C45 Weather Data—Applications in Forensic Engineering Investigations

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The goal of this presentation is to show how recorded weather data can assist analysis for atypical forensic engineering cases.

This presentation will impact the forensic community and/or humanity by providing additional tools in investigating cases. Humanity is impacted by the fact that weather records provide a higher level of accuracy in the engineer's analysis and greater confidence in the results.

The use of weather data is a routine and common practice in forensic engineering investigations. Organizations such as the National Weather Service (NWS) and National Climatic Data Center (NCDC) provide recent and historic data for hundreds of individual weather stations. This data is frequently used in analyzing structural failures that may have been caused by high winds, ground snow depths, and precipitation. Records pertaining to phenomena that obscure visibility, such as fog and direct sunlight, are used in accident reconstruction. Weather data can also be used for less common cases where assessing the capability of a mechanical system is pertinent. Two such cases will be examined in this presentation.

The first case involves a claim of ice formation at an outdoor car wash. While ice would be expected during cold weather, this particular car wash was equipped with a hydronic snow-melting, or radiant heating, system. This system included pipe embedded in concrete that contains a heated solution flowing through a closed loop. The fluid produces heat that radiates into the concrete and serves to melt ice and snow that have accumulated on the surface. A component in designing radiant heating systems is the determination of the heating requirement. This requirement is set forth by the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) HVAC Applications Handbook.

The heat flux required at the snow-melting surface "q_o" is determined by the following equation:

$$q_o = q_s + q_m + A_r(q_h + q_e)$$

The sensible heat flux "q_s" is that which is required to raise the temperature of snow falling on the slab to the melting temperature. The latent heat flux "q_m" is the heat flux required to melt the snow. These quantities are based on recorded dry bulb temperatures and snowfall rates. The snow-free area ratio "A_r" is used to reflect the insulating effect of partial snow cover.

The convective and radiative heat flux "q_h" through the slab is examined for the snow-free surfaces. This quantity is based on the recorded temperatures and wind speeds near the slab surface. The evaporation heat flux "q_e" is the heat required to evaporate water from a wet surface. Temperatures, wind speeds, and humidity levels are used to compute this quantity.

The claim involved a slip-and-fall accident inside a bay of the car wash on a day with below-freezing temperatures. Witness statements on the day of the accident and a photograph of the car wash bay the day after the accident support the contention that ice formed in the area of the fall. Subsequent analysis determined that the radiant heating system was on during the time of the fall. Testing performed after the accident revealed that the system adequately heated the slab above freezing temperatures. However, the weather conditions during the testing date were not comparable to the day of the accident.

The heat flux analysis was performed for the day of the accident, where ice was reported to have formed, the day after the accident, where photographs documented the ice formation, and the day of the testing, where it was determined that the system was adequate. This analysis accurately predicted that the heating system would not have been sufficient to prevent ice formation on the day of and after the accident. Moreover, the analysis showed that the heating system would have adequately heated the slab on the day of the testing.

The second case involves allegations that roof improvements caused damage to a residential HVAC system. The home contained three separate attic spaces and two cooling systems. The roofing tiles were replaced during a month in early spring. The roof replacement involved replacing the powered attic vents with continuous ridge vents. The original construction included only two powered vents, which left one attic space without outflow air. It was alleged that the new ventilation system was inadequate, which produced excessive heat in the attic and caused the refrigerant lines to "freeze up."

The cooling systems were repaired prior to the inspection of the home. Moreover, the HVAC repair company did not adequately document the work performed to the units. The dates of repairs did not coincide with the installation of the vents. The failures of the HVAC systems occurred in late summer, several months after the roof was completed.

An analysis was performed in accordance with the ASHRAE Fundamentals Handbook and an airflow model for attic thermal performance devised by the Florida Solar Energy Center. The following equation details the total mass flow rate "m_{tot}" based on observed conditions:

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$$m_{tot} = R\sqrt{m_{buo}^{2} + m_{wind}^{2}}$$

The total airflow is driven by the mass flow rate in the lower attic caused by buoyancy “m_{buo}” and the wind-driven mass flow rate “m_{wind}”. The “R” variable is based on the increase in flow caused by the larger soffit inlet area as compared to the ridge outlet area. These quantities are based on ambient temperatures and wind speeds recorded by nearby weather stations.

The analysis was performed for the time period extending from early spring to late summer. Airflow rates for each day were computed given the new ridge/soffit ventilation system. These results were compared to the maximum possible airflow rates produced by a powered ventilator. The analysis showed that the ridge/soffit ventilation system consistently outperformed the original system by at least 40% to 80% for the loss dates. These results represent a worst-case scenario as the new system was compared to a powered fan that was continually running. The original powered fans were activated by a temperature switch. Thus, airflow would only be forced out of the attic when the temperatures reached a sufficient level. The conclusions reached by the mass flow analysis revealed that the new ventilation system improved conditions in the attic spaces. Thus, the claim that the cooling system was overloaded due to excessive attic temperatures is without merit.

The above cases detail the usefulness of weather records in forensic engineering investigations. The cases are relatively uncommon and may provide attendees with additional tools in their professions. Moreover, the weather data are derived from independent and reputable sources, which will connote similar qualities to the engineer’s work.

Weather Data, Heat Flux, Mass Flow Rate