Building Enclosure Commissioning of a Student Athletic Facility

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ABSTRACT

This paper will present a case study of a high performance, partially below-grade student athletic facility and the building enclosure commissioning process used on this project. The authors will discuss the building enclosure systems utilized on the project that were commissioned with respect to waterproofing, fenestration, air barrier and thermal barrier systems. They will discuss the process used which followed many of the steps in NIBS Guideline 3, which outlines the technical requirements for building enclosure commissioning. The paper will present the case study from the designer of record and building enclosure commissioning agent viewpoints.

Additional topics of discussion will include the challenges of constructing a higher performing building above current standards and the importance of commissioning the enclosure on structures of this type.

INTRODUCTION

Commissioning is a process intended to improve the overall quality of a project. Building enclosure commissioning is a growing trend, becoming more common in the United Sates. The process is being implemented on more and more school and higher performing building projects. The project examined in this case study is a student athletic facility located in the mid-Atlantic region of the United States; the facility is contained mostly below grade, with a new playing field and track assembly forming the roof. See Photos 1 and 2 for an overall view of the building.

Photo 1

Overall view of completed Student Athletic Center.

Photo 2

Overall view of roof of completed Student Athletic Center.

The project contained many challenges for waterproofing and air barrier construction. The commissioning authority was retained on the project in the midst of a redesign of the below grade slabs and some of the structural systems as part of an effort to reduce overall project costs. They completed two design reviews, assisted the team in reviewing waterproofing system options and reviewed the work in progress on the project. We describe the process utilized by the designer of record and the building enclosure commissioning authority below in more detail.

OWNERS PROJECT REQUIREMENTS (OPR), BASIS OF DESIGN (BOD) AND ARCHITECTURAL PROGRAM

The successful introduction of a project BOD (basis of design) is contingent on open and active communication between all disciplines within the design team, the owner, commissioning authority (CxA) and pre-construction management team. The development of the BOD beyond its introduction is only possible through an immediate understanding of the intent of this document and what differentiates it from the OPR (owner project requirements) and the project programmatic requirements. Although these three documents serve very unique purposes in the development of any project, they are all factors by which the success of the others may be gauged. Understanding how each document is unique in-and-of itself, yet are symbiotic to one another will allow the project team to use them all to their greatest advantage in creating a comprehensively successful project. A comprehensive commissioning process can be implemented more easily with a well-developed, detailed, yet concise set of Owner Project Requirements (OPR), that include their intended performance requirements for the project, including energy efficiency, and expectations for air tightness, water tightness and overall thermal efficiency and a BOD that flows and expands upon the designers intent to successfully implement programmatic components to fulfill the OPR and thus the BOD. This includes refined specifications that clearly define performance expectations and functional performance testing requirements to validate those expectations, and critical direction in the drawings, not on means and methods which are the responsibility of the contractor, but on critical sequencing of specific details in order for them to meet the performance expectations.

The BOD serves several unique roles from a projects initiation through the completion of construction and commissioning. The BOD becomes the vehicle for documenting assumptions that the design team may have relative to their unique disciplines and previous, similar project experience. Within the documentation of these assumptions, design team members are able to explain why a certain approach may be taken over another, thus creating the beginning of the project's history. It is important to realize that the character of these narratives is vastly different from that which may be put forth in an outline specification/project narrative in that it is more "comparative" than it is "absolute." If conceived in a comprehensive and meaningful way, the BOD also provides a means by which all team members may be held accountable for decisions made and direction provided throughout all phases of the project; hence the reason that the BOD should be a "living" document for the duration of any project.

As the BOD establishes the design team's initial understanding of the project and documents decisions made throughout all phases, the OPR (owner project requirements) is the document that establishes the owner's goals from very specific project attributes to expectations associated with life-cycle performance. The OPR will also be used to document the owner's goals relative to the degree of certification, functional performance testing and long-term measurement and verification that is necessary to validate their requirements.

Uniquely different from both the BOD and the OPR, the project program is used to specifically define the use of the building and associated spatial requirements. As well, the program may also be used to establish any unique requirements within each space and any adjacencies that may be critical to the efficient use of the space.

