

ADDING AIR BARRIER AND THERMAL IMPROVEMENTS TO EXISTING FACILITIES

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In the United States, buildings consume about \$200 billion in energy costs each year, representing a significant portion of our nation's energy use and carbon footprint. While the energy efficiency of new buildings has improved dramatically over the last two decades, more than 70% of the building stock in the U.S. is over 20 years old and does not meet current insulation or air infiltration requirements. Any improvements to thermal performance of these buildings will help with overall energy conservation. In addition to conserving energy, retrofitting an existing building is often more cost-effective and a more sustainable approach than constructing a new building. Upgrades can extend the service life of the structure, increase the asset value, and contribute to a healthier, more comfortable environment for occupants. In taking the long view, many leading U.S. corporations and universities, as well as federal, state, and local governments, are committed to reduce energy use across their portfolios by 20% over the next 10 years.¹

Over the past several years, the author has been a part of multiple projects involving the installation of air barriers and thermal insulation over a variety of existing construction types, ranging from solid masonry and concrete to stud-framed buildings. Each building type has its own performance characteristics and concerns that need to be addressed prior to performing building enclosure upgrades.

The first step with any building enclosure modification is to understand the condition of the existing assembly and how it currently performs. It is important to note that no two walls are the same, and their current condition will vary based upon wall design, quality of original installation and materials used, weathering, the function of the space being enclosed, and the level of proactive maintenance.

When an air barrier or insulation is added to an existing assembly, the wall's performance and how it interacts with moisture, air, and temperature will change. Understanding how modifications will affect the existing assembly and whether it can manage the new building physics is critical. The condition of the existing building wall will dictate the level of modifications the building can handle and what repairs may need to be performed prior to initiating thermal improvements.

This article will detail the considerations that must be taken into account with various types of building wall assemblies, including:

- Masonry
- Precast concrete panels
- Metal-stud-framed
- Wood-framed

MASONRY WALLS

Throughout the United States, many older solid masonry structures are being renovated to improve energy efficiency and comfort. The installation of interior thermal

insulation is frequently one of the only possible solutions for thermal upgrade of the building envelope when the exterior appearance cannot be changed.

In an effort to study methods of interior insulation retrofits, Gale Associates (Gale) performed a study for a Boston-area university on three dormitory housing projects. The three dormitories, constructed in the 1920s-1930s, were of similar architectural styles, massing, construction techniques, and materials. The buildings are composed of load-bearing brick masonry and terra cotta walls with plaster interiors, sloped slate roofs with dormers, and multi-lite double-hung wood windows. In recent years, the original uninsulated masonry wall assemblies at two of the buildings were both renovated, insulation was incorporated into the wall systems, single-pane wood windows were replaced with double-hung insulated wood assemblies, and the roofs were replaced.

Gale performed a nondestructive visual survey, an infrared (IR) survey, and a WUFI® (*Wärme und Feuchte instationär*)² analysis to determine whether the renovated wall systems function adequately with respect to dew point location and moisture accumulation over time. Additional analysis was performed to provide a comparative study of the thermal performance of the three in-place wall assemblies.

The following is an overview of the wall assemblies and the results of our WUFI and IR analysis.



Figure 1 – Typical solid masonry wall dormitory.

CASE 1: ORIGINAL 1930s CONSTRUCTION

The unrenovated wall assembly consisted of solid load-bearing masonry composed of an exterior wythe of brick masonry (Figure 1), an approximately 7-in.-thick terra cotta infill, and interior plaster walls.³ The construction represents a fairly common transitional-period, load-bearing wall system that undergoes consistent wetting and drying cycles. As there were no vapor barriers in the system, the wall was able to seasonally adapt and dry from the interior or exterior of the assembly (depending on which side was heated), limiting the potential of condensation and frost inside the walls. The WUFI simulation indicated that the overall water content of the system was undergoing a consistent wetting and drying cycle. Over the five-year analysis period, the water content of each of the materials, as well as the overall water content of the assembly, decreased. While this type of wall system is not optimal in terms of energy efficiency, it performs hygrothermally well over time and has a good track record when maintained.



Figure 2 – Infrared image of SPF-insulated building. Note thermal bridging from uninsulated interior walls and floor slabs.

