BRICK BY BRICK: TRADITIONAL AND UNCONVENTIONAL MASONRY RESTORATION STRATEGIES

ABSTRACT

Exterior masonry wall design and construction practices have evolved to include mass, transitional, barrier, and cavity walls. As the inventory of these buildings age into the future, repair and/or restoration will be required. It's not a question of if, but rather when and how.

Although time-tested, traditional repair strategies are suitable for many projects, other lesser-established unconventional strategies can be considered to improve exterior wall performance. Over-cladding or exterior coating application can be implemented to fundamentally transform the exterior wall into a cavity wall or barrier wall, respectively. Unconventional interior repairs, including the use of crystalline waterproofing technologies, urethane foam, or variable vapor retarders in conjunction with insulation can also be considered to improve wall performance with respect to water leakage, air infiltration, and/or thermal properties. This article covers both traditional options and "outside-the-box" strategies for masonry restoration and repair projects. This article also includes discussions related to building science, air and vapor transport related to traditional and unconventional strategies, and several case studies.

LEARNING OBJECTIVES

- Define masonry wall types as mass, transitional, cavity, or barrier walls that can be constructed of many different materials.
- Demonstrate an understanding of building science associated with masonry walls and the impacts of various restoration strategies.
- Review various traditional and unconventional masonry restoration options to overcome issues associated with water leakage, air infiltration, and thermal performance.
- Describe advanced technologies that can be applied to renovations associated with exterior masonry walls.

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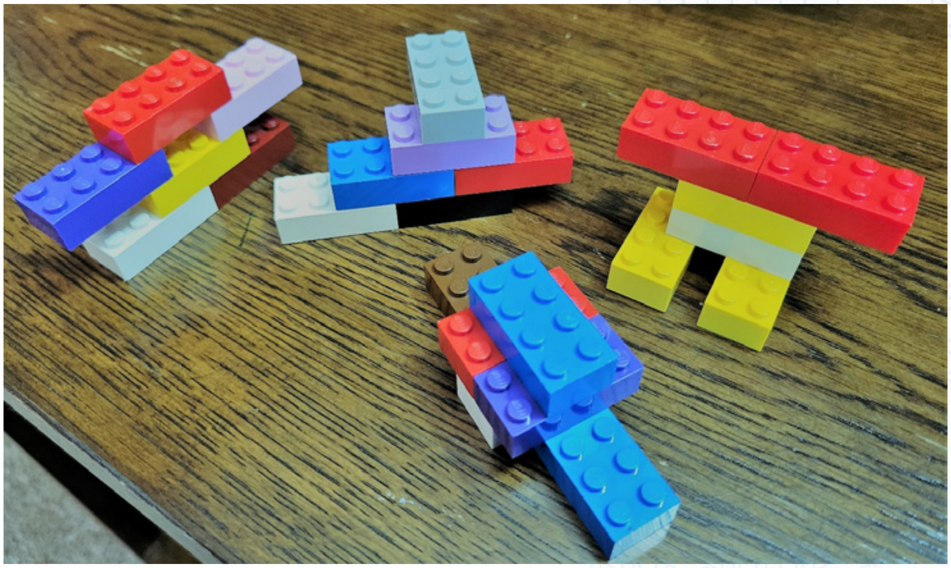

FIGURE 1. Four of 915,103,765 possible ways to combine 6 eight-stud LEGO bricks.

Exterior masonry walls are designed and constructed using a variety of materials and with various strategies to limit air movement into and out of buildings, manage moisture, and provide thermal control. Even if buildings are constructed similarly, exterior walls will differ with respect to material properties, conditions during fabrication and construction, and workmanship. Given that there are 915,103,765 ways to combine six 8-stud LEGO bricks (**Fig. 1**), there must be an unlimited number of ways to configure different exterior masonry walls. No two exterior masonry walls will be exactly the same.

Although buildings are often designed for useful service lives in excess of 50 years, and exterior masonry walls can be expected to last for more than 100 years if properly maintained, buildings begin to age immediately. Aging exterior masonry wall components and systems will need to be maintained and repaired over time. It is not a question of if but rather when. This paper explores opportunities to improve exterior masonry wall performance with respect to moisture management, air infiltration considerations, and thermal properties. In addition to traditional restoration strategies such as repointing that are generally well known by structural engineers, building enclosure consultants, and qualified restoration contractors, this paper explores unconventional restoration strategies as a series of case studies.

