BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

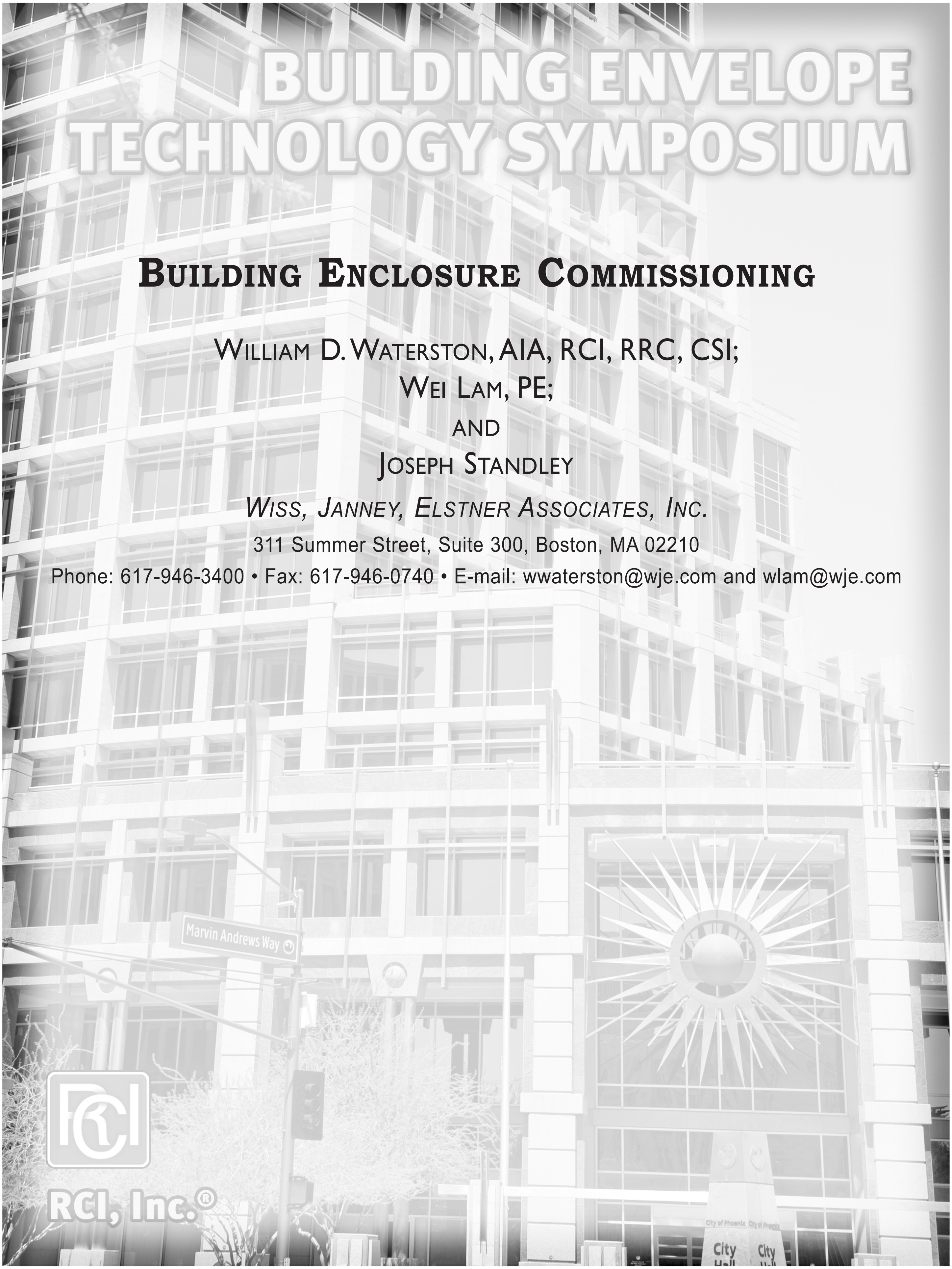
Building Enclosure Commissioning

William D. Waterston, AIA, RCI, RRC, CSI;
Wei Lam, PE;
and
Joseph Standley

Wiss, Janney, Elstner Associates, Inc.