CASE 2: RENOVATED ASSEMBLY WITH SPF

The renovated wall assembly composed of solid load-bearing masonry, comprised of an exterior wythe of brick masonry, an approximately 7-in.-thick terra cotta infill, a 1-in.-thick application of closed-cell

spray polyurethane foam (SPF),⁴ a 1½-in. metal stud wall, and gypsum interior or sheathing. The WUFI simulation indicates the dew point occurred within the SPF layer. The water content of the overall assembly showed an adequate performance, with the overall water content of the system undergoing a consistent wetting and drying cycle with minor accumulation of moisture over the five-year cycle in the brick masonry and terra cotta. Provided that there are no vapor barriers on the outside face of the insulation (only an air barrier was reported), these conditions will allow for the insulation to dry out to the exterior.

The addition of an air barrier in a solid masonry wall system (to which insulation is added) is recommended to minimize the water vapor transport through exfiltration air through the wall. Although closed-cell SPF insulation can act as a vapor barrier, the thickness of SPF applied in this case was not sufficient for it to function as a complete vapor barrier, allowing some inward drying potential (Figure 2).

As WUFI is only capable of accounting for a “perfect” continuous wall system, it does not account for areas where insulation may not have been continuously applied, particularly at transitions, such as around floor joists/slabs, window perimeters, etc.,

which could result in air exfiltration and moisture infiltration at these areas (Figure 3). Furthermore, WUFI assumes that the masonry/terra cotta wall to which the SPF was applied is in “perfect” condition and any defects such as cracked or spalled brick, mortar deterioration, etc., have been repaired. The integrity of the exterior masonry wall system is important as the lack thereof could increase the bulk-water accumulation within the masonry wall and potential for freeze-thaw damage due to the change in the temperature gradient as a result of the added insulation.

CASE 3: RENOVATED ASSEMBLY WITH BATT INSULATION

The renovated wall assembly consisted of solid load-bearing masonry comprised of an exterior wythe of brick masonry, an approximately 7-in.-thick terra cotta infill, a 2½-in. metal stud wall filled with 3-in. batt insulation, a polyethylene vapor barrier, and gypsum interior sheathing. The WUFI simulation indicated that the dew point occurred within the batt insulation. The water content of the overall assembly showed a slight increase with each wetting and drying cycle. As the dew point occurred within the insulation layer, the elevated relative humidity (RH) and accumulation of moisture within this layer poses some concern for mold growth and corrosion of metal components. The lack of drying of the insulation and brick/terra cotta layers can result in the premature deterioration

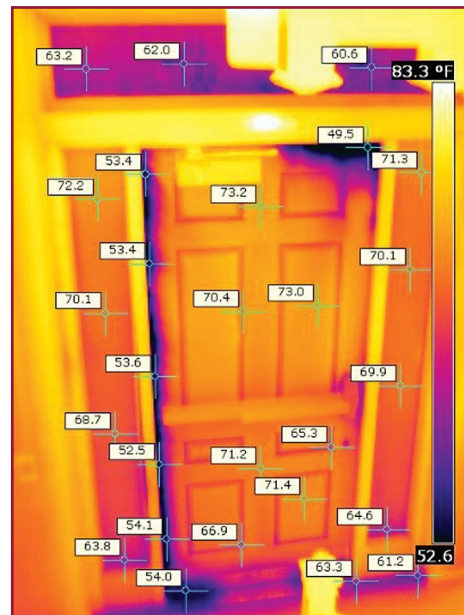


Figure 3 – Infrared image of air leakage at a door showing up to a 22°F temperature change due to poor weatherstripping.



Figure 4 – Infrared image of interior space. Note thermal bridging of metal studs that bypass batt insulation.

of these materials due to condensation and frost. As previously mentioned, the results obtained through the WUFI analysis were based on a “perfect” continuous wall system and did not include the metal studs. The thermal imaging (*Figure 4*) indicates the shortcoming with this insulating method where thermal bridging of the batt insulation can significantly reduce the thermal performance of the insulation R-value and can increase the rate of deterioration due to the interruption of the insulation.