BUILDING BLOCKS (MASONRY UNITS)

Fabrication of masonry units began millennia ago with materials that were available to local populations. As manufacturing technology and transportation infrastructure advanced over time, masonry units became readily available around the world. Due to its versatility and durability, masonry remains popular as a construction material today. Common types of masonry units include clay and concrete units, natural stone, calcium silicate units, and glass block, among many others. The specifications for each type of unit are based on several properties, including compressive strength, absorption characteristics, saturation coefficients, and others that can be evaluated by means of standards available through ASTM International and industry organizations. For exterior masonry wall assemblies, masonry units are typically bound together with mortar and, in some instances, with grout. The characteristics of several common masonry unit types are briefly summarized in the following sections.

Natural Stone Units

The first natural stone units used in exterior wall construction were crudely stacked. As craftsmanship improved and tools advanced, natural stone units were shaped into polygonal or square units so that close-fitting joints could be achieved. Common types of stone used in exterior wall construction include granite, limestone, sandstone, and marble. These units today are available in a wide range of sizes, shapes, textures, and finishes achieved by polishing or machine tools. The specific properties of each stone vary, and the absorption properties are typically dependent on the density of the stone. Many natural stone units can be used in load-bearing wall assemblies, as a veneer, or as part of a rainscreen cladding system.

FIGURE 2. Various forms of exterior masonry wall deterioration.

Clay Masonry Units (Brick)

Clay masonry units have been in use for at least 10,000 years. Originally, these units would often be air- or sun-dried for five years or more. Today, the entire brick-making process can be completed in less than a week with a kiln, which allows for the firing of bricks in a continuous process. Immediately after firing, clay masonry units begin to absorb moisture from the environment, and the accumulation of moisture within the units results in slow, irreversible expansion. Clay masonry units can be hollow, solid (units that are more than 75% solid), or 100% solid. They are currently classified by three grades: severe weathering (SW), moderate weathering (MW), and negligible weathering (NW). Grade SW units are the most durable with respect to exterior conditions.

Calcium Silicate Units

Calcium silicate units are manufactured using sand, lime, and water. They are air dried, but unlike clay masonry units, they are exposed to steam under pressure to cure. The manufacturing process attempts to emulate how stone is formed within the earth, though in a much more rapid manner. During the manufacturing process, raw materials chemically react to form a calcium silicate hydrate binder, resulting in integrally bonded units. Unit strength depends on the quality of the binder, the pressure of the press, and autoclaving conditions. Calcium silicate units exhibit shrinkage over time and deform when loaded, but they are rarely subjected to high enough stress levels in service that creep becomes significant. There are currently two defined grades for calcium silicate units: those appropriate for severe weathering (SW) and moderate weathering (MW) conditions.

Concrete Masonry Units

Concrete masonry units (CMUs) are fabricated with portland cement, aggregate, and water. Additives and pigments can also be included to aid with moisture resistance, curing, coloration, and finish properties. CMUs derive their strength from the cement hydration process, and much of concrete technology is applicable to CMUs. CMUs can be fabricated as concrete blocks or concrete bricks. Concrete blocks are used in both load-bearing and non-load-bearing applications, whereas concrete bricks are more typically used within non-load-bearing veneers. Block CMUs are classified as Type I (moisture controlled) or Type II (non-moisture controlled), and Brick CMUs are classified as Grade N (architectural veneer) or Grade S (general use). CMUs exhibit shrinkage over time due to drying shrinkage, carbonation shrinkage, or both drying and carbonation shrinkage. Repeated drying and wetting of units can also result in reversible shortening and expansion, respectively.

MASONRY DETERIORATION MECHANISMS

Like most construction materials, masonry is subject to deterioration over time in the presence of moisture, other environmental factors, and loading (**Fig. 2**). The following are several types of masonry distress:

» **Cracking:** Cracking is defined as a splitting within masonry units, mortar joints, or both, due to one or many internal or external stresses.

» **Delamination and spalls:** Delamination involves debonding of the exterior surface of a masonry unit and can present a potential fall hazard. A delamination that has separated from the unit, revealing the inner surface of the masonry unit to the elements, is classified as a spall.

» **Bond line separation:** This type of masonry distress is a failure in the bond between masonry units and mortar joints.

» **Mortar washout:** Mortar washout is defined as mortar deterioration and erosion of the mortar from within the joint.

Cracking, delamination, bond line separation, and mortar washout all can allow water to intrude into an exterior masonry wall. Water can pass through imperfections or cracks as small as 0.005 in. (1.3 mm; slightly thicker than a human hair), and it can enter through even smaller cracks when it is subjected to a pressure differential. Once water enters beyond the exterior face of a masonry wall, it can cause additional distress including the following:

» **Deterioration from freezing and thawing cycles:** When water freezes and expands within the pores of a masonry unit, internal tensile stresses within the material can lead to cracking, delamination, and possibly spalled units (**Fig. 3**).

