 34

ROOF KNOWLEDGE ASSESSMENT

Answers to questions on page 33:

1. **A) Buildings located in Climate Zones 1 through 7.**

   B) In construction where moisture or its freezing will not damage the materials.

   C) Where other approved means to avoid condensation in unventilated framed walls, floors, and ceiling cavities are provided.

2. **The vapor retarder must be placed on the warm-in-winter side of the insulation.**

3. **All seams should be sealed with tape (stapling alone is not adequate).**

4. **Three percent; the three percent skylight exemption was developed to result in about the same energy use as a building with no skylights.**

5. **60°**

Reference: IECC, Chapter 8: Design by Acceptable Practice for Commercial Buildings.

Photo 22:
Specialty metal brackets and hanging scaffolds used to provide worker access.

areas, the roof slope prevented the use of the specialty brackets and required the use of hanging scaffolds similar to those used on vertical walls (see *Photo 22*).

Conclusion

By the end of 2005, the entire project had been completed within the expected timeframe and without interruption to the building's day-to-day operations. The finished product not only will provide a long-term, watertight assembly, but is also a recognizable landmark in the Hartford, Connecticut real estate market, known for its aesthetic beauty.

At the time of bid, an allowance of $20,000 was included as a safeguard for cost overruns; however, due to the diligence and cooperation of all parties involved, a credit of approximately $3,000 was presented to the owners. This meant that unexpected costs were limited to less than 1% of the contract price.

In retrospect, this project underscored what can be accomplished when the abilities, dedication, and cooperation of designer, contractor, and building manager are exceeded only by the willingness of the building owner to do the very best job that can be done.

Remo Capolino, RRC, PE

Remo R. Capolino, RRC, PE, received his bachelor's degree in civil engineering in 1991 from the University of Connecticut. Between 1989 and 1996, he served as treasurer and then president of the Association of General Contractors' (AGC) Student Chapter and on the Advisory Committee and then Board of Directors of the Northeast Roofing Contractors Association (NERCA). Remo also served on the Board of Directors for the National Roofing Contractors Association (NRCA), where he assisted in updating the *NRCA Roofing and Waterproofing Manual, 4th Editon.* He is employed by Wiss Janey Elstner Associates Inc. in Shelton, CT, and is on the Peer Review Committee for *Interface* journal.