MASONRY WALL SUMMARY

The addition of insulation within a solid masonry assembly results in a shift in the temperature gradient and the natural wetting and drying cycles of the wall. Without the correct placement and correct physical characteristics of the air barrier, insulation, and vapor-permeable layers, newly insulated walls can experience moisture accumulation through condensation that results in frost within the wall and leads to deterioration of the new interior wall components and original wall assembly. As can be illustrated by the three dormitories, the original construction exhibited superior hygrothermal performance compared to the two renovated structures but lacked an air barrier and thermal efficiency.

The thermographic analysis indicated that the renovated buildings experienced less heat loss than the uninsulated building. It is important to note that some areas—such as at building corners and primarily at changes in plane of building elevations (i.e., areas adjacent to stairwells) and around floor slabs—can be difficult to thermally isolate from the interior, causing thermal bridging through the newly installed insulation. This project and other similar projects indicated that SPF insulation provides the best thermal break to the exterior wall assembly while also controlling the movement of water vapor via air transport. The use of 1 in. of closed-cell SPF insulation is preferred over the batt insulation with a vapor barrier as it will still allow drying to the interior and, unlike batt insulation, is an air barrier and will reduce the possibility for moisture from contacting or infiltrating into occupied space.

It is important to note that a hygrothermal analysis must be performed on each individual wall system to determine the appropriate insulation thickness and determine what types of barriers should be considered. Evaluating the exterior masonry surfaces to identify all masonry defects

(cracked or spalled masonry and open or cracked mortar joints) is necessary so that repairs can be performed prior to performing interior energy upgrades.

PRECAST CONCRETE PANELS

In January 2014, a Boston hospital retained Gale to investigate significant interior condensation occurring in and around patient suites. This 16-story concrete structure, composed of exterior precast concrete wall panels with punched aluminum window openings, was constructed in 1979.

The original installation included 1 in. of expanded polystyrene (EPS) insulation installed against the interior face of the precast concrete panels. Subsequent interior modifications include removal of this insulation and the installation of 2 in. of mineral wool insulation. This noncontinuous insulation layer is interrupted by metal hat channels secured to the back side of the precast panels to support the gypsum wallboard. A reinforced polyethylene sheet product was installed between the furring and the interior gypsum sheathing.

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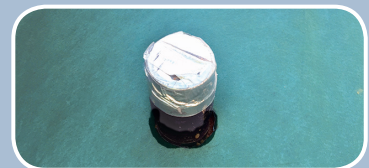


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Figure 5 – Locations of thermal data logger probes.

Test cuts performed at the exterior walls revealed the mineral wool to be damp, with moisture condensing and running down the inside face of the precast concrete panel. Further test cuts showed that the interior polyethylene vapor barrier was not installed in a continuous manner, seams were not taped, and large openings were left around mechanical and plumbing penetrations. Like most hospitals, the interior was slightly pressurized, driving warm, humidified air through gaps and voids into direct contact with the precast concrete wall panels. This resulted in the development of excessive amounts of condensation.

With the assistance of single-point data loggers, the interior conditions were found to range from 67.8°F to 71°F, with relative humidity (RH) ranging between 42% and 55%. Exterior temperatures ranged from 14°F to 24°F. The data logger analysis was performed using a battery-powered digital thermometer data logger meter. These meters display and store temperature readings from the thermocouple temperature probes that are attached to various surfaces and exterior wall components. Figure 5 shows where the thermal probes were placed:

1. Interior surface of the precast concrete panel
2. Interior surface of the interior gypsum wall board
3. Surface of the steel support angle for the precast panels at the floor above

Figures 6 and 7 chart out the temperatures logged. As shown in these graphs, the temperature readings of each of the probes fluctuated along the same ranges as the exterior temperatures. Note that