311 Summer Street, Suite 300, Boston, MA 02210

Phone: 617-946-3400 • Fax: 617-946-0740 • E-mail: wwaterston@wje.com and wlam@wje.com



RCI, Inc.®

ABSTRACT

Over the past decade, commissioning of the building enclosure has steadily evolved and gained acceptance in the building design and construction industries. This includes development of building enclosure commissioning (BECx) standards such as the National Institute of Building Science (NIBS) Guideline 03, and, most recently, ASTM E2813-12, *Standard Practice for Building Enclosure Commissioning*. WJE will share its experience gained through involvement in development of both of these standards and provide insight on the future of BECx. The distinction between a formal BECx process and traditional quality assurance peer review and quality control construction observation services will be discussed. Through a presentation of case studies, WJE will review fundamental and advanced aspects of the BECx process, important lessons learned, and recommendations for engaging and working with a Building Enclosure Commissioning Authority (BECxA).

SPEAKERS

William D. Waterston, AIA, RCI, RRC, CSI — Wiss, Janney, Elstner Associates, Inc.

WILLIAM WATERSTON is an associate principal at Wiss, Janney, Elstner Associates, Inc. (WJE) in Boston, MA. His work includes the investigation, evaluation, and design of roofing and waterproofing systems. He is also experienced in construction document preparation and specification writing. He is both a registered architect and a Registered Roof Consultant. Mr. Waterston served as chairman of the RCI Building Envelope Symposium and is the author of several articles on roofing material choices and roofing practices. He has presented at Build Boston, RCI, and Construction Specifications Institute meetings and symposia.

Wei Lam, PE — Wiss, Janney, Elstner Associates, Inc.

WEI LAM, PE, is an associate principal at Wiss, Janney, Elstner Associates. For more than 15 years, his career has focused on performance and design related to heat, air, and moisture control related to building enclosure systems. Mr. Lam is regularly involved in building enclosure commissioning for academic and healthcare projects. He is a registered professional engineer and a contributing member of ASCE, ASHRAE, and BEC-Boston. He is an investigator in ASHRAE project 1478 RP, measuring the airtightness of mid- to-high-rise buildings built after the year 2000.

NONPRESENTING COAUTHOR

Joseph Standley, EIT — Wiss, Janney, Elstner Associates, Inc.

JOE STANDLEY, EIT, is an associate at WJE. Mr. Standley has experience in both architectural and structural investigations, with specific experience on projects ranging from waterproofing, roofing, and façade inspections, to structural-load tests and material testing for both new and existing construction. Mr. Standley regularly preforms design peer review, façade testing observation, and construction observations.

Building Enclosure Commissioning

Over the past decade, the practice of building enclosure commissioning has been increasingly adopted by building owners to achieve successful building projects. As a result, commissioning has been defined more rigorously, refined, and gained acceptance in the building design and construction industries. This is especially true in complex building types such as hospitals or museums, where building enclosure performance is critical. Building enclosure (envelope) commissioning (BECx) encourages a focus on quality assurance during the design phases, and quality control and validation during the construction and occupancy phases of a facility.

Some may argue that BECx is simply a fancy new term for the same services building enclosure consultants have been providing for years. These traditional activities include peer review of construction documents, periodic construction observation, and performance testing. As this paper will demonstrate, a comprehensive definition of BECx includes these elements but also a host of other activities that are intended to improve the quality of construction projects and increase value to the owners, occupants, and users of a building (ASHRAE, 2005).

The idea of commissioning buildings and building systems was first formalized by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), who formed a committee in 1982 to document best practices to realize facilities that performed according to criteria set forth by building owners. Based on the work of this committee, ASHRAE published its original technical commissioning Guideline 1 for HVAC&R in 1989. Following this work, ASHRAE developed Guideline 0, which outlines the general requirements of a commissioning process not focused on any particular discipline. Guideline 0 has become the basis of the National Institute of Building Sciences' (NIBS) technical commissioning guideline series, which includes NIBS Guideline 3, "Building Enclosure Commissioning Process."

In recent years and with growing demand for these services, the industry has sought to further define and clarify the process and requirements related to building enclosure commissioning or BECx. This has resulted in publications and standards, including ASTM E2813, *Standard Practice for Building Enclosure Commissioning*, and the General Service Administration's "Building Commissioning Guide."

