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Dating Hail: Investigation and Determination of the Date of Occurrence of Hail Impact Damage

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ABSTRACT

Hail impact can damage roof coverings, building exteriors, and exterior equipment and appurtenances. Following a hail event, evaluations to determine the extent of hail impact distress are common. However, many buildings experience multiple hail events over their service life and, in some cases, it is necessary to delineate the extent of damage from different hail events. Weather data resources are useful to determine the dates of reported hail occurrences and the reported or estimated hail sizes in the vicinity of a given site. However, data collected during a site investigation provides valuable, site-specific information, and such an investigation is necessary to evaluate a building for damage related to hail impact. Determination of damages caused by a specific hail event (or events) requires even more extensive site investigation. This paper discusses data collection and site investigation methodologies utilized to determine the date of occurrence for hail impact damage. Case studies are presented to illustrate useful investigative techniques and to provide examples of data collection used to determine the date of hail occurrence.

INTRODUCTION

The scope of most hail damage investigations is to determine if hail caused damage to a building or building system. However, in some cases it is important to determine the date of occurrence for hail damage or for potentially damaging hail. Many buildings and roofing systems experience multiple hailstorms during their service lives. Determining the date on which hail damage occurred, or delineating between hail damages related to different hail storm events, can be important for building owners and can help insurance companies determine the proper coverage period for insurance claims related to hail.

Damages from hail impact result from the transfer of energy from the hailstone to the impacted material or surface. Factors such as the size, density, and shape of a hailstone affect the damage potential. Determining the date on which hail damage occurred often requires the investigator to consider multiple data sources, including weather data and data collected from an on-site investigation.

DATA COLLECTION

Data useful to an investigator to aid in the determining the date on which hail damage occurred at a given site includes weather data and site investigation data, potentially in combination with historical imagery of the site.

Weather Data. Weather data related to hail includes free public data available from governmental entities and paid-for data provided by third-party weather analysis services or professionals. Common sources of the free governmental data are the storm event databases maintained by the National Oceanic and Atmospheric Administration (NOAA) through their National Centers for Environmental Information (NCEI) and Storm Prediction Center (SPC). These databases provide reports of hail size and the approximate respective location (latitude/longitude). The reports may also include a narrative description of the storm event or report, which can include more precise information about where the hail report was made. While, in the authors' experience, this data is valuable, these are hail reports by weather "spotters" and the potential for inaccuracies in hail size or location should be considered. It is also rare for a spotter report to be located at the specific site being investigated for hail damage.

Third-party forensic weather services generally utilize human observation data combined with radar data and proprietary algorithms to provide an estimate of hail size at a given location during a hail event. This weather data can be useful, but is an estimate of hail rather than a confirmation of the actual occurrence of hail at the site. Additionally, third-party weather reports employ varying algorithms with varying inputs into the algorithms, such that different results may be obtained from different vendors.

Thus, determining the date on which hail damage occurred at a site is not as simple as looking at the weather reporting and estimate data. Rather, site-specific investigation is important to determine the characteristics of hail that actually occurred at a given site, and this site investigation data is combined with the available weather data to determine the most likely date of hail damage.

Site Investigation Data. Data collected directly from a given site is the most reliable data when considering the occurrence, sizing, characteristics, and damage potential for hail. The appearance of burnish marks (also commonly called "splash" or "spatter" marks) and indentations on various surfaces typically provide the most useful clues for determining the timing of hail occurrences at a site.

A burnish mark results when an object, such as a hailstone, removes the exterior layer, algae, dirt, oxidation, or film on the surface of a material, leaving a localized area with a different coloration (**Figure 1**). Burnish marks from hail indicate the precise locations of hailstone impacts and provide information regarding the size of the impacting hail and the directionality of the hail, if any. Burnish marks become less distinct (or "fade") over time due to natural weathering of the surface. For this reason, burnish marks often provide the best and most reliable evidence of a recent hail occurrence at a site. The amount of time before burnish marks fade or are no longer visible varies based on the material/surface and the exposure conditions.

Figure 1. Burnish marks on a single-ply roof membrane.