» **Efflorescence:** Efflorescence is generally a benign form of distress in which light-colored minerals are deposited on the surface of masonry units after water evaporates from within the walls. Efflorescence can occur on both the interior and exterior sides of the walls.

FIGURE 3. Deterioration of brick veneer from freezing and thawing cycles.

- **Corrosion of metal components:** Water provides an ideal environment for steel corrosion if chlorides or other corrosion-promoting chemicals are present. Depending on the function of metal components within wall systems, the formation of corrosion products can exert expansive stresses on masonry, leading to cracking and spalls. Additionally, masonry veneer can become unstable if masonry ties corrode and can no longer provide resistance to out-of-plane loads.

Displacement, bowing, and bulging can also occur due to compression stresses, inadequate lateral support, lack of adequate movement joints, or a variety of other reasons (**Fig. 4**). Dimensional changes can also occur due to creep of CMUs or a backup concrete structure, volume changes (masonry walls are constantly expanding or contracting), and other factors. Displacement and dimensional changes can cause masonry to deteriorate, especially in areas of restraint where the natural movement of exterior wall components is restricted.

TYPES OF MASONRY WALL SYSTEMS

The design of masonry exterior wall systems has evolved over time. Most of these systems primarily fall within the categories of mass, transitional, cavity, and barrier walls.

Mass Masonry Walls

Mass masonry exterior wall systems were commonplace in buildings constructed before the 1950s. Buildings supported by load-bearing mass masonry walls are generally limited in their height to approximately four

FIGURE 4. Two examples of masonry wall bowing due to lack of movement joints.

FIGURE 5. A thin layer of insulation provided on the interior side of a mass masonry wall.

stories, although taller exceptions are common. The tallest modern load-bearing mass masonry building on record is the 16-story Monadnock Building in downtown Chicago, Illinois, constructed in 1891.

The large thermal mass of mass masonry structures assists in reducing temperature fluctuations within buildings. As such, insulation was typically not provided within or inboard of the walls. In some cases, a thin layer of insulation was provided on the interior side of mass masonry walls (**Fig. 5**).

Multi-wythe mass masonry wall systems rely on their thickness and solid construction to absorb water and evaporation to discharge water that accumulates within the walls. The performance of mass masonry walls depends on several factors, including the ability of the masonry and mortar joints to reject and shed most water during precipitation events. When masonry units and mortar joints exhibit cracking and deterioration, more water can penetrate into the walls, potentially exceeding the absorptive capacity of the walls. Over time, water intrusion and cycles of freezing and thawing further deteriorate the masonry units and erode mortar within interior wythes of the masonry. As the mortar and masonry units within the walls deteriorate, water passes more easily through the walls. Eventually, restoration and repairs will be required to address water leakage issues and potential structural concerns.

In general, thick mass masonry walls (approximately 15 in. [380 mm] and thicker) are significantly more reliable with respect to resisting water leakage than thinner mass masonry walls because the thicker walls have greater water storage capacity.

Today, mass masonry walls can be constructed of single-wythe CMUs. Walls with fully grouted cores will generally provide better moisture resistance than walls constructed with cores only grouted at locations containing steel reinforcement. Integral water repellants are often included in single-wythe CMU walls to provide additional resistance to water penetration.

Transitional Walls

Transitional masonry walls encompass many wall systems developed over a short period during the late 19th and early 20th centuries following the advent of iron, steel, and concrete structural framing. In this type of wall construction, masonry and steel components were typically constructed side by side within a wall assembly. Transitional masonry structures could be built taller than their mass masonry predecessors, and they included many of the first US skyscrapers. One famous transitional structure is the Rookery Building in Chicago (1888). The proportions of the vertical loads supported by iron and steel building components and by masonry components vary widely depending on the detailing implemented.

Moisture management in transitional masonry structures is similar to that in mass masonry structures: the masonry walls absorb water and release that moisture to the exterior environment or to the building interior via evaporation. The marriage of materials in transitional walls is potentially problematic because iron or steel framing within a wall assembly is vulnerable to moisture-related deterioration. Embedded iron and steel elements that exhibit corrosion impart expansive forces on the surrounding wall elements, resulting in cracking of masonry and mortar joints. Transitional masonry walls are also susceptible to distresses caused by differential movement and thermal expansion of the multiple construction materials incorporated into the same wall.

