THE LONG-TERM PERFORMANCE OF ANY EXTERIOR BUILDING ENCLOSURE ASSEMBLY IS DIRECTLY RELATED TO THE LEVEL OF PLANNING IMPLEMENTED DURING THE INITIAL PHASES OF THE DESIGN PROCESS. IT REQUIRES THE COMBINED EFFORTS OF THE OWNER, BUILDING ENCLOSURE COMMISSIONING PROVIDER (BECxP), DESIGN TEAM, AND CONTRACTORS.

Commissioning consultation services typically begin during the creation of the owner’s project requirement (OPR) document. The services continue through peer reviews of the building enclosure specifications and drawings at each design stage, focusing on the enclosure’s ability to resist moisture intrusion and air infiltration, and to maintain a continuous thermal enclosure. Extending into the construction process, the BECxP (hired by the owner in the majority of instances) oversees peer reviews of the shop drawings and contractor coordination meetings, and performs periodic site observations and mockups/in-field testing to confirm the performance capability of enclosure components.

Building enclosure commissioning can often help avoid common issues in building construction, such as water intrusion, which frequently results in indoor air quality (IAQ) concerns, mold growth, air infiltration, and associated energy loss. There are countless examples of enclosure failures that cost owners, insurance companies, and contractors millions of dollars to remedy the resulting mold and moisture problems. The BECxP can identify design and construction issues at a significant discount as the costs for building enclosure commissioning services are generally but a small fraction of the potential repair costs.
Building enclosure failures

When it comes to remaining dry and comfortable, many new buildings fail to perform as well as expected. Enclosure leaks and/or air infiltration are among the primary causes of lawsuits against design architects. Once construction starts, the contractor is mostly focused on constructing the building in accordance with the drawings while remaining on schedule and within budget. It is the BECxP’s responsibility to maintain the team’s focus on the proper construction of the critical weather, vapor, and air barrier components of the enclosure.

Some of the key causes of enclosure failures include:
• reliance on a single rainwater barrier;
• new untested building materials;
• complex geometries;
• repetitiveness of problem details;
• lack of technical understanding of moisture intrusion mechanisms;
• lack of understanding of inter-relationship with HVAC systems;
• lack of modeling/review/testing/startup; and
• lack of defined expectation of the building’s performance with regard to the selection of materials and details.

Building enclosure commissioning has become more common since 2000. Since the turn of this century, there has been a push for tighter buildings with the introduction of air barriers into the building codes, as well as the introduction of sustainability guidelines, such as the Leadership in Energy and Environmental Design (LEED) rating system. The inclusion of air barriers promised energy savings and higher performance buildings. Instead, the new science was not understood by the designers or installers, and small defects in the exterior enclosure led to significant moisture, mold, and IAQ problems. Air leakage and poor connectivity of enclosure assemblies created a situation where buildings were not meeting the promised performances.

Evolution of enclosure commissioning

With this history of moisture intrusion in buildings, commissioning of the building enclosure became more important to address infiltration issues before project completion. Building enclosure consultants turned to HVAC commissioning, which had been successful over the previous decade. As a process, building enclosure commissioning follows a similar pattern as HVAC commissioning:
• identification of the project performance objectives;
• design-phase peer reviews; and
• construction-phase inspections and testing.

However, for the building enclosure, there is typically nothing comparable to the test and balance and other functional test procedures routinely specified in contract documents for HVAC systems. Further, while HVAC systems can be tweaked and fine-tuned once the building is completed, waiting until construction has been completed to test the building enclosure is too late because the façade components are already in place.

The American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) Guideline 1-1996, The HVAC Commissioning Process, had been in place for 20 years to help engineers and owners properly design, construct, and test HVAC systems in buildings. In 2006, the National Institute of Building Sciences (NIBS) issued a Building Enclosure Commissioning Design Guide that described the specific application of...
Implementing enclosure commissioning
The building enclosure commissioning process should begin when the owner is first considering building a new facility or renovating an existing one. The earlier the commissioning process begins, the easier it is to incorporate the commissioning comments into the construction documents. The commissioning process in Figure 1 is recommended for each building enclosure system—waterproofing, air barriers, roofing, opaque walls, and fenestration.

Pre-design phase
To initiate the commissioning process, the BECxP should conduct a workshop with the owner, user groups, and design team (if available) to identify the building enclosure performance requirements and level. The items discussed can include program requirements, climate, facility function, budget, delivery schedule, and durability.

If the owner is looking for a building that will last more than 50 years, the materials and detailing proposed during the design should have similar anticipated service lives that correlate to their use. The owner should also identify the commissioning budget and scope to define the project expectations and responsibilities. The BECxP then compiles a commissioning plan, which includes laying out the project requirements, responsibilities, and scope of the commissioning process.

Design phase
The most important aspect of the design phase is the technical peer reviews. While the function of the commissioning team is not to review all items related to the design and construction of the building, the focus is on specific key components within the building enclosure design, or issues occurring during construction known to allow moisture and/or air infiltration. It must be stressed that enclosure commissioning procedures should not slow the design process—all peer reviews should occur within the timeframe of the originally scheduled owner reviews.

