The Role of Building Sciences in Predictive Maintenance Programs

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ABSTRACT

Following California's lead, Congress has indicated plans to introduce legislation to require EPA to set national guidelines for what levels of toxic mold (stachybotrys spp.) constitute a "health risk". Best's Review, an insurance industry publication, recently reported at a national mold symposium, sponsored by the Property Loss Research Bureau, that attorneys for the insurance industry encouraged insurance companies to pursue subrogation in mold claims. From claims of health troubles to damage to buildings, mold poses a growing problem.

For over twenty years infrared thermography has been used to diagnose building components. Roofs, walls and structural components in addition to the electrical and mechanical systems have all been included in the list of uses for thermal imaging. However, as building sciences have matured and infrared cameras, also known as thermal imagers have improved, the use of nondestructive thermal imaging to examine the building envelope for potential mold causing water leaks provides the opportunity to expand the role of predictive maintenance in facilities.

Water intrusion is the most significant factor in building premature deterioration. In addition to contributing to the growth of mold, water penetration of building materials can reduce insulation effectiveness, corrode metals and cause the chemical breakdown of many organic materials. Rain penetration is not the only source of moisture; condensation, ground water and facility processes can all contribute to moisture in the building envelope.

The amount of effort and expense that can be justified to identify and minimize water penetration is changing. Given that insurance companies intend to purse subrogation in mold claims, the facility manager who fails to recognize and act upon a water penetration situation may well be held liable for damages.

This paper will detail the procedures of non-destructive evaluation on a variety of buildings and report the findings of these inspections.

Keywords: Building Sciences, Building Envelope, IR inspection, IR thermography, Moisture, Mold

1. INTRODUCTION

If building components are to be incorporated into a facility predictive maintenance program, it is important to define the scope of the inspections to be performed. For purposes of this paper let us limit our scope to potential sources for excess moisture or water in facilities. The most common sources are as follows:

~ Roof Leaks	~ HVAC Condensation	~ Plumbing Leaks
~ Construction Defects	~ Production Processes	~ Environmental Factors

Each of these areas is self explanatory perhaps with the exception of environmental factors. Include are floods, site drainage, high groundwater table and climate. The impact of these environmental factors will vary depending on the goal of the inspection program. If that goal involves reducing the growth of mold, environmental factors such as climate play a big part in the program. For example, mold growth is facilitated by heat and humidity. Temperatures between 68 and 86 degrees Fahrenheit along with relative humidity in excess of sixty percent are factors that support mold growth.

Given this information certain production processes or operations, which produce both heat and moisture, should also be analyzed to determine the extent of inspection and monitoring required to make decisions on moisture remediation. These additional monitoring efforts would be in addition to or in conjunction with current predictive maintenance programs. Depending on the construction type and use of a facility, the biggest concern from excessive moisture can range from structural building damage in a factory setting to sick building syndrome from black mold (aspergillus variecolor) in school and office buildings.

2. BUILDING ENVELOPE INSPECTION

The complexity of inspection varies in direct relationship to the complexity of the facility being inspected. One factor that assists in the inspection of a building envelope is the use of pressurization or depressurization of the structure. This process can greatly enhance the thermal visualization of conductive and convective (air leakage) losses. Air leakage often locates points of water leakage in the building envelope. To conduct this type of inspection a series of tests performed in the following manner can document conductive and convective losses of the building envelope. These losses can translate in potential moisture problems with the building envelope with the presence of condensation (conductive) and water leaks (convective).

1. Thermo graphically inspect the building under normal pressure, that is, settings maintained during the operation of the heating, ventilating and air conditioning system. In multistory buildings, determine which floor represents the neutral plane of the building. Where possible, document the operating pressures at each floor above and below the neutral plane floor.

2. Pressurize or depressurize the structure. Sustain the highest even interior pressure, not to exceed 50 Pa (.20 w.c.), through each floor of the structure. Document sustained pressure at each floor of the structure.

3. Thermo graphically inspect the building envelope during sustained positive operating pressure. Following same inspection pattern as conducted in the first infrared inspection. Document surface temperature for comparison with the first inspection.

Using this method a three story EIFS (exterior insulation finish system) building was inspected for water leak problems.

