Full-Scale Stand-Alone Blindside Waterproofing Mock-up and the Lessons Learned

By David Leslie, RWC; and Jerry Carter

INTRODUCTION

The construction of buildings is a team effort involving numerous stakeholders. It takes multiple people from various disciplines to bring a building to fruition for the owner. For the project to be successful, collaboration is critical. Three key elements are required for effective collaboration: a singular goal, alignment of expectations, and a common language. One way to solidify these points is through the process of constructing a stand-alone site mock-up. This article will discuss our unique example of constructing a full-scale mock-up of pre-applied blindside waterproofing for a structural shotcrete wall, and the lessons learned through the process.

STAKEHOLDERS AND EXPECTATIONS:

A successful project has three traits: the finished building is delivered on time, is within budget, and performs as intended. However, diverse stakeholders may perceive a project from different vantage points. With various people and disciplines involved in the construction, it is only natural that there may be a range of expectations. It is important to define the stakeholders and to highlight their key expectations. The following are examples of expectations the various stakeholders may bring to the project.

- **Owner's Core Expectation –** Performance and budget: Owners expect the building to perform to meet their requirements and that the people constructing it are professional and capable of accomplishing the task within their available budget.
- **Designer's Core Expectation –** Reputation and performance: Designers expect that the people selected and the products installed will meet the intent of their design and performance requirements.
- **Contractor's Core Expectation –** Time and budget: Contractors expect that the design, people, and products selected will meet the designated timeframe of their proposal and meet the project budget.
- **Subcontractor's Core Expectation –** Workmanship and quality: Subcontractors expect that the design and products selected, along with the logistics and coordination managed by the contractor during construction, will meet the framework of their bid.
- **Manufacturer's Core Expectation –** Connections: Manufacturers expect that the design correctly utilizes and specifies materials for the project-specific conditions and that the contractors properly install them as a system.

KEY POINTS

The process of constructing a full-scale mock-up provides the opportunity to establish the key points by defining a singular goal, aligning expectations, and creating a common language before issues develop on the actual building. These points are critical to a successful project, but in some cases can be difficult to achieve.

We must first understand that all new construction projects are unique. They are often a new design, on a new site, and constructed by a new team. Considering the various vantage points from the stakeholders and their highlighted core expectations, it is easy to understand how the construction process can sometimes become contentious. Compounding the situation are the varying communication styles often used by the various stakeholders. Designers typically communicate with drawings and written words. Manufacturers communicate with numbers that describe physical properties of their materials and diagrams that illustrate step-by-step instructions for installation. Contractors communicate with hands-on physical objects. Add these different aspects together, and it is not hard to understand how issues can arise during the construction process.

Before going much further, it is important to capture the thought process that not only went into the construction of the

Figure 1 – The stand-alone blindside mock-up shortly after the shotcrete was placed.

project-specific mock-up that we will describe in this article, but also into its writing. During the processes of both, there was a continuous exchange of insights—the sharing of expectations, observations, and ideas. To capture a sense of our interactions, the remainder of the article has been formatted to reflect those conversations.

Jerry Carter represents the designer stakeholder and is a member of SmithGroup's Building Technology Studio with a specialization in the building enclosure, and for this project, he focused on the design of below-grade waterproofing systems.

David Leslie represents the manufacturer stakeholder. He is the director for technical services and product management at Polyguard Products. For this project he focused on the design and training of installers for below-grade waterproofing systems.

PROJECT HISTORY

Jerry Carter:

SmithGroup, an architectural engineering firm, partnered with a design–build contractor to develop a new university laboratory building. The building included two stories of below-grade construction and is at the corner of the project site close to the intersection of two streets. The placement of the building created a situation with tight site constraints, which required an earth retention system and a blindside waterproofing application. The contractor recommended the use of Polyguard's Underseal® Blindside™ Membrane as they have had a history of working with their products on several other successful projects.

Pre-applied waterproofing applications create a difficult scenario in that designers, manufacturers, and contractors are unsure how well the waterproofing system will perform, as one cannot review or inspect it after the concrete is installed. This application method is also called "blindside" and is typically the result of zero-lot-line sites or limited-area sites for excavation.

The characteristics that SmithGroup expects for blindside waterproofing membrane systems include a history of successful projects demonstrating durability and longevity of the membrane systems, trained and certified installers, and fully adhered membranes that mitigate lateral migration of water between the membrane and the concrete substrate. At SmithGroup's request, these expectations led to Polyguard providing them with a list of successful projects using their product, holding discussions with their technical staff regarding installation and quality control procedures, inviting them to tour their manufacturing facility, and providing large product samples for in-house evaluation. All of this culminated in further evaluation on a full-scale, stand-alone project mock-up (*Figure 1*). To our knowledge, a stand-alone blindside mock-up had never been produced before with this product. After the mock-up was completed and the shotcrete was installed and cured, the formwork was removed to allow an opportunity to evaluate the membrane from the backside.