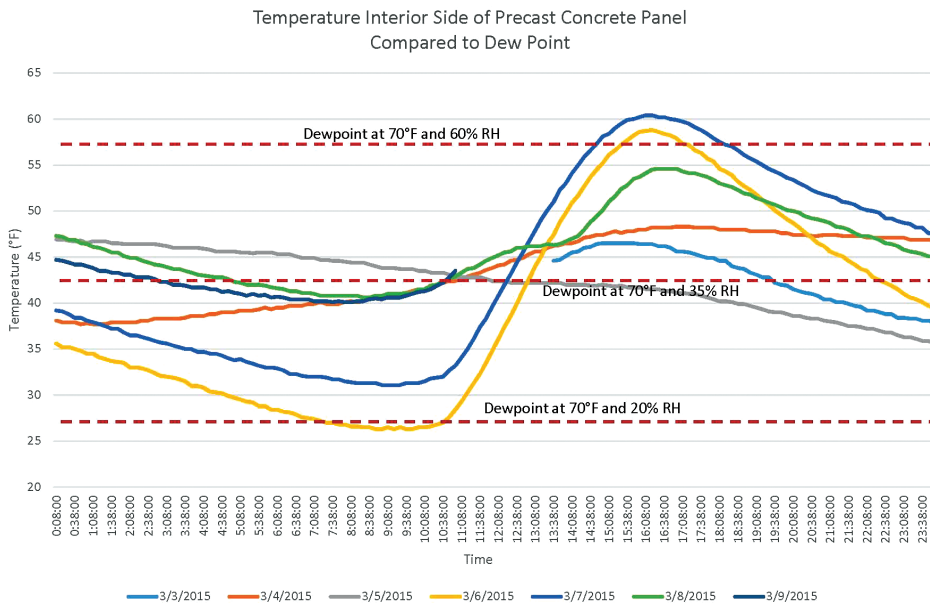


Figure 6 – Temperatures on the interior side of precast concrete panel compared to dew point.

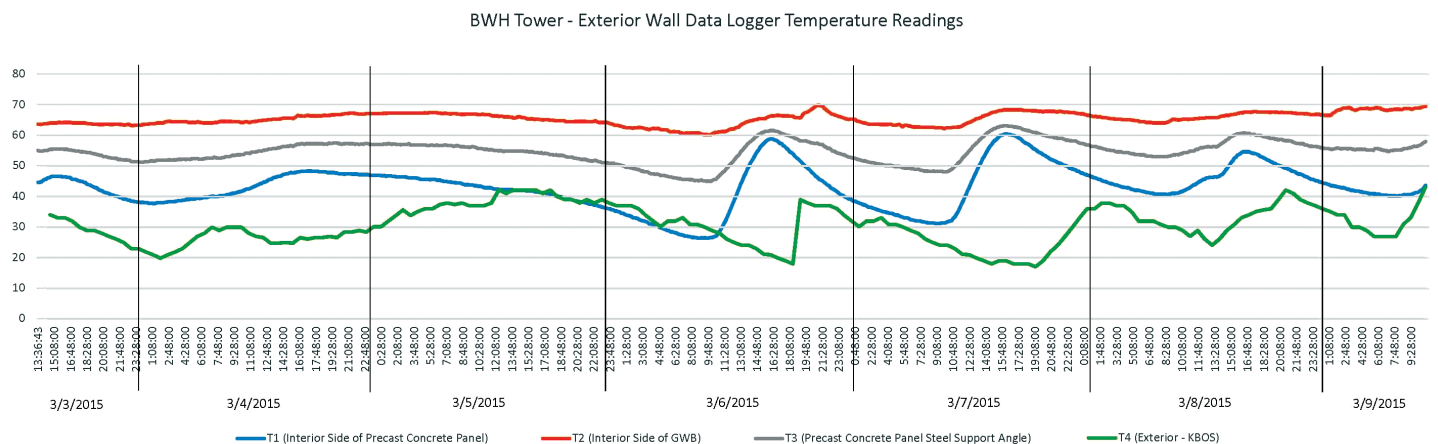


Figure 7 – Exterior wall data logger temperature readings.

the exterior temperatures are taken from the Logan International Airport Weather Station, approximately five miles from the site. The graphs clearly show that the temperature of the interior surfaces of the precast concrete panels exhibited temperature readings that followed closely to those of the exterior temperatures. The difference in temperature between the exterior and the interior side of the precast panels ranged from approximately 20°F down to 5°F. It is worth mentioning that the most significant condensation was occurring in a suite on the north side of the building, but the temperature data loggers were performed from a suite on the south side due to room usage. On March 6, 7, and 8, the temperature peaks recorded are due to solar heat gain experienced on the south elevation.