Similar to mass masonry walls, transitional walls typically were not insulated. However, limited insulation was sometimes provided on the interior side of transitional walls.

In the mid-20th century, designers developed newer types of transitional walls with masonry veneer constructed outboard of CMU backup walls. In many cases, these walls were designed and constructed with a fully or partially grout-filled collar joint to connect the veneer to the backup walls. Originally, header courses were used to mechanically connect the veneer to the CMU. Eventually, mechanical ties and anchors were introduced. These types of walls with no air-and-water barrier (AWB) or clear drainage plane between the brick and CMU often are susceptible to water leakage.

Cavity Walls

The cavity wall system became widely used by the 1980s and is the most prevalent type of exterior masonry wall construction today. Properly designed and constructed modern cavity wall systems are often more effective at limiting water leakage when compared with mass masonry and transitional walls. Cavity wall design assumes that masonry veneer joints will allow water penetration beyond the exterior wall surface under certain conditions. A water management system consisting of a water-resistive barrier, through-wall flashing, weeps, and accessory components is required to manage and discharge water that enters the wall drainage cavity.

In modern wall construction, water-resistive barriers are constructed over solid substrates (concrete, CMUs, plywood sheathing, oriented strand board sheathing, or exterior gypsum sheathing); however, it should be noted that a water-resistive barrier is not required over concrete or CMU backup walls in all jurisdictions. In many cases, insulation is provided within the drainage cavity, although insulation provided on the building interior or between exterior wall stud framing remains common practice in certain locales. Emerging technologies that incorporate insulation and water-resistive barriers into a single product are also becoming more commonplace.

Since masonry veneer is nonstructural, it must be anchored to the structure or backup wall to resist out-of-plane loads. In cases where thick continuous exterior insulation is required, engineered masonry tie assemblies may also be required.

Barrier Walls

Barrier walls can be constructed of precast or cast-in-place concrete, insulated and formed metal panels, and exterior insulation and finish systems (EIFSs) and stucco applied directly over a backup substrate without a drainage plane. They offer only a single line of defense against bulk water penetration and are considered by some as a zero-tolerance wall system. Water that penetrates beyond the exterior surfaces of the wall and sealant joints will penetrate into the building and can cause water-sensitive concealed materials to deteriorate.

Typically, masonry has not been used as part of barrier wall systems due to the nonhomogeneous nature of such walls. However, thin masonry units can be embedded into precast concrete wall panels to provide the concrete barrier wall with a masonry aesthetic. Single-wythe CMU walls can also essentially be changed from a mass wall to a barrier wall by applying an elastomeric coating to the exterior face of the CMUs.

CONVENTIONAL MASONRY RESTORATION REPAIR STRATEGIES

Conventional masonry restoration repair strategies have been described in many previous technical publications and discussions of such repairs are not the main subject of this paper. Typical masonry restoration strategies for exterior walls include, but are not limited to, the following:

- Repointing of mortar joints
- Replacement of unit masonry materials
- Routing and sealing of cracked masonry units and mortar joints
- Application of sealant at joints between dissimilar materials and within skyward-facing joints
- Application of a penetrating water repellent to exterior wall surfaces
- Restoration or replacement of corroded steel elements such as lintels and shelf angles
- Installation of through-wall flashing at localized areas such as above lintels and below copings
- Providing supplementary anchorage or employing stabilization techniques

However, without proper design and industry-standard construction methods, conventional masonry restoration strategies can have limited benefits or result in aesthetic concerns. As an example, repointing is a common repair practice that requires removing deteriorated mortar to a uniform depth and placing new mortar within the joint. The deteriorated mortar should be removed to a uniform depth that is a minimum of twice the joint width, generally ¾ in. (19 mm), or until sound mortar is reached. If mortar is not removed to an adequate depth, deficiencies in the joint within the depth of the wall may not be uncovered (**Fig. 6**). Repointing performed to a limited depth is likely to provide only minimal benefits when compared with grinding and repointing to at least a ¾ inch depth (**Fig. 7**).

FIGURE 6. Voids in a mortar joint were uncovered following grinding during a repointing project.

FIGURE 7. Mortar joint repointing to an insufficient depth of approximately ¼ in. (6.4 mm).

FIGURE 8. Water-repellent staining on an exterior masonry wall surface.

Water repellents should not replace or be considered equivalent to essential details that resist water penetration such as through-wall flashing and weeps in masonry cavity wall construction. Additionally, only products that permit evaporation and the passage of water vapor, such as siloxanes and silanes, should typically be applied to exterior masonry walls. Although water repellents are widely used as part of exterior masonry wall restoration projects, they typically do not provide protection at crack locations in masonry units and mortar joints. Additionally, water repellents must be reapplied at regular intervals of approximately 5 to 10 years to remain effective. In cases where water repellents are incorrectly applied, staining can occur (**Fig. 8**).