Beyond burnish marks, other physical evidence of hail impact can include indentations, impressions/deformations, tearing, fractures, spalls/chipping, and punctures. Such evidence varies based on the impact energy (generally correlated to hail size) and the type of material or roof assembly impacted. Some materials may lose impact resistance or become more brittle as they age. Therefore, an investigator can use the profile of hail impact evidence observed at a given site and combine this data with information regarding the known or approximate ages of the affected materials and the available weather data to date the occurrence of hail at the site.

One condition frequently associated with hail impact is the indentation of metal panels and surfaces. Indentations can be caused by various types of impact, and the existence of an indentation is not a definitive indication that hail has occurred at a site. However, a widespread random distribution of circular indentations in light-gauge metal surfaces is generally consistent with hail. The resistance to indentation from hail impact generally increases with the metal material's thickness. For instance, it is common to observe indentations from hail impact in 26-gauge metal roof panels, but no appreciable indentations in 20-gauge cover panels for heating, ventilation, and air conditioning (HVAC) equipment at the same site. Such indentation evidence can be used in combination with burnish mark observations and weather data to help date hail occurrences.

If a surface is prone to both burnish marks and indentations from hail impact, then the presence or absence of burnish marks that coincide with indentations can be used to determine if recent hail has caused indentations. On such a surface, an indentation with a coincident burnish mark is evidence of recent hail, while the lack of a burnish mark at an indentation indicates a previous hail impact, as the burnish mark has faded and is no longer visible (**Figure 2**). This type of information is valuable and illustrates the advantage of visiting a site relatively soon after the hail occurrence.

Figure 2. Burnish marks and indentation on a metal surface. The indentation is not coincident with the burnish marks, indicating that they occurred at different times.

Similarly, the conditions of fractures in brittle materials can provide evidence of the relative age of distress. An example is a fracture in a concrete roof tile. When the fracture occurs, it will have a "fresh" or clean appearance and sharp edges (**Figure 3**). Over time, the fracture will "weather", with the fracture surface typically losing its relatively fresh/clean appearance as the exposed surface becomes stained or discolored. With the passage of sufficient time, the fracture surface often will appear similar in color to the exposed surface of the surrounding roof tiles. Therefore, consideration of the relative weathering characteristics of fracture surfaces can, in some cases, be used in combination with other data to determine the date of occurrence of a hail event with the potential to cause the fracturing, or to at least rule out a certain date or dates.

Figure 3. Fracture at a concrete roof tile. The fracture appears fresh and there is a large burnish mark coincident with the fracture location.

Materials that become brittle over time, such as plastics and some roof materials, can also provide useful information for evaluating when hail occurred. Extremely brittle materials that are easily fractured or punctured are susceptible to hail impact damage, and the lack of impact damage in such materials likely indicates a lack of hail impact or hail impact of only a limited size and energy. Polyvinyl chloride (PVC) roof membranes offer another example. Research has shown that PVC roof membranes lose a percentage of their plasticizer content as they age (Graveline 2007 and Koontz 1999). Accordingly, the authors of this paper have observed that some PVC roof membranes become embrittled and more susceptible to fracturing from hail impact over time. Careful observation of such membranes for damage, or comparison of such membranes of varying age, can provide information regarding hail impact and the likely date(s) of occurrence.

The evaluation of other easily-deformed or damaged materials can also be used to evaluate hail occurrences. One frequent form of hail impact evidence is the deformation of exposed condenser coil fins on HVAC units. Condenser coil fins are relatively malleable and are readily deformed from even minor impact. For buildings that are not newly constructed, it is common to find HVAC units of varying ages. Comparison of the conditions of the HVAC units by age and directional exposure can be used to evaluate the hail history at a given site.

Figure 4. Older unit (foreground) with deformations throughout the coil fins, with a newer unit (in the background) lacking this pattern of deformation.

Similarly, exterior insulation and finish system (EIFS) cladding is a brittle cladding material with a relatively soft substrate, typically expanded polystyrene foam. Softer surfaces tend to absorb more energy than harder surfaces, and EIFS can often be used effectively to document a hail event that is significant enough to cause fractures in the brittle surface. A comparison of data collected from the EIFS to weather reports and other evidence collected at the site may prove useful in dating a damaging hail event.