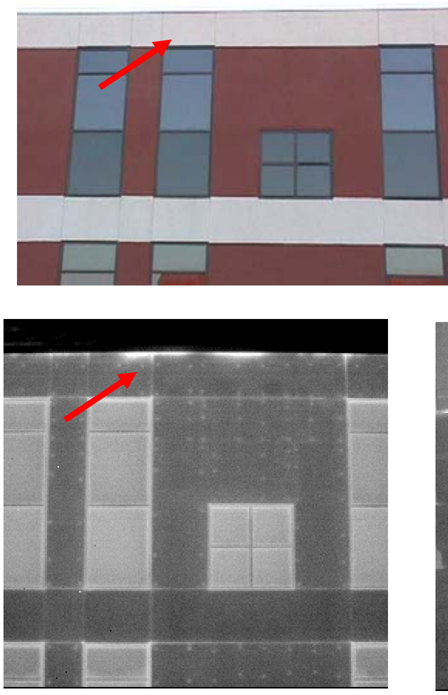

FIGURE 1

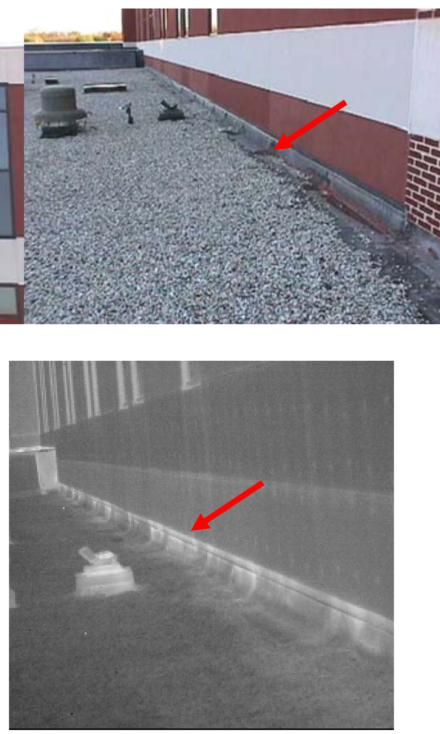

FIGURE 2

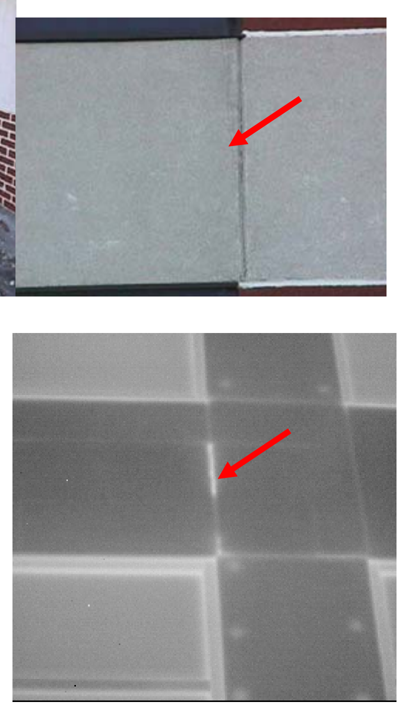

FIGURE 3

The south wall of this newly constructed three-story building was the focus of the inspection. At the junction of the new construction and the single story existing construction an active leak had developed. After pressurizing the facility and thermally imaging the exterior elevations, three leakage sites were documented. Beginning with **FIGURE 1**, the parapet cap flashing was found to be leaking. In other words, it was exhausting warm interior air from under the metal cap detail. While this finding might be considered typical of building of this construction, at this south elevation was the only elevation that presented this thermal pattern. Additionally, the active water leaks only occurred when there was a driving rain storm (except when snow was involved) from the southeast. Pressure differential at this location measured just less than 18 Pa with an interior pressure of 18.2 Pa on the third floor. These two facts, keeping in mind that no other elevation, north, east or west presented this thermal pattern offer strong evidence that this location could leak water under certain environmental conditions. Additionally, this air leakage is an energy and comfort concern for the building.

At first floor roof level, the location where the new three story building was connected to the existing one story building, a pattern of air leakage was also present, **FIGURE 2**. At this location the interior pressure measured 11.5 Pa and the leakage site, which is at the base flashing detail, measured positive 3.8 Pa. After discussions with facility personnel, it was discovered that when snow would "drift" against this wall a water leak would develop. Further examination of the base flashing detail revealed a significant crack at the bottom of the EIFS. As with the first leak site, given certain environmental conditions this detail was a location for water leakage into the building.

Finally, a third location of air leakage on this wall was documented. **FIGURE 3** shows the seam of two insulation boards and the crack in the finish system leading to the leak. This thermal pattern was found in numerous locations throughout the south elevation. While some were large, most were very small. Many were at locations where the caulking had not properly adhered to the finish. Each crack presents a very definite thermal signature of air leakage. Again, if air can leak through the wall under induced positive pressure, water can leak into the building with certain environmental conditions.

All of these areas were confirmed to be contributing to the water leak problems within the building. Each of the problems could easily be corrected when the focus of the repair could be directed to the problem areas.

3. THE ROOF AS PART OF THE BUILDING ENVELOPE

A building envelope inspection as part of the predictive maintenance program would not be complete without inclusion of the roof. The use of infrared cameras or thermal imagers has been an accepted nondestructive low slope roof inspection technique for over twenty years.