The Executive Summary from NIBS Guideline 3 (GL03) states

> The process of commissioning the enclosure follows a similar process as other building systems. However, commissioning the enclosure differs from commissioning other building systems in the focus on materials and assemblies. The enclosure is designed and field-assembled from numerous materials with varying properties. These materials are manufactured by different companies for a specific function, assembled mostly on-site one piece at a time by many different trades people [sic] working for several different contractors with often minimal coordination. The work is performed in all possible weather conditions with the intention of meeting very well-defined performance criteria. The performance of the enclosure cannot be verified until the entire building is completely enclosed. At this time, it is not possible to tune or dial-in the performance. To access a non-performing subsystem or assembly might be very expensive. Thus, the most reliable means to achieve performance targets during construction is to assure that an expert with technical knowledge of the design and installation of the systems being proposed for the building is integrated into the design process and to visually observe the installation of a statistical sampling of the work. Verification testing should be performed throughout the installation of the enclosure subsystems and components.
>
> GL03 describes a process that provides the flexibility for an owner to incorporate building enclosure commissioning into their [sic] project. The Building Enclosure Commissioning (BECx) process is utilized to validate that the performance of materials, components, assemblies, systems, and design achieve the objectives and requirements of the owner as outlined in the contract documents. The most effective commissioning process ideally begins at project inception (during the predesign phase) and continues for the life of the facility (through the occupancy and operations phases).

Commissioning relies on a well-developed set of owner project requirements (OPR) and is a critical component of BECx as the building moves from concept to reality. The direction for the commissioning team is provided by the OPR, which is defined early and refined through predesign, design, construction, occupancy, and operations phases of the project. The OPR includes design criteria and quality standards for the building as well as long-term durability and performance guidelines, sustainability, acoustical, safety, and security objectives. The OPR provides guidance to the designers and others on the construction team as the project advances. The designer then develops a basis of design (BOD) for the various components of the enclosure that draws upon the requirements listed in the OPR.

There is a significant distinction between true commissioning and a traditional peer review and construction observation services provided by the architect or engineer of record. With commissioning, there is involvement in the entire building design and construction process by an experienced commissioning professional, the building enclosure commissioning agent (BECxA), acting on behalf of the owner. This agent focuses on the quality and performance aspects of the building, providing input on product selection, compatibility of materials, durability of detail assemblies, quality of construction, building operations, etc. Conversely, peer reviews tend to focus on review of construction details or the design as it develops, in an effort to improve the quality of the construction documents, which is only one component of BECx process.

The commissioning process is applied in various levels within all phases of the design and construction process to improve the quality of the completed building or system and assure that the building or system conforms to the OPR. The earlier commissioning can be integrated into the design and construction process, the higher the quality of the delivered building or system. Beginning the commissioning process at project inception will maximize benefits and minimize the cost (NIBS, 2012)

TOOLS USED IN BECx

The BECxA employs several tools through the project life. These tools include specifications, mock-ups of systems, construction checklists, periodic site observations, field testing and monitoring of issues and deficiencies, and remediation of deficient conditions. All of these are used for the verification of the performance of the built components within the building enclosure.

COMMISSIONING SPECIFICATIONS

As the project moves into construction documents, it is important to establish a commissioning specification and system-specific performance testing requirements within the technical specifications. The project specifications should include specification sections related to building enclosure commissioning that define and describe the commissioning process for the project. There are three locations for this information. The first includes general commissioning requirements. MasterSpec includes Section 019113 - General Commissioning Requirements, which covers the "general requirements that apply to implementation of the commissioning process without regard to the system or equipment being commissioned."

The second will be specific commissioning aspects for only the building enclosure, such as Section 019119 - Exterior Enclosure Commissioning. The work included in this section includes requirements common to all exterior enclosure-related sections:

- Validation of installation of exterior enclosure components
- Component performance verification
- Documentation of test procedures and installation
- Coordination and requirements for testing events and preparation
- Coordination of the Building Enclosure Commissioning Report

The third location for commissioning-related specifications will be within the technical specifications themselves, where validation testing and mock-up construction and other system installation items are specified. This includes specific tests to be performed on the materials and systems, the frequency and quantity of testing, pass/fail values for each test, and retesting of failed tests. Quality control and monitoring that detail the commissioning aspects of the material or system are also included in the technical sections.

MOCK-UPS

Mock-ups are used for critical assemblies such as windows and walls and at interfaces between complex systems. Mock-ups of building components such as curtain walls are constructed at laboratories for a variety of testing situations. Testing is performed to confirm that the system meets specified performance criteria. Site mock-ups are built for visual approval at the site, with example corners and materials that will be used on the building. The site mock-up is typically used to establish expected quality of work. They can also be used to verify that the systems meet specified

Figure 1 – Example of a simplified lab mock-up containing a punched window opening and rainscreen stone panels.