The prime architectural design team has the final say, as they are ultimately responsible for signing and sealing the construction documents. However, the BECxP focuses on potential moisture and/or air infiltration issues including (but not limited to) roofs, walls, sealants, air barriers, flashings, windows,
waterproofing, curtain walls, and other associated components. Additionally, it is important to focus on the role of the building enclosure as a complete air barrier since it is the connection of components that leads to most construction issues.

Typically, a building is designed for the HVAC system to provide positive pressure to prevent air infiltration into the building. For the HVAC system to work properly, the enclosure system has to function as intended. The BECxP evaluates how the wall systems and fenestration will function together to form a complete air barrier system.

The quantity and timing of the technical peer reviews varies depending on the projects’ complexity and the level of commissioning desired. At a very minimum, one review should be performed before mid-construction documents level.

A typical recommendation is for three reviews occurring at the 50 percent and 100 percent design development phase, and 50 percent construction document phase. The earlier reviews focus on type of assemblies, components, and their relationships and compatibility. The 50 percent construction document review is used to perform a constructability review including the component interface detailing. Depending on the nature/difficulty of the design, an enclosure contractor (part of the construction team) may assist in a review of detail constructability, pointing out areas where a detail would be difficult to construct or where a simplified detail might work more effectively. A fourth review or back check can occur at the 90 percent construction document level.

The earlier reviews are important as at this point in the design—it is often too late to make substantial changes to the design phase if problems are identified.

After each review, the BECxP attends meetings with the owner and design team to review comments and develop modifications to the drawings and specifications where necessary. The comments issue log is updated to keep track of the comments to be incorporated in the next construction document set as well as to track responses.

To facilitate the construction phase of the commissioning process and preclude critical commissioning elements from being overlooked, the BECxP prepares enclosure commissioning specifications. The specifications are written by the enclosure commissioning team, but integrated into the overall construction documents by the designer. The enclosure commissioning specifications outline the:

- critical building enclosure systems requiring commissioning;
- mockup/model construction requirements for the enclosure systems;
- various building enclosure functional test requirements; and
- contractor participation requirements during the testing.

For the building enclosure, one of the goals of the commissioning specifications is to alert the various enclosure subcontractors that the enclosure is to be tested to withstand water intrusion and air infiltration, and they have responsibilities for assisting with the testing.

Pre-construction phase

While the pre-construction phase is not always clearly delineated in the various industry standards, guidelines of ASTM, ASHRAE, and NIBS all reference BECxP attendance at a pre-bid conference. The intent of this phase is to introduce the subcontractors to the commissioning process and to review their role and responsibility in the commissioning process. It also provides a good opportunity to vet the proposed material, components, and procurement methods regarding compliance with the owner’s project requirements.

For instance, a contractor may offer a time or cost savings by switching materials or possibly panelizing the project. This gives the BECxP an opportunity to note if the proposal provides equal or better performance than the owner is anticipating.

Construction phase

Because the building enclosure subcontractors are often unfamiliar with the commissioning process, one of the first steps for the BECxP is to conduct a
Commissioning the building enclosure helps avoid common issues in construction, such as water intrusion, which frequently results in concerns about indoor environmental quality, mold growth, air infiltration, and energy loss.

The general contractor and the subcontractors for the various components of the building enclosure are required to attend. The enclosure commissioning plan is reviewed and includes the project goals, each parties’ responsibilities, and the various inspections and functional test procedures to be performed.

Followup meetings are held with all the enclosure contractors to review the various shop drawings with close attention paid to tie-ins between differing components of an assembly (e.g. window frame to wall and air barriers).

The primary goal is to address a major issue in exterior enclosure construction, which is the diffused responsibility entailed in the construction of the building enclosure. This is an issue as no single entity is responsible for guaranteeing the enclosure is properly constructed. Identifying the “by others” is critical to understanding the constructability and sequencing of the enclosure.

The commissioning team reviews submittals and substitutions as related to moisture control and air barrier criteria throughout the construction process, and to finalize the functional test procedures for moisture intrusion testing.

**Testing of mockup wall**

Since the opaque roofing, waterproofing, wall, door, and window systems must be completely constructed before the enclosure can be tested for watertightness, a mockup is highly recommended. It should include opaque wall, door, window sections, and tie-ins to roofs and sub-grade waterproofing systems in order to set the standard of quality for the enclosure. The mockup allows the subcontractors to work out the project sequencing and provides an opportunity to fine tune details should construction issues arise. The BECxP reviews the installation of each component of the wall assembly for compliance with the construction documents, manufacturer’s installation instructions, and construction checklists.

Each component making up each mockup is photographed for future reference. The photographic documentation is critical to the mockup’s success for setting the standard of quality. Many components in an enclosure assembly are concealed by the next layer of the enclosure. For example, the embedded wall flashings are covered by the membrane waterproofing. Without photographs, there would be no way of referring back to the successful installation to determine if deviations occurred.

