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The Designer's Dilemma: Modern Performance Expectations and Historic Masonry Walls

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ABSTRACT

Designers of building rehabilitation projects are often called upon to improve the structural, waterproofing, or thermal performance of wall systems in buildings undergoing rehabilitation work. The design of such improvements frequently requires envelope modifications that must be carefully analyzed to ensure that they are effective and to avoid unintended and negative consequences on building performance. The presentation will review modern envelope design requirements and provide recommendations for general design considerations and detailing, along with analysis techniques that can be used to assess the viability of rehabilitation options for existing masonry wall systems illustrated with examples from the presenter's experience.

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INTRODUCTION

Contemporary performance expectations often require designers to improve the structural, waterproofing, and/or thermal performance of wall systems in historic masonry buildings during rehabilitation work. The design of such improvements almost always involves the addition or alteration of one or more of the "four barriers": namely, water, air, thermal, and vapor barriers that are frequently incorporated into modern wall assemblies. When applied to traditional masonry wall systems, these modifications, though intended to provide improvements in performance, can cause damage to the existing wall assembly. Therefore, such modifications must be carefully analyzed to confirm that they provide the desired performance improvements while avoiding unintended and negative consequences on the material and system durability. This article will review some contemporary envelope design requirements and will provide recommendations for general design considerations along with analysis techniques that can be used to assess the viability of rehabilitation options for traditional masonry wall systems.

BACKGROUND

The primary function of the building envelope, to separate the interior and exterior environments, has remained the same throughout time. Historic buildings constructed with traditional masonry walls (i.e., mass masonry) use the durability and thickness of the wall to perform this function. Today's building envelopes (e.g., curtain walls, rain screen assemblies, etc.) use systems assembled from numerous materials to perform the same function, albeit with the intention of greater control. The primary method that most wall assemblies use to control the interior environment and isolate the exterior from the interior is the implementation of the four primary barriers within the building envelope: the water, air, thermal, and vapor barriers. The general intent of each of these barriers is to maintain a controlled interior environment, but the materials and performance criteria used in these barriers are under constant development and refinement. The following provides a brief summary of each barrier:

- **Water Barrier:** A water barrier resists liquid water infiltration. The concept of a water barrier has existed since the earliest building construction; one of the main functions of a building is to keep water from entering the building and keep occupants and contents dry. The effectiveness of water barriers has evolved over time with the advancement of waterproofing materials (e.g., sheet metal, bituminous membrane waterproofing, etc.) that can, with proper detailing and construction, provide a complete barrier to water penetration in modern construction.
- **Air Barriers:** An air barrier is installed in a building envelope to control unwanted air infiltration and exfiltration. Air barriers are a relatively new performance requirement within building envelopes. Although most traditional builders understood that limiting drafts improved occupant comfort and constituted quality construction, most historic buildings lack the materials and detailing required to achieve an airtight building envelope. In today's building construction, an airtight assembly is an attainable goal with modern-day materials (e.g., sealants and self-adhered waterproofing membranes), construction processes, and testing equipment to confirm airtightness.
- **Thermal Barriers:** Similar to water barriers, the concept of a thermal barrier has existed for centuries, with the earliest types being massive masonry, earth, and air (e.g., attic spaces) to insulate the building interior from exterior temperatures. Thermal barriers in modern wall systems are constructed with high-efficiency thermal insulation products installed within the wall assembly to reduce the conductive heat loss through the wall assembly and to isolate the building interior from the ambient exterior conditions.
- **Vapor Barrier/Retarder:** The concept of a vapor barrier, developed with the advent of modern sheet membrane products and coatings, is relatively new in the construction industry (i.e., within the past century). Vapor barriers are typically required when the control of moisture vapor in humid environments (both interior and exterior) is necessary to limit condensation and moisture accumulation on the exterior of a building.

Historic buildings with traditional masonry walls, a stockpile of buildings that are the subject of considerable rehabilitation work, typically lack these dedicated barriers. When these buildings undergo rehabilitation and reuse projects, building owners often request, and building codes frequently mandate, that the design improve the thermal performance of the building envelope. In other cases, the programmatic demands of rehabilitation projects, such as humidity control required for archival storage, dictate envelope performance improvements. The selection of individual components and materials, as well as the relative configuration of materials that are combined in a traditional masonry wall assembly, are influential factors in the resulting building envelope performance and must be carefully analyzed during the design of any improvements in order to balance intended positive impacts with potential deleterious effects.

