Masonry Walls: Considerations Before Interior Retrofits and Window Replacement Projects

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Abstract

Interior retrofit projects may require repairs to the building’s exterior masonry walls due to moisture intrusion and mold or code-mandated improvements triggered by change in use. Walls and windows may also need to be retrofitted or repaired due to age-related deterioration, moisture intrusion damage, or to improve overall building aesthetics. The decision to retrofit is typically made without properly evaluating the air, moisture, and thermal behavior of the existing wall system; the conditions of the wall system; and without establishing reasonable performance expectations/criteria of the wall system. Modifications to the exterior wall, such as new windows and flashings, vapor retarders, and thermal insulation can have detrimental effects on the wall if not properly evaluated and designed. It is important to understand the interaction of the new and existing building materials and assemblies prior to constructing modifications that can affect the behavior of the in-place systems. Regardless of the reason for retrofitting, an evaluation of the exterior wall is warranted to ensure the goals of the retrofit project are fulfilled.

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MASONRY WALLS: CONSIDERATIONS BEFORE INTERIOR RETROPTS AND WINDOW REPLACEMENT PROJECTS

Frequently, the decision to retrofit mass masonry walls is made without properly evaluating the air, moisture, and thermal behaviors of the wall system, and reasonable performance expectations/criteria for the wall system are not established. Modifications to a mass masonry wall, such as adding vapor retarders and thermal insulation, can have detrimental effects and accelerate deterioration of the masonry wall. It is important to understand the interaction of the new and existing building materials and assemblies prior to constructing modifications that could affect the behavior of the in-place wall systems. Regardless of the reasons for a retrofit, an in-depth evaluation of the exterior wall conditions is warranted to ensure the performance expectations of the retrofit are fulfilled. Hygrothermal analysis of the existing mass masonry walls is required to understand the effects of the proposed retrofit.

LEARNING OBJECTIVES

1. Understand that a retrofit project may require repairs to the building’s exterior mass masonry walls to improve the weather resistance of the wall by addressing deficiencies that contribute to excessive moisture infiltration into the mass masonry.

2. Understand how a retrofit project can negatively affect the building’s exterior mass masonry walls by altering the wetting/drying cycles and the thermal gradient through the wall assembly.

3. Understand the need for hygrothermal analysis to gain an understanding of the air, moisture, and thermal behavior of the retrofitted exterior wall system, and to establish reasonable performance expectations for the retrofitted exterior wall system.

4. Understand the interaction of the new and existing building materials and assemblies that can affect the behavior of the original mass masonry wall.

INTRODUCTION

Due to concerns for improved thermal performance and occupant comfort, many building owners are considering the addition of thermal insulation and/or vapor retarders to the inside face of their buildings’ exterior walls as part of interior retrofits. Experience indicates that those involved with these significant capital improvement projects typically do not adequately consider the existing conditions of a building’s exterior walls or the implications of changing its walls’ thermal and moisture characteristics.

Much of the redevelopment performed today includes restoration of mass masonry buildings. These structures, which are generally solidly built and may last for a century or longer, provide a large building inventory and are, in many cases, historically significant. These robust buildings are often being converted to residences and commercial spaces that typically require energy improvements. Although mass masonry walls were sometimes plastered on the interior, they were rarely insulated. The thermal properties of brick masonry—with a typical R-value of 2.4 for a 12-inch wall—are comparatively minimal when compared to other building envelope components that can decrease with moisture content.

Retrofits of mass masonry walls typically involve the addition of thermal insulation and/or air-vapor barriers.

Reducing energy consumption is typically a significant concern for building owners due to increasing energy costs and dictates that retrofits should incorporate a means of reducing heat flow through the exterior wall assembly. However, if these additional components are not properly analyzed, the placement of retrofit insulation and air/vapor control assemblies can have detrimental effects on mass masonry walls.