Figure 2 – Example of complex lab mock-up containing curtain wall, louvers, metal panels, and multiple inside- and outside-corner conditions.

Figure 3 – Spray rack installed in front of large curtain wall system during laboratory mock-up testing.

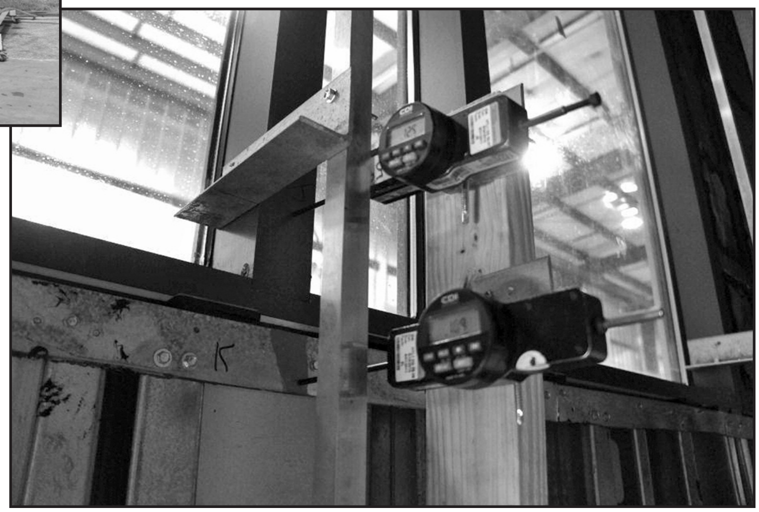


Figure 4 – Deflection gauges installed on framing system during laboratory structural testing of mock-up frame.

requirements, such as air and water infiltration resistance.

Laboratory settings allow for testing and analysis in a controlled environment. Structural testing, water and air infiltration, and even impact testing can be performed in the laboratory setting. The BECxA helps the design team determine the validation and quality testing required for each system. The laboratory mock-up may range in size and complexity, depending on the level of validation required by the owner and BECxA, as well as the project budget. Mock-ups may be as simple as a stand-alone curtain wall section or as complex as a wall containing multiple cladding systems. It is suggested that the laboratory mock-up contain typical conditions, complex details such as inside or outside corners, and transitions from one cladding type to another. The key is to build the lab mock-up as similar to the actual construction as possible while incorporating as many of the "difficult" details as possible. This provides two major benefits for the project: First, the installing contractor is afforded an opportunity to make a "trial run" and truly learn how to build the assemblies; and second, the design and construction becomes validated through a series of rigorous tests. Lab mock-up testing should be witnessed by the contractor, BECxA, architect, engineer, and owner. See *Figures 1* through *6*.

Site mock-ups represent a portion of the building enclosure and include typical construction of walls and windows but

Figure 5 – Airplane engine used during dynamic water penetration testing of laboratory mock-up.

Figure 6 – Laboratory setup for impact testing of a window assembly.

Figure 7 – Site visual and assembly mock-up with various materials used in the building wall.

should also include corners and intersections. The site mock-up, like the lab mock-up, affords the contractor and design team a trial run and helps develop and understand sequencing, material-to-material joints, flashing details, and support details. Often the site mock-up remains on site for the duration of the project to serve as a benchmark of the accepted details and quality standards for the included systems and assemblies. In some cases, such as projects that do not have the budget for lab mock-ups, the site mock-up may also be used to perform tests. Involve the manufacturers of the materials used for key components of the building enclosure, such as the air barrier, flashings, sealants, curtain wall, or wall panels to review and comment on the assembly. *Figure 7* is an example of a site curtain wall mock-up.

CONSTRUCTION CHECKLISTS

Checklists are developed by the BECxA for use by field personnel observing the installation of the components and systems. They can be used by the general contractor, the subcontractor, the architect, or the BECxA. They are developed after the submittals are approved by the architect, since they utilize details from the product installation guidelines specific to the products and systems being installed. Product names and designations are used directly from the submittals so that observers can easily identify the specific components that have been approved and are expected to be installed. *Figure 8* is an example checklist developed for under-slab vapor retarder installation.

Consider adding information about the compatibility or the integration with adjacent materials that may be installed by another trade. Ask for letters from manufacturers to confirm compatibility. Materials may be compatible with each other, but they may not adhere. This can be important in the sequencing of applications of sealants and air barriers or other materials, since silicone sealants adhere to many substrates, but few materials adhere to cured silicone.

