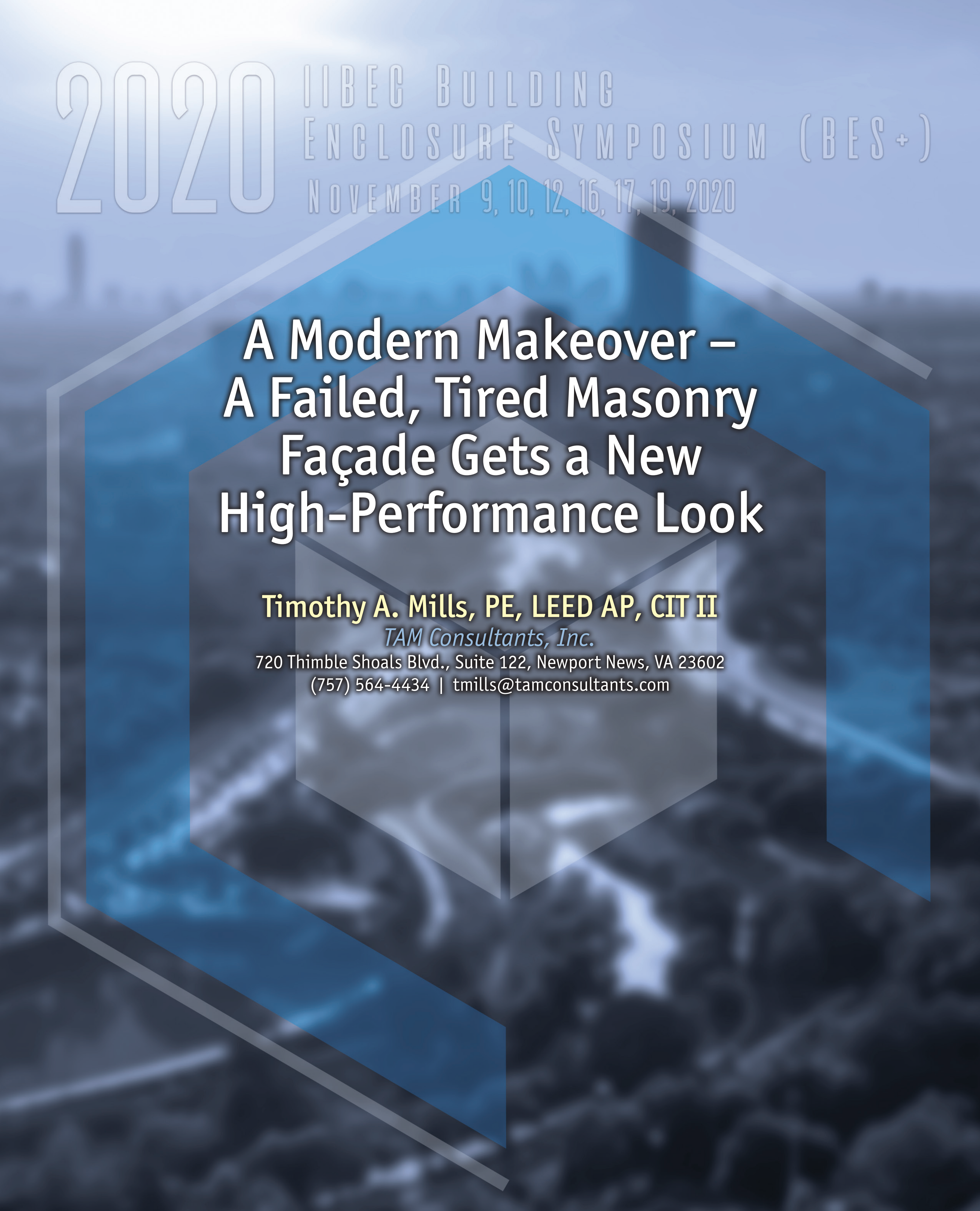

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A Modern Makeover – A Failed, Tired Masonry Façade Gets a New High-Performance Look

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ABSTRACT

This paper presents a case study of a medical research/office facility that, at nearly 35 years old, needed major exterior repairs. This mid-1980s building was constructed with thought given to energy conservation and durability by using continuous thermal insulation in the wall assembly and a durable masonry cladding system. Unfortunately, defects in the original design and construction created an exterior wall assembly that developed cracks in the exterior masonry and deterioration of the supporting steel members. Also, the building lacked an air barrier and leaked air badly, defeating the original energy conservation considerations. The lack of vertical masonry control joints led to widespread cracking and corrosion of supporting steel relief angles. The assessment of the masonry defects discovered that the wall assemblies lacked a weather barrier and an air barrier. Large air leaks were discovered during the cladding assessment, creating another challenge in developing restoration concepts. The assessment resulted in repair options that were presented to the owner for consideration.

