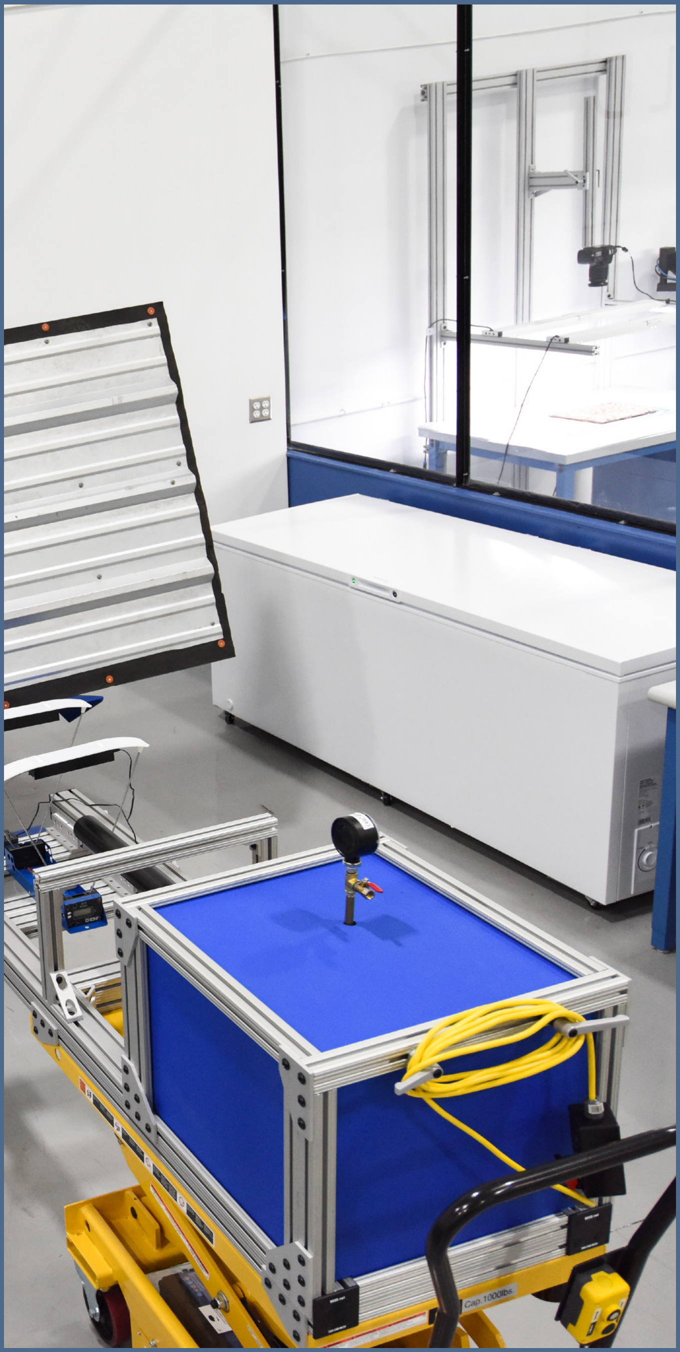

PERSPECTIVES

How Technology is Revolutionizing Complex Roofing Assessments

Our perspectives feature the viewpoints of our subject matter experts on current topics and emerging trends.

OVERVIEW

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

Roofing consultants and engineers can generally make a confident determination, after a thorough roof inspection, that results in one of three possible outcomes; 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 utilizing roofing labs, infrared thermography, drones, and in-field testing equipment.

ROOFING LABS

A roofing lab can help identify roof materials as well as determine if the roofing material is damaged, through scientific analysis. Samples, preferably 12” X 12” 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 sampling 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 the sampled roofing membrane to be placed under six inches of water for a continuous seven-day period. After this portion of the test is complete, the bottom of the membrane is cycled 25 times with 1 psig of air, allowing for even the tiniest of openings to reveal leakage.

VISUAL INSPECTION

Regardless of the roof covering, samples are examined visually with both unaided eye and under magnification to discern punctures, tears, or bruises typical of hailstone impacts. Bituminous roofing, including built-up roofing (BUR) and modified bitumen (mod-bit), as well as composition shingles can be desaturated in a vapor degreaser 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. Fractures 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.

Figure 1 *- Impact testing.*

IMPACT TESTING

Disagreements often arise regarding the causes of marks in roofing, especially when the marks are claimed to be attributed to hail. To identify possible hail strikes in a 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.