Specific building enclosure assemblies—such as curtain walls, punched windows, flashings, and tie-ins to roofs—are typical areas of concern as related to water intrusion or air infiltration. Therefore, rigorous functional procedures are performed based on the following standards (other tests may also be required, depending on the assembly):

- American Architectural Manufacturers Association (AAMA) 502/503, *Voluntary Specification for Field Testing of Newly Installed Fenestration Products*; and
- AAMA 501.2, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed*

**WHO IS YOUR BUILDING ENCLOSURE COMMISSIONING PROVIDER?**

The role of a building enclosure commissioning provider (BECxP) is described in National Institute of Building Sciences (NIBS) Guideline 3-2012, *Building Enclosure Commissioning Process*. It states commissioning authorities and building enclosure commissioning authorities should be knowledgeable about the commissioning process requirements. They should be in charge of administrative tasks and be acquainted with the building design and project construction processes.

Basic architectural and building science knowledge is required. Per NIBS, a building enclosure specialist needs to be an expert “in building enclosure systems anticipated to be used on the proposed building and possesses the experience and technical qualifications to design, critique, validate, and support the team in the project development and construction validation.”

Even though there are no recognized BECxP certification programs, the University of Wisconsin-Madison College of Engineering Department of Engineering Professional Development launched a Commissioning Process (CxP) certification program in 2003. Its certifications include the Building Enclosure Commissioning Process Professional (BECxP) and Building Enclosure Specialist (BES).

Finally, ASTM is starting a Building Enclosure Personnel Certification program in conjunction with a NIBS training program. The anticipated start date for the certificate and training sessions is this fall.
The specific test method depends on the particular fenestration type.

Windows and doors specified in the contract documents are designed to meet criteria outlined in similar laboratory tests. For field testing, these tests involve placing the door or window assembly under an interior negative pressure differential, while simultaneously simulating a measurable wind-driven rain event over the outside face of the assembly. Due to various fenestration assembly sizes and configurations, the testing apparatus must be modified accordingly. The general contractor, with the BECxP’s guidance, builds a test assembly based on the requirements detailed in the test standards.

**Monitoring construction**

Based on the changes put in place to address deficiencies uncovered during mockup testing, modified details should be developed for incorporation into revised shop drawings. Each subcontractor is required to perform its work using the modified details and certify the work was performed as detailed. The BECxP and general contractor should follow up the mockup testing with periodic field inspections to determine whether or not the subcontractors are performing the work properly. The commissioning team should also conduct random water spray and/or pressure chamber testing periodically as a check to visual observations.

The BECxP performs periodic site visits to observe and document ongoing construction activities with deficiencies noted and tracked in an ongoing construction issue log. Periodic meetings are held to review ongoing issues and to identify any deviations from the OPR and contract documents.

**Acceptance and post-construction phases**

While no project should depend on final acceptance testing, there are commissioning tests performed at the end—not to identify pass/fail project compliance, but rather to document results of the commissioning process. One typical test is to confirm the air barrier functions of the enclosure are properly constructed. The BECxP conducts air infiltration testing using a blower door assembly following the protocols detailed in ASTM E779-87, *Test Method for Determining Air Leakage by Fan Pressurization*. While not currently commonly performed, this test is required for enhanced commissioning and as part of the 2015 *International Energy Conservation Code* (IECC). Other acceptance tests may include moisture testing of horizontal waterproofing, additional air and water testing of fenestrations, and infra-red (*i.e.* thermal imaging) of low-slope roof systems.

As the construction phase comes to an end, many owners are continuing the commissioning process, which becomes an ongoing routine in the life of the facility. The BECxP assists the owner in documenting the commissioning process in the final commissioning report. The final report documents the entire design and construction process and includes modifications and changes occurring during construction, as well as responses to the design and construction issue logs.

Since most facilities are complex and require annual maintenance, the BECxP oversees contractor training sessions held to train the facility and maintenance staff in the building features and upkeep. The close-out process may also include owner/user review meetings and warranty period walkthrough to resolve any outstanding performance issues and have them rectified while the facility is still under warranty.

**Where to next?**

ASTM E2813 is in the process of being updated to reflect the ongoing industry efforts to align with the new ASTM E2947, as well as relevant comments received since initial publication. Some of the changes include clarifying the minimum test requirements for enhanced and fundamental commissioning (optional tests have been removed from the standard).

As noted, the building enclosure commissioning provider can include additional tests based on the facility’s complexity and the owner’s performance
Abstract
Building enclosure commissioning helps avoid common issues in building construction, such as water intrusion, which frequently results in indoor air quality (IAQ) issues, mold growth, air infiltration, and associated energy loss from the insulation. There are countless examples of enclosure failures that cost owners, insurance companies, and contractors millions of dollars to remedy the resulting mold and moisture problems. The BECxP can identify design and construction issues at a significant discount, as the costs for building enclosure commissioning services are generally but a small fraction of the potential repair costs.

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