In this paper we will review all steps, from the initial assessment of the building through the various design concepts and options, and the construction challenges for the new lightweight metal panel overcladding system with a modern appearance to align with the owner's corporate image and other research facilities.

SPEAKER

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Timothy Mills graduated with a BS in engineering from Brooklyn Polytechnic Institute of New York in 1983. Prior to forming TAM Consultants in 2002, Mills worked at a number of multidiscipline design and inspection firms. He has published numerous articles, presented at conferences and symposia, and completed nearly 1,500 residential home and commercial building inspections and 300 energy audits. He is an instructor for ABAA training courses that educate and certify contractors in the proper installation of air barriers and is a certified ABAA Auditor for their quality assurance program, as well as a Certified Level II Infrared Thermographer.

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BACKGROUND

Occasionally, building renovation projects present an opportunity to renovate old, tired, worn out, or outdated features and totally transform the building or the facility into something completely new or different. Such is the case with the transformation of a circa 1980s office building and research facility into a modern, more energy-efficient, transformed building (*Figures 1, 2,* and *3*).

The facility, located in the Mid-Atlantic region in climate zone 4, was originally constructed in two phases: phase one in the early 1980s and phase two very shortly thereafter. Construction was similar in both phases. Recently, the facility was undergoing an extensive interior renovation, including mechanical, electrical, industrial process, and build-out of high-tech manufacturing space.

Prior to this recent renovation, the exterior brick cladding was showing some signs of distress. Aesthetically, the building's architecture was dated, and repairs to the cladding systems were warranted. The building had already undergone some prior exterior renovation a decade earlier where the ribbon-style windows had been replaced and a new single-ply roofing system had been installed. These building elements were in satisfactory and functional condition and were not in need of renovation or replacement. Therefore, replacement of the roof and windows was not part of an exterior repair plan.

The design team discovered a significant number of horizontal and vertical hairline cracks in the exterior brick cladding, particularly at locations where steel relief angles were expected to be located. Initially, the design team chose to design and detail extensive exterior masonry repairs to the cladding system. This effort also called for replacing steel relief angles, although their condition was undetermined at the time, as they were concealed. These initial design decisions were made without the benefit of a full forensic evaluation and a determination as to the cause of the observed masonry deficiencies. A forensic study would have provided critical as-built information and a review of the long-term performance of the various building enclosure elements.

Figures 1, 2, and 3 – Elevation views of brick façade prior to project commencement.

Figure 4 – Inspection location at a window head corner revealing the condition of the loosely placed rigid foam board sheathing and poorly installed PVC flashing.

FORENSIC STUDY

Prior to the exterior work taking place, it was determined that the project team might benefit from a forensic study of the exterior to better understand some of the defects that had been discovered, identify their root cause, and review various options for restoration or repair. A forensic study would also allow for a more in-depth evaluation to better understand why cracks had occurred in the exterior brick cladding and to provide recommendations for restoration, repair, or even the possibility of recladding the building.

The forensic study included a review of the original drawings to the extent that only a limited number of drawings were available. This offered critical insight pertaining to how the masonry cladding was supported, the locations of a number of the steel relief angles, and the details associated with their construction. The study included two days of field work, as well as a certain amount of deconstruction. Observations included a closer visual survey from the grade level up of the condition of the exterior masonry, identifying areas of weathered or damaged masonry (particularly mortar); as well as the location of various horizontal, vertical, and step cracks in the brick cladding system; and verification of the embedded steel elements. Crack maps for each elevation were generated by overlaying field-observed deficiencies onto elevation drawings or doing the same over photographs of each elevation, to create a picture of the distress that was observed. Photographs can be stitched together to create panoramic views of an overall big picture of the building, allowing for the overlay of crack and deficiency locations. In addition to creating crack maps of each elevation and reviewing the existing drawings, the team created observation openings in the brick cladding in several key locations, as well as openings in interior finishes at critical locations, in order to see how the building was constructed and to determine the condition of concealed elements inside the cavity wall, including the general condition of the steel supporting members. Bricks were removed at a window head condition (*Figure 4*), a base-of-wall through-wall flashing condition, and a steel relief angle condition. In several locations, interior finishes were also removed to allow for the inspection of the back side of the brick cladding, sheathing, and construction of the entire wall assembly (*Figure 5*).

The findings of the forensic study changed a few significant assumptions regarding the condition of several of the building cladding, structural, cavity, and wall assembly elements. It became apparent that the as-constructed condition of the brick did not provide for any masonry control joints. Masonry control joints were not shown on the original plans. There were no vertical control joints near corners, at openings, or at the ends of the brick

Figure 5 – Forensic study image where the brick cladding was inspected from the inside of the building by removing interior finishes and sheathing. Note through-wall flashing at bottom of photo.

panels supported by steel relief angles. There were no soft joints (backer rod and sealant joints) in any of the masonry cladding systems. The lack of soft joints at critical areas to allow for a certain amount of stress relief in the masonry cladding, for differential movement between brick cladding that is footing supported, and brick cladding that is building-frame supported, was determined to be the primary cause of the horizontal and vertical cracks on the building. Horizontal cracks in mortar joints occurred at every relief angle location, and vertical cracks occurred close to building corners, as might be expected in the building where vertical control joints are normally expected. Industry associations generally recommend control joint placement at changes in wall height; at changes in wall thickness, such as at pipe and duct chases and pilasters; at movement joints in foundations and floors; at movement joints in roofs and floors that bear on the wall; near one or both sides of door and window openings; and adjacent to corners of walls or intersections within a distance equal to half the typical control joint spacing. The study also found a limited number of step cracks at window head corners—primarily due to distress caused by the different load-bearing conditions (steel vs. footing-supported masonry).

At the locations where brick extraction allowed for the inspection of the embedded structural steel relief angles, it was found that the steel members were in much better condition than assumed and anticipated.

One critical finding was that the exterior wall assemblies were originally constructed with numerous deficiencies. The building was constructed at a time when sensitivity to energy conservation was a significant factor. Construction occurred in the early 1980s after several worldwide energy crises, which had an impact on building design. The building is constructed with a steel frame with exterior walls composed of interior painted gypsum, light-gauge metal-framed stud walls with 6 in. of Kraft-faced fiberglass batt insulation. For exterior sheathing, the assembly includes ¾ in. of rigid extruded polystyrene insulation board (no gypsum sheathing) with a masonry cavity and brick masonry exterior cladding. The use of an extruded polystyrene for exterior sheathing is somewhat unique for the time period and, to a certain extent, has made a comeback more recently with the need for continuous insulation (CI) in modern buildings. However, at the time of construction, there appeared to be little consideration for air- or weathersealing the foam board sheathing.

Figure 6 – Forensic image of one of the methods used, fastening brick cladding anchors to the steel studs where the anchors were field-welded in place; note large hole melted in the foam sheathing.

Findings also included some unique features where the brick masonry ties were welded to interior studs or welded to steel washers, which were welded or screw-fastened to the interior studs (*Figure 6*).

This construction technique must have required pushing the masonry anchors through the exterior extruded insulation board to allow the anchor to be welded to the studs. This construction technique created thousands of holes in the exterior sheathing, as well as burn marks and melted insulation due to the welding activities.

In addition, it was determined that the exterior foam board sheathing was installed loosely with screws and washers with no efforts made to seal joints or provide any sort of weather or air barrier. In most instances, masonry cavities were found to be bridged with excessive mortar.

Through-wall flashings were found to be composed of a plastic PVC membrane sheet, which was loosely fastened to the foam board insulation or run up behind it where gaps occurred between adjacent insulation boards. The plastic flashing had long since lost its flexibility and was brittle and easily damaged.

The forensic investigation was completed during the cooling season. When openings were made in the brick, at each location a large volume of cold air from the interior conditioned spaces was felt rushing out (exfiltrating) from the masonry cavity.

Overall, the exterior wall assemblies appeared to be of stout construction consisting of steel stud metal framing generally 8 in. deep and, in some cases, composed of double studs, presumably in an effort to reduce thermal shorts through the wall assembly. Wall studs were welded to top and bottom tracks without the benefit of slip tracks with the inability to accommodate floor-to-floor or roof deflection. This is not a good practice, although it was determined that this condition did not appear to impact building performance.

The brick units themselves were found to be in remarkably good condition with little indication of weathering. Some weathering was observed in patchy areas in the mortar joints at a few locations.

REPAIR OPTIONS

Given the findings, it was clear that simply repointing or restoring the exterior brick cladding would not solve many of the issues discovered during the forensic study. One of the positive findings of the forensic study was that the supporting steel relief angles were in much better condition than anticipated and therefore could remain in place without the need for any rework or repairs. These angles were supported by steel channels that were hung from the floor and roof beams above.

Due to the discovery of the lack of a proper weather or air barrier, the large volume of exfiltrating air that was observed inside the masonry cavity, the poor installation techniques of the PVC through-wall flashing products, and the poor placement and installation of the extruded foam board sheathing, the new challenge became addressing the in-the-wall deficiencies without tearing the building apart.