SELECTING & REMOVING ROOFING SAMPLES

Contemplate the following when removing roofing samples:

- Roofing samples should be removed by qualified roofers, preferably the roofer 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 that roofing samples are collected from, 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 as marks in and conditions of roofing from these areas are most likely understood as being mechanically caused.
- Roofing samples should not only include 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 impacts for comparative-type testing with simulated hail in a lab.

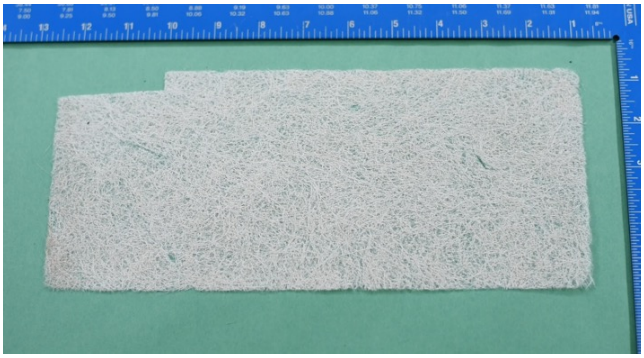

Figure 2 *- Roofing membrane after being desaturated in vapor degreaser.*

INFRARED THERMOGRAPHY

Infrared thermography (IR) can be an effective way to evaluate a roofing assembly when there are questions concerning the presence and extent of moisture. On many commercial roofs, finding the actual source of water intrusion is not simple, since the water trails may not link directly to the source of the leak.

Infrared thermography is the process of acquiring and analyzing thermal radiation captured by a non-destructive thermal imaging device, often referred to as an infrared camera or an IR camera. These devices detect variances in heat energy emitted by objects and present this information as a thermal image. Once captured, thermal images of roofs are then analyzed to identify the thermal patterns. By supplementing a roof inspection with infrared thermography, additional information can be obtained that would not otherwise be visible to the naked eye or would require significant destructive testing to be performed.

Roof IR inspections must be conducted when the roof surface is dry, and when the interior of the structure is at least 18°F (10°C) different than the outdoor temperature. This difference in temperature allows for the areas holding potential moisture to be identified with the IR camera since the presence of moisture in an area of the roof will be cooler or warmer than the surrounding areas.

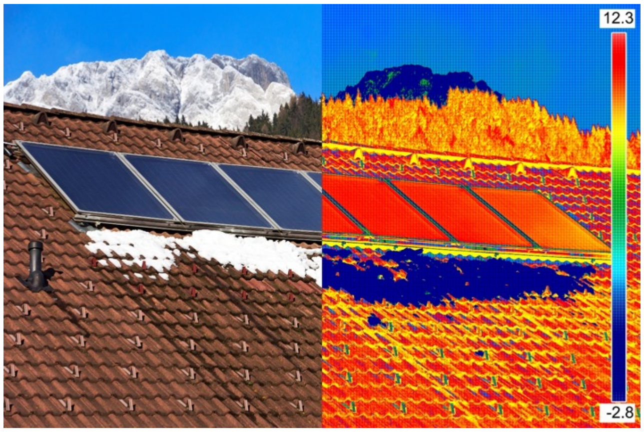

***Figure 3** - Comparison of digital image & infrared thermal image.*

A common and significant misconception about the use of IR cameras for roof inspections is that IR cameras can detect moisture. It is important to note that thermal images depict thermal radiation patterns in materials and can be present on the surface from affected substrates; thermal images do not depict moisture or distinguish between wet or dry. Therefore, while irregularities or anomalies on roofs detected as thermal patterns may indicate potential locations of moisture, temperature differentials and variations in thermal patterns often occur due to a variety of other factors. For this reason, the analysis of the thermal images of roofs should be conducted by a properly trained, experienced, and certified Infrared Thermographer, utilizing additional field instrumentation and/or testing to evaluate whether temperature anomalies are wet conditions, cold conditions, or are related to conditions other than moisture.

A roof IR inspection can be conducted via a handheld IR camera or an IR enabled drone. A handheld IR camera is a good tool to use to detect thermal patterns during a rooftop inspection. One advantage of the handheld IR camera is the ability to simultaneously produce the IR and digital image. Even on flat or low-slope roofs, it's a good practice to have a spotter on the roof with the IR camera operator since the operator can be easily distracted and not be cognizant of dangers involved in roof inspections. It's 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.

***Figure 4** - Evaluating roofing materials for moisture.*

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) are used as a secondary tool in locating moisture on a roof, but core samples are the ultimate necessity to confirm that the thermal patterns observed by the IR camera are actually the presence of moisture.

Test standard 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 perils and wear can affect them.