David Leslie:

The process of evaluating the products, collaboratively designing the systems, and validating the assembly through the trial run of a mock-up is what every manufacturer wishes would occur on all projects. It Building enclosure material manufacturers do not produce the finished product or system. Manufacturers make components that must be designed into the building by one group and assembled on the building by another. This being the case, having a design firm take the time to visit our facilities, to study the composition of the products, and learn the physics behind the design theory of the system is invaluable and greatly appreciated.

Bringing together design, material, and installation into a successful project must

start with a common understanding of the core function of the various systems and how to achieve that function. With pre-applied waterproofing, the core function is to prevent water intrusion, and that is achieved by the system being installed watertight and remaining watertight through completion of the building. A critical phase of the construction is the concrete foundation, because pre-applied waterproofing is not complete until the concrete is placed.

The process of assembling the concrete structure is an arduous endeavor requiring the meshing of multiple trades. There is site preparation, soil stabilization, concrete forming, setting of the structural steel, concrete placement, concrete finishing, and waterproofing. Each element builds upon the other. Constructing a building on a zero-lot line site adds another level of complexity because the perimeter of the excavation functions as the outside form and will never be exposed again. So, every component of the perimeter shoring/form must withstand the rigors of constructing the wall (i.e., rebar setting and concrete placement), including the waterproofing. This is especially true regarding structural shotcrete, which will be shot at 90 mph directly onto the waterproofing membrane. Therefore, durability and longevity are vital components of the pre-applied waterproofing system in order to remain watertight throughout construction.

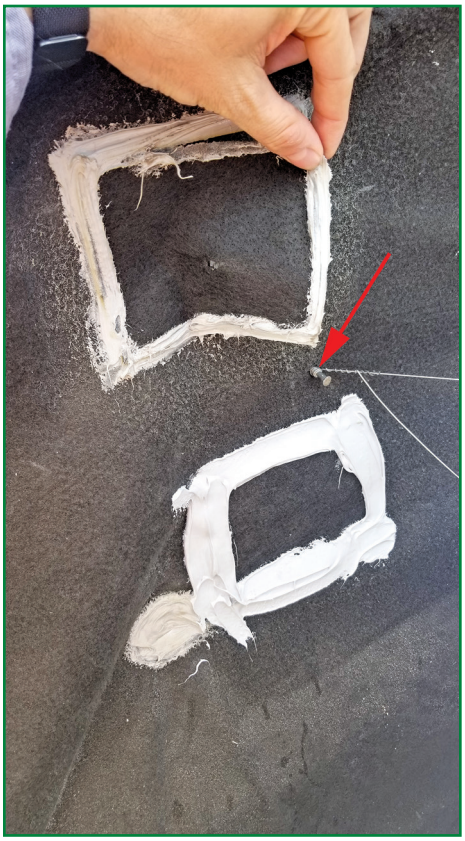

Figure 2 – Following the waterproofing installation onto the earth retention system, additional striker pins were observed after the waterproofing installers completed their work.

Well-consolidated concrete, by nature, has water resistance. For liquid water to pass through concrete, there needs to be a hole, a crack, a cold joint, or a void. The process of casting concrete typically produces well-consolidated concrete. Unfortunately, it is much more difficult to consistently consolidate shotcrete, which significantly increases the opportunity for areas of porous concrete. In the presence of water, there are three components needed for lateral water migration to occur: a breach in the waterproof membrane, an interface between a water-resistant substrate and the waterproof membrane, and a pressure differential caused by a hole, a crack, or cold joints in the substrate. In the case of shotcrete, the areas of porous concrete do not provide an interface of a water-resistant substrate. So, the theories of lateral water migration for structural concrete are less applicable with shotcrete and an important reason for the system to remain watertight throughout construction.

It is from these vantage points, and the fundamental understanding of pre-applied waterproofing with a structural shotcrete wall, that the lessons learned were applied to establish the anchor points for a successful project.

LESSONS LEARNED

1. Other trades' impact on waterproofing (*Figure 2*)

Jerry: In a pre-applied waterproofing application, the waterproofing installer is the first trade that installs a product after excavation. Every trade will follow them and have direct access to the waterproofing membrane, leaving the installer's work vulnerable. Educating other trades that follow the waterproofing installer is a key for success to waterproofing a space below grade. Learning this lesson on a stand-alone mock-up allows for mistakes to be made without impacting the built project.