The case studies presented below include examples of data collection and analysis beyond what would be typically required to determine only the extent of damage, and also illustrate the types of methodologies and reasoning used to determine dates of hail occurrence.

CASE STUDIES FOR DETERMINING DATES OF HAIL OCCURRENCE

Case Study #1. This first case study is relatively straightforward and illustrates some of the common data gathering that can be used to determine the date(s) on which hail occurred at a given site. A property with 18 single-story metal buildings, clad with 26-gauge metal roof and wall panels, was evaluated for evidence of hail impact, including indentations in the metal panels and the date of the relevant hail occurrence(s). The buildings were numbered 1-18. Historical aerial imagery was used to determine the approximate ages of the buildings, as indicated in **Table 1**.

Table 1. Construction Date Ranges for Subject Structures based on Aerial Imagery.

Date Range	Building Nos.
December 20, 2002 to February 28, 2003	1-5, 7
February 28, 2003 to November 28, 2003	6, 8-11
September 27, 2005 to January 31, 2006	13-17
January 31, 2006 to February 3, 2007	12, 18

A distinct pattern of indentations consistent with hail impact was present on the roof panels and west wall panels of Buildings 1-11 (**Figure 5**). By contrast, there was no pattern of such indentations at Buildings 12-18. Burnish marks observed throughout the site were approximately 3/8" [1.0 cm] across or less, and these marks were not coincident with the indentations at Buildings 1-11.

Figure 5. Circular indentation in metal panel roofing.

Considering the known ages of the respective buildings, it was determined that the hail that caused indentations in the metal panels at the site had occurred in the time period between 2003 and 2005. The weather data indicated two hail events in the vicinity of the site within that period, both in the spring of 2005. Since the site visit was conducted in 2018, approximately 13 years after these storms, it was not possible to determine which of the two storms contained the indentation-causing hail (or if perhaps both storms did). Nonetheless, the determination of the discrete time period of 2-3 years for this hail was sufficient for the purposes of the investigation.

Case Study #2. This case study is more complex than Case Study #1, and involves determination between two distinct hail events for a large commercial facility. The facility had modified bitumen membrane roofing covering the main large roof sections, with metal panel roofing at some smaller areas. The facility also had numerous rooftop mechanical units and exhaust fans of varying ages. The two hail events of interest occurred only approximately two years apart: one in April 2016 and the other in April 2018. Available weather data indicated larger hail from the 2016 hail event when compared to the 2018 event (2.6" [6.6 cm] versus 1.0" [2.5 cm] diameter hail, respectively according to one weather source).

The investigation began in August 2018, just over 4 months from the date of the most recent reported hail event. Several surfaces exhibited large, faded burnish marks measuring up to 2 1/2" [6.4 cm] across and smaller, less faded (i.e., more recent) burnish marks measuring up to 1/2" [1.3 cm] across (**Figures 6 and 7**). The larger and more faded burnish marks typically exhibited a distinct west-to-east orientation, while the smaller and less faded burnish marks had a slight east-to-west orientation or no orientation (i.e., the hail generally fell straight down).

Figure 6. Large, faded burnish mark 2" across with west-to-east directionality.

Figure 7. Smaller, less faded burnish marks.

A small building with metal panel roofing was located just to the east of the main building. This smaller building had a lower roof height than the main building and was therefore partially "protected" from directional hail travelling west-to-east. On this roof, large burnish marks were oriented west-to-east and had coincident indentations measuring up to 1 1/2" [3.8 cm] in diameter. There was also a pattern of the smaller burnish marks with no distinct orientation and with no coincident indentations in the metal panels. The larger burnish marks and indentations did not exist at the west-most portion of the roof, closest to the taller main building (**Figure 8**). This provided further evidence of the different orientation and sizing of the two hail events, as the west-most portion of this low metal panel roof was protected from the 2016 hail that fell west-to-east.

Figure 8. Lack of large burnish marks at the west portion of the low metal roof adjacent to the taller main building. The chalk mark denotes 1/2" [1.3cm] maximum burnish mark size at the area along the west side of the roof, close to the adjacent building.