COMMISSIONING MEETINGS

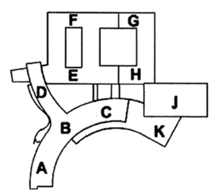
Conduct meetings with each trade and with the general contractor to review the requirements of BECx. These can occur as a part of the preconstruction meetings. The construction checklists should be reviewed in detail along with the review of testing and quality control measures. Shop drawings and submittals should also be reviewed during this meeting.

SITE OBSERVATIONS

Periodic site observations by the BECxA are important. Utilizing checklists when observing the installation of a component is a great method to record what was completed or installed. The observer must be specific about where any deficiency is located, using column line, elevation number, or some other specific locator to assist in finding and repairing the work. The BECxA is typically on site only periodically and must rely on the quality control methods of the

Under Slab Vapor Retarder - VR-1

Area Inspected:



Inspector: **Date:**

Weather:

Notes:

Stego Industries 15 Mil Vapor Retarder

- ☐ Unrolled directly over aggregate, sand, or tamped earth base
- ☐ Completely covering concrete placement area
- ☐ Seams overlapped min. 6"
- ☐ Seams tapped using Stego Tape
- ☐ Penetrations sealed with Stego Wrap, Stego Tape, and/or Stego Mastic
- ☐ Terminated on vertical surfaces with term bar
- ☐ Damaged sections patched and sealed with Stego Tape

Stego Tape

- ☐ Substrate free from dust, dirt, and moisture
- ☐ Pipe penetrations:
  - ☐ Stego Wrap slit/cut around pipe
  - ☐ Base sealed with Stego Tape/Mastic
- ☐ Installed above 40°F

Stego Mastic

- ☐ All surfaces dry and free of loose materials, oils, and other contaminants
- ☐ Stored above 40°F
- ☐ Pipe penetrations:
  - ☐ Stego Mastic liberally applied with brush, roller, or sprayer
- ☐ No solvent-based products applied over this product
- ☐ Apply layer of mastic to foundation wall prior to installing nail strip/termination bar

Volclay Waterstop- Rx

- ☐ Substrate clean and dry
- ☐ Rolled or brush-applied WB-Adhesive 5 mils thick along entire receiving surface
- ☐ Adhesive dried 5-10 min or until black
- ☐ Waterstop pressed into adhesive min. 15 seconds
- ☐ Waterstop installed within 2 hours of adhesive turning black
- ☐ Recoated with adhesive if waterstop not applied within six hours
- ☐ Tightly butt coil ends; do not overlap
- ☐ Maximum practicable lengths to minimize coil end joints
- ☐ Cut into strips around pipes and penetrations
- ☐ Waterstop remains in direct contact with all irregular surfaces

Figure 8 – Example checklist for under-slab vapor retarder installation.

Figure 10 – Air leakage testing of insulation fastener. ASTM E1186.

Figure 9 – Cavity wall drainage testing on newly constructed cavity wall. ASTM C1715.

Figure 11 – Air leakage and water penetration testing of newly installed curtain wall unit. ASTM E1105 and ASTM E783.

contractors to follow through between visits. The BECxA should plan for longer site visits when construction activity increases and the number of components and systems installed is greater. Consider participating in a review of the deficiencies with the GC and building enclosure subcontractors at the end of the site visit, or develop methods to create and issue reports immediately to reduce the risk of deficient conditions being covered.

FIELD TESTING

Field testing should be performed by an independent third party and, when possible, observed by the BECxA. ASTM E2813 contains in Annex 2, Table A2.1 (ASTM International, 2012)—a listing of test methods and practices that may be utilized in building enclosure commissioning.

In the project specification, include not only the number and type of tests to be performed but also the consequences of failed tests. Also specify when during the construction the testing is to occur, such as during the first 10% of the installed system. Require that failed tests be repeated on the remediated unit or area and a new unit or area be selected for an additional test. As an example, if the specifications call for four ASTM E1105 tests to be performed on the installed window system when construction is 10% complete, the four tests should be performed. If all four pass, no additional tests are required. If one or more fail, those failed units are remediated and retested, and that same number of untested windows are found and tested. This process continues until four tests are passed on previously untested windows.

Figures 9 through *14* show testing of building envelope components in progress.