David: There is nothing more frustrating than revisiting a project after a final inspec-

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Figure 3 – During placement of shotcrete, installation of an additional striker pin was observed, which created penetrations in the waterproofing membrane that could not be detailed by the waterproofing installer.

tion, only to find the system completely destroyed, and then to be asked if it is warrantable. The answer can be yes, but it will take more time and money that was not in the schedule or budget. Sorting things out during the mock-up saved significant time and money.

2. Seeing is believing (*Figure 3*)

Jerry: Every project has quality control measures to ensure that the end goal is communicated across the project team. Designers often will include pre-installation meetings as a requirement in the specifications. Some of these meetings will include members of the trades that follow the waterproofing installer. Discussion will outline the importance of other trades' work and that damaging other's work should be avoided. No trade plans to damage someone else's work, but it happens. During a stand-alone mock-up, which includes the entire below-grade wall, every trade gets to finish their work. Though they were warned not to, and though they didn't think it would happen, damage to the waterproofing membrane occurred prior to the shotcrete application. Issues between the trades were resolved prior to work on the actual building.

David: Having everyone in one place at the same time is so powerful. Being able to see it, then touch it, and then discuss it, gave everyone the ability to communicate and understand how to work together in a way that could never happen without a mock-up.

3. Striker pin (or rebar tie-back anchor) detail (*Figure 4*)

Jerry: To achieve a well-consolidated shotcrete wall, limiting the movement of the reinforcing steel is required. Based on the floor-to-floor height at the new university laboratory building, tie-back anchors were used to restrict reverberations of the reinforcing steel during placement of the shotcrete. The initial anchor, coined "striker pin" for this project, was observed during the stand-alone mock-up. The type of anchor was selected by the subcontractor installing the reinforcing steel. During the stand-alone mock-up, the striker pins demonstrated a difficult detail to successfully waterproof repeatedly. As a result of several discussions amongst all parties, the design–builder revised the striker pin to a stainless-steel hex bolt, providing a stable anchor and depth adequate to detail waterproofing onto. The stand-alone mock-up provided a platform to discover and discuss a critical detail that would occur hundreds of times below grade.

David: Intentionally penetrating a waterproofing membrane is not a good idea, but sometimes it can't be avoided. The striker pins were required for the project, but we did not realize that standard pins are unstable and could not be made watertight. It wasn't until we saw the pins in use that we could understand that different pins were required and how to make them watertight.

4. Overspray of shotcrete (*Figure 5*)

Jerry: A stand-alone mock-up provided access to the backside of the wall that would not be accessible on the building itself. After removal of the lagging boards and drainage panels, the waterproofing membrane was exposed for observation. Areas of disbonded membrane were observed approximately the same height as the first lift of shotcrete. After destructive removal of the waterproofing membrane, it was discovered that the disbonded areas were covered in a thin layer of shotcrete as a result of overspray from the first lift of shotcrete, creating a bond-breaker for the second lift. The overspray was well bonded to the waterproofing membrane, while the shotcrete did not bond at all to the oversprayed shotcrete. Without destructive

Figure 4 – Striker pin installed and detailed with waterproofing was observed to be inadequate, demonstrating a difficult detail to achieve repeatedly in the field.

Figure 5 – Observations from the backside of the mock-up showed the membrane did not bond in the oversprayed shotcrete areas (see arrow).

observation to the backside of the stand-alone mock-up, this would not have been discovered.

David: Considering we were working with a structural shotcrete wall, reduction of lateral water migration was not the driving factor for a good bond to the wall; the driving factor was durability. An intimate bond of the membrane to the substrate increased the overall durability of the system. Seeing a fresh lift of shotcrete fail to stick to old shotcrete overspray was astonishing and something we needed to address.

5. Impact of shotcrete (*Figure 6*)

Jerry: The process of installing shotcrete applies significant force upon impact, and having the project team (owner representatives, architects, engineers, design–builders, subcontractors, and manufacturer representatives) observe this force made an impression on the importance of durable details that have been proven to work for similar installations. Every pre-applied waterproofing system is different, and each manufacturer tackles the impact of shotcrete differently.

David: Until you have seen concrete shot out of a hose at 90 mph, you cannot fathom the forces involved. Yes, the impact of the aggregate hitting the wall is intense, but the forces on the membrane are no joke. It is amazing how much load is put on the laps.

Figure 6 – Observations of the placement of shotcrete.

Figure 7 – Earth retention tie-back observed after form work was removed prior to the application of waterproofing detailing.

6. Detensioning of tie-backs (*Figure 7*)

Jerry: Stand-alone mock-ups provide an opportunity to validate construction sequencing at difficult details. Detensioning of tie-backs occurs after the shotcrete is placed and when the wall has strength to resist the imposed load from the soils. An example of this process was used on the mock-up, and it demonstrated accessibility to this condition after the infill forms were removed.

