Microscopic Roof Leaks Destroy Fasteners And Insulation

By John Willers, RRC, FRCI, PE

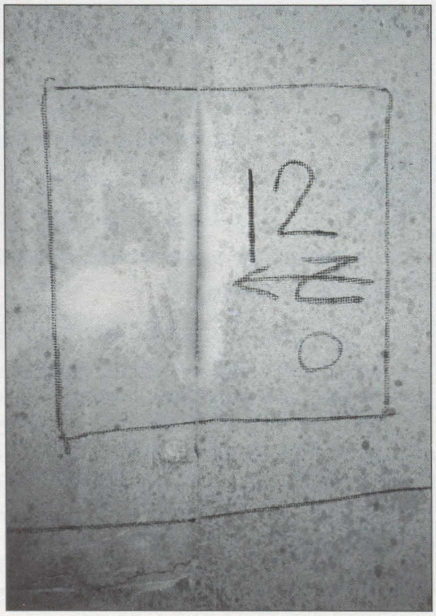
A routine roof moisture survey performed in 1993 resulted in the discovery of a mode of roof leakage I had never before observed nor dreamed of. The source was capillaries within a single ply membrane.

Not only had the roof insulation become wet from these microscopic leaks, but the membrane was no longer as resistant to wind uplift. The shafts of many of the fasteners had rusted through, leaving only the fastener head and the stress plate on top of the edge of each sheet of membrane. In this article I will describe the project, my mission and how I discovered this source of leakage.

The Project

The 1,000,000 square foot warehouse had been constructed in Virginia in 1987 and was used to store dry goods. The structure consisted of a steel frame, steel bar joists, and metal roof deck. The configuration of the roof framing formed a series of ridges and valleys so that the roof deck sloped to provide positive roof drainage. The flutes in the roof deck were oriented parallel to the roof slope.

The roofing consisted of a 1.75″ thick layer of phenolic foam insulation and a mechanically attached single ply roof membrane. The membrane was a white, reinforced, 45-mils-thick, calendared elastomeric sheet. This membrane had been installed by placing individual five-foot wide sheets over the board insulation and the edges of each sheet were secured with self-tapping screws and plates. The laps were heat welded.



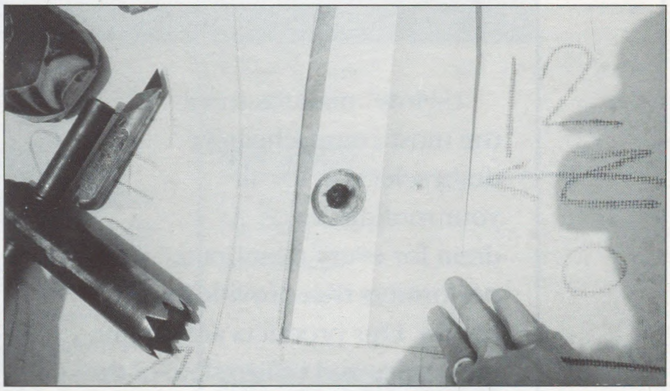
In 1991, approximately four years after the building had been constructed, the building owner observed that corrosion had formed at certain areas on the underside of the roof deck. An investigation of the corrosion revealed that it was severe, and that the phenolic foam insulation was the primary factor which caused the metal roof deck to corrode. The owner also learned that the catalyst for this corrosion was water. Therefore, the owner wanted to identify the source of the moisture.