Based on information presented by the building facility staff and documented during multiple site visits, condensation typically occurred in the building when there were back-to-back days where the exterior temperatures were below 30°F. Due to the exterior wall construction and lack of insulation, the concrete wall temperature is cooled below the interior dew point during prolonged periods of cold temperature. Gaps and voids in the interior air barrier allow warm interior humidified air to come in contact with these cold surfaces, resulting in water vapor condensation. Similarly, the existing windows, which were nonthermally broken, incurred similar condensation issues.

Several interior and exterior insulation options were considered, but the client preferred an interior retrofit that would allow thermal modifications to be performed at each floor over an extended period of time. Gale performed thermal and hygrothermal modeling analysis utilizing “THERM” Finite Element Simulator, Version 7.3, developed at Lawrence Berkeley National Laboratories

with support by the U.S. Department of Energy, and WUFI to perform one-dimensional hygrothermal analyses by transient modeling.

Since the existing window systems were considered in poor condition and beyond their serviceable life, new thermally improved aluminum curtainwall assemblies, suitable for high-rise building applications, were recommended. The proposed interior-glazed curtainwall system will have thermal separators and insulated glazing for increased thermal performance. More importantly, the window opening will be slightly reduced to allow for thermal isolation of the window from the surrounding concrete panels, contributing to cold conductivity and resultant condensation. Currently, the existing aluminum window frame is in direct contact with the uninsulated concrete panels. By reducing the window dimensions, a thermal break and insulation will separate the window frame from the concrete panel to achieve higher thermal performance.

It should be noted that the installation of insulation upgrades to the exterior of the façade would provide the best thermal performance as thermal bridging through the existing cladding and structural elements can be significantly reduced. Similar to the masonry buildings previously discussed, the increased cost and change in building appearance can make this option not feasible. Instead, internal spray-applied insulation is often the most cost-effective option. In this case, installing spray-applied insulation over the existing precast concrete panels was the best option. The main advantage of using SPF is that it creates a continuous and seamless air- and vapor-impermeable thermal barrier between the interior and exterior of the building envelope with a high level of reliability.

MODELING

As part of the design phase for the high-rise, precast concrete wall panel construction, several hygrothermal models and two-dimensional modeling were performed for the exterior wall. The following is an overview of the wall assemblies and the results of our WUFI and thermal analysis.

ASSEMBLY 1:

The wall assembly modeled in this case is based on the existing nonthermally broken aluminum windows within the original exterior wall construction, consisting of the following components, listed from the exterior:

- 8-in.-thick precast concrete panels
- 1-in. EPS with periodic vertical furring strips



YOU CALL ME RAIN



HYDROTECH CALLS ME OPPORTUNITY

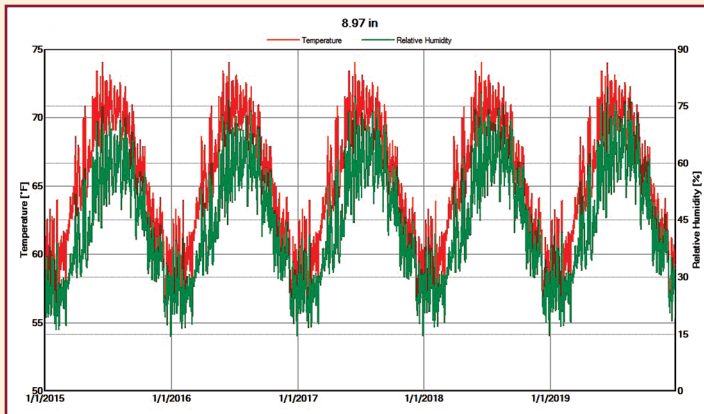


Figure 8 – Temperature and humidity readings at the interior surface of the expanded polystyrene insulation.