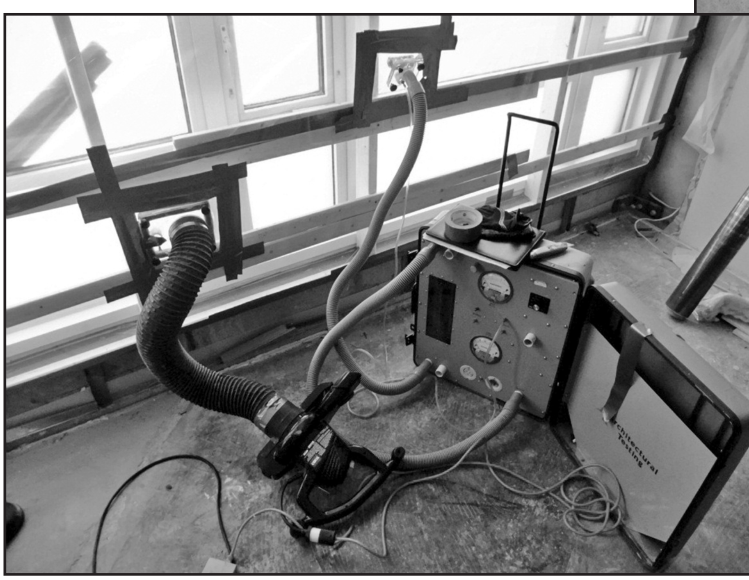
MONITORING ISSUES AND DEFICIENCIES, AND REMEDIATION: TRACKING

Each issue or deficiency observed and recorded by the BECxA should be reported to the construction team in a timely manner. A tracking system of each issue or deficiency should be utilized. Such a system should describe the issues and allow for contractor comment, along with confirmation of resolution and approval or acceptance of remediation by the BECxA. Some BECxA use a log or spreadsheet of issues

Figure 12 – Water penetration testing of curtain wall system. AAMA 501.2.

Figure 13 – Pull testing of EIFS mock-up. ASTM D4541.

Figure 14 – Air leakage testing of window. ASTM E783.



and resolutions. These can be quite numerous on large projects, so managing all the data becomes a burden. Several projects have utilized a computer data management system called VELA, which allows for different members of the design and construction team to author an issue, post the item, and direct it to one or more of the parties involved in the project. This system also allows for posting of photos and comments. It is also web-based, making for timely input of issues. It has proven to be an effective way to communicate and record issues, along with when and how they were resolved, especially when all the team members utilize the program.

OBSERVATIONS FROM SEVERAL RECENT BECx PROJECTS

Based on our experience with several commissioning projects, we have made the following positive observations on the BECx process:

- A BECxA has full involvement during design team meetings to provide comments on architectural drawings as they are developed. We discovered that meetings in person over a two- or three-day session to review all details prior to each design phase completion are very effective. The design team is most familiar with the development of design elements and the reasoning for various decisions as the project has developed. Challenging aspects of the design, such as breaches in the thermal envelope, integrity of the air and vapor barriers, or potential construction sequencing problems, are great discussion points. The implementation of hygrothermal modeling or other advanced analytical techniques is useful in comparing alternatives. There is also opportunity to provide input on the methods of testing and quality assurance methods to be included in the specifications.
- A BECxA has full involvement in major shop drawing reviews. This can be most useful if this is done alongside the design team in a face-to-face meeting for the major systems or components, such as the curtain

wall assembly. Including the curtain wall fabricator in these face-to-face meetings can also be effective.

- A BECxA is a full participant in all mock-up testing and observes construction of the mock-up. This provides an opportunity to learn the ins and outs of the systems, how the components are installed, what trouble the construction team may have, and any remediation that would be required as the system is installed in the building.
- Regular site walk-throughs and meetings with the contractors responsible for the construction of the building enclosure are important while the project is in the early stages of construction. Involvement of the various tradesmen in discussions with the air and vapor barrier installing contractor is beneficial, because all parties will develop an understanding of the impact of their components to the overall quality and performance of the wall assembly. Similarly, the roofing contractor, curtain wall installer, or metal panel erector can provide input to improve the overall completed project.
- Observation of field-testing, with the knowledge of mock-up testing, can assist in diagnosing test failures.
- The BECxA should insist on using online systems for tracking site observations and deficiencies or corrective items. These have proven very effective in organizing and communicating to the team. This makes reporting of new issues a more streamlined and organized process. It is important that issues are recorded promptly so that the team members can correct them quickly. We found a verbal review of issues encountered during our visit is valuable when made after every site visit with the building enclosure subcontractors.

