The Building Blocks of Enclosure Evaluation

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Building owners and facility managers have a responsibility to maintain their facilities in a safe and operational condition. A major component of any building is the building enclosure, which is the physical separator between the exterior and interior environment (roofs, wall, window, doors, and waterproofing). Maintaining the building enclosure requires a systematic evaluation to assess the condition of each building component and to determine the required repairs and system replacements, both now and in the future, to maintain each system. Proper maintenance and prompt repairs can reduce the potential for future leaks or deficiencies and can extend the service life of the building. Whether the intent is to address a known existing concern or to perform an assessment to identify the condition of the various enclosure systems to project future work and funding needs, the following approach can provide a framework for the evaluation procedures and potential test methods to consider. Additionally, published industry standards, (such as the American Society for Testing and Materials (ASTM)) evaluation, practice, and test methods, should be consulted for various steps in the process.

Historic photographs available from the City of Boston, Massachusetts, USA archives can be compared to the current building configuration to identify changes.

Research a building's history before determining its future

The foundation of any evaluation is to identify what information is already available.

EXISTING DOCUMENTATION

- **Historical data** | Gather information for registered historical buildings from national parks department, local historic societies, or local libraries and town records. Photographs or Google Earth aerial views from different time periods could identify previous alterations or additions.

- **Existing design or as-built documents** | The owner or FM team may possess hard-copy or digital drawings, specifications, product submittals, warranties, etc. from the original building construction, previous repairs, or building additions.

- **Previous evaluation reports** | The owner or FM may have existing reports from consultants previously asked to review and assess a particular system or issue.

- **Applicable codes and industry standards** | The approximate age of the building and a review of the code requirements, industry standards, and local construction practices at the time of construction can provide insight into the system configurations and construction methods likely to have been used.

Drones can provide high resolution views of roofs and other hard-to-reach areas.

EXISTING SERVICE HISTORY

- **Leak Audit** | FM teams can identify active leak locations and the conditions under which they occur. Whether a leak occurs during every precipitation event, or only during wind-driven precipitation events, certain seasons, particular wind directions, etc. can provide insight into the potential source(s). Leaks may be linked to a roof system, wall system, groundwater/subgrade waterproofing system, window system, transitions between systems, or even an HVAC system issue depending on the conditions during which it occurs.

- **Previous Repair Records** | Reviewing records and communicating with facilities personnel can identify areas that have undergone similar repairs multiple times. These repairs could be addressing symptoms instead of the source. Also, if repairs were recently performed, recurrent defects may not yet be readily visible.

Perform a Visual Field Evaluation

Performing a visual field evaluation is one of the most important elements of an enclosure evaluation as it identifies the building's current condition and the potential deficiencies that are or could compromise the building enclosure. The areas to be evaluated should be carefully selected to obtain a broad, yet thorough, understanding of the existing conditions. It is also important to understand the intent of the evaluation. Is it to identify a specific isolated leak? Understand the enclosure's overall condition? Note deficiencies to be repaired? Determine the maintenance necessary to preserve the enclosure's safety, thermal efficiency, and function? Each of these will merit different evaluation methods and focal points.

ACCESS METHODS

The following access methods can be utilized to reach difficult areas during the field evaluation:

Ground-level observation (via high-powered binoculars) is a useful, low-cost option to spot potential problematic areas. High-powered binoculars and vantage points such as adjacent buildings help improve field of view and data collection. Downsides include no hands-on evaluation and potentially a limited ability to view the entire building.

Small Unmanned Aerial System (sUAS) vehicles (drones) are gaining popularity because they can quickly and cost-effectively provide views of buildings using high-definition video and photography. They can access difficult areas including steep-sloped roofs, towers, or steeples. Recent technological advancements include infrared scanning, 3D modeling, and time-lapse recordings. Drones do have some restrictions and must be operated by certified drone pilots at approved locations and heights.

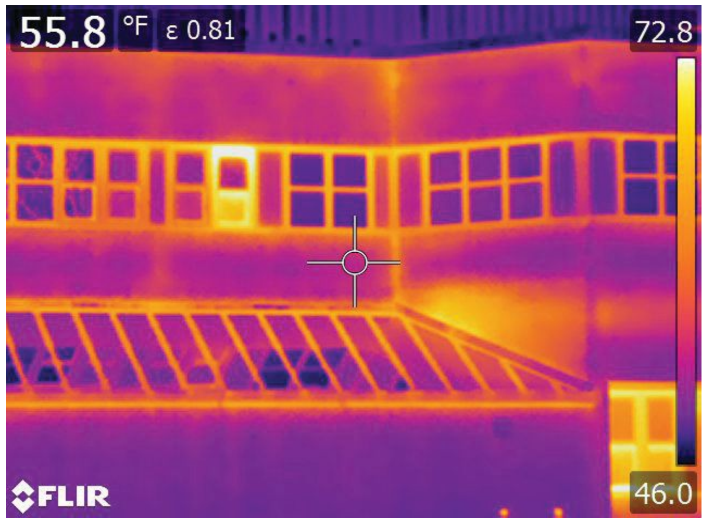
Aerial lifts/scissor lifts/crane basket access allow hands-on evaluation and can relocate quickly and conform to irregular building geometry. Lifts often require permits and additional coordination which can be costly. Lift access is typically combined with ground observation. Crane baskets can access higher elevations but are limited to where they can be used.

Swing staging offers a suitable platform for observations, test cuts, and testing. It is more appropriate for straight vertical drops. Roof access is required to set up and move the swing staging. Structural analysis of the roof framing may be required to confirm the building can support the swing staging setup.

Rope access/rappelling is a method similar to mountain climbing that allows the evaluator to safely access structures by descending and ascending via suspended ropes. It is a relatively inexpensive, useful method to perform evaluation and limited testing. Training and certifications are required.

Defect Identification and Documentation

Proper defect identification can expose the factors contributing to deterioration, determine necessary repairs, and select the correct repair material. When reviewing building defects, it is important to consider all the underlying contributing factors, which may not be immediately apparent. For example, correlating the previously performed interior leak audit with the documented exterior defects can assist in determining the cause of various problems and prioritizing repairs.



Infrared Thermography shows temperature differences, which can indicate moisture, air leakage, and thermal bridges within the building enclosure.

Perform Focused Testing

The visual field evaluation can identify areas requiring additional testing. Testing may verify a hypothesis about sources of moisture infiltration, air infiltration or other causes of damage. Test cuts may be necessary to identify the existing configurations (roofing materials, wall type, etc.), attachments (how a window is anchored to the building framing), or transitions (window flashings, roof-to-wall transitions, etc.). The system, condition, or specific concern will dictate which of the following test method(s) should be selected.

NON-DESTRUCTIVE TESTING

The following test methods can be performed without sampling or damaging the building enclosure:

- **Infrared thermography (IR survey)** detects the infrared energy emitted from an object to identify its temperature. Temperature differences can indicate potential moisture, air leakage, thermal bridging or other concerns. (ASTM C1153)

- **Electric field vector mapping** uses electric potential gradients, a voltmeter and electrical probes to detect roof membrane punctures and moisture intrusion. (ASTM D7877)
- **Capacitance moisture survey** uses an alternating electric current, a transmitting electrode and a receiving electrode to identify moisture within a roof system based on the increased impedance reading. (ASTM D7954)
- **Concrete sounding** can identify potential suspect areas (voids, delamination, etc.) within concrete based on differences in sound using chain drag, hammer contact, rotary percussion, etc. (ASTM D4580)
- **Ground penetrating radar** uses high-frequency electromagnetic waves to inspect materials including brick, masonry and concrete structures. It can be used to locate reinforcing steel within concrete and to map subgrade geologic conditions. (ASTM D6432)
- **Rilem tube testing** can determine the porosity and potential for moisture penetration by affixing a cylinder or tube to the face of the masonry element and monitoring the volume of water absorbed over a known time.
- **Air leakage testing** can identify where air flow is infiltrating the enclosure using fans, tracer gases, etc. (ASTM E3158, ASTM E741, and ASTM E779)
- **Crack gauge monitoring** affixes a gauge to the face of an existing crack to monitor expansion over time. Knowing whether a crack is stagnant or expanding can determine appropriate repair selection.
- **Hygrothermal modeling** uses software to model the heat and moisture movement through a proposed or existing wall system to help determine placement of a vapor retarder or air barrier. (ASTM E3054)

DESTRUCTIVE TESTING

In some instances, it may be advantageous to perform investigative testing that includes temporarily dismantling portions of existing systems to expose underlying attachments, substrates, and conditions to gain additional insight into the given system. The primary destructive test method are as follows:

- **Leak testing,** though sometimes considered non-destructive, has been included in this section since interior finishes may be damaged. The intent is to apply moisture to isolated areas in a methodical way at the time of installation or to recreate reported leaks. (ASTM E1105)
- **Water spray testing** employs a spray rack to expose a large area of a window or curtain wall system to moisture.
- **Hose spray test** applies moisture with a hand-held nozzle, and can focus on isolated areas such as cracks, open joints, or transitions between systems. It can also simulate wind-driven rain.
- **Flood testing** fills an enclosed area with water to identify potential leaks.

Hose spray testing can be used to identify water infiltration sources.

- **Test cuts** can provide insight into the existing layers, securement methods, and material conditions. For instance, a rusted steel lintel within a masonry wall may not be visible, but once uncovered, could explain step cracked masonry since steel expands during rusting, applying stress to surrounding masonry. Simply replacing the damaged masonry without uncovering and addressing the source (the rusting steel lintel) could leave new repairs susceptible to similar damage.
- **Test cores** from concrete or masonry elements can provide insight into the depth of a unit and its homogeneity.
- **Material samples** taken from various materials during test cuts can be tested in a laboratory to ascertain additional information.

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LABORATORY TESTING

These tests are performed on samples taken during destructive testing and relocated to a controlled laboratory environment.

- **Gravimetric analysis** determines the moisture content of a material through weighing, oven drying, and reweighing. (ASTM C138)
- **Water Absorption** measures the porosity and water absorption potential of a material. (ASTM C121)
- **Petrographic analysis** uses x-ray diffraction, differential thermal analysis, infrared spectroscopy, scanning electron microscopy, chemical reactions, etc. to separate, examine and identify material components of a sample. It can determine the type and approximate strength of a mortar sample. (ASTM C1324) It can identify minerals and constituents that may make a stone element susceptible to color change or accelerated weathering when exposed to adverse conditions, such as de-icing salts. (ASTM C1721) It can also identify air entrapment, aggregates, mix design and strength of concrete. (ASTM C856)
- **Flexure testing** determines a material's strength and elasticity through incremental load testing in particular configurations. (ASTM C78 and ASTM C120)
- **Compressive strength testing** establishes a material's compressive strength through incremental load testing in particular configurations. (ASTM C170)
- **Abrasion resistance testing** ascertains a material's potential abrasion resistance. Stone's abrasion when subjected to foot traffic is determined by measuring material loss from exposure to a power-driven grinding lap. (ASTM C241) Mortar's abrasion resistance is established by rotating-cutter methods. Concrete's abrasion resistance is determined by sandblasting or rotating-cutter test methods. (ASTM C944 and ASTM C418)
- **Hazardous material testing** of suspect materials sampled in accordance with Environmental Protection Agency (EPA) test methods and local jurisdiction requirements can identify the presence of known hazardous materials such as asbestos, lead, or polychlorinated biphenyls (PCBs). Identifying these materials allows for appropriate encapsulation or abatement procedures since uncovering hazardous materials during construction can negatively affect project schedules and budgets.

Perform an Engineering Analysis of the Building Enclosure

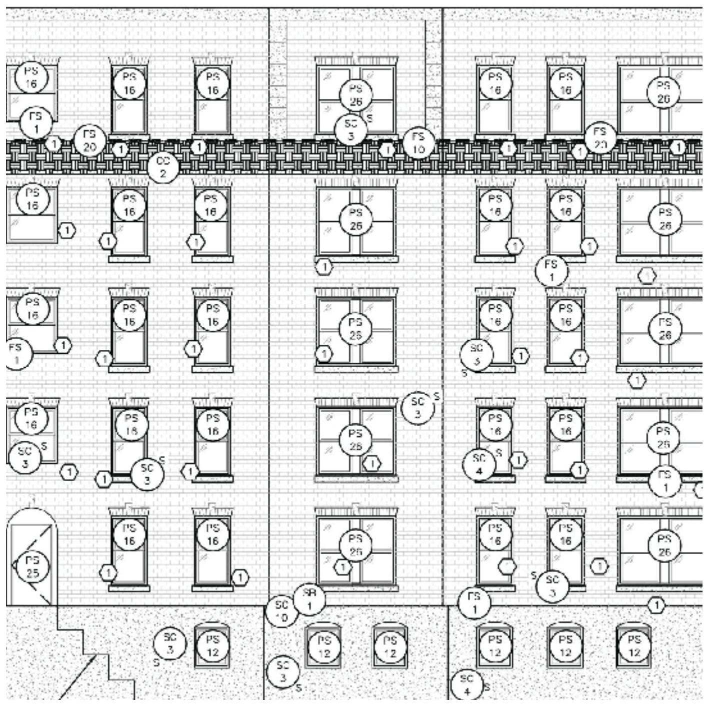
Using information obtained from researching the building's history, performing a visual field evaluation, documenting defects, and testing, the evaluator can perform an engineering analysis on the building enclosure. The building enclosure engineering analysis typically includes the following criteria:

- Assessment of documented in-place conditions and deficiencies
- Analysis of test results
- Structural analysis
- Thermal analysis
- Drainage analysis
- Vapor drive analysis
- Material fire resistance requirement analysis

Once these criteria have been reviewed, the design document development can begin.

Develop Design Documents

The design documents will indicate the location(s) and scope(s) of work to be performed, the performance requirements to be met, and the materials to be used. It is important that the repairs not only treat the symptoms, but also address underlying causes to reduce the potential for future recurrence.



Elevations drawings can be annotated to indicate the locations(s) and scope(s) of work to be performed.

The design should consider the effect of the work on the building operation, structure and surroundings. The lead time or installation timeframe for a material may be a determining factor to limit the impact to building occupants. Product selection should consider performance requirements, code requirements, compatibility with surrounding materials, remaining service life of the building, construction schedule, maintenance requirements, aesthetics and cost. Historic buildings may have strict limitations on the materials that can be used.

Cost estimates for the work outlined in the design documents can provide owners and FMs with an understanding of the potential construction cost of the proposed work. Often, due to budget limitations, not all a building's problems can be rectified in a single project. Knowing the cause and origin of the problems, the extent of moisture infiltration, and the critical areas of the facility can assist in prioritizing and phasing repairs to maintain the project budget.

Allocating the necessary time and expense to perform a thorough assessment that employs each building block of the enclosure evaluation can save the owner money by providing focused, quality repairs that extend the service life of the building enclosure. FMJ

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