As mentioned previously each document, although unique in their purpose and generation, is used to scrutinize, support and develop the other. In order for this process to have the greatest impact on the development of the design, they must be developed during the very early phases of documentation, if not before. An ideal phasing model would allocate a period of time prior to the project documentation beginning in earnest for the generation of BOD and the OPR acknowledging the fact that a traditional schedule for documentation includes a programming phase.

BUILDING ENCLOSURE COMMISSIONING PROGRAM – STUDENT ATHLECTIC FACILITY

The building enclosure commissioning program at the student athletic facility included the following steps:

- Review of the Owner Project Requirements (OPR)
- Development of the Basis of Design (BOD)
- Commissioning focused design review of Construction Documents.
- Commissioning focused design review of Addendum drawings based on redesign of the below grade structure and waterproofing after value engineering.
- Review of mock-up construction.
- Periodic review of the ongoing construction.
- Performance of some of the functional performance testing during construction.

We described the general process for the development of the OPR and BOD above. The Owner had stringent requirements for energy efficiency goals and water tightness. As such, the design reviews concentrated on the waterproofing and air barrier systems for the structure. As the majority of the structure is cast in place concrete, including the back-up wall for above grade brick masonry, the concrete is the primary component for most of the air barrier system, with transitions to the curtain wall system being critical for air barrier continuity. The structure is predominantly exterior insulated, with continuity of the thermal barrier at parapet walls provided by blocking and insulation on the roof side of the wall carrying to roof insulation. The insulation system was carefully coordinated with the position of the curtain wall system and insulation at curtain wall shadow boxes.

There are four critical components of the structure that greatly benefited by the commissioning program which we discuss in more detail below; the below-grade waterproofing system, the air barrier tie-ins, the hot-applied rubberized asphalt roofing membrane and the curtain wall system. Although all portions of the enclosure benefited from the enclosure commissioning process, these four introduced the most challenges and we will discuss each in turn.

BELOW-GRADE WATERPROOFING

The Owner had very specific project requirements for a high-performance building that would be water tight, yet constructed within reasonable economics. The original design of the structure had a robust mat slab over a mud slab with substantial volumes of concrete being placed. The Owner's representative asked the team to review options to improve the waterproofing system while finding a way to reduce the substantial nature of the structure and reduce costs related to the concrete. The argument was that by reducing the concrete, any cost increase due to enhanced waterproofing systems and details would be greatly offset by the reduction in a mat slab of continuous deep thickness, with the deeper thickness only necessary mostly at column locations and the net delta would provide the Owner a reasonable cost savings with limited risk of reducing the overall systems performance to keep water out. The team recognized this would introduce unique waterproofing challenges at columns. In order to meet the OPR to keep the building watertight, through commissioning-focused design reviews the team decided to utilize a waterproofing membrane that could be integrated with the concrete. The sheet-applied product chosen has an adhesive that chemically interacts with the concrete to provide an integral bond. In addition, the below-grade and above-grade waterproofing system was procured from a single manufacturer as the Owner had requested a single-source warranty wherever possible. The system for the roof was supplied by a different manufacturer.

During construction, the enclosure commissioning agent performed periodic construction visits to review the waterproofing system installation. Using construction checklists and tracking issues and deficiencies identified in field reports, these site visits identified installation errors that would result in potential water leakage should they not be corrected. The field reports including a table to track of unresolved items, providing an easy means for the contractor and subcontractor to keep track of open issues and ensure repairs were completed prior to concrete pours. The contracting team and enclosure commissioning agent reviewed the horizontal below mat slab waterproofing again just before each pour was scheduled to begin and the waterproofing subcontractor provided personnel to repair any remaining deficiencies prior to placing concrete at the slab-on-ground. Common deficiencies found by the team include fishmouths in the waterproofing membrane that can lead to tunneling, tape seams that were not fully adhered, and inside and outside corner details, especially at recesses for the columns that were not originally detailed correctly and provided tenting of the membrane instead of allowing it to lie flat and damage caused by placement of steel reinforcing. See Photos 3 through 4.

Photo 3

Tunnelling and fishmouths at membrane T-joints. These locations were repaired prior to casting concrete.

Photo 4

Improper detailing around a wire penetration through the waterproofing membrane. The detailing tape is loose and not installed continuously around the penetration. A proper boot was eventually installed at the base of this penetration.

