Systematic Approach to Evaluating the Building Envelope

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ABSTRACT

A major responsibility of a facility manager is to ensure that his or her building is as watertight, energy-efficient, and safe as possible. This often means investigating and evaluating the building envelope (roof, walls, windows, waterproofing, and structure) to define and resolve existing problems as well as to eliminate future problems, thereby extending the service life of the building.

Whether an owner is investigating a leakage problem themselves or he's hired a consultant for a larger-scale investigation, this approach can serve as a guide to determining and repairing problems with the building envelope.

SPEAKER

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RESEARCH A BUILDING'S HISTORY BEFORE DETERMINING ITS FUTURE

Collect Historical Data

Historical data will assist in determining the original design intent, possible construction variations, and recurring problematic areas in the building. Historical information includes:

- Design documents, specifications, plans: any information that helps define how the building was designed or constructed.
- Codes and standards that were applicable at the time of the building's construction.
- Test reports on any kind of materials or systems, such as window systems, masonry components, roofing systems, etc., to compare with the original design documents.
- Construction documents (i.e., change orders, inspection reports, shop drawings, as-built drawings).
- Local practices or what was normally installed by contractors at that time and in that region (e.g., maybe they had trouble installing an envelope system or component that they had little or no experience with).

Determine the Original Design Intent and Effectiveness

Figuring out the original design intent is also key in determining what could be causing problems with a building envelope. For example, investigating problems with the roof system would include reviewing the structural, thermal, drainage, and vapor drive to understand performance requirements. For windows, the infiltration requirements, thermal-resistance levels, and the structural capabilities of the window openings necessary to keep the windows in place and under specific wind loads are necessary. When examining walls, the required thermal resistance, the structural requirements, anticipated moisture infiltration, and the drainage system are critical to understand.

In addition to the design intent, the original design effectiveness should be considered. Was this design appropriate for the location of the building? Can it perform as intended? Is the building in a high-exposure area or protected from a harsh environment?

Examine the Building's Service History

A full understanding of how the building is serving its occupants is important to all facility managers. Occupant interviews regarding active leaks provide valuable information during a building evaluation. Maintenance reports will provide useful information regarding where the building has been repaired and where the problem areas exist. All of this information helps the investigator better understand the condition of the building and determine the areas that need to be more closely reviewed.

The next step is to perform a thorough leak audit of the building to determine where leaks are occurring and under what conditions. The leaks can be affected by weather. If the leaks occur only after a wind-driven rain, then it could indicate more of a wall leakage problem as opposed to a roof leakage problem. If they are affected by temperature, then it could be a condensation/HVAC issue.

PERFORM A FIELD INSPECTION

One of the most important aspects of performing building envelope evaluations is the field inspection. After compiling the available design documentation and researching the building's service history, it is necessary to examine the existing conditions. The field inspection operations will serve to complement and expand the data obtained from the previous service history and design documentation, as well as indicate variations between original design and construction.

The scope of the field inspection will establish the types of field procedures that will be required to obtain the necessary information for a complete building envelope evaluation. Based on the information compiled to this point, the areas for inspection can be carefully selected to obtain a sample of potential building deficiencies.

Access Methods

There are several access methods that may be utilized to reach difficult wall/building areas to gather data:

- *Two-Man Ground Lifts* – Two-man ground or rolling lifts can double as observation and testing platforms with the ability to relocate quickly and conform to irregular building geometry. Accessible land directly adjacent to the building is necessary for rolling lifts.
- *Swing Staging* – Swing staging, like the two-man ground lift, offers a suit able platform for observation and testing but is more suitable for straight vertical drops with a flat building geometry. Roof access is required to set up and move the swing staging.
- *Rappelling* – Rappelling, or industrial rope access, is a method borrowed from mountain climbers that allows the investigator to safely access structures by descending and ascending suspended ropes. It is an inexpensive, useful method of vertical building access to perform evaluation and light test procedures, with the ability to relocate quickly.
- *Ground Observation* – Ground observation with the use of binoculars is useful to spot potential problematic areas, or simply to verify or acquire quantities of components. High-powered binoculars and vantage points such as adjacent buildings or roof levels will help to improve the field data collected.