Retrofitting and converting mass masonry buildings can involve several design challenges. Adding thermal insulation and/or air/vapor barriers to a mass masonry wall may cause performance and durability problems—particularly if other wall issues, such as moisture infiltration and deterioration of wall components, are not diagnosed and adequately addressed.

Figure 1 – Example of mass masonry wall construction with brick inner wythes.
If the rate of wetting of the wall exceeds the rate of drying, this may cause freeze-thaw damage to the masonry and/or biological growth on adjacent organic materials, such as wood trim, wood framing, and gypsum. The storage capacity of the mass masonry wall, and the extent and duration of wetting and drying of the wall, must be properly analyzed when assessing the risk of moisture-related issues.

MASS MASONRY WALLS

Historically, mass masonry walls functioned as both the structural system and the building envelope. Masonry walls built prior to 1900 were usually thick, consisting of multiple interlocking wythes of brick (Figure 1). The typical mass masonry wall is comprised of an exterior wythe of weathering brick with solid tooled mortar joints. The inner wythes are typically comprised of poorer-quality common brick that may include partially filled head and collar joints. Header bricks are typically used to tie the wythes of brick together. Some buildings may include one or more wythes of structural terra cotta tile at the interior, which were typically grooved to receive the interior plaster finish, mass-produced, and more economical (Figure 2).

In general, masonry materials are porous, with varying levels of porosity depending on the material, and will, therefore, absorb moisture into the wall assembly. The wall’s mass acts as a “sponge” that absorbs moisture, thereby mitigating moisture migration to the interior. Drying of the mass masonry wall is primarily achieved by ventilation and vapor diffusion.

A masonry wall’s thickness assists in preventing bulk water from entering the interior. Additionally, their large thermal mass provides “inertia” against temperature fluctuations, “flattening out” thermal changes. Essentially, the walls store moisture and heat, functioning as a “reservoir,” and since the walls are typically vapor-permeable, they allow moisture vapor to dry to the exterior, and, notably, to the interior.

WETTING/DRYING AND FREEZE-THAW CYCLES

Moisture infiltration causes problems for building owners, maintenance personnel, and occupants. Many common moisture problems can be traced to poor decisions in design, construction, and/or maintenance. However, these problems can be avoided with a solid understanding of moisture behavior in mass masonry walls.

The principles of moisture migration through mass masonry walls are relatively straightforward. In general, gravity causes moisture to flow downward, warmer air contains more moisture than cooler air, and moisture moves from higher vapor pressures to lower vapor pressures.

Mass masonry brick walls require a balance between wetting and drying. A fundamental principle of a mass masonry wall is its ability to absorb and store moisture during significant rain events. This stored moisture then dissipates with time to the exterior side of the wall by solar drying, and...
to the interior side of the wall due to conditioned air having a lower humidity level than the exterior. Moisture storage within the mass masonry wall assembly bridges the time between wetting and drying of the masonry. If a balance between wetting and drying is maintained, moisture accumulating within the wall will be limited, which will mitigate moisture-related interior problems.

All mass masonry buildings allow moisture to penetrate the walls to some extent, since brick and mortar by their nature absorb moisture. Moisture intrusion into porous masonry walls may occur in several ways, including precipitation, water vapor diffusion through the masonry and/or open joints, stored moisture within the masonry, capillary flow of free water, and groundwater. These wetting mechanisms are exacerbated by wind and pressure differentials.

The wetting and drying characteristics of mass masonry walls are critical to adequate functionality of the walls—particularly in colder climates. Uninsulated multi-wythe mass masonry walls allow for thermal conductivity and an outward heat flow. Therefore, the walls are less prone to the damaging forces of freeze-thaw cycles. Problems typically occur when buildings are abandoned and are without heat and maintenance for years, and moisture within the wall can cause freeze-thaw deterioration of the brick and mortar within the mass masonry wall. Problems can also occur with occupied buildings that have been retrofitted with thermal insulation at the exterior walls (Figure 3). When insulation is added on the inside face of the masonry wall, thermal conductivity of the wall is reduced, which results in the wall remaining colder for longer periods, rendering it more likely to be impacted by freeze/thaw deterioration.