Design Considerations For Historic Masonry Buildings

Designers struggling with balancing performance expectations of modern wall systems with the realities of a traditional masonry wall must consider both the anticipated changes to the function of the masonry with the interrelation and unintended consequences of the introduction of the four barriers. Each barrier can provide useful improvement to the wall system performance; however, practical considerations and unintended consequences may prohibit their use in many applications. In the following sections, we discuss the typical performance expectations, practical limitations, rules of thumb, and analysis tools that a design professional should consider when planning for a rehabilitation project.

Water Barriers

Water barriers are a material or collection of materials acting in concert to prevent the infiltration of bulk water (e.g., rainwater) into the building interior. While historic masonry buildings offer protection from the exterior environment, these wall systems typically do not include a dedicated water barrier that limits the penetration of water within the wall system. Instead, traditional masonry wall systems typically resist rainwater penetration through other mechanisms. These include often overlooked features, some of which are often perceived as unrelated to water penetration resistance in modern construction, including the configuration and condition of the mortar joints; the presence of large overhangs that shield the wall from rain; surface articulations with drips; sloped, sky-facing surfaces; recessed windows; and, in some cases, concealed metal flashings.

Though critical to the aesthetic appearance of a building, roof overhangs and façade articulations play an important role in reducing the exposure of building walls to rainwater. Buildings with large overhangs are inherently more water-resistive than those that lack these features by providing a deflection surface for rainwater, thus reducing the amount of rainwater that is deposited on the surface of the wall, particularly at the upper levels of the building near the roof. Water that is allowed to drain down the surface of the masonry is prevented from penetrating into the interior of the wall by the thickness of the wall, sound masonry (i.e., a lack of cracks), and competent mortar joints. Given the lack of a dedicated water barrier, historic masonry buildings generally rely on the mass (i.e., thickness) of the masonry construction to absorb water during rain events and to slowly release this moisture through evaporation at other times. This was considered generally acceptable performance, assuming the local climate includes adequate drying time between subsequent rain events. In some instances, such as prolonged rainy weather, some water was expected to penetrate to the interior, resulting in dampness on the building interior, a performance issue that has become less tolerable with the introduction of moisture-sensitive construction materials and interior finishes in modern construction.

While it is often the aim of rehabilitation projects to eliminate all moisture penetration to the building interior, installing a dedicated water barrier material into a traditional masonry wall system is usually impractical or impossible without significant demolition and reconstruction. As a result, a system of old and new measures typically is implemented as part of a rehabilitation project to improve the water penetration resistance of the masonry wall while still utilizing the moisture storage capacity of the masonry.

These measures should include a careful survey of the exterior, combined with selective demolition and water testing to identify the sources of bulkwater penetration and allow for the design of appropriate repairs. Rehabilitation of the exterior wall system to address deterioration and damage to the original masonry materials, including repointing mortar joints and replacing cracked and damaged masonry elements, is the first step in improving the water penetration resistance of the system.

Figure 1 – View of stone masonry removal during a rehabilitation project to allow for the installation of dedicated waterproofing above window openings in an historic mass masonry wall.

Figure 2 – View of dedicated waterproofing and flashing installation in an historic mass masonry wall assembly during a rehabilitation project.

In some instances, such as brick, stone, or other unit masonry construction, deficiencies in the original design can be addressed during rehabilitation, including detailing provisions that were overlooked or omitted in the original construction (*Figures* 1 and *2*). These may include tried-and-true measures, such as adding through-wall flashings at wall openings, parapets, and railings and covering the sky-facing masonry materials with metal flashing. The addition of these measures offers reasonably predictable benefits that can be verified readily through the application of water testing. These measures, when correctly designed and executed, offer few drawbacks to the function of the masonry wall assembly. Water testing of completed repairs can provide a reasonable assurance of proper installation and efficacy of the repairs.

Air Barrier Systems

Many contemporary buildings are now being constructed with a continuous air barrier with the intent of providing a more controlled interior environment and improving energy efficiency and occupant comfort through the reduction of heat losses and heat gains due to uncontrolled flow of air across the building envelope. Air barriers provide a continuous physical barrier to the infiltration and exfiltration of air through the building envelope. As such, they must be able to resist the combined pressure of wind, stack effect, and mechanical systems. They typically are constructed of sheet membranes, fluid-applied membranes, sheet metal, and similar materials that can be configured to provide system continuity. Careful detailing is required at transitions between systems, such as at the interface between wall construction and fenestration, to ensure continuity.