BUILDING SCIENCE OF DIFFERENT WALL TYPES

Until masonry cavity walls became prevalent, AWBs, through-wall flashing, and cavity drainage systems were not typically included in the design and construction of exterior masonry walls. Today, although modern building codes typically require flashing at various locations, the use of a dedicated AWB in cavity wall assemblies is still not always required for some wall types in certain types of buildings. Although the use of vapor retarders has become commonplace on the interior side of frame walls in cold climates, vapor retarders are often misused because some designers and tradespeople do not fully understand building science related to air movement, vapor drive, and moisture management.

Similarly, exterior masonry wall assemblies were traditionally constructed without the use of insulation. In cases where insulation was provided as part of the exterior wall assembly, the insulation was usually placed on the interior face of the masonry wall, or in cases where wood stud walls or cold-formed steel back-up walls were used, batt insulation was placed between the studs. The placement of insulation between exterior wall studs remains a common practice today, primarily in light commercial and residential structures. Due to thermal bridging, such insulation only provides partial thermal benefit when cold-formed steel framing is used. It should be noted that continuous exterior insulation is now required by many energy codes, especially in cold climates.

The concept of a "perfect wall" has been around for many years. Theoretically, a perfect wall would have exterior cladding to shed water and protect the control layers (rainwater control layer, air control layer, vapor control layer, and thermal control layer) that are located on the exterior of the building structure. Also, a perfect wall could be constructed in any climate, although claddings and control layers will need to be selected accordingly.

The inventory of existing exterior masonry walls is immense and varies widely. While it may not be possible to construct a "perfect wall" when dealing with existing conditions in a restoration capacity, there are means available to improve exterior wall properties with respect to water penetration, air infiltration, and thermal performance.

CASE STUDIES

The following case studies illustrate traditional and unconventional methods that can be considered to mitigate problems with walls that fail to meet design or performance requirements. Several of the approaches described within can also change the exterior aesthetics of the building, which is a primary concern for some owners.

Case Study 1: Transitional Masonry Wall → Properly Detailed Cavity Wall at Localized Areas

The subject residential building is a four-story steel structure constructed in 1980 in a cold climate. The exterior walls consist of brick veneer over CMU backup walls and include elements of both cavity and transitional wall types. An investigation revealed that reported water leakage at window locations was due to water infiltration through the masonry exterior walls above the fenestration. To address these issues, a repair program including through-wall flashing and weeps above lintels was developed. A new AWB above the through-wall flashing was also installed to ensure a continuous drainage plane above the through-wall flashing.

The condition of the backup masonry varied throughout the building and included areas of out-of-plumb masonry, loose masonry units, and significant voids in the backup CMUs. Project specifications required repairs to the backup wall in the form of repointing, parging, and unit replacement to ensure a suitable substrate for the AWB and through-wall flashing (**Fig. 9**). Although

FIGURE 9. Preparation of a backup wall prior to installation of the AWB and through-wall flashing.

traditional through-wall flashing repairs are typically limited to the three or four courses above steel lintels, the additional repairs performed for this project were intended to limit the possibility of water leakage through deficient areas of the backup wall structure above the areas of through-wall flashing repairs (**Fig. 10**).

Case Study 2: Masonry Cavity Wall without AWB → Overclad with Drainable EIFS

The exterior walls for this building were constructed in 1981 as an addition to an existing medical facility located in a cold climate. Exterior walls at this area of the building include brick veneer over a CMU backup wall, glass-and-aluminum storefront systems, exposed concrete columns, and precast concrete wall panels at roof-to-wall transition locations. Hospital staff had complained of cold interior temperatures and condensate formation near exterior walls during winter months for many years. An investigation revealed that the extent of exterior wall insulation within the building ranged from minimal to nonexistent. Additionally, the windows were offset from the interior insulation, and their placement within the wall assembly rendered the windows "heat starved" and susceptible to condensation during periods of cold exterior temperatures.

The project team had originally considered an interior insulation strategy that would involve the application of spray polyurethane foam (SPF) on the interior side of exterior walls. However, this strategy was complicated by access restrictions, the presence of steel spandrel beams that would limit the efficacy of SPF application at top of wall conditions, and other concerns; therefore, the team ultimately implemented an exterior insulation strategy using drainable EIFS as a rainscreen. This solution also allowed for

FIGURE 10. Installation of brick veneer following installation of the AWB and through-wall flashing.