Since it is virtually impossible to remove all moisture sources from mass masonry walls or to remove all forces driving moisture movement, the most feasible solutions to moisture infiltration are maintaining or improving the rate of drying of the wall and controlling the amount of precipitation that migrates into the wall.

**VISUAL EVALUATIONS**

The importance of the initial visual evaluation of the exterior mass masonry walls cannot be overstated, as it provides valuable information on wetting patterns, signs of erosion, and freeze-thaw deterioration. Evidence of stains, corrosion, decay, microbial growth, and efflorescence/cryptoflorescence are important indications to establish the condition of the wall and gain an understanding of the feasibility of improved energy-efficiency retrofits.

Deficiencies in mass masonry brick walls can adversely affect the thermal conductivity and moisture performance of the wall (Figure 4). The initial visual evaluation can reveal deficiencies that include those caused by physical/mechanical causes such as cracking, chemical causes such as cryptoflorescence, and biological causes such as vegetation growth. Typically, the following mass masonry wall deficiencies must be diagnosed and adequately addressed to complement improved energy-efficiency retrofit projects:

- Cracked and displaced brick masonry caused by forces such as differential settlement, thermal and moisture movements, cryptoflorescence, and freeze-thaw
- Bulged brick masonry caused by separation from inner wythes due to deterioration of mortar joints and/or brick headers, foundation settlement, and structural issues
- Eroded mortar joints caused by weathering, freeze-thaw cycles, and lack of periodic maintenance. Typically, deteriorated mortar joints are common in historical buildings with lime-based mortar, and in highly industrialized areas where chemical degradation of the cement binders is common due to pollut-
 project-specific data for hygrothermal analysis.

Equilibrium Moisture Content testing.

Porosity/Specific Gravity/Absorption, and tests, which include: Bulk Density/Electron Microscopy; and ASTM hygric Resistance Index), Thermal Dilatometry

Water Absorption, Saturation Coefficient, durability tests, which include: Boiling

durability and hygric testing should be performed on representative samples of brick masonry to determine physical properties. The results of these tests may be used to refine hygrothermal analysis. Typically, if the masonry walls are in fair condition, then improved energy-efficiency retrofits may be feasible. However, if the bricks and/or mortar joints are deteriorated, then other improvements should be evaluated.

HYGROTHERMAL ANALYSIS

The addition of thermal insulation and vapor retarders to the exterior side of an exterior wall can eliminate interior surface condensation, improve occupant comfort, and reduce the loads on HVAC systems. However, condensation within the mass masonry wall may still occur that can alter the behavior of the wall, resulting in damage or reduced performance. To avoid potential moisture-related problems, the moisture balance of the mass masonry wall should be properly evaluated utilizing hygrothermal analysis during the retrofit design process.

Hygrothermal models are used to calculate heat and moisture flow through a wall assembly to determine the risk of condensation and moisture accumulation. Hygrothermal models are practical building design tools. These models require a set of reliable inputs—ideally from project-specific hygric and durability testing, to provide results that are meaningful to the designer. Some of these inputs are the set of heat, air, and moisture transport properties of the wall materials. Properties of brick and mortar that must be evaluated include porosity, density, matrix density, thermal conductivity, equilibrium moisture content, water vapor permeability, water absorption coefficient, and air permeability.

The properties of bricks and mortar may vary within a large range. The user of hygrothermal models must be careful when choosing properties from standard tables that provide material properties. To get meaningful results from the hygrothermal analysis, the properties of these materials—especially of the bricks—should be determined using standard procedures, including a project-specific moisture analysis. It should be noted that the analysis methods apply to “typical” wall sections and do not consider atypical critical elements, such as thermal breaks, corners, and window openings. Therefore, hygrothermal analysis results should be used with caution by an experienced designer.