DRONES

The use of drones in the United States is rapidly growing each year and as technology and manufacturer competition advances, the drones are becoming more affordable (and soon to be likely more regulated). In a commercial environment, the use of a drone can be an ideal tool to gather data or solve problems with respect to roofing assessments. Drone technology has advanced to the point that flying the drone and capturing photographs/videos can be done with basic training of the equipment. However, in commercial use, a certification from the FAA for the drone and a license for the pilot is required to lawfully operate a drone.

One question that often arises is why use a drone in lieu of a person? The answer comes from the level of detail needed along with a perspective view. 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. Drones 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 drone.

Drones 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 similar to what you would expect if you were standing on the roof itself and seeing it with your own eyes. The adage, "A picture is worth a thousand words," is even more profound when considering the vantage view from a drone hovering 100 feet above a building with a roof covering that has been removed by a hurricane. This simple picture can not only tell the story of the missing roof covering but could also provide valuable details as to complexity of repairs if access to the building was limited. Further, a drone 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.

Figure 5 *- Drone assessment.*

The number of companies that are utilizing software and aerial imagery from drones 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 drones, satellite photographs and aerial images from airplanes were used to derive measurements of roofs. With the advancement of the satellite photographs, aerial images and now the drones and artificial intelligence behind advanced software, gone are the days of climbing on the roof to determine how many square feet of membrane is 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 thereof, 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 in Google Earth, a drone photograph will typically be much better resolution and much closer to the roof surface to see colors and roof types (sometimes not possible with aerials or satellite photos).

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

- Is the drone operator properly licensed by the FAA?
- Is the operator properly trained in the operation of the drone?
- Is the operator properly trained in the collection of data needed?
- Is the operator knowledgeable in the area that they are inspecting?
- Do you have permission to fly the drone over the property to be inspected?
- Do you have the right drone for your specific type of evaluation?
- Is the property safe to operate a drone?
- Are you near an airport?
- Outsourcing drone work—leave it to the experts.

IN-FIELD TESTING EQUIPMENT

In-field testing equipment is used to collect performance data from the roof assembly in the field. This data is 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 PULL-OUT

The are many types of nails, screws, and specialty-mechanical fasteners utilized in roofing. Capacities of fasteners can be determined by pull testers such as the Com-Ten Series 36. The tester consists of a screw jack and load cell. The wheel of the tester is rotated, a nd the fastener is pulled from its base material. The Com-Ten 36 has a capacity of 2,000 pounds.

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 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 pull-out testing is evaluating existing metal decks that have some form of corrosion and concern about the decks ability to resist tensile loads from the fasteners, especially with regards 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.

***Figure 6** - Vacuum uplift testing.*

VACUUM UPLIFT TEST

The vacuum uplift chamber 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 Sheets 1-52* or *ASTM E907-Standard Test Method for Field Testing Uplift Resistance of Adhered Membrane Roofing Systems* (the ASTM E907 is presently in re-development). 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 the fields of the roof.

The vacuum is applied to roofing via a 5' X 5' 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 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 blow-off of an adhered membrane from a roof. The vacuum uplift test can be applied to those areas that appear intact 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 utilizes 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' plywood panel which is bonded with adhesive to roofing. A strip 2" to 3" 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.

The first step in roofing assessments involves the correct identification of the roof assembly. Next, the assessor 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.

ACKNOWLEDGMENTS

We wish to thank our colleagues Scott Morrison, PE, Chad Zielinski, PE, and Dan Parker who provided insight and expertise that greatly assisted this research.

MORE ABOUT J.S. HELD'S CONTRIBUTOR

Dan Parker is a Senior Vice President in J.S. Held's Building Consulting Practice. He is a roof damage expert specializing in damage assessment and forensic analysis of all types of roof coverings. Dan's experience includes forensic analysis of a wide range of industrial, multi-family, commercial, transportation, educational, governmental, and residential projects throughout the country. In addition to Dan's roofing expertise, he has extensive experience with damage assessment involving other types of losses such as fire, water, theft, vandalism, flood, and earthquakes. His knowledge of damage assessment comes from hands-on experience during his tenure with some of the world's most respected companies including DSI, Allstate, CNA and Haag Engineering just to name a few.

Dan can be reached at dparker@jsheld.com or
+1 470 287 3929.

REFERENCES

- "FLIR Helps Roofing Professionals Find Moisture with Airborne Inspections." (2019). Retrieved from https://www.flir.com/discover/instruments/moisture-restoration

- American National Standards Institute (ANSI 2011) FM 4473 Test Standard of Impact Resistance of Testing of Rigid Materials by Impacting with Freezer Ice Balls

- ASTM International (2013) ASTM 7281 Standard Test for Determining Water Migration Resistance Through Roof Membranes ASTM International developed by Subcommittee D08.20