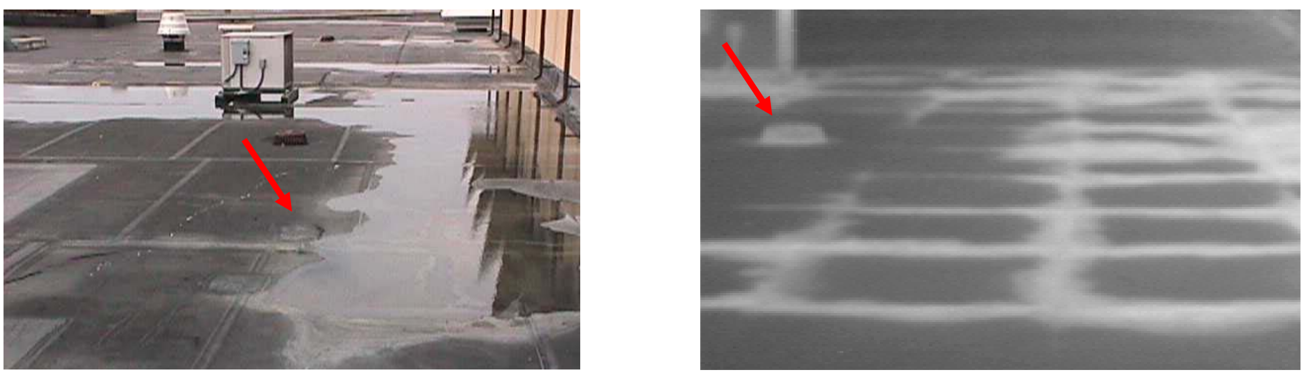

FIGURE 4

SECTION OF EPDM ROOF WITH STANDING WATER

INFRARED IMAGE OF WET INSULATION EDGES

However, it is important to note that there are currently three types of instruments that are capable of detecting roofing system moisture. Infrared cameras (see **FIGURE 4**, Note: water seen in match photograph was not present at time of infrared inspection.) provide the only method that is real time visual with no data grid required. Nuclear gauges detect and measures hydrogen through the use of a radiation source. To accomplish the inspection of an entire roof, a grid would be established and data taken with the gauge at each point on the grid (see **FIGURE 5**). The third type of nondestructive testing instrument is the electrical capacitance gauge. This gauge measures the dielectric constant of the test point. Roof materials have a value of 2-4 and water approximately 80. Once again a data grid is required and the instrument is either placed or rolled on the roof surface and the gauge meter read the dielectric constant for locations of wet and dries roofing materials.

Not all of these test methods are good for all types of low slope roof systems. Additionally, as with any nondestructive testing, a combination of two types of test methods will allow a more accurate inspection. The value of a detailed visual inspection should not be overlooked in the establishment of an inspection program.

FIGURE 5

Plotting data points on a low slope roof surface with a neutron thermalization moisture meter.

As discussed earlier, adding roof inspection to the predictive maintenance program requires establishment of goals for the inspection portion of the program. When inspecting low slope roofing there are three categories: maintain, recover, or remove and replace. The category of maintenance would include quality control inspections on new construction. Figure 6 is an example of an inspection where new construction is being added to an existing building. The concern here is that water had been introduced during construction and might be trapped in the insulation. The infrared inspection was valuable in identifying that water was trapped and where the water soaked insulation boards were located. This inspection allowed the most cost effective remediation.

FIGURE 6

NEW CONSTRUCTION CONNECTED TO EXISTING INFRARED SHOWING WET INSULATION

The importance of maintaining a watertight roof is paramount in providing a watertight facility. As shown, nondestructive testing complements visual inspection and provides information that is other wise unobtainable.

However using an infrared camera alone or on a roof system, which does not thermally image accurately, can spell disaster for the inspection program.

There has been no discussion in this paper of how to conduct an infrared low slope roof inspection. If the reader is seeking protocol for these inspections the author suggests referring to the American Society for Nondestructive Testing at its Web site: http://www.asnt.org.

4. SUMMARY

There is a lot of information to gather and decisions to be made prior to incorporating building envelope inspections into an existing predictive maintenance inspection program. This has been a brief discussion of only two components of that inspection, building walls and roof systems. Other considerations include the heating, ventilation and air conditioning system, plumbing and production processes. Each facility manager will need to assess the need and level of inspection required to meet that need.

Some of the decision may rest on the number of indoor air quality complaints that a facility has received. As public awareness about the economic and health consequences of allowing irritants such as toxic and black molds to exist in indoor environments grows, a preventative inspection program could be time and money well spent. However, mold is just one possible source of indoor air quality complaints. Currently in some industries mold is being called "the next asbestos". This leads to the potential to spend a lot of money for remedies that do not solve the problem.

Keep in mind that water intrusion is the most significant factor in both premature building deterioration and the growth of mold. While rain penetration of the building envelope is not the only source of moisture, it could be the most preventable with a good program of inspections and maintenance.

5. REFERENCES

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