Figure 8 – View looking up and towards the edge of the shotcrete mock-up wall.

David: Ninety percent of leaks happen at terminations, transitions, and penetrations—basically, where there is a lack of continuity. Constructing the mock-up gave us the ability to create continuity in the team communications and, thus, the ability to address these critical areas.

7. Securement of waterproofing at end of pour/shooting of shotcrete (*Figure 8*)

Jerry: The mock-up demonstrated what could happen when a membrane is not completely secured to its substrate. As an incidental occurrence, and since this was a stand-alone mock-up, the waterproofing installers did not take the care to secure the membrane at the edge of the mock-up wall. The finished shotcrete did not cover all the installed waterproofing area for the stand-alone mock-up. This created about a two-foot-wide area at both ends of the mock-up. After the completion of the installed shotcrete, overspray was observed on the exposed membrane. By not being secured to the substrate, the membrane could conform to the sprayed shotcrete and did not remain flat against the lagging wall. The membrane curled at the edge of the shotcrete, creating areas that did not bond to the shotcrete.

David: Other than the configuration, this is the same situation as the pockets for detensioning the tie-backs. The continuity with the team creates continuity with the system and goes a long way to addressing the majority of potential leaks.

8. Bond of waterproofing demonstrated by destructive testing (*Figure 9*)

Jerry: As one of SmithGroup's expectations for installed waterproofing membranes, the bond that is achieved between the membrane and the shotcrete was important. In addition to the stand-alone mock-up wall, a smaller mock-up—approximately 4 x 4 ft.—was constructed. The intention of this mock-up was to perform a pull test in the field similar to what is done as a lab test for ASTM D903. The smaller mock-up was

Figure 9 – Pull test of the waterproofing membrane by hand on a smaller 4- x 4-ft. mock-up.

the result of a concern that destructive removal of the lagging boards and drainage board on the stand-alone mock-up could jeopardize the integrity of the waterproofing membrane's bond to the shotcrete. With the understanding that field tests and lab tests are not replicas, a performance value published on the product data was used as a benchmark for the field test. Unfortunately, the field version of the pull test was never performed. The significant force needed to pull the membrane away from the substrate by hand was observed to be difficult and demonstrated a successful bond.

David: No matter what numbers you put on a data sheet or lab test that you run, there is nothing like the empirical "data" from trying to yank something off the wall.

PROJECT ANCHOR POINTS

The three anchor points established during the construction and deconstruction of the mock-up were:

- **The goal:** Make a building that does not leak.
- **The expectation:** Everyone is responsible for making a watertight system.
- **The common language:** Teamwork.

CONCLUSION

Any mock-up should provide lessons learned within the construction processes, but this mock-up revealed far more. Our stand-alone blindside waterproofing mock-up provided a rare look behind the wall (literally) and gave us an understanding of how the project-specific materials functioned. There were three surprising observations that would not have been possible without deconstructing the lagging wall:

- How significantly the shotcrete overspray affected the bond between lifts of the assembly
- How large the areas of moderately consolidated shotcrete were observed in the mock-up
- How tenaciously the blindside membrane bonded to the areas of well-consolidated shotcrete

Given the uncertain efficacy of blindside waterproofing installations and the uncovering of these surprise observations found in the mock-up, we understand the significant demand placed upon the waterproofing system. The use of a stand-alone mock-up not only gave us insights into improving the processes on this project, but it gave us a better understanding of the obstacles inherent in most structural shotcrete blindside waterproofing.

As an industry we all agree that mock-ups are an important tool in the production of a successful project, but this mock-up revealed insights into blind-side waterproofing that were previously inaccessible. The lessons learned and the subsequent application to the stakeholders' expectations were well worth the significant time and expense committed to constructing this full-size stand-alone mock-up, let alone the importance of future projects.

David Leslie, RWC

David Leslie, RWC, is director of technical services and product management for Polyguard Products. His three decades of industry experience include product development, contracting, and consulting. He is a published author, public speaker, expert witness, and holder of multiple patent applications. Leslie is an active member of IIBEC, a Licensed Field Auditor with ABAA, and a member of SWRI. His core belief is that there is no good reason for a building to leak, and he has committed his career to keeping people dry.

Jerry Carter

Jerry Carter has been a member of SmithGroup's Building Technology Studio for 11 years. He specializes in the design and restoration of plazas and garden roofs, conventional roofing, and below-grade waterproofing. He also plays a key role in developing and maintaining SmithGroup's master specifications related to the exterior enclosure. Carter received his bachelor's and master's degrees in architecture from Lawrence Technological University. He is currently vice-chair for the local chapter of the Building Enclosure Council.