Figure 1 – Inspection of wall using swing staging.

Identifying the Defects

Proper defect identification will help to determine the required types of repair, aid in proper repair material selection, and reveal the influences that are contributing to the deterioration. It is important to acknowledge which factors have caused degradation of the building and its components and how one deficiency and its intended repair may influence or amplify another. Careful and thorough defect identification is critical to obtain long-lasting, quality repairs. It is necessary to eliminate the cause of the defect and not solely treat the symptom.

Correlating the interior leak audit with exterior defects assists in determining the cause and origin of various problems because it narrows down the exterior testing areas. It also helps managers prioritize repairs and a replacement sequence of work. Quite often, due to budget limitations, managers cannot rectify all of the building's problems. Knowing the cause and origin of the problems and the extent of moisture infiltration can assist in prioritizing the repairs to fit a particular budget.

TESTING METHODS

The objective of field testing is to correlate paths of moisture infiltration with the observed damages. Anyone can observe moisture coming into a building during harsh weather events, but the most reliable way to test is to actually recreate the leakage in a controlled manner so that the path of the leaks may be traced.

Testing also allows verification of the hypothesis for the cause of leakage.

There are many different types of testing that can be used during the investigation to suit a particular building's needs. These testing categories include:

- Non-destructive testing
- Destructive testing
- Laboratory testing

NON-DESTRUCTIVE TESTING

Non-destructive testing uses a variety of non-invasive tools. This type of testing requires little to no damage or interference to the building envelope. The various methods of non-destructive testing include:

- *RILEM Tube* – This calibrated device is adhered to exterior masonry walls to determine the porosity and condition of various components, including brick masonry units, mortar joints, head joints, and embedment joints.
- *Water Spray Rack (ASTM E1105)* – This test simulates a wind-driven rain condition on a facility. It can assist in determining the specific cause and origin of moisture infiltration when it is used to test independent components of the envelope. Water spraying a large area in an uncontrolled fashion will not reveal specific causes of moisture infiltration.
- *Hose Spray Test (AAMA 501.2)* – This test method also simulates wind-driven rain in small, segmented areas using a standard garden hose that has a calibrated nozzle with a pressure gauge attached. The spray is directed at a specific joint, crack, or defect to reveal potential moisture intrusion.

Figure 2 – Performing a RILEM tube test to determine porosity of a masonry wall.

- *Differential Pressure Test (ASTM E1105)* – A pressure chamber is typically constructed on the interior of the facility at a specific location to test moisture drive through an assembly or component. The assembly or component is subjected to a negative force while a spray rack test is directed simultaneously at the assembly to draw the moisture into the facility simulating a negative pressure under a wind-driven rain condition.
- *Infrared Thermography* – Infrared thermography photographs the building exterior to determine the locations of wet components. Components such as insulation and sheathing, will act as heat sinks if they are contaminated with high levels of moisture. During the day, moist and dry components absorb heat. At night, the moist areas release the heat much slower than the dry areas. By reading the heat signature, infrared thermography will help expose the moist problem areas. Small test cuts are required to verify moisture-contaminated areas.
- *Soundings (ASTM D4580)* – There are different ways to perform sounding tests, including the hammer tap test. In this test, a 16-oz hammer is tapped against concrete for sound. A hollow sound indicates areas in which the concrete has separated from the reinforcing steel, typically due to exfoliation or corrosion of the steel. Another method of sounding is chain dragging a heavy 15-ft link chain along a concrete surface to listen for hollow sounds, indicating defective concrete. This method is commonly used on parking garages and loading docks to cover larger areas effectively.
- *Pachometer Survey* – A magnetic device used to locate embedded steel reinforcement and help determine the concrete cover over the reinforcement. Generally, the pachometer is fairly accurate when measuring 1/4-in to 3-in thick concrete cover and when reinforcing placement is not too congested.
- *Polysheet Tapedown* – This test determines the presence of moisture coming through a concrete surface, typically a slab-on-

Figure 3 – Water spray test used to locate source of leak.