Some of the repair options that were considered include:

- Only repointing and repairing the brick cladding system. This approach would have required an extensive amount of saw cutting to provide relief joints (both vertical and horizontal, at every relief angle). In addition, a challenge to this approach would be matching the existing brick and mortar to provide a seamless repair. This option would also ignore the significant issues with the building's air and weather barriers.
- Sealing the exterior brick cladding with a vapor-permeable silicate-based paint coating. This would have been applied over the existing cladding system, completely sealing it from water penetration. Such an approach would still require extensive rework of the brick cladding system to provide relief in the form of control joints to prevent movement of the brick cladding system from damaging the applied coating. This approach also would not address the issues inside the wall.
- Sealing the existing brick cladding system by using it as a substrate for a vapor-permeable air/weather barrier and an applied lightweight recladding system such as pre-finished metal panels or EIFS. Although more costly, a recladding approach would provide the architect an opportunity to transform the exterior of the building, keeping it more in line with the owner's corporate image, and allow for installing an air/weather barrier using the existing brick cladding system as a substrate, and to add more insulation to the wall assembly. This approach would also greatly reduce

Figures 7 and 8 – Ongoing installation of the liquid-applied vapor-permeable air and weather barrier being applied to exterior gypsum sheathing and brick cladding.

the amount of rework on the brick cladding system, as vertical relief could easily be added without the need for matching architectural final appearances. The applied weather barrier system could tolerate a certain number of hairline cracks in the substrate, eliminating the need to install horizontal soft joints at each of the steel relief angles. Hairline cracks in the air barrier would need to be pre-treated prior to the application of the system. A lightweight metal cladding system could easily accommodate a small amount of substrate movement.

Ultimately, installation of a lightweight metal cladding system was selected.

DESIGN

During the design phase, a certain amount of effort was required to verify that the existing selected substrate—the brick cladding system—could be used as an acceptable substrate for the new air/weather barrier and support the new cladding system. This effort included an engineering evaluation of the adequacy of the existing masonry ties and the ability to fasten a new cladding system to the existing brick. Therefore, a certain amount of structural analysis was required as well as fastener pullout resistance testing at the existing brick cladding to ensure that the additional assembly could be adequately supported. Fastener spacing of the new cladding system was also a consideration to ensure that none of the existing masonry ties became overloaded.

As part of the design effort, vertical control joints were saw cut into the building elevations at critical locations. These new control joints were addressed with the application of new backer rod and sealant. On either side and adjacent to the new vertical control joints, new stainless steel and brass masonry repair anchors were installed to properly support the cladding at these areas. The new design included the selection of a prefinished metal cladding system, including both vertical and horizontal panel selections with a custom layout and custom accent colors. The new assembly included a vapor-permeable liquid-applied air barrier installed over the existing brick (*Figure 7*), horizontal or vertical light-gauge Z members (*Figure 8*) with an additional layer of mineral wool insulation (*Figures 9* and *10*).

Figure 10 – Ongoing work where the liquid-installed air barrier is visible, as well as horizontal Z tracks and thermal insulation prior to installation of metal wall panels.

Figure 9 – Base-of-wall condition where through-wall flashing is secured to the primed air-barrier membrane to flash out water before the base-of-wall insulated concrete panels below.

Figure 11 – The installed cladding system was tested using ASTM spray nozzle techniques.

As with any recladding effort, the architect created new elevations paying particular attention to the numerous openings and penetrations in the exterior façade, including simple items such as hose bibs; electrical boxes; surface mounted conduits; lighting fixtures; openings for doors, windows, and entrances; security cameras; and a myriad of other building-mounted equipment. There were numerous site visits and detailed discussions about each of these details with the general contractor and installer to ensure the final fit finish and appearance met the architect's

Figure 12 – Finished metal cladding system depicting custom colors and variation of panel types and details.

Figure 13 – Completed wall depicting various metal panel types as well as insulated concrete-coated rigid insulation panels at base of wall.

expectations. The new design included tying in the new metal cladding system to the roof with a matching prefinished manufactured fascia metal system with an extruded aluminum closure.

The architect also elected to provide additional thermal insulation at the base-of-wall condition, tying the new metal cladding system to an insulated concrete panel system using extruded insulation which extended to below grade (*Figure 9*). At some locations, a new below-grade bentonite-based waterproofing system was also installed. The architect went to great lengths to detail as many of the as-built conditions as possible and tie the new system into the existing building elements. Finally, water-hose nozzle testing was used to field-verify weathertightness of the new installation (*Figure 11*).

The end result is a dramatic transformation of a dated building façade into a modern facility that is more energy efficient and far more airtight and weathertight than the original building (*Figures 12, 13, 14,* and *15*). IIBEC

> The architect went to great lengths to detail as many of the as-built conditions as possible and tie the new system into the existing building elements.

Figure 14 – Completed end wall with custom colors and variation of metal building wall panels.

Figure 15 – Another view of the completed end wall with custom colors and variation of metal building wall panels.