The Investigation

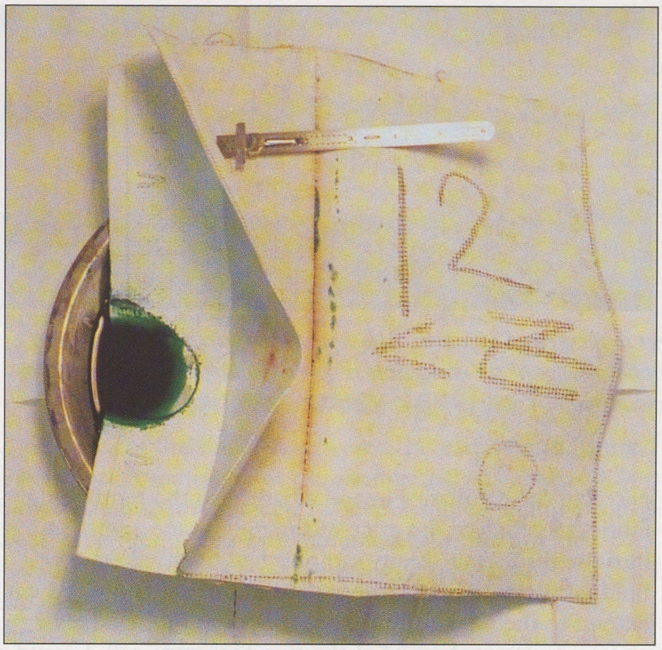
First, the locations of active roof leaks were obtained from personnel working in the warehouse and the underside of the roof deck was examined to identify the locations where the metal roof deck was corroding. A comparison of the leak locations and locations where corrosion was evident revealed that active roof leakage was not associated with a majority of the areas of deck corrosion.

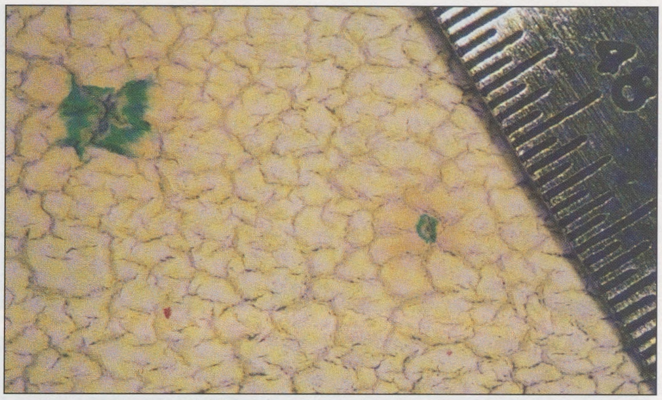
Next, interior temperature and relative humidity were measured. This information was evaluated and it did not indicate that wet insulation would result from the absence of a vapor retarder.

The next action taken was to conduct a moisture sur-



1. (Left) 12″ x 12″ membrane sample No. 12 before cutting. Note membrane lap and rust stains adjacent to the edge of the overlying membrane. 2. (Above) 12″ x 12″ membrane sample No. 12 after cutting. Note the large rusty spot in the center of the stress plate which is the rusted fastener head.





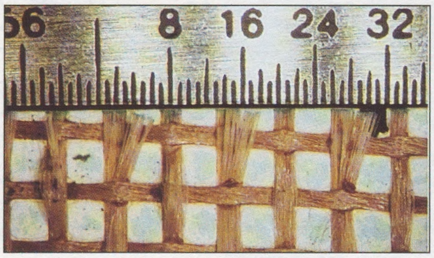
3. (Left) 12″ x 12″ membrane sample No. 12 with fastener hole exposed to green food dye over night. Note the original rusty stains adjacent to the edge of the heat welded lap, and the green stains from the food dye that had traveled through the membrane capillaries from the fastener hole. 4. (Above) Weathered surface of the membrane. Note the green food dye stains and the faint, rusty stains at the perimeter of each of the green stains. The scale is divided in 64ths of an inch.

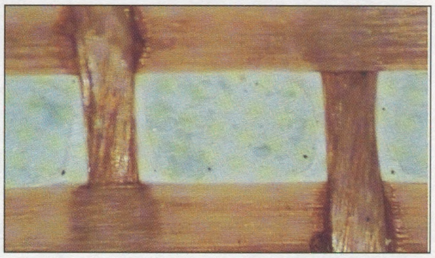
vey. Wet areas of insulation were found and fifteen insulation samples were obtained to confirm the findings of the capacitance-type moisture meter. As expected, wet insulation was found above those areas where the metal deck showed corrosion from the interior. Also, I found areas of wet insulation in other areas where there was no indication of metal deck corrosion at the interior. There was no doubt that the insulation was wet and laboratory analysis later revealed moisture contents ranging from 1,134% to 3.8%, by weight. The top surface of the metal deck was examined when insulation samples were obtained and there was no paint visible, only severe rusting at all 15 locations.

I examined the membrane, the heat welded laps, and the flashings to find the source of the moisture entry. I was on my hands and knees looking for a membrane puncture. I probed seams looking for an open lap, inspected flashings for defects, and looked for evidence of previous membrane repairs. Some punctures were found, some defects were found in the laps and flashings, and there was evidence of previous repairs. However, these conditions were not present at a majority of the areas of wet insulation. What caused the insulation to become wet? Areas of wet insulation were found at high points in the roof where there were no penetrations and no visible defects.

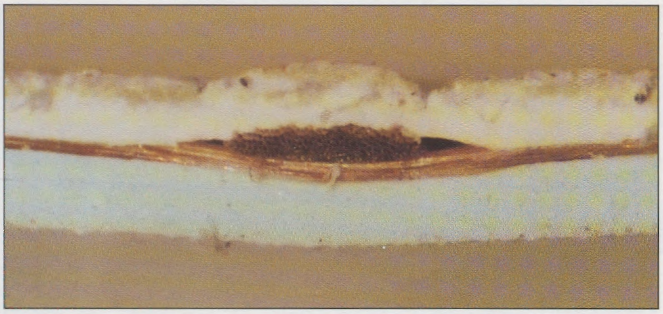
My final action on the roof was to show the roofing contractor, an authorized applicator, where the insulation samples had been taken so permanent membrane repairs could be made. We discussed my findings to date. The lead mechanic explained that he had repaired many roofs in Virginia with this same membrane and had not observed any obvious punctures, open laps or manufacturing defects, only severe chalking of the membrane. On one occasion he held a piece of the weathered membrane to the sun and observed pin holes through the membrane. Yes, this membrane was severely weathered and chalky. I held several of the membrane samples I had collected to the sun and—no pin holes. Perhaps I needed a more weathered sample. We cut another membrane sample from an area that the mechanic said had resembled other roofs he had repaired recently. The sample was cast to the sun and, again, no pin holes.

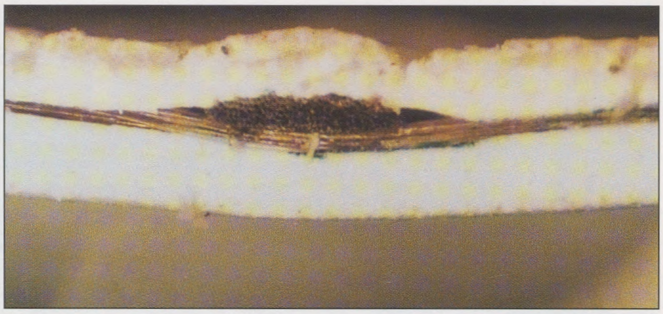
We packed our tools and samples and headed home to North Carolina, discussing possibilities all the way. We had a microscope in our lab. We could examine the membrane under the microscope and we would then see if





5. (Left) An example of rust stains adjacent to the edge of a heat welded seam. The spacing between the center of each stain is approximately 12″, which matches the spacing of the fasteners in the membrane lap. 6. (Center) The bottom layer of the membrane has been peeled away to expose the reinforcing fabric. 7. (Right) Closer view of photograph #6. Note the void spaces adjacent to each strand of reinforcing fabric.