At vertical walls, a self-adhered sheet membrane was applied in two-layers, with seams at the upper layer detailed with liquid membrane and staggered vertically and horizontally from the first (inner) layer of waterproofing. The waterproofing was then covered over with drainage and protection board adhered in place and tied to foundation drains, and then covered with insulation. Deficiencies found by the commissioning agent included fishmouths where the sheet applied membrane was not rolled into place and use of end of day termination mastic that was not allowed to fully cure prior to installing the second sheet. See Photos 5 and 6. The deficiencies were corrected by the contractor and reviewed by the commissioning agent to verify compliance.

Photo 5

We observed several water-filled bubbles on the north elevation during construction. Note the unprotected top membrane edge and unadhered lap joint (circled).

Photo 6

Installation of the waterproofing and drainage/protection board along vertical walls.

By taking a proactive team approach in the field, the design and construction team in coordination with the commissioning agent for the enclosure provided the Owner a waterproofing system that was more robust and durable. The building has not experienced any leakage to date and has completed its first full year of operation.

AIR BARRIER TIE-INS AND CURTAIN WALL UPGRADES

As noted above, the main air barrier system component for this project is the cast in place concrete walls, roof deck and slab on grade. Critical tie-ins between the concrete and curtain wall system were required, including the air tightening of shadow boxes. This included details to provide membrane tie-ins between the brick masonry clad above grade walls and the curtain wall jamb and sill and curtain wall head and roofing system at concrete parapet walls. The waterproofing system for the brick masonry walls was a fluid applied air and weather barrier; this required integration with self-adhered sheet membrane to complete tie-ins to the parapet wall and roof system hot-applied waterproofing. Self-adhered transition membrane integrated with the fluid applied air and weather barrier wall membrane needed to be integrated with the curtain wall system to form the window head, jamb, and subsill flashings and air barrier seals. This needed to be carefully integrated to avoid any conflict with the curtain wall systems own silicone sealants, which represent a compatibility issue with the self-adhered membrane used for these transitions. In addition, an inner air seal between the inboard side of the curtain wall and the frame was also provided as humid interior air during winter months that travelled beyond the window surround and insulation plane would easily reach dew point; a sealant joint tie-in was therefore provided between the curtain wall frame and the concrete walls at the inboard side.

At the parapet walls, self-adhered membrane was carried up and over the walls and tied into more robust roofing self-adhered membrane that was integrated with the roof hot-applied waterproofing by torching the polyethylene facer off of the self-adhered membrane and weaving it into the layers of hot-applied roofing.

For the curtain wall system, the sill pan system and sub-sill membrane were to be placed between the return leg of the curtain wall and the frame at the very edge of the wet zone of the fenestration system. This detail presented challenges at vertical members that the contracting team worked around to ensure continuity of the flashing and air barrier by notching the verticals, while ensuring a continuous substrate for waterproofing and no breach into the frame that would result in incidental air leakage inboard of the thermal break at the verticals.

At the top of the curtain wall, the designer employed shadow boxes to hide the underlying concrete parapet. The majority of the curtain wall is at the main gymnasium that during sporting events would have high occupancy and a heightened level of occupant driven moisture in the interior air. As many of these events occur over colder months, with stack effect (the natural buoyancy of hot air to rise), this moisture-laden air would rise to the roof and upper levels of the curtain wall, stagnate, which can increase the volume of moisture, and condense if not controlled and kept from passing to a location below the dew point of the interior air. At the shadow box condition, the upper lite of the fenestration system and thus the box would extend below the edge of the roof slab. Although the edge of the slab would receive an air and fire seal between the back of the shadow-box metal back-pan and the curtain wall framing and the slab, the air seal occurred about one third up from the base of the shadow box edge. The shadow box system therefore required a continuous air seal between the metal back-pan and the curtain wall frame. The commissioning agent and design team reviewed three options:

- Installation of preshimmed butyl sealant between the metal back-pan which had integral return legs and the curtain wall frame, and then redundant sealant within the frame and at all frame joinery of the shadow-box and curtain wall. The metal back pan would be fastened such that the butyl tape would be compressed, but fasteners would not pick-up butyl and arrive at an incompatibility with the shadow-box sealant.

- Uncured EPDM at all frame joinery and around the perimeter of the metal back pan.
- Sealant applied with bond breaker at all frame joinery and the perimeter of the shadow box. The back pan would have upgraded fastening to restrain movement against the sealant joints.