Computer-based methods are based on dynamic analysis using weather data for specific locations such as temperature, relative humidity (RH), rain, and user-defined interior climatic conditions. Wärme und Feuchte Instationär (WUFI) is a software program that performs one-dimensional analyses by transient modeling of heat and moisture. The WUFI program was developed by the Fraunhofer Institute of Building Physics in Germany and the Oak Ridge National Laboratory in Tennessee. Another program that is available for moisture and heat analysis of the exterior wall is MOIST, developed by the National Institute of Standards and Technology (NIST) and updated by Purdue University. The advantage of these programs compared to conventional static-state analysis is that they model the moisture and thermal conditions of a selected wall assembly over a certain period—typically a two- to three-year cycle—using weather data. The more advanced models include refinements such as the effect of air and water leakage. This paper will focus on WUFI analysis, as it is the most commonly used tool for hygrothermal analysis in the building enclosure industry.

WUFI produces three types of results for each wall assembly: water content of the assembly, RH levels and dew point within the assembly, and the potential for mold growth within the assembly. Each of the three listed components are analyzed at each layer of the assembly. This feature allows the designer to evaluate the potential performance at each layer of the assembly. The definitions of each of these results, and what they mean with respect to each case, are as follows:

Water Content

The water content of the assembly can be considered as an overall factor, as well as in the individual component.

- Optimum water content performance means that the initial moisture from construction can dry out from the assembly, and that no accumulation of moisture occurs.
- Adequate water content performance means that while the initial water content of the system (from construction) may not dry out from the assembly, the system undergoes wet-dry cycles. The wet-dry cycle signifies that the system does not retain moisture.
- Marginal water content performance means that the results obtained over
the analyzed period indicate that although the system is undergoing wet-dry cycling, the system is experiencing moisture accumulation with each consecutive cycle.

- Failure in water content performance means that the system accumulates moisture over time without drying, or retains more moisture than it can dry.

**Relative Humidity/Dew Point**

This section presents two graphs: one that compares the temperature to RH, and one that compares temperature to dew point. Both graphs assist the designer in determining whether there is a potential for condensation within the assembly layers and where that condensation may occur. Furthermore, elevated RH values within an assembly can result in a potential for mold growth and corrosion.

It is important to note that while significantly advanced compared to traditional “static state” calculations such as dew point calculations, the WUFI software has limitations. The program’s calculations are based on ideal construction, such as continuous insulation and vapor barriers and, therefore, do not provide any considerations for deficiencies in the existing and/or new assemblies, such as open mortar joints and voids. Also, the program is designed to model porous materials; therefore, materials such as metals or other impermeable materials are more difficult to model and require manipulation of the material properties in WUFI.

Due to its German origins, the preprogrammed material selections are consistent with European markets. Consequently, not all materials used in the United States are available. Additionally, many historic materials, such as those used in mass masonry wall construction, are not available. The addition of supplemental materials can be difficult, as typical properties required to create a new material in the database are not readily available and may require project-specific information from testing. Therefore, some substitutions of the specified materials must be made with comparable materials. Even though it may not be possible to model the exact field conditions, redundant modeling can determine general patterns of the wall assembly’s behavior. The intent of utilizing the WUFI program is to identify theoretical performance trends of the wall system, not to establish specific numerical data.

WUFI is only able to model one-dimensional systems or a “section cut” of the wall. The interactions between bridged materials, such as insulation and framing, cannot be accounted for in the analysis. Although a two-dimensional version of WUFI (WUFI 2D) is available, it is not commonly used and is typically considered a complement to WUFI Pro, not a replacement. In general, WUFI 2D is intended for complicated geometries, such as building corners, window locations, foundation connections, etc., where heat and moisture transfer are nonuniform.

**CASE STUDY**

The following is an analysis of a historical mass wall assembly in Baltimore, MD. The analysis was performed to determine the theoretical performance of the wall systems in terms of condensation and drying potential for two possible retrofit scenarios. WUFI Pro was utilized to perform the one-dimensional hygrothermal analysis.