8. (Left) Cross sectional view of membrane. Note void spaces adjacent to the strand of fabric. Also note the crevices in the weathered surface of the membrane. 9. (Right) Photograph #8 after setting the opposite edge of the membrane in green food dye. Membrane sample was 1/2″ wide and set on edge for viewing. Green food dye was visible within seconds after applying it to the opposite edge of the sample.

there were holes in the membrane. All the way home, we anticipated the outcome.

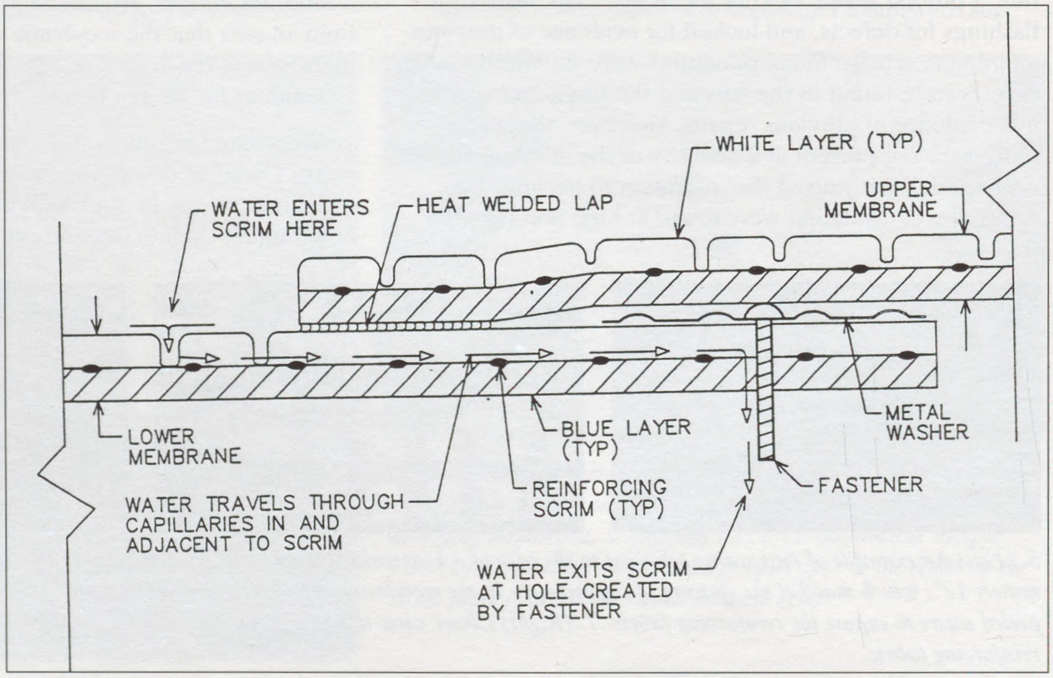
The Source of Moisture

The next day we took the most weathered piece of membrane and placed it under the microscope. The weathered surface looked like the Badlands I had seen in the Anza-Borrego Desert State Park in southern California. I could see parts of the strands of reinforcing fabric—but no pin holes. I turned the sample over and adjusted the focus. The smooth, unweathered surface showed some relief due to the reinforcing fabric, but no pin holes.

I began to experiment with green food dye placed on the weathered surface of the membrane samples and quickly saw the green dye appear 1/2″ or 1″ away. Water could readily travel through the membrane. I then realized that there were brown colored stains at the edge of many of the heat-welded seams. Were these rust stains? I placed green food dye on the surface of the membrane over a rusty stain and, with the aid of the microscope, watched a rusty spot about 1/2″ away. Within a few seconds, the rusty color turned green. I picked away at the weathered surface to expose the reinforcing fabric on another sample and tried this experiment again. It was easy to see that the green food dye was traveling through the membrane by way of the capillaries in and adjacent to the reinforcing fabric.