FIGURE 11. Mock-ups installed to evaluate adhesion of the AWB to substrates and the EIFS insulation to the AWB.

FIGURE 12. Completed overclad area of the EIFS adjacent to the existing masonry exterior wall.

a change in exterior aesthetics.

To achieve a rainscreen design with continuous exterior insulation, the exterior of the existing masonry walls was restored by means of localized brick replacement and limited repointing to allow for application of a continuous AWB on the exterior face of the masonry. Mock-ups were used to verify adhesion of the AWB to existing substrates and the EIFS insulation to the AWB (**Fig. 11**) before work on the overclad commenced (**Fig. 12**). Thermal modeling was also performed to verify adequate thermal performance at window locations and at roof-to-wall transitions.

Case Study 3: Masonry Cavity Wall → Overclad with Metal Panel Rainscreen System

Located in a moderate climate near the Atlantic Ocean, the subject building is a multistory medical building constructed in 1995. Lower levels of the building are constructed of brick veneer, an air space, spunbonded polyethylene building wrap, exterior gypsum sheathing, and cold-formed steel stud framing with batt insulation between the studs. Performance issues with the exterior wall assembly had not been reported during the building's service life, but the owner wanted to make aesthetic changes so this existing building would more closely match the architecture of newer buildings constructed by the hospital system.

As the building enclosure consultants for the project, the authors reviewed existing building drawings, architectural drawings and specifications, and shop drawings for the proposed exterior wall overclad using a metal panel open-joint rainscreen assembly. Because the new metal panels were a delegated design item, the subcontractor's specialty design engineer was responsible for providing engineering calculations for anchoring the metal panels to the building structure. The design for this overclad also included a new AWB applied over the brick veneer that would render the existing building wrap redundant.

Various options for attaching the metal panel rainscreen cladding were considered (**Fig. 13**). An investigation that involved the making of exterior investigative openings determined that the cold-formed steel stud vertical framing was installed at an irregular spacing. Therefore, the specialty design engineer worked with the project team and anchor manufacturer to perform a series of in situ tests to verify the in-plane and out-of-plane resistance

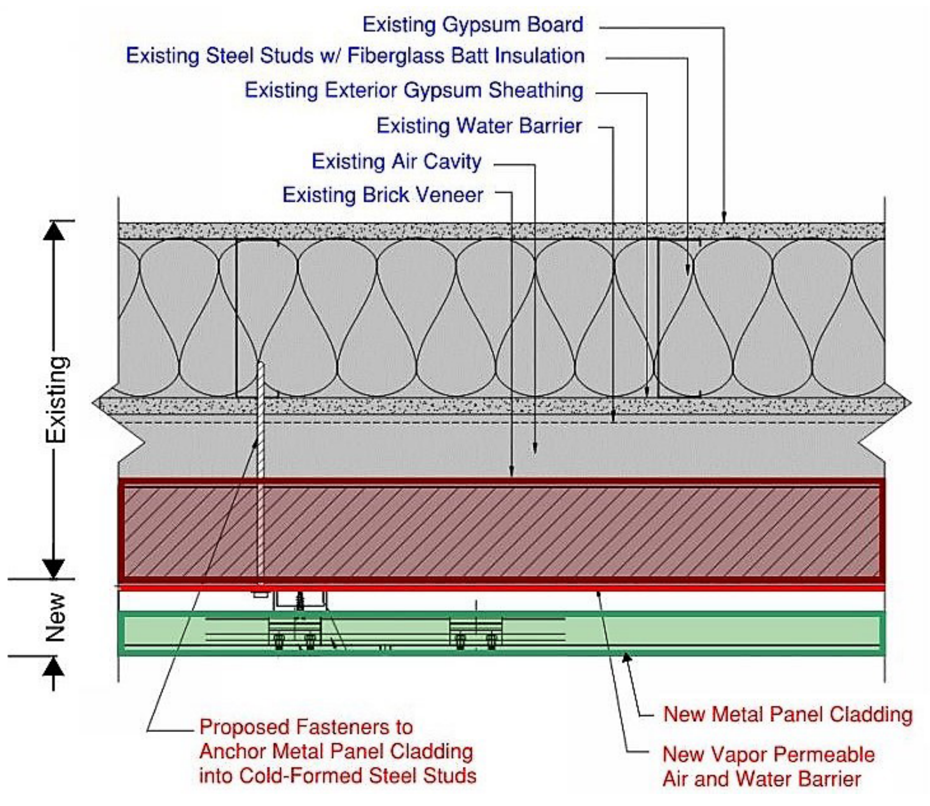

FIGURE 13. Schematic detail depicting metal panel rainscreen installed over a brick-veneer cavity wall.

of the existing veneer to support new loads imparted to it from the new metal panel cladding system. Ultimately, a solution was developed so that the new metal panel cladding could be installed directly into the brick veneer, with supplementary anchors provided into the existing framing to ensure redundancy of load paths.

Case Study 4: Masonry Cavity Wall without AWB → Interior Barrier Accomplished Using Crystalline Waterproofing

The exterior walls that are the subject of this case study were constructed in 1992 as an addition to an existing medical complex located in a cold climate. Before the interior spaces within this area of the hospital were renovated, the authors were retained to perform a building enclosure condition assessment at the property.

Exterior walls are constructed of brick veneer, an air gap, extruded polystyrene insulation, and CMU backup walls. Copper through-wall flashing is provided above lintels and at the base of the wall. No AWB had been provided on the exterior face of the CMUs. The interior spaces had previously been used for storage and light administrative uses, but the renovated spaces were designed to be used for medical purposes; therefore, a higher-performing exterior wall assembly was required. Given the deficiencies of the through-wall flashing, gaps in the backup CMU walls, and lack of a continuous AWB, the preferred solution would have been to remove the brick veneer and install a new AWB and through-wall flashing system. However, the owner deemed such a recladding solution to be not practical due to budget and schedule constraints.

Following demolition of interior finishes, water leakage through the field of the walls and at through-wall flashing locations was documented on several occasions during precipitation events. Therefore, the authors recommended a hybrid repair strategy that would incorporate traditional masonry repairs and window replacement in conjunction with application of a crystalline waterproofing system on the interior face of the CMU walls (**Fig. 14**). In general, the crystalline waterproofing application required the following:

- Cleaning the interior faces of CMUs and mortar joints so the surfaces would be free of foreign materials.
- Repointing cracked and deteriorated mortar joints on the interior face of the wall.
- Wetting the wall to a saturated surface damp condition and rewetting continuously until water was no longer accepted.

FIGURE 14. Crystalline waterproofing application on the interior side of a CMU wall.

Applying the crystalline waterproofing system in accordance with the manufacturer's approved installation instructions. The final thickness of the interior waterproofing system was approximately ¼ in. (6.4 mm).

After repairs were completed, the interior of the building was monitored for approximately three months until new interior finishes were installed. No water leakage was documented during precipitation events or during field quality control testing after the repairs were completed and the windows were replaced.

Case Study 5: Mass Masonry Wall → Exterior Barrier Accomplished Using Translucent Vapor-Permeable Coating

Constructed in 1972 in a cold climate, the subject building is a five-story residential structure with two-wythe mass masonry exterior walls. The two masonry wythes are connected with header courses every sixth course. The building had a long history of water leakage and exterior wall performance issues. An investigation revealed that water leakage was prevalent throughout the building because the header courses that extend from the exterior to the interior of the building provide a direct path for water leakage once water penetrates the exterior surface of the walls.

The authors determined that traditional repairs alone would unlikely resolve the water leakage issues at the building because the exterior wall system lacked sufficient mass. The recommended repair project involved localized brick replacement, 100% repointing, and sealant replacement. In addition, a translucent vapor-permeable coating was applied to the restored exterior wall surfaces. The translucent coating was applied in two thin layers to ensure that the coating would remain vapor permeable after repairs were completed, thus allowing for evaporation of water that may penetrate through coating imperfections over time. This strategy essentially changed the wall behavior from that of a mass masonry wall to a barrier wall system, thus improving the performance of the exterior wall with respect to water penetration. Although the translucent

FIGURE 15. Translucent silicone coating applied to the exterior face of a two-wythe mass masonry wall.

FIGURE 16. Interior insulation and a variable vapor retarder installed on the interior side of a mass masonry wall.

silicone coating has resulted in a slight sheen that was not present in original conditions, the exterior masonry remains visible through the coating (**Fig. 15**).

Case Study 6: Mass Masonry Wall → Mass Wall with Interior Insulation and Variable Vapor Retarder

The subject university building was constructed in 1911 in a cold climate near the Atlantic Ocean. Exterior mass masonry walls have an ashlar granite facing and granite rubble on the interior side of the wall. Wood lath and an interior plaster finish had originally been provided throughout the building. These conditions remained in place for over 100 years until a comprehensive restoration was undertaken beginning in 2018. As part of this masonry restoration and window replacement project, the university requested that the building be upgraded to improve its energy efficiency.