Ultimately, due to cost constraints, the third option of using sealant was chosen. The shadow boxes were site constructed in the following order:

- Installation of the metal back pan, with sealant applied between the back pan and frame at the perimeter.
- Installation of backer rod for perimeter edge seals temporarily tacked in place with sealant.
- Installation of fillet seals and perimeter seals at the shadow box to cover all curtain wall and shadow box frame joinery and the interface between the curtain wall and the shadow box.
- Temporary protection against weather to allow the seals to initially cure.
- Installation of the shadow box insulation system.
- Installation of the shadow box front pan which was also sealed in place.
- Installation of the glazing.

See Photo 7 for a view of this air sealing work in progress.

Photo 7

Air seals at shadow box back pan underway during construction.

FUNCTIONAL PERFOMANCE TESTING OF HOT-APPLIED ROOFING

The hot-applied rubberized asphalt roofing system went through several functional performance tests prior to and during application. These included:

- Testing of the concrete slab for interstitial relative humidity (RH) and temperature.
- Plastic mat tests on the slab to look at drying and surface evaporation at the surface of the concrete.
- Test patches of waterproofing membrane at numerous locations at the roof deck to check for adhesion.
- Verification of the hot-applied kettle temperature during application.
- Thickness testing of the membrane during application using the manufacturer recommended thickness gauge.
- On-site observation of the application of the hot-applied roofing membrane.

The combination of the three initial tests of interstitial RH, plastic mat testing and test patches supplied at approximately fifteen locations around the roof provided the design and construction team the opportunity to evaluate the drying rate of the slab prior to applying the membrane, that during its application and initial curing, can result in blistering and punctures with excessive upward moisture drive. As the hot-applied membrane is applied, the temperature drives moisture upward and creates a rapid rise in evaporation rate and vapor drive near the upper surface as the moisture is heated to a level where it is essentially steam. This rapid moisture movement can create pinholes in the membrane where the steam pressure exceeds the capacity of the membrane, and blistering where as the membrane cools, the moisture condenses typically within layers of hot-applied membrane and creates blisters. Excessive blistering and pinholes will compromise the long-term integrity of the waterproofing system. The team installed numerous interstitial RH and temperature probes to examine the conditions at the mid-point of the slab, and aligned these near plastic mat tests and test applications of membrane. Although typically used in the flooring industry, the interstitial temperature and RH test is useful in evaluating the concrete to examine how much moisture may remain. The probe readings identified a slab that was drying slowly, as would be expected in late fall in the mid-Atlantic region, and the plastic mat tests revealed that drying near the surface would be slow, as long as the slab did not receive considerable heat from the sun prior to application. This introduced a shortened time window for application on the roof, where morning dew/frost on the roof needed enough time to dissipate prior to application of the membrane, but application would need to be completed prior to the slab receiving excessive heat from the sun. The applicators therefore scheduled application from approximately 10 to 11 am in the morning through 2 to 3 pm in the afternoon, checking for pinholes and blisters. They utilized additional mat tests and test patches during the application cycle placed at the location for the next-days' work. The commissioning agent made on-site observations and found that this process provided minimal blisters and pin-holing of the membrane. The contractors completed the application with limited amount of rework based on the information and guidance that came from the functional performance testing.

See Photo 8 for a view of functional performance testing completed prior to placing the hot-applied roofing.

Photo 8

Installation of sleeve for interstitial RH probe used as part of functional performance testing prior to installing hot-applied waterproofing.

CONCLUSIONS AND RECOMMENDATIONS

Based on the case study provided above and the authors experience on other projects, commissioning programs should:

- Include initial meetings to discuss the Owner's Project Requirements. Many Owners have a sense of what they are looking for in a new project, but need additional assistance in most cases by the design team to assist them in defining the requirements that the Basis of Design and designer program will need to fulfill.
- Allow for open discussion of options for changes in the building enclosure systems, understanding the potential impact on cost as well as long-term performance of the assembly, ultimately educating the Owner to allow them to make a reasonable decision.
- Provide periodic on-site review during construction and well thought out and applied functional performance testing of building enclosure systems and components throughout the construction process.
- Use the results of the functional performance testing to provide additional parameters for consideration by the contractors for implementation during construction.
- Teamwork and regular communication between the design and construction team and the commissioning agent will provide a higher quality project.

REFERENCES

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