Was water penetrating the weathered surface of the membrane, entering the capillaries in and adjacent to the reinforcing fabric, traveling to the edge of the membrane and then into the insulation? Many samples had been taken over field fabricated seams, where the reinforcing fabric did not extend to the edge of the sheet. Exposed fabric edges occurred only at the end of the five-foot wide roll. I could explain how water was entering the membrane and traveling within the membrane, but how could this water pass through the membrane into the insulation?

Another examination of the membrane samples revealed laps that also contained fasteners and stress plates. Some only contained the head of a fastener and the stress plate as the shaft of the fastener had completely rusted through. This was the answer! The outlet for the moisture was every 12″ in the lap where the fastener punctured the membrane and the reinforcing fabric. That could also explain why there were rust stains adjacent to the membrane laps as mentioned above, and why many of the samples taken at seams were not secured. The shaft of the fastener had rusted through and the interior of the lap con-



tained only a fastener head and a stress plate.

I took one of the membrane samples, placing the lower portion of the lap in a pan of green food dye. I was careful to elevate the balance of the membrane so that only the fastener hole was in contact with the green food dye. I left the sample over night. The next morning the rusty edge of the lap was now green. Green spots were visible to the naked eye within approximately 6″ of the fastener hole (See photograph #2). The source of the moisture had been found as shown on the accompanying drawing.

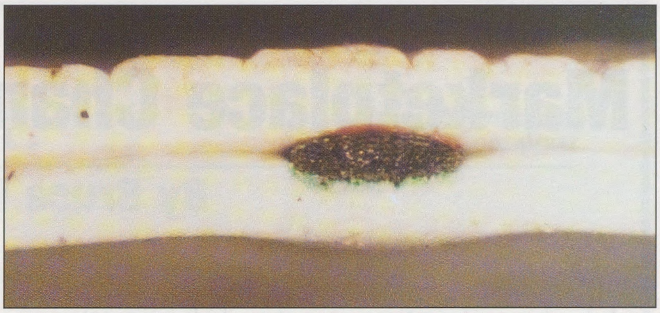
Additional Investigation

Samples of the membrane were also tested for moisture absorption. A sample of newer membrane was obtained from a patch that had recently been installed. Samples of weathered membrane were obtained from the original installation of 1987. These were tested by submerging each sample in water for 24 hours, removing them from the water, surface drying each sample and obtaining the "wet" weight of each sample. The samples were oven dried for 36 hours and reweighed. Moisture content by weight was computed. The newer membrane sample showed a moisture content by weight of 2.7%. The weathered membrane samples showed moisture contents averaging 7.8% by weight.

The thickness of the membrane was also checked using an optical comparator. The three-component membrane (surface layer, reinforcing and underlying layer) has a nominal thickness of 0.045 inches, according to the manufacturer. Measurements were taken at cross sections of the weathered membrane and at cross sections of the tab or underlying portion of this same membrane which had not been exposed to the weather. The average measurements of the samples examined are:

	Unweathered Samples	Weathered Samples
Total thickness	0.041″	0.033″
Surface layer	0.020″	0.013″
Reinforcement	0.008″	0.007″
Underlying layer	0.013″	0.013″

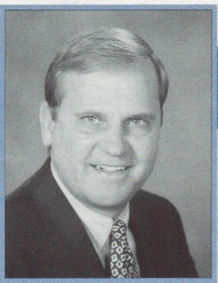
Within six years, the surface layer had weathered from a thickness of 0.020″ to an average thickness of 0.013″. Additionally, the surface of the membrane had weathered to form crevices as shown in photograph #4. These crevices were deep enough to expose the reinforcing fabric.



10. (Top) Another example of green food dye traveling through capillaries. 11. (Bottom) Edge of membrane at fastener hole. Note the frayed reinforcing fabric.

Conclusions

Moisture can readily wick through some membranes and, if the surface becomes weathered or cut edges are not adequately sealed, moisture can then enter and attack the fasteners and insulation. The result can be damaged fasteners, thus reducing the wind uplift resistance of the membrane, and wet insulation, thus reducing the roof system's thermal efficiency.



About The Author

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