During the investigation, it was observed that burnish marks maintained their appearance better on some surfaces than others. For example, on the cap flashing, burnish marks that were ultimately determined as having occurred during the 2016 hail event had not significantly faded at the time of the August 2018 site visit. Similarly, burnish marks from the 2016 event also maintained their appearance on the finish of some window frames which had significant surface oxidation. At other surfaces, however, the burnish marks from the 2016 hail event were significantly faded or were no longer visible by August 2018. Additionally, some appurtenances that were present in 2018, but not in 2016, provided further information regarding the size and characteristics of the April 2018 hail impact at the site.

Information gathered from multiple sources throughout the site were used to determine that hail with a maximum size on the order of 3" [7.6 cm] in diameter occurred during the April 2016 hail event, while much smaller hail, less than 1" [2.5 cm] in diameter, occurred during the April 2018 hail event. This was generally in line with the available weather data, although the estimated hail sizes that occurred at the site, as determined based on site observations, differed somewhat from the reported and/or estimated hail sizes obtained from weather sources. This case study shows that data from multiple sources, including data from different materials of varying ages, can be important when analyzing the date of hail occurrence. This case study also illustrates the variability of visible weathering of burnish marks on different surfaces.

Case Study #3. Multiple buildings owned by a school district, spanning nine (9) campuses, were evaluated for hail impact, including for impact that occurred during a specific time period. The buildings involved in the investigation had a wide variety of common roof coverings, including multiple large roofs covered with single-ply thermoplastic (PVC) membranes. Fractures in the PVC membranes (**Figure 9**) and a pattern of indentations at a portion of the metal roof panels and appurtenances were observed and determined to be consistent with previous hail at the campus sites. Eight (8) of the nine (9) campuses were located within a radius of less than 3/4 mile [1.2 km]. The scope of the investigation included a request to determine if hail damage had occurred during a specific one-year time period of interest (this period was approximately 4-5 years prior to the site visits).

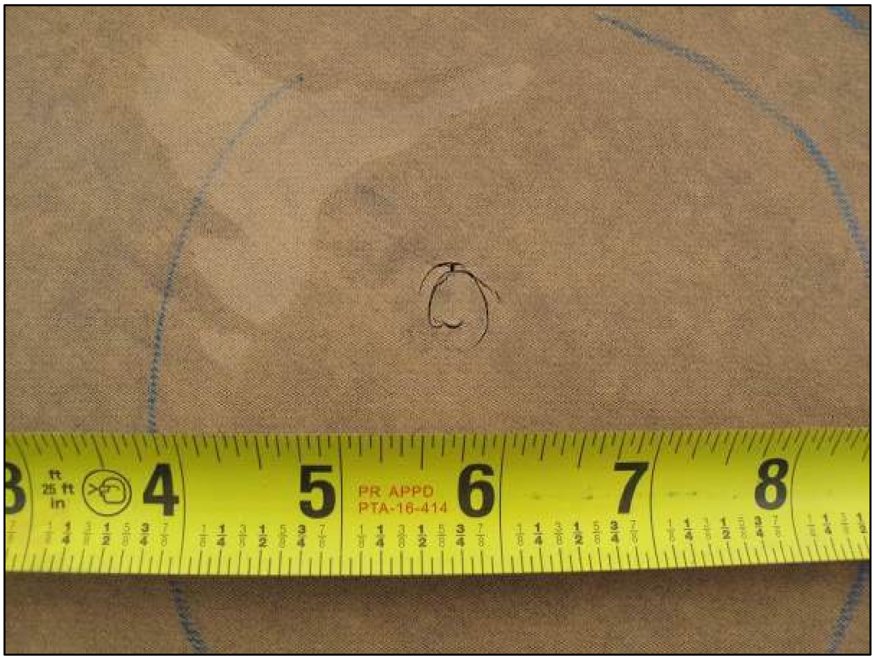

Figure 9. Circular fracture in a PVC roof membrane.

The roof coverings at the evaluated buildings had been present for many years, and had most likely been exposed to multiple storm events during their service lives. In order to analyze the contribution from storm events that had occurred during the specific one-year time period of interest, available weather data was reviewed, and the following site conditions were considered and analyzed:

- The presence or absence of hail-created burnish marks on surfaces.
- The presence or absence of hail-created indentations on metal roof panels, metal roof vents/fans, parapet wall metal copings, and exposed condenser coil fins of rooftop packaged cooling units, with consideration given to the respective ages of the affected items.
- Analysis of available meteorological weather data.

Burnish marks consistent with hail impact were observed at the campuses. These burnish marks were slightly faded and limited in size to approximately 3/8" [1.0 cm] in width and smaller. This indicated the limited size of the recent hail, but the marks were generally consistent with hail that had occurred subsequent to the time period of interest. Indentations in metal roof appurtenances and roof panels were not coincident with burnish marks, and were therefore not consistent with the recent hail that created the burnish marks at the campuses. While this ruled out the most recent hail, it did not specifically rule out the time period of interest.

Based on the evaluation of metal appurtenances and surfaces of a known age, it was determined that, while a pattern of indentations consistent with hail impact existed throughout the campuses, items that had been installed as recent as approximately 6-8 years prior to the site visits did not exhibit such indentations. In fact, multiple metal panel roofs that had been installed prior to or during the time period of interest did not have a pattern of circular indentations consistent with hail impact (**Figure 10**). Further evaluation of exposed condenser coil fins throughout the campuses indicated that units manufactured within approximately 10 years prior to the site visit exhibited only relatively small circular deformations, on the order of 1/4" [0.6 cm] in width and smaller. However, older units exhibited significantly larger circular deformations up to 1" [2.5 cm] in width.

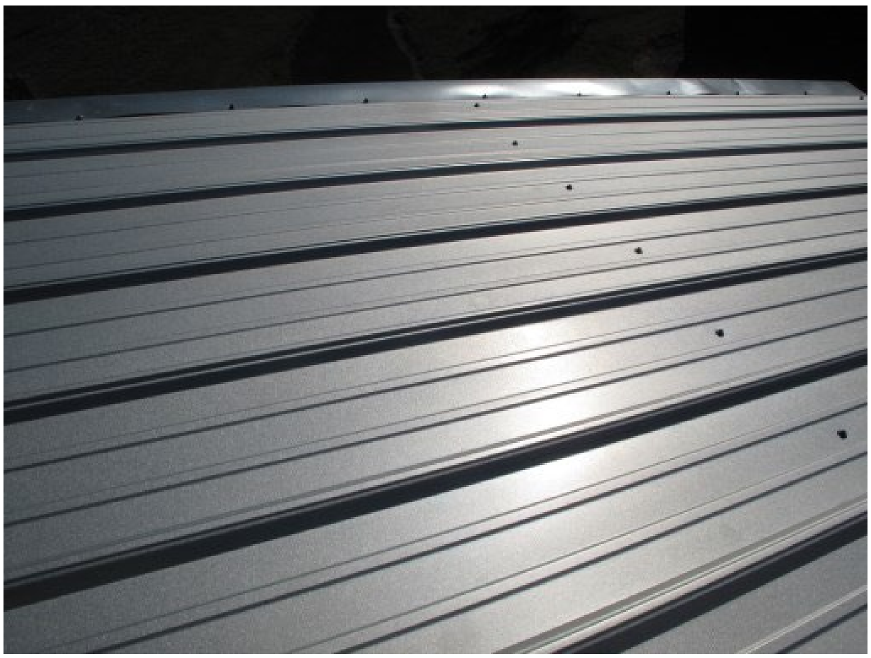

Figure 10. Lack of indentations in a metal panel roofing.

Based on the conditions observed throughout the campus sites, it was determined that hail that occurred during or subsequent to the time period of interest (approximately 4-5 years prior to the site visits) was of limited size and was not capable of causing damage to the roof coverings or indentations in the metal panels. This was consistent with the weather data, which indicated limited hail within the time period of interest and larger occurrences of hail prior to that period. Based on careful evaluation of the site conditions, it was determined that the hail that had caused damage to the roof coverings and indentations in the metal roof panels at the campuses had occurred prior to the time period of interest.

CONCLUSIONS

Much of the data collection necessary to determine the date on which hail occurred at a site is similar to that required during an investigation to determine the extent of hail damage. However, gathering additional data and performing a more detailed analysis of this data is often required. The case studies presented in this paper illustrate the successful use of data collection, including site-specific data collected and analyzed using forensic investigation methodologies, to determine the dates (or approximate dates) on which hail occurred at the respective sites.

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