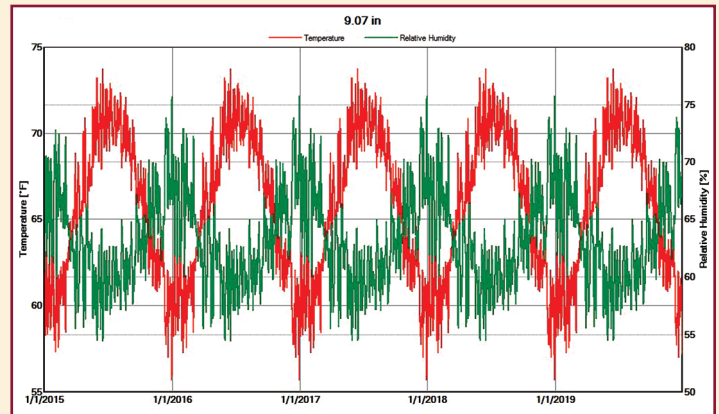


Figure 9 – Temperature and humidity readings at the interior surface of the gypsum wallboard.

- Vapor barrier (noted to be noncontinuous and open at penetrations)
- 5/8-in. gypsum wall board, painted

At the interior face of the insulation, the RH passes 80% briefly (Figure 8). Typically, if the humidity surpasses 80% for prolonged periods of times, corrosion of metal framing can occur. While the model did not indicate this being an issue, it was in close proximity to a dangerous range where risk could be increased if the vapor barrier was not completely continuous and allowed additional moisture within the system. Figure 9 indicates the interior gypsum wallboard surpassed 70% RH, a trigger point for mold growth during the summer months.

The key performance of this wall is dependent on the vapor barrier remaining in good condition. While the insulation maintains the interior wall surface at a higher temperature, it also reduces the temperature of the interior surface of the concrete. Should moist interior air hit these colder surfaces, condensation could occur. The thermal conductivity of the precast concrete panels is also virtually unchanged around the window opening.

ASSEMBLY 2:

The wall assembly modeled in Figure 10 had the existing nonthermally broken aluminum windows within the existing exterior wall construction with prior interior modifications. The assembly consisted of the following components, listed from the exterior:

- 8-in.-thick precast concrete panels
- 2-in. mineral wool insulation, with periodic vertical furring strips
- Vapor barrier (noted to be noncontinuous and open at penetrations)
- 5/8-in. gypsum wallboard, painted

The modeling indicates the thermal performance that occurs on the interior at the insulation layer. The continuity of the interior vapor barrier is critical to the success of this wall assembly. The interior face of the concrete wall is significantly cooler than the interior temperature. When a six-air-change-per-hour air leak was introduced through the interior

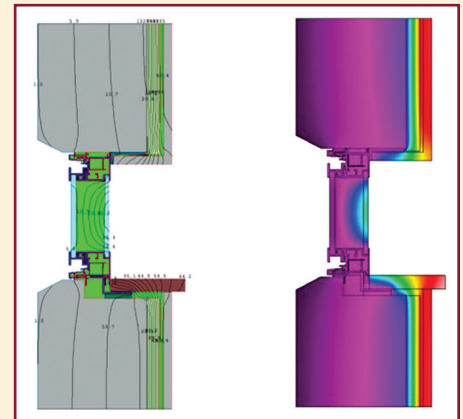


Figure 10 – Two-dimensional image of existing (modified) wall assembly.

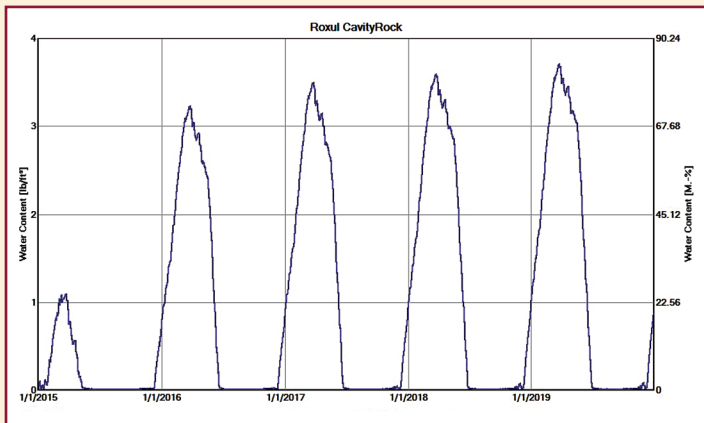


Figure 11 – The graph shows the increasing moisture content of the mineral wool each winter.