The WUFI model is based on the procedure and failure criteria outlined in ASHRAE Standard 160. Based upon information provided, the following assumptions were made in performing the WUFI analysis:

- Based on historic climate data for Baltimore, MD, a “cold-year” model was utilized, as it is the most severe for vapor condensation occurrences.
- The walls were analyzed assuming a northeast exposure, which results in the most severe exposure conditions for the selected location.
- Indoor climate conditions were conservatively estimated from a WUFI-generated sine curve for a medium moisture load, based on an RH of 50% +/-10% and a temperature of 70°F +/- 2°F. These assumptions are consistent with the information provided from the mechanical engineer, relating to the HVAC systems. It should be noted that indoor climate conditions can potentially have a significant impact on the moisture-related performance of a wall assembly, so accuracy of these conditions is important in achieving the most reliable results.
- Based on time and budget constraints, project material testing was not performed. In the WUFI simulation, the terra cotta layer is modeled as “Fired Clay Brick.” WUFI does not contain specific data for terra cotta masonry; the fired clay brick in the database has similar bulk density and permeability as the unglazed terra cotta masonry, but has different thermal characteristics.
- Two wall designs utilized foil-faced insulation. To represent the impermeability of the foil-faced insulation for the WUFI analysis, two layers of low-perm vapor retarders were used in consecutive layers to simulate a vapor-impermeable membrane.
- Material properties and positioning of wall components were kept the same for the analyzed wall assemblies where possible, to directly compare the assemblies without the addition of unnecessary variables.
- The WUFI models were run for a minimum three-year calculation period.

**WALL TYPE 1 SUMMARY**

The results for Case 1 (Table 2) indicate a consistent yearly moisture content pattern for the wall assembly. The solid brick masonry and terra cotta exterior wall...
appears to be the major contributor to the overall moisture content of the system. Both layers fluctuate in moisture content throughout the three-year calculation period relative to the exterior climate changes. The terra cotta fluctuates between about 7 and 18% moisture content. The polyisocyanurate insulation and the interior gypsum board both experience consistent yearly patterns of moisture content. The insulation peaks near 5% moisture content by mass during yearly fluctuations, and the interior gypsum board peaks near 1%. The insulation immediately sheds its initial moisture content, but shortly regains the moisture within the first year of the calculation, while the gypsum board maintains a yearly pattern significantly below its initial moisture content (Figures 6, 7, and 8).

**WALL TYPE 2 SUMMARY**

In lieu of a fluid-applied air barrier and polyisocyanurate insulation behind the existing solid masonry wall, Type 2 utilizes closed-cell spray foam insulation of the same thickness and approximate R-value as the polyisocyanurate used above. The calculation results for Type 2 show similar yearly moisture content patterns for the solid masonry exterior wall. The spray foam insulation in this scenario behaves similarly to the polyisocyanurate insulation from Type 1, but peaks slightly higher at about 6.5% moisture content yearly. The interior gypsum board sharply declines in initial moisture content and maintains a consistent yearly pattern thereafter, with values similar to the interior gypsum board from Type 1 (Figures 7, 9, and 11).

**CASE STUDY ADDITIONAL CONSIDERATIONS**

Although the wall assemblies do not appear to have a probability for mold growth based on the WUFI analysis, the relatively high moisture content of the masonry could be detrimental to the mass wall assembly and lead to premature deterioration. Often the delicate balance of protecting the interior and the long-term performance of the wall assembly are the driving factors in...
the placement and material selection of the vapor retarders and thermal insulation. On one hand, it is important to limit vapor drive, which is a moisture transport to interior materials, but on the other hand, trapping moisture in the masonry materials can lead to premature degradation of the masonry, which could result in freeze-thaw damage. Furthermore, adding insulation to a non-insulated wall will reduce the risk of dew point on/within the interior materials, but could increase dew point on the inner wythe and the likelihood of degradation due to freeze-thaw cycling as previously mentioned.