Historically, designers and builders of masonry buildings understood the importance of minimizing uncontrolled air leakage to provide a reasonably controlled interior environment and acknowledged that these provisions constituted quality construction. Their design goals included the elimination of unwanted drafts during cold weather and provisions for ventilation during warm weather. Traditional builders constructed their buildings to rely on the air-penetration resistance inherent in tight masonry construction and sought to minimize gaps at windows and transitions to other wall openings where drafts might occur. Operable windows provided ventilation when needed. Despite these practical provisions, traditional masonry buildings lack high-performance materials and continuity of systems required for an air barrier according to contemporary standards. Even with high-quality masonry construction, perfect, airtight continuity cannot be achieved in traditional masonry walls, which almost always include some cracks and separations in the masonry and gaps at transitions to windows and other envelope systems (e.g., roofs). Most other historic building envelope systems (e.g., roofs, windows, doors) also lack the airtight performance required for the successful implementation of an air barrier and undermine air barrier performance by preventing continuity.

Modern-day air barrier performance can be incorporated into historic masonry buildings through the detailing of remedial repairs to address obvious discontinuities in the construction of the building exterior. The major breaches for air penetration in traditional masonry wall construction occur at penetrations and transitions in the masonry, including window and door perimeter detailing and the roof-to-wall interface. Common contemporary construction materials, such as self-adhered membrane, expansive foam insulation, or sealant, can address the discontinuities at window-wall and window-to-door interfaces. Discontinuities at the transition between the masonry wall and the roof construction typically are more difficult to detail due to the frequent interference between the wall and roof framing. Transitions to other construction areas (e.g., building wings and additions) must also be reviewed for continuity. Modification or replacement of poorly performing systems, such as windows, is an obvious and frequent strategy used to address deficiencies in these systems but can sacrifice historic materials and components unnecessarily. Designers often choose to repair existing sash and frames, which may include replacement of single glazing with insulated glass units and the addition of storm sash on the interior or exterior of existing windows, to limit air penetration through these systems to a tolerable level without wholesale replacement or possible costly reconstruction of masonry at the perimeter of the windows.

The addition of an air barrier in the rehabilitation of traditional masonry walls improves the building envelope performance, occupant comfort, and energy efficiency and offers very little if any disadvantage. Similar to the installation of the water barrier, the design of an air barrier system for a historic masonry building should begin with a careful investigation of the entire building envelope to fully understand the as-built conditions.

Figure 3 – View of a thermal image of a masonry building with window openings and a metal door. Note the higher temperatures are darker (reds and yellows in full color), indicating heat loss through the window glazing and frame metal door as well as the lower parapet in the photo.

Several tools are now available to assist the designer in resolving discontinuities in the existing building envelope. These include such qualitative tools as smoke pencils and infrared thermography to identify air leakage in the building envelope under artificial pressurization/ depressurization. Once the designer has identified all primary paths for uncontrolled air leakage in the existing wall systems, a design can be developed to address these discontinuities in conjunction with other planned modifications to the wall systems. Additional testing during or shortly following completion of construction can verify performance of the repairs. This may include more qualitative testing (i.e., pressurization and smoke pencils) or quantitative testing, including measurement of actual building envelope air leakage through the use of calibrated pressurization fan equipment.

Infrared thermography is another tool for identifying air leakage paths or thermal inefficiencies in the building envelope. The infrared camera produces images that show the temperatures of building materials at an instant in time (*Figure 3*). Anomalies in the temperature (i.e., cooler places) denote possible air leaks or a lack of thermal insulation. Additionally, infrared thermography can be used to validate improvements in the air barrier performance by taking comparative images before and after differential air tests on the assembly. The results of these tests provide a qualitative method to measure improvements and can be used as input to the mechanical design.

Thermal Barriers

Thermal insulation is a standard design element for almost all contemporary buildings and is a well-understood system in the context of contemporary construction. It is provided in most building envelope systems to provide a barrier against heat transfer (i.e., heat loss during cold weather and gains during hot weather), which results in a more stable interior environment and reduction in heating and cooling loads. This improves the consistency of the conditioned interior climate, reduces the potential for condensation, and can reduce the energy consumption and operating costs.

Older buildings typically did not include dedicated thermal insulation in the building envelope; rather, they relied on other traditional methods to temper the exposure of the building interior to temperature extremes, including relying on the thermal buffering quality of the thick masonry walls to offer some resistance to heat loss and gain, and providing ancillary spaces, such as attics, courtyards, and porches, to shield the building interior from direct exposure to exterior temperatures. In traditional masonry walls, the mass of the masonry also dampens the daily temperature swings by absorbing heat during the day and releasing it throughout the cooler conditions at night. Combined with the use of operable windows for ventilation during warm weather and durable masonry construction to retain heat during cool weather, the traditional masonry construction allows building occupants to achieve some semblance of personal comfort, even during temperature extremes.

Given the need for providing a more consistent interior environment both for occupant comfort and for mechanical system performance, it is often desirable to add thermal insulation to existing buildings to improve the effective R-value of the wall assembly. This work typically involves the addition of thermal insulation to the interior surface of the exterior walls during a rehabilitation to minimize alterations to the appearance of the building exterior. Maintaining or restoring the appearance of the building exterior is one of the primary objectives for reuse of historic buildings through rehabilitation projects. Careful consideration of materials and analysis of the effect of insulation on the thermal performance of the existing wall system are required to avoid unintended deleterious consequences.

The typical issues that arise with the addition of thermal insulation to traditional mass masonry wall systems are directly related to the benefit; that is, the addition of thermal insulation separates the thermal conditions on the building interior from the exterior conditions. This effectively isolates the masonry construction from the building interior, resulting in greater thermal variations in the masonry, which will shift the temperature distribution toward the exterior, causing the inboard surface of the wall to decrease in temperature. While masonry construction is generally durable and moisture-tolerant, even in applications where it is directly exposed to exterior temperatures and rainwater, the extent of that durability is finite. By isolating the masonry from the beneficial heat of the building interior during cold weather, the masonry experiences lower material temperatures and less opportunity to dry. Masonry that is allowed to experience more thermal fluctuations in concert with exposure to water is at an increased risk of freeze-thaw damage that can degrade even the most robust masonry systems (*Figure 4*). The reduced masonry temperatures not only allow for more cycles below freezing but also drive the location of the freeze line farther into the masonry construction, away from the deliberate location of the most durable masonry materials and into the less durable backup materials. For example, the collar joint between granite masonry cladding and the brick masonry backup is typically filled with grout. Granite has a relatively high freeze-thaw resistance, whereas more absorptive materials, such as mortar/grout and brick masonry, have less resistance and can deteriorate more rapidly with exposure to increased freeze-thaw cycling and decreased material temperatures.

Figure 4 – View of stone masonry deterioration from freeze-thaw following the installation of thermal insulation on the building interior.

A number of calculation approaches, ranging from simple to more complex methods, are available for determining heat transfer rates and temperature distribution in the wall assemblies, including the following:

- The simplest of the methods is a one-dimensional U-factor calculation that can be used to determine the rate of steady-state heat conduction through the assembly in question. The calculation can provide an overall U-factor for the wall and can be extended to calculated temperatures between adjacent materials. However, the method is limited to steady-state conditions (i.e., cannot predict performance during dynamic conditions such as daily temperature cycles) and is best suited for calculating heat transfer through homogeneous materials or assemblies (i.e., continuous insulation and not insulation between studs).
- A two-dimensional, steady-state, conductive heat-transfer analysis can be employed with assemblies containing layers composed of dissimilar materials (i.e., insulation between stud framing). Computer modeling software, such as THERM 5.2, typically is required to complete a two-dimensional heat transfer analysis and provide more-accurate results (*Figure 5*). Such computer methods provide a good starting point; however, they might not be appropriate for the analysis of historic masonry buildings as they do

not account for heat-storage capacity in the materials or the variations in material properties (i.e., dependence of thermal conductivity on moisture content). A more complex transient computer model that accounts for specific heat storage capacities in materials, such as Delphin 5.6.5, might be required.

- Three-dimensional transient modeling software, such as HEAT3, can be used to provide realistic and more accurate heat transfer and temperature distribution for wall assemblies, particularly where details include complex geometry. This type of analysis becomes particularly beneficial when condensation risk and durability issues, such as freeze-thaw cycling damage, become important.

Recent advances in computational analysis are providing more reliable methods to analyze the dynamic performance of wall systems and can better predict in-service performance. Computational models allow for easy modification to building components to facilitate examination of multiple options, making them highly useful for analysis of rehabilitation options; however, computer modeling is susceptible to error if not carefully developed and executed by a knowledgeable practitioner. The user must have a high degree of technical familiarity and experience with both the computer program and the building to confirm that the model is built with reasonable resemblance to the actual building conditions, to develop the appropriate material parameters, and to interpret the results correctly.

In some instances, it is also advantageous to monitor the building envelope during and after installation of the thermal barrier to verify performance. This can be as simple an exercise as monitoring utility consumption (i.e., electricity, heating fuel) over a long duration, instantaneous analysis using infrared thermography, or providing temperature sensors at critical locations within the wall assembly. These monitoring techniques are useful for verifying performance, but they should not be used to replace construction monitoring and testing methods that are needed during construction to confirm the quality of the work. Focusing on providing sound air-barrier detailing at locations where it is missing will provide the most benefit to the overall building energy performance.

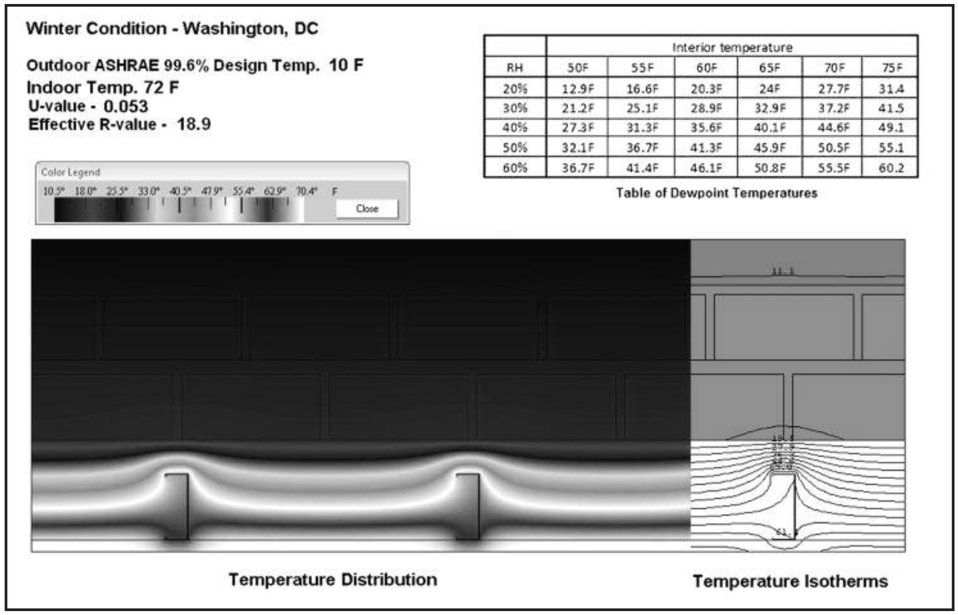

Figure 5 – View of a graphic output from a thermal analysis of a rehabilitation option for a masonry wall system using THERM. The original wall included precast panels set into the face of solid brick-masonry backup. The rehabilitation option shown includes adding open-cell (½ lb/cu ft) spray-foam insulation inboard of the brick masonry and between steel studs that support interior finishes.

Vapor Barriers (Vapor Retarders)

Some provisions of recent model building codes require vapor retarders within wall assemblies to control the flow of water vapor and reduce the potential for condensation on moisture-sensitive construction materials within the wall assembly. While historically referred to in most standards as vapor barriers, these materials are essentially retarders that impede but do not block the flow of water vapor through the wall assembly. Vapor retarders can be used to limit the risk of condensation through placement on the side of the thermal insulation with the higher partial pressure of water vapor (typically the warm side in cold or temperate climates) for the predominant duration of the year. If a vapor barrier is omitted, warm moisture-laden air can diffuse toward the colder parts of the building envelope, the temperature of the moisture-laden air will decrease, and its relative humidity will increase. If the temperature of the air or the surfaces of materials within the wall assembly decreases substantially and reaches the dew-point temperature, the air will become saturated. Reducing temperature below the dew point will result in condensation. Properly placed vapor retarders practically prevent the flow of water vapor and, consequently, the occurrence of condensation within the building envelope, thus eliminating many moisture-originated building envelope problems, such as degradation of wood-based materials and mold growth.

The placement of a vapor barrier within the building envelope requires careful consideration for the particulars of the local climate and interior design conditions. In new construction projects with contemporary wall assemblies located in cold climates, vapor barriers generally can be placed on the interior face of the thermal insulation (warm side of the insulation between the interior finishes and the insulation) to impede the migration of interior warm air into the wall assembly. In warm climates, the vapor barrier is generally placed on the outboard side of the wood/metal frame wall to impede the inward flow of water vapor from the typically warm and humid outdoors.

In most traditional masonry-wall rehabilitation projects, omitting the vapor retarder is more effective at reducing moisture buildup within the masonry than providing a properly located vapor barrier by allowing the walls to dry out to the interior and exterior. Recent model building codes, such as the International Code Council (ICC) International Building Code 2009 (Section 1405.3), are beginning to acknowledge this by allowing the elimination of the vapor retarder pending analysis indicating acceptable moisture performance for the proposed wall system. Hygrothermal com-

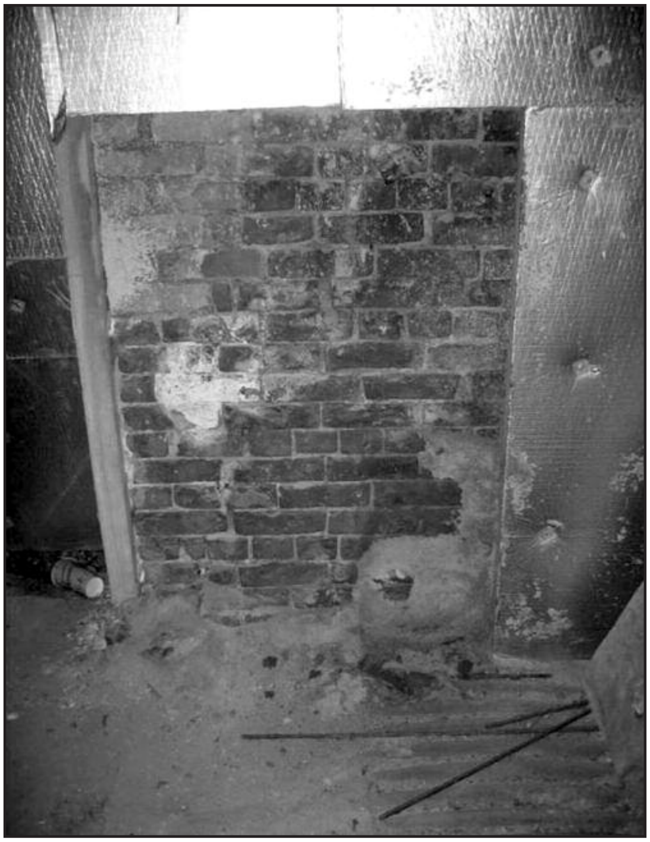

Figure 6 – View of the interior face of a brick-masonry wall system where deterioration resulted from the installation of a vapor barrier (foil facer) and thermal insulation.

puter modeling (see discussion below) and other performance-based design analysis can provide reliable and accurate predictions of the dynamic performance of the wall system that can be used to justify nonstandard design solutions where needed.

Adding a vapor barrier to a traditional masonry-wall system is fraught with potentially deleterious consequences that often outweigh any perceived positive impact and should be avoided in all but a specific few applications and environments when supported by careful analysis. The same mechanism that makes a vapor barrier function to impede water vapor flow can work against the wall system by locking moisture in the masonry and preventing drying of the wall toward the building interior, exterior, or both. Over time, this can lead to moisture accumulation in the wall and reduced durability of the masonry (*Figure 6*). Given the moisture storage capacity inherent in mass masonry, reducing the drying potential of the wall can lead to greater moisture accumulation and extended wetting duration. Combined with the addition of thermal insulation, a vapor retarder can exacerbate freeze-thaw deterioration and greatly diminish the durability of the masonry wall.

While vapor barriers are sometimes deliberately installed in wall systems during rehabilitation (e.g., to contain high-humidity environments within a building), in other instances, they are unintentionally installed due to a lack of oversight of material selection or the introduction of contemporary materials with an unknown performance record. Typical sources of unintended vapor barriers include remedial exterior paint and elastomeric coatings, insulation materials, and interior finishes (e.g., vinyl wall coverings). Exterior coatings may be installed as part of a rehabilitation project to address bulkwater infiltration into the masonry, whether due to original low-quality, porous masonry materials or deteriorated masonry finishes (e.g., stucco). Careful analysis of any surface-applied coatings needs to occur to ensure that the drying mechanism for the masonry wall is not altered. Just as noted for the exterior of the masonry walls, interior finish coatings also can restrict vapor flow to the building interior (an important drying direction during the cooling season in hot, humid climates). Careful review and selection of interior finishes must be performed to avoid this risk.

Likely, the most common unintended vapor barrier installed in wall systems during rehabilitations is thermal insulation. The moisture storage potential of mass masonry walls often results in extended periods of elevated moisture or dampness at the interior surface of the wall. As such, designers often select durable insulation materials that are not adversely affected by contact with moisture, such as extruded polystyrene (XPS) and closed-cell spray-foam insulation, for installation directly against the interior surface of the masonry walls. These products provide some of the highest available R-values per unit of thickness of any standard construction product on the market, a high-priority criterion for energy-conscious rehabilitation projects. However, both products are vapor retarders and can significantly reduce the flow of moisture vapor toward the building interior, leading to prolonged moisture accumulation in the system and increased risk of masonry deterioration (*Figure 7*). Likewise, the use of permeable insulation may present a risk for interior, moisture-laden air to

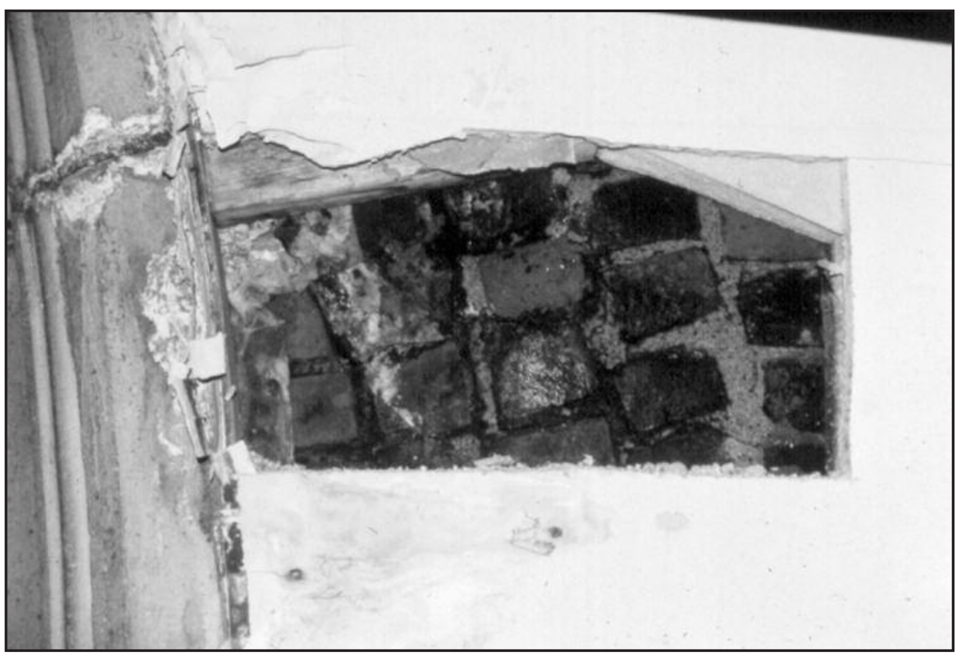

Figure 7 – View of moisture accumulation and masonry damage on the interior face of an historic masonry-wall system following the installation of extruded polystyrene (XPS) insulation behind the interior plaster finishes during a recent rehabilitation project.

diffuse through the system and condense on the inboard side of the insulation, which is buffered from the interior conditions. Where the need for installing a vapor retarder outweighs the anticipated disadvantages, the designer must analyze the effect of the vapor retarder on the overall wall performance, particularly in conjunction with thermal performance.

Since the installation of vapor retarders is often driven by a need to control condensation in conjunction with the use of thermal insulation, several tools have been developed and are widely used by design professionals to evaluate rehabilitation options that introduce thermal insulation and vapor barriers into traditional masonry walls. These tools can be used to calculate simultaneous heat and moisture transfer through building envelope assemblies and are often provided with internal material and climatic databases to accommodate an array of materials and climatic conditions in simulations. The software packages come with user-friendly interfaces to provide an easy way to modify construction configuration and boundary conditions.