The following have been found to be negative or difficult aspects of the BECx process:

- The design team can become reliant on the BECxA to solve or design difficult design conditions or detailing between systems or refuse to resolve design issues identified by the BECxA.
- The design or construction team can become overly reliant on the BECxA site walk-through and may not devote enough of its own time and effort toward QA/QC. Monitoring of construction quality by each subcontractor is important and requires pressure from the construction manager, general contractor, or owner.
- Checklists are developed and issued by the BECxA, but may not be fully implemented in the field by the contractor and its subcontractors. The BECxA should insist on receiving copies of completed checklists for systems installed between BECxA visits. If this is done early, good habits can be developed. Asking for them later can be disappointing.
- As the project moves through construction, it may be difficult to stay on top of all the design changes that happen after the bid documents are issued. It can also be difficult to follow RFIs. This is due to the much smaller time involvement of the BECxA in comparison to the other members of the design/construction team; the BECxA is typically involved on an intermittent basis, whereas the design/construction team is involved on a day-to-day basis. Being part of discussions and reading documents from the design team are difficult but necessary to track changes that may affect the building enclosure.
- Closing of issues discovered during site walk-throughs can be a difficult communication process. The contractor is to provide photos, comments, and other documents to indicate what was done to remedy a deficiency to assure that the quality standards are met. Often, the contractor documentation is provided well after the condition is covered, or there is no documentation provided at all. Working with the contractors early can improve this, but recording what has been done or doing paperwork is generally not a priority for contractors. Once they have to remove completed work to prove that something was done, they then remember to record it before it is covered up.
- Depending on construction sequence, there may be a lot of "work-in-progress" issues identified by the BECxA during site visits. These types of deficiencies are often ignored by the contractor. With multiple observers, it is possible that the same issue may be recorded by the designer of record or other observers, making for duplicate work by the construction team.

The following should be avoided:

- The BECxA should only review approved submittals. The ideal workflow would have the architect review and approve the submittal, then forward the submittal on to the BECxA. If the BECxA has no further comments, the submittal is forwarded to the GC. If the BECxA has additional comments, the submittal is returned to the architect for additional review and the process starts again. Otherwise, the BECxA and architect are simultaneously reviewing submittals and providing redundant or sometimes contradictory comments. The submittal process is especially difficult for the BECxA, because his or her time commitment to the project is much smaller than the rest of the design/construction team. No one likes the added time this may create. When concurrent reviews are completed, it is often the architect who has to resolve the duplication.
- BECx is often rolled into the electrical/mechanical commissioning contract. While these are both commissioning, the timing of involvement during the project is quite different. These two disciplines are not related and should be completely separate.
- The GC or the construction manager should avoid reassigning personnel assigned to focus on the building enclosure construction issues and coordination. When personnel change, project history is lost, quality control processes may not be understood, and additional time is dedicated to training. Dedicate one person for the duration of the project.
- The BECxA is often asked to attend meetings, provide comments, or complete other tasks within a tight schedule, often with limited or no

advanced scheduling. This is challenging to accommodate, because the BECxA may be typically involved in several concurrent projects that have similar time-sensitive needs.

SUMMARY

As stated in the NIBS Guideline 3, “The Building Enclosure Commissioning (BECx) process is utilized to validate that the performance of materials, components, assemblies, systems, and design achieve the objectives and requirements of the owner as outlined in the contract documents. The most effective commissioning process ideally begins at project inception (during the predesign phase) and continues for the life of the facility (through the occupancy and operations phase).”

BECx is a defined process that includes a host of activities that are intended to improve the quality of construction projects and increase value to the owners, occupants, and users of a building. These activities and processes of the BECxA begin with assisting in defining the owner’s project requirements; performing design reviews of the building enclosure, specification, and documentation of the validation measures; observing mock-ups; periodic observation; and observing testing and remediation of deficiencies. These are all focused on delivering a building that performs to the established OPR. BECx is not the same for every project, but it is an effective process. It is particularly well suited for complex or high-performance building projects.

SOURCES

ASHRAE Guideline 0-2005. Atlanta, GA: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 2005.

ASTM E2813, *Standard Practice for Building Enclosure Commissioning*, Conshohocken, PA, ASTM International, 2012.

NIBS Guildeline 3-2012, *Building Enclosure Commissioning Process BECx*. National Institute of Building Sciences, 2012.