**Building Code Requirements**

Depending on the scope of the retrofit project, the local building code may mandate improvements to the wall, including thermal insulation and/or air/vapor barrier due to various triggers. The International Energy Conservation Code (IECC) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 covers thermal insulation and air-vapor barrier requirements for new wall assemblies. The International Existing Building Code (IEBC) outlines the prescriptive, work area, and performance methods for determining what improvements, if any, are required.

Projects involving existing buildings fall into the following categories: repair, alteration, change of occupancy, addition, and/or relocation. Typically, an interior or exterior retrofit project will fall into the alteration or change-of-use category and is therefore subject to compliance with thealteration or change-of-use category and is therefore subject to compliance with the
code requirements for new wall assemblies, which include providing new thermal insulation and air-vapor barriers. For example, consider a former warehouse, a semi-heated space that is being converted to an apartment building—fully conditioned space for dwelling. It should be noted that buildings that have been designated as “historic” by the local governing body or are on the National Register of Historic Places can achieve waivers.

**DESIGN CONSIDERATIONS: MOISTURE INFILTRATION REMEDIATION**

The designer should consider wetting from precipitation and vapor diffusion condensation utilizing hygrothermal analysis. The most significant wetting is typically that of driving rain and is the most critical aspect of controlling moisture content within a mass masonry wall. The extent to which the moisture is transported through the masonry assembly is a function of the exterior conditions at the face of the wall, the wall composition, and the material's porosity. It should be noted that moisture can travel through intact header bricks and mortar collar joints, and particularly through collar joints with significant voids.

The key is controlling the amount of precipitation that infiltrates the mass masonry wall. Controlling rainwater infiltration at the exterior face of the building may be effectively accomplished by repairing all noted masonry deficiencies. These repairs typically include: replacement of displaced and/or bulged, cracked, and spalled bricks; raking and repointing of deteriorated and cracked mortar joints; repair of foundation and structural issues; repair of weather-resistant vapor-permeable coatings; removal of vegetation growth; and repair of localized moisture infiltration, such as deteriorated roof scuppers and leaders. The exterior repairs should adequately shed rainwater, stormwater runoff, irrigation water, and snowmelt away from exterior walls. Rainwater infiltration at the exterior face of the building may also be mitigated with capillary breaks, such as flashings that include a drip edge offset from the exterior face of the building. The addition of flashings should be carefully considered, since they can create a slip plane if they are not properly designed.

For walls with significant internal voids, grout injection may be considered. Masonry sealers and coatings may be considered with caution, as they require periodic reaplication. Special consideration should be given to remediation of fenestrations. Any indications of problems with liquid water management must be resolved.

Remedial measures at the exterior wall to mitigate bulk water intrusion do not necessarily ensure dry interior surfaces. To effectively manage moisture intrusion by vapor diffusion, the designer must select materials with appropriate vapor permeability. Vapor drive is often not well understood by designers and contractors. Correct selection of building materials and assemblies for a given climate is critical for mold prevention.

In general, low-permeability materials must be kept above the dew point during the heating and cooling seasons. The interior assemblies should have high vapor permeance to avoid cold-weather vapor diffusion condensation and provide an adequate level of inward drying during warm weather.

**DESIGN CONSIDERATIONS: THERMAL INSULATION / VAPOR RETARDER RETROFITS**

The designer should consider reducing the heating and cooling demands of the building. Retrofit thermal insulation can be used to manage heat flow through a mass masonry wall and prevent condensation on the interior surfaces during heating conditions. Hygrothermal analysis should be used to identify the proper insulation materials and the thickness of these materials for each project. However, only once the moisture infiltration problems at the mass masonry walls are identified and resolved may the designer consider improved energy-efficiency retrofits.

The addition of thermal insulation at the interior face of the masonry will reduce the temperature of the interior face of the masonry during cold weather. Therefore, conditioned air that contacts the interior face could condense. If the condensation accumulates faster than the wall can dry, the interior face of the brick masonry may become saturated. Thermal insulation retrofits should be avoided in buildings with poor-quality mass masonry walls and/or uncontrolled rising damp problems. As previously discussed, insulating mass masonry walls can cause durability and condensation/mold problems; and, therefore, improving thermal efficiency at other areas of the building enclosure should be evaluated, particularly if there are concerns over loss of usable space and/or historic features.