One of the more useful hygrothermal analysis products that is becoming a trusted tool for many designers is WUFI Pro 4.2 (WUFI), a computer program developed by the Fraunhofer Institute for Building Physics. WUFI is a one-dimensional heat and moisture transport model that includes wetting and drying in component materials, solar radiation, and wind-driven rain exposure. WUFI and similar software can be used to determine the risk of moisture condensation and accumulation within wall assemblies and to evaluate various insulation strategies for the walls. When used with well-researched material property data, surface transfer coefficients, and boundary condition temperatures (e.g., values from the American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE] 2009 *Handbook of Fundamentals*), these programs can give reliable results that provide a quantitative tool for evaluating rehabilitation options (*Figure 8*). As noted in the previous sections, reliance upon computer analysis is not without risk: one-dimensional WUFI analysis does not account for air movement and two-dimensional effects of moisture movement through the wall systems, both of which can result in elevated moisture levels. A failure to understand the limitations of the analysis software and the misapplication of material properties are common sources of error in analysis projects and can lead designers down a path fraught with negative consequences.

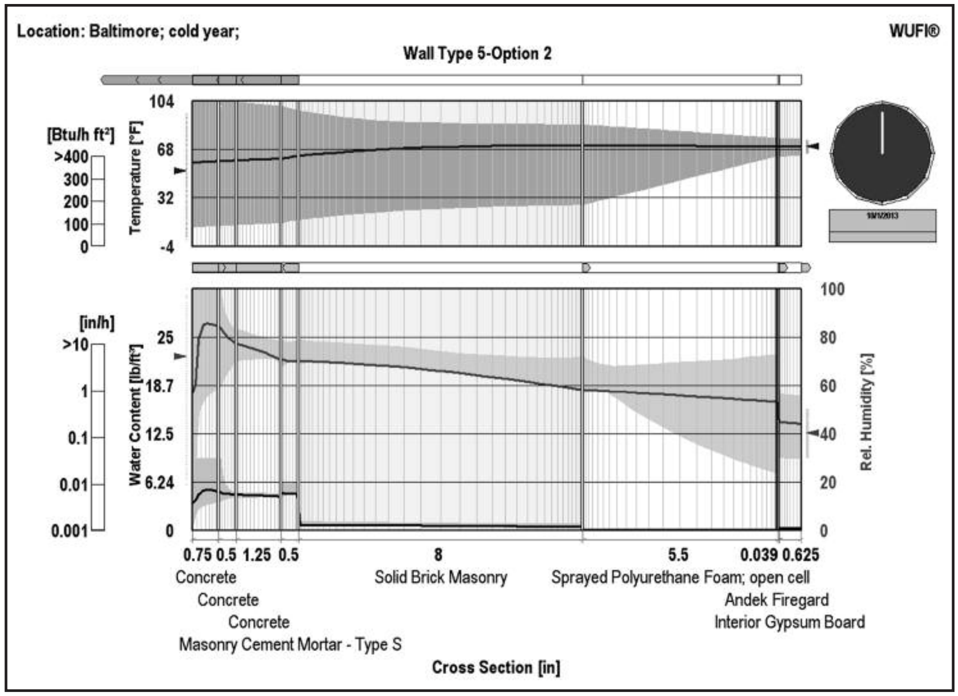

Figure 8 – View of a graphic output from the hygrothermal analysis of a rehabilitation option of historic masonry-wall system using WUFI. The restoration option (described in Figure 5) allows the brick masonry to dry to the interior and exterior, resulting in acceptable levels of moisture within the brick masonry as indicated in the resulting graph.

CONCLUSIONS

Historic masonry buildings generally lack the construction materials and systems necessary to provide performance in line with that of contemporary wall systems. Mass masonry wall systems do not have dedicated water barriers, generally lack detailing and system continuity necessary for air barriers, lack efficient thermal barriers, and do not include and are often not compatible with vapor barriers. It is desirable to improve the performance of these masonry walls through careful implementation of modifications during rehabilitation projects; however, care must be taken to minimize unintended consequences through diligent analysis and careful consideration of materials and detailing. Designers must focus on the selection and installation of insulation products, material permeability, and accounting for the interplay between these systems. In general, the retrofit approach should focus on reducing wetting at the surface of the masonry wall while limiting changes to the drying characteristics of the wall, including the rate and direction of drying. Design professionals need not be afraid of the challenge of renovating historic masonry buildings; however, they should be suspicious of strategies that fundamentally change the performance of traditional masonry in an attempt to meet contemporary performance expectations.

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