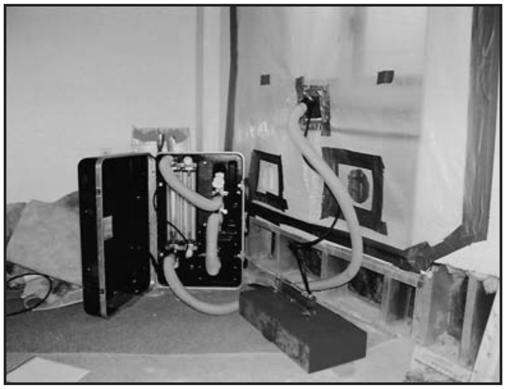

Figure 4 – Air infiltration test.

grade type of assembly where the typical problem is tile or membrane separation from the floor. A 2-ft x 2-ft section of polyethyl ene is sealed to the concrete with duct tape and removed 24 hours later. If there is moisture beneath the polyethylene, it is a good indication that there is a vapor drive through the concrete section.

- *Glass-Slide Epoxy or Crackometer* – This device is sealed in place over a crack and periodically checked to determine if any movement has occurred. If it has, the glass will crack or the meter will record movement.
- *Optical Illuminated Boroscope* – A boroscope requires a 5/8-in diameter pilot hole through an exterior wall system to allow the cavity walls of brick veneer, stud wall backup of exterior insulated finish systems (EIFS), or other types of constructions to be observed without large-scale destructive testing.
- *Smoke/Dust Tracer* – A simple and useful test, the smoke/dust tracer helps to find air infiltration. It is moved across the interior face of a window to observe the smoke and dust particles for air infiltration through the assembly.
- *Moisture Meter* – A Delm horst meter is a simple digital device that detects the presence of moisture in various building components. This test is typically accompanied by a gravimetric analysis (oven dry ing of samples), which is used to confirm the results of the Delmhorst meter.
- *Flashlight and mirror* – These everyday, simple tools can be very useful. Placing the mirror into the plenum or behind difficult-to-access areas with the flashlight will help observe concealed conditions.

Figure 5 – Performing a boroscope analysis to view wall cavity and related back-up wall components.

Figure 6 – Using a smoke/dust tracer to find air infiltration.

DESTRUCTIVE TESTING

When the main objective is to determine the existing composition and configuration of concealed assembly conditions, destructive testing is warranted. The most common methods of destructive testing are test cuts and borings.

Roofs

Test cuts in the roof assembly are necessary to determine the condition of the underlying insulation and substrate. Cutting into the system will help to verify if roofing problems are causing a corroded steel deck, or a spalled and cracked concrete deck, etc. Test cuts will also expose the as-built configurations of flashing components, roof-to-wall locations, curb locations, etc. This information is critical to the appropriate remedial design in order to specify appropriate flashing details.

Exterior Walls

Test cuts on exterior walls are a useful tool when trying to identify the origin of moisture infiltration. For masonry walls, it is most effective to make test cuts at window heads and sills, and at any through-wall flashing locations that may be suspected of allowing moisture intrusion. Masonry test cuts can expose defective through-wall flashing that is allowing moisture intrusion. Test cuts will also help determine the underlying conditions of the steel components in wall systems, which include wall ties, reinforcing steel, sub-steel columns, etc.

Gathering Samples for Laboratory Testing

Destructive testing is also used to obtain sampling for lab analysis. Sample sealants, coatings, painted finishes, roofing materials, etc. can be sent to a laboratory to determine the presence of lead or asbestos. Samples of masonry or concrete can also be used for different laboratory analyses to help identify causes of moisture/air infiltration (descriptions of these analyses follow).

LABORATORY TESTING

Laboratory testing will help obtain a better understanding of existing material types, presence of contaminants, possibility of hazardous components, and provide valuable information concerning proper surface preparation, material selection, and implementation of repairs. The following laboratory tests are some of the more useful when performing building envelope evaluations:

- *Gravimetric Analysis* – This is basically a moisture content test. After weighing and recording the *in-situ* existing sample, completely dry it in an oven and re-weigh it. The weight difference indicates moisture content and is particularly useful for insulating materials. Testing moisture contents of samples is critical to verify results from non-destructive moisture scans.
- *Asbestos and Lead* – Test the paint, sealants, plasters, roofing materials, etc. to determine if asbestos or lead is a component of existing materials. This is helpful to provide an accurate cost estimate for remediation of hazardous materials. This simple test is inexpensive at any testing lab and allows the proper remediation methods to be specified to avoid costly change orders.
- *Petrography* – Petrography determines the "make-up" of concrete. This test will indicate the size and type of aggregate, air/void ratio, type of cement, and general mix design data of the concrete. Any materials testing lab will perform this test; however, it is expensive and time consuming.
- *Compression/Tension* – By determining the actual compressive strength and modulus of rupture for the concrete, a similar strength characteristic of new repair material may be selected to maintain appropriate section behavior and extend repair life.
- *Air Entrainment* – Provides an indication of the existing concrete's durability and freeze-thaw resistance. Air entrainment is generally indicated by petrography.
- *Presence of Carbonization* – This is completed by spraying a solution of phenothe lene on the concrete substrate and record ing the depth of the solution's color change. This will indicate to what depth carbon dioxide has progressed into the concrete. Carbon dioxide will degrade the cement matrix of the concrete and lower the pH level of the concrete. The passivation layer surrounding the reinforcement is then destroyed, allowing corrosion of the reinforcing steel. Corrosion of reinforcement by carbonization usually occurs over a broad area.
- *Chloride Ion Content* – Chlorides from marine atmospheres or mists from road salts entering the concrete substrate, and salts originally introduced to the concrete via admixtures or aggregates will allow an accelerated corrosion of reinforcing steel, usually at concentrated or specific locations. The chlorides are not consumed in the corrosion process, but rather act as catalysts in the corrosion process. The corrosion will progress along the reinforcing bars, causing concrete debonding, cracking, and spalling.
- *Reinforcement Placement, Depth, Quantity, and Type* – This information may be established with the use of a pachometer or similar electronic metal detector. It is useful in determining required steel replacement

Figure 7 – Steel reinforcement corrosion resulting from high chlorides and presence of carbonization.

and structural capacities during engineering analysis phases.

ENGINEERING ANALYSIS

Using field-obtained information, laboratory results, and collected data from service history and the original documentation, a comprehensive engineering analysis should be performed. The engineering analysis should include an assessment of field and laboratory data, structural analysis, and the following:

- Thermal analysis
- Drainage analysis
- Vapor drive analysis
- Fire rating requirements
- Cost estimating (often the most important component of engineering analysis for the building manager)

General considerations for the repair of defects and replacement of components should include the following:

- Determine the effect, if any, the repairs have on the structure, surroundings, and operations of the building.
- Ensure proper preparation of surfaces to be repaired, and provide chemical and mechanical bonds for new materials.
- Material selection should include an understanding of performance limitations and should rely on the products' past acceptable performance. Material selections should include consideration of the following:
    - Compatibility
    - Maintenance
    - Life cycle

A THOROUGH EVALUATION = LONG-TERM COST SAVINGS

An in-depth evaluation of the building envelope enables the architect/engineer to develop accurate specifications for contractor bidding, which will also be used during construction. The quality of the initial field evaluation reflects directly on the quality and performance of repairs as outlined in the specification documents. A thorough investigation also promotes an efficient design specification, thereby reducing the possibility of increased costs via change orders, due to unforeseen conditions.

The time and expense to perform an initial, well-focused evaluation will save the building owner/manager money in the long run and result in repairs that extend the service life of an important asset: the building.