One option for retrofit thermal insulation is semi-permeable spray foam, such as high-density closed-cell polyurethane foam, which is typically sprayed onto the interior side of the mass masonry wall. (Typically, a Class II semi-permeable vapor retarder has a perm rating between 0.1 and 1.0.) Spray foams are well suited to mass masonry walls because they can be applied over irregular surfaces, provide good continuity at transitions, and allow any water that is absorbed into the masonry to evaporate and diffuse to the exterior and/or interior.

Constructions for retrofit spray foam thermal insulation on a mass masonry wall typically include a metal stud wall held off the masonry 1 to 2 inches to allow the foam to adhere to the masonry and to eliminate thermal bridging at the studs. The interior finishes must be vapor-permeable, or the stud wall must be back-vented. It should be noted that the long-term effects of retrofit spray foams to thermally insulate mass masonry walls is not well documented.

Another option for retrofit thermal insulation is semi-permeable rigid foam board, such as extruded or expanded polystyrene or unfaced polyisocyanurate, which is typically face-fastened to the interior side of the mass masonry wall with taped joints. This method is usually used in conjunction with a liquid-applied vapor-permeable coating applied on the interior face of the exterior masonry wall, which may require pointing or pargeting to provide a proper substrate for the coating (Figure 12). It is typically not recommended to install an adhered sheet vapor retarder, as there can be adhesion issues associated with walls that contain moisture.

**SUMMARY**

Moisture control is fundamental to the proper function of any building, and particularly to thermally retrofitted mass masonry walls. Controlling moisture is also important to protect occupants from adverse health effects and to protect the building, its mechanical systems, and its contents from physical and/or chemical damage. Moisture control may include relatively simple and inexpensive measures, such as repointing brick masonry joints, replacing...
cracked and spalled bricks, removing vegetation, adding flashings or shedding/drainage improvements, and fixing localized leaks.

In colder climates, insulating mass masonry buildings on the interior side is typically required to meet occupant comfort requirements, environmental goals, economic restraints, and building code requirements. Many such interior retrofits have been successfully completed by installing continuous foam insulation, combined with vapor retarders, exterior repairs, and moisture control. Hygric and durability testing of materials in conjunction with hygrothermal analysis by an experienced designer are important aspects of planning and designing successful energy-efficiency retrofit projects at mass masonry buildings.

**RELEVANT CODES AND STANDARDS**

ASHRAE 4.1.1.5. *Changes in Space Conditioning.* Whenever unconditioned or semi-heated spaces in a building are converted to conditioned spaces, such conditioned spaces shall be brought into compliance with all the applicable requirements of this standard that would apply to the building envelope, heating, ventilating, air-conditioning, service water heating, power, lighting, and other systems and equipment of the space as if the building were new.

ASHRAE 4.2.1.3 *Alterations of Existing Buildings.* Alterations of existing buildings shall comply with the provisions of ASHRAE and will not result in the increase of energy consumption of the building.

ASHRAE 90.1


ASHRAE Handbook – Fundamentals


IECC C501.6 *Historic Buildings.* No provisions of this code relating to the construction, repair, alteration, restoration and movement of structures, and change of occupancy shall be mandatory for historic buildings provided a report has been submitted to the code official and signed by a registered design professional, or a representative of the State Historic Preservation Office or the historic preservation authority having jurisdiction, demonstrating that compliance with that provision would threaten, degrade or destroy the historic form, fabric or function of the building.

IECC C505.1 *General.* Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code.

IECC R505.2 *General.* Any space that is converted to a dwelling unit or portion thereof from another use or occupancy shall comply with this code.


U.S. Department of Energy. “Installing Rigid Foam Insulation on the Interior of Existing Brick Walls.” Alterations to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction.