How Technology is Revolutionizing Complex Roofing Assessments

By Dan R. Parker, Jr. and Chad Zielinski, PE

OVERVIEW

Roofing assemblies have progressed through the evolution of many different types of materials. The diversity of roofing materials requires consultants to have a keen knowledge of the various types, along with an understanding of how wind, hail, or other perils—natural or manmade—can affect those materials.

Roof consultants and engineers can generally determine, after a thorough roof inspection: there is damage, there is no damage, or there may be damage. Just as important, when there is damage, the roof consultant or engineer should deliver a definitive answer on repair versus replacement.

The evaluation of roofing conditions and development of repair scopes is often complex and requires more than just a visual observation of the site. Through the advancement of technology and scientific research, experts are better able to determine the condition and performance of roofs by using roofing labs, infrared thermography, unmanned aerial vehicles (UAVs or drones), and in-situ testing equipment.

ROOFING LABS

Through scientific analysis, technicians and engineers in a roofing lab can help identify roof materials and determine whether the material is damaged. Samples—preferably 12 x 12 in. and including all materials above the decking—can be removed from the roof and sent to a lab. When samples are cut, the roof assembly and its method of attachment can be identified. The samples may also reveal more than a single roofing layer. Some primary roof coverings, such as built-up roofing, may require additional effort to identify their type and number of reinforcements. Once in the lab, technicians and engineers are also able to identify the primary roof covering and other constituents, including base sheets, cover boards, primary insulation, vapor barriers, and thermal barriers.

Another form of off-site sample analysis is water column testing, which is performed in accordance with ASTM D7281, *Standard Test Method for Determining Water Migration Resistance Through Roof Membranes*. This test requires placing the sampled roofing membrane under six inches of water for a continuous seven-day period. After this portion of the test is completed, the bottom of the membrane is cycled 25 times with 1 pound per square inch gauge (psig) of air, allowing for even the tiniest of openings to reveal leakage.

Regardless of the roof covering, samples are examined visually with both the unaided eye and under magnification to discern punctures, tears, or bruises typical of hailstone impacts (*Figure 1*). Bituminous roofing—including built-up roofing (BUR) and modified bitumen (mod-bit), as well as composition shingles—can be desaturated in a vapor degreaser (*Figure 2*) and their reinforcements extracted and examined for fractures or strained regions characteristic of hail. For instance, fractures (other than anvil strike types) initiate in the lowermost reinforcement and are longest in the lowermost reinforcement and progressively shorten in reinforcements above. Plastic single-ply membranes can be examined while backlighted by high-intensity light. The light enables inspection of the reinforcement for fractures or strained regions within the plastic matrix without dissolving the plastic away.

Disagreements often arise regarding causes of marks in roofing, especially when the marks are claimed to be attributed to hail. To identify possible hail strikes in the lab, comparative impacts are made against roofing samples with simulated hail in accordance with ANSI FM 4473, *Test Standard for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls*. For this, roofing membranes are supported in the same way as they were in the field and impacted by various sizes of ice balls propelled at free-fall speeds that are equivalent to those of similar-sized naturally occurring hailstones. Qualitative comparisons are then made between the existing marks, reportedly caused by the naturally occurring hail, and those of the simulated hail—assessing sizes of marks as well as the patterns of the marks. Impacts also can be made to develop threshold sizes for hail-caused damage to roofing.

Frequently, lab technicians and engineers are asked to determine the most probable date that the impact occurred. Roofing samples can be examined in the lab to discern their degree of weathering and, with supplemental information, determine the relative age of the features of concern. The field information can include sizes of spatter marks (areas of grime and oxide that have been removed from surfaces by hailstone impact), sizes of dents in metal roof appurtenances, and widths of dents in aluminum fins of HVAC units (the best gauge of specific hailstone size at a site). Other information includes National Weather Service weather records (final records from the National Centers for Environmental Information and preliminary records from the Storm Prediction Center) and predictions from radar analyses. The information garnered from the roofing materials and appurtenances, plus weather information and radar analyses, can provide a basis for identifying the most likely date of the involved storm.

Contemplate the following when removing roofing samples:

- Roofing samples should be removed by qualified roofing contractors or consultants—preferably those selected by the building owner—with knowledge of the roof and its history. It is critical that the roofer maintain necessary licenses, certifications, and existing roof warranties.
- When selecting the locations from which the roofing samples are collected, areas that are representative of the involved roofing or the roofing issue in dispute should be the primary location of collection.
- Roofing samples generally should not be removed from areas of high traffic because marks in and conditions of roofing from these areas are most likely understood as being mechanically caused.
- Roofing samples should include not only the roofing membrane, but also all materials above the decking.
- Roofing samples must be removed and handled with care, ensuring samples are not creased or torn.
- Marks made to identify samples or areas of interest must not be made within areas of interest.
- Samples destined for water column testing must locate features of interest near their centers to facilitate the water column fixtures.
- Sizes of samples and locations of areas of interest must be considered to enable sufficient areas for comparative-type testing with simulated hail in the lab.

Figure 1 – Impact testing.

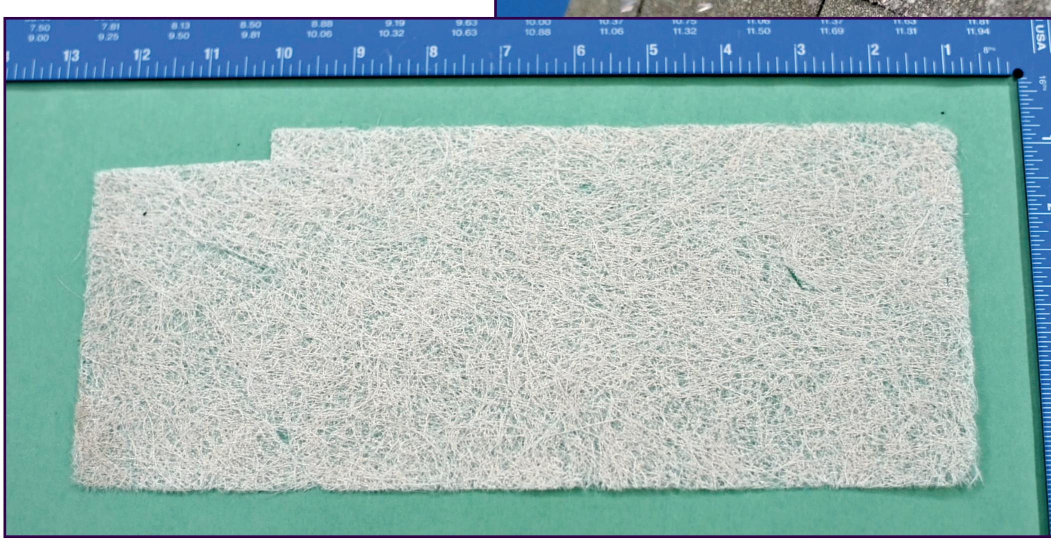

Figure 2 – Roofing membrane after being desaturated in vapor degreaser.

zant of dangers involved in roof inspections. It is also important to identify on a diagram the location of the area(s) of IR images to later document where the IR images were taken.

With the use of any IR camera, it must be reemphasized that this is not a stand-alone tool, and it only identifies a difference in thermal radiation, not the actual presence of moisture. Capacitance meters (or more commonly called moisture meters—see *Figure 4*) are used as a secondary tool in locating moisture on a roof, but core samples are ultimately necessary to confirm that the thermal patterns observed by the IR camera actually indicate the presence of moisture.

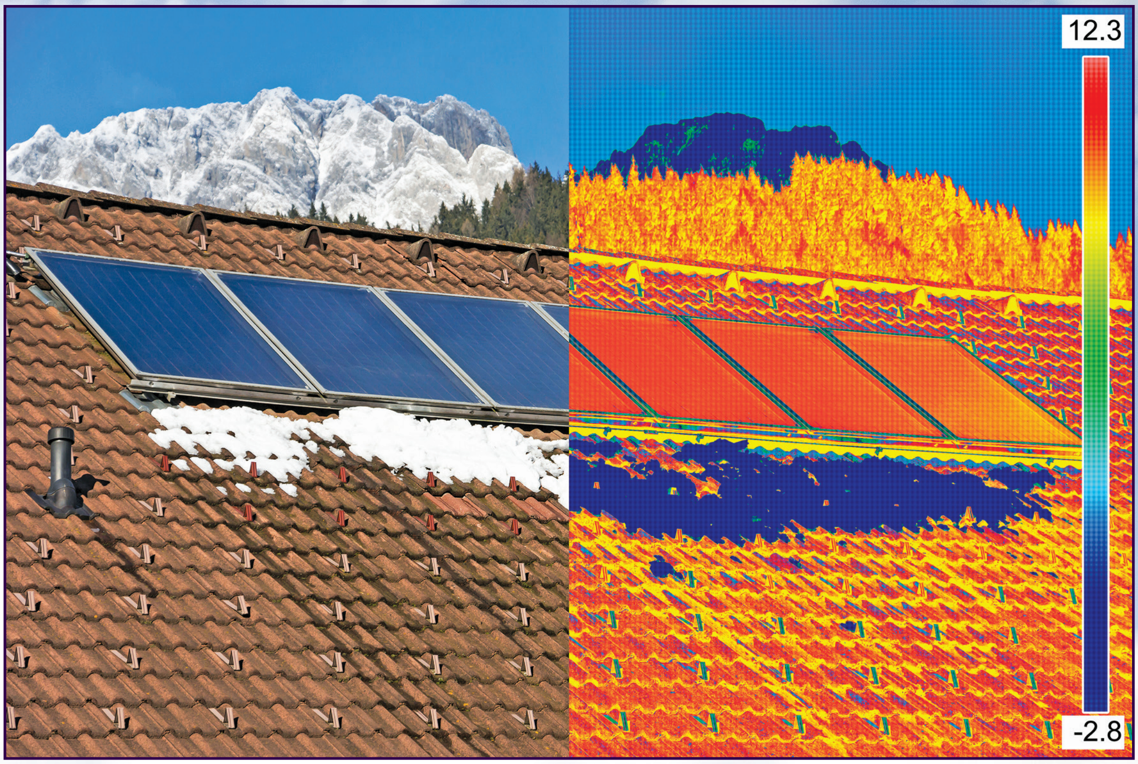

Figure 3 – Comparison of digital image and infrared thermal image.

ASTM C1153-10(2015), *Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging*, provides guidelines and best practices when performing an infrared scan on a roof. As with all technology for roof inspections, the user must have strong subject matter expertise of the materials being viewed and an understanding of how loads and wear can affect them.

UAVS

The use of UAVs is rapidly growing each year, and as technology and manufacturer competition advance, UAVs are becoming more affordable (and more regulated). A UAV can be an ideal tool to gather data or solve problems with respect to roofing assessments.

Figure 5 – UAV assessment.

UAV technology has advanced to the point that flying the UAV and capturing photographs/videos can be done after basic training on the equipment. However, in commercial use, a certification from the Federal Aviation Administration (FAA) for the UAV and a license for the pilot are required to lawfully operate one (*Figure 5*).

One question that often arises: Why use a UAV in lieu of a person? The answer comes from the level of detail and perspective view needed. A person evaluating a roof assembly for hail or wind damage would be the best course of action; however, there are times when having a person physically examine the roof is not possible or there are safety concerns. UAVs can be an invaluable tool to collect data, especially when the roof is not safe to walk on or not readily accessible due to its pitch, location, or fragile roofing materials (clay tile, asbestos, etc.). Consider a seven-story building with a 12:12 pitched roof surfaced with clay tiles. This would be a perfect example of a roof assembly that could be examined with the aid of a UAV.

UAVs can be used to examine roof coverings from a close distance, and the photographs/videos are high definition (typically 1080p or 4k resolution), which provides photographs with a level of detail comparable to those one could obtain from standing on the roof itself. The old adage, "a picture is worth a thousand words" is even more profound when considering the view from a UAV hovering 100 feet above a building with a roof covering that has been removed by a hurricane.

If access to the building is limited, a simple picture can tell the story of the missing roof covering and provide valuable details as to the complexity of necessary repairs. A UAV can also assist with the documentation of roof appurtenances such as the number of HVAC units or curbs, and roof features, such as chimney saddles or slope transitions.

The number of companies that are utilizing software and aerial imagery from UAVs to calculate the roof area is also increasing. This competition for business breeds better accuracy in the result of these calculations and their ability to be integrated into estimating software. Prior to UAVs, satellite photographs and aerial images from airplanes were used to derive measurements of roofs. With the advancement of satellite photographs, aerial images, and now the UAVs and artificial intelligence behind advanced software, gone are the days of climbing on the roof to determine how many square feet of membrane are required or the number of shingle squares needed to replace the roof.

A photograph or a video of a roof, regardless of any damage or lack thereon, may prove useful at some point in the future. While similar to an aerial photograph taken by companies such as Pictometry or a satellite photo from Google Earth, a UAV photograph will typically provide much better resolution and be much closer to the roof surface, enabling the viewer to see colors and roof types (sometimes not possible with aerial or satellite photos).

For best practices and to be successful in operating a UAV, consideration should be given to the following:

- Is the UAV operator properly licensed by the FAA?
- Is the operator properly trained in the operation of the UAV?
- Is the operator properly trained in the collection of data needed?
- Is the operator knowledgeable in the

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area that he or she is inspecting?
- Do you have permission to fly the UAV over the property to be inspected?
- Do you have the right UAV for your specific type of evaluation?
- Is it safe to operate a UAV on the property?
- Are you near an airport?

IN-FIELD TESTING EQUIPMENT

In-field testing equipment is used to collect performance data from the roof assembly in the field. These data are often essential in determining repairability or potential design/performance concerns. Field testing equipment is typically used to assess new roof assemblies after installation to ensure that they meet their required performance specifications; however, this same equipment can also be used to evaluate existing roof assemblies to determine similar performance data.

Fastener Pullout

There are many types of nails, screws, and specialty mechanical fasteners utilized in roofing. Capacities of fasteners can be determined by pull testers. The tester consists of a screw jack and load cell. The wheel of the tester is rotated, and the fastener is pulled from its base material.

The pull tester can be used to ensure that the tensile capacity of fasteners in new construction, including roofing, is as specified. In instances where fasteners have failed, the pull tester also can also be used to determine fastener capacity. This can provide the basis to determine whether failure of the fasteners resulted from fastener design, materials defects, fastener installation, or fastener maintenance.

A common application for fastener pullout testing is evaluating existing metal decks that have some form of corrosion and where there is a concern about the deck's ability to resist tensile loads from the fasteners, especially with regard to uplift requirements in accordance with current model building codes. A metal deck capable of providing the proper pullout capacity of fasteners 30 years ago may not be capable of resisting pullout specifications based on the new wind uplift requirements.

Vacuum Uplift Test

The vacuum uplift chamber (*Figure 6*) is a tool used to measure the uplift capacity of fully adhered roofing assemblies. The purpose of the vacuum uplift chamber is to try to lift the adhered roofing membrane assembly using negative pressure to simulate wind loading in accordance with FM Property Loss Prevention Data Sheet 1-52 or ASTM E907, *Standard Test Method for Field Testing Uplift Resistance of Adhered Membrane Roofing Systems* (the ASTM E907 is presently in redevelopment). Uplift pressures are calculated in accordance with ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, which is incorporated in the *International Building Code* (*IBC*). Uplift pressures are greatest in corners of the roof, followed by the edges, and then within the field of the roof.

The vacuum is applied to roofing via a 5- x 5-ft. dome. Vacuum pressure is applied and incrementally increased until the target pressure is achieved, roof system failure occurs, or the membrane stretches beyond specified values. When failure occurs, the roofing is cut and observed to determine the

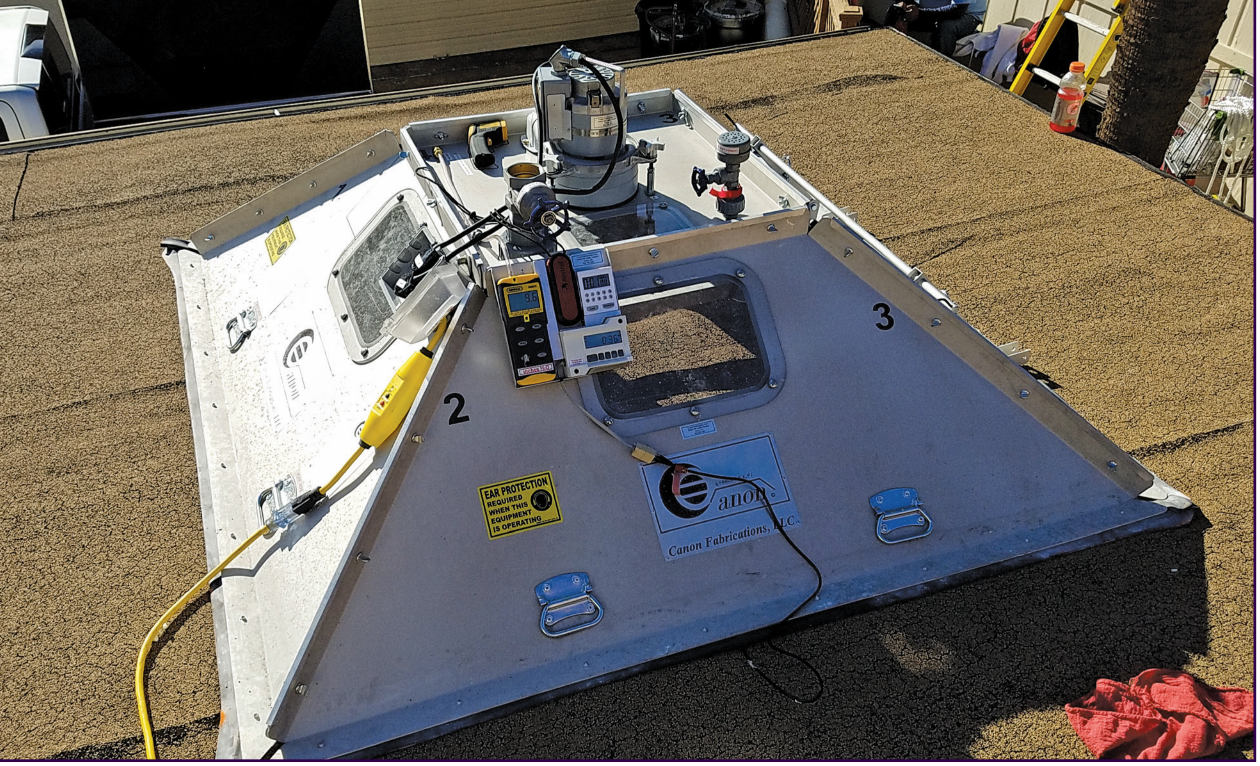

Figure 6 – Vacuum uplift testing.

The first step in roofing assessments involves the correct identification of the roof assembly. Next, the consultant needs to be able to determine if the roof has sustained damage and develop the scope of repairs. In complex situations, proper use of technology can assist in evaluating the performance of roofing assemblies in a quantitative manner that extends beyond visual observation, while also aiding in the development of the scope of repairs.

cause of failure.

Beyond the justification of new roofing capacity, the vacuum uplift test plays an important role in the forensic world. Consider the partial blowoff of an adhered membrane from a roof. The vacuum uplift test can be applied to those areas that appear intact in order to measure their capacity so that the appropriate repair can be determined.

Another example would be a membrane roof bonded to cover board or insulation that has been struck by hail. The membrane may no longer be bonded to the cover board or insulation at areas where the bonds were broken by hailstone impacts. In certain situations, and when conditions are right, the vacuum uplift test can be used to determine whether the roofing membrane still maintains adequate capacity by testing in the corner, edge, and field zones. The testing can provide the basis to determine whether roofing uplift capacity is adequate, partially adequate, or inadequate.

Bonded Plate Test

The bonded plate test uses the same standards as the vacuum uplift test and the same standards and codes to calculate uplift roofing pressures. The uplift force is applied mechanically to a 2- x 2-ft. plywood panel, which is bonded with adhesive to roofing. A strip 2 to 3 in. wide is cut from roofing around the edges of the plywood panel to isolate the tested roofing area. The plywood panel is pulled mechanically with a mechanism atop a tripod with a load cell. Similarly, the load is applied in increments, then maintained for a prescribed period. The regimen is repeated until the target pressure is achieved or roof system failure occurs. If failure occurs, the roofing is cut and examined to determine the cause of failure.

CONCLUSION

Whether a commercial roof with massive expanses that cover acres of area, or a single-family residential structure with two roof slopes, combining expertise with cutting-edge technology better supports the scientific analysis of roofing matters.

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