Exterior insulation was not permitted on this historic structure, so a repair approach was developed that provided an air gap on the interior face of the wall, 3 in. (76 mm) of mineral wool insulation, a variable vapor retarder (a "smart" air barrier), and interior drywall finishes (**Fig. 16**). A variable vapor retarder exhibits low permeance during seasons of low humidity (winter), and high permeance during periods of high humidity, thus allowing for vapor diffusion and limiting moisture accumulation within the wall assembly over time. To vet this potential solution, the architect's building enclosure consultant used WUFI Pro 6.2 software to calculate the transient, one-dimensional, heat and moisture transport to determine the increase in moisture accumulation over time, percent saturation in the granite, and freezing and thawing potential of the masonry. The analysis compared results of a variable vapor retarder with that of a traditional vapor retarder over a 10-year period on various building elevations. The results indicated that the variable vapor retarder approach was superior to the approach using a traditional vapor retarder.

Additional thermal modeling was undertaken to vet detailing associated

TABLE 1. Items to consider before implementing unconventional masonry wall repair strategies

Properly detailed cavity wall at localized areas
» Areas not addressed during the repair program will still include deficiencies and will be susceptible to air infiltration/exfiltration and water leakage.
» Repair of the backup walls is required to ensure a sound substrate for the AWB and through-wall flashing.
» New brick and mortar may not match existing adjacent areas, resulting in potential aesthetic concerns following completion of repairs.
Overclad with drainable EIFS or metal panel rainscreen
» Overcladding provides an opportunity for aesthetic changes with respect to the existing walls.
» Overcladding includes a new water drainage plane on the exterior face of the veneer for redundancy and water penetration resistance.
» Localized repointing and unit masonry replacement will likely be required to ensure a suitable substrate for AWB application.
» An EIFS overclad will provide continuous exterior insulation. A metal panel rainscreen overclad can also be designed to included continuous exterior insulation.
» If an EIFS is used, mock-ups are recommended to verify adhesion characteristics of the AWB to the substrates and the EIFS insulation to the AWB.
» If a metal panel rainscreen is used, the load path for attaching metal panels must be established by means of calculations and/or testing.
» Thermal modeling is recommended to evaluate interface conditions at fenestration and at roof-to-wall transitions.
Interior barrier accomplished using crystalline waterproofing
» Traditional masonry repair strategies should be implemented in tandem with interior crystalline waterproofing repairs.
» Interior finishes must be removed to access the repair area. Repointing the interior face of CMU joints will likely be required.
» Application of the interior waterproofing will result in a slightly thicker wall, possibly reducing interior space within the building.
» Field quality control testing is recommended following implementation of repairs and before installation of new interior finishes.
Exterior barrier accomplished using translucent vapor-permeable coating
» Localized brick replacement and 100% repointing may be required before coating is applied.
» Evaluation of aesthetic and performance mock-ups is recommended before a building-wide repair program is established.
» Applying the coating too thickly can cause a chalky appearance and can inadvertently result in vapor-retarding properties.
» Application of a translucent coating will change the appearance of the building and result in a sheen.
» Subsequent recoating projects will need to be performed using compatible materials.
Mass wall with interior insulation and variable vapor retarder
» Hygrothermal and thermal analyses are recommended before repairs are implemented on a building-wide scale.
» Traditional masonry repair strategies should be implemented in tandem with these repairs to limit moisture penetration into the walls.
» Evaluation of mock-ups is recommended to allow for review of variable vapor retarder integration and termination detailing.
» The additional materials will result in a thicker wall, thus reducing interior space within the building.

AWB = air-water barrier; EIFS = exterior insulation and finish system.

with the new aluminum-clad wood windows and aluminum frame windows that were installed during the restoration project. Several mock-ups were implemented to review detailing and integration of the windows with the new interior smart air barrier. Air site leak detection field quality control testing using theatrical fog was also performed to verify continuity of the smart air barrier at interface conditions with the windows.

CONCLUSION

Unconventional masonry repair strategies can assist with addressing concerns associated with water leakage, air control, vapor diffusion, and energy efficiency. In many cases, these strategies can be successfully implemented by combining traditional repair strategies with the unconventional strategies. **Table 1** lists some of the items that should be considered before implementing the unconventional strategies described in this paper.

Just as there are countless variations of masonry walls, an extensive array of possible maintenance and repair strategies is available for consideration by knowledgeable engineers and building enclosure professionals. Although many buildings will eventually experience performance issues related to water leakage, air control, or thermal issues, conventional and unconventional repair strategies can be used to maintain and repair both historic and relatively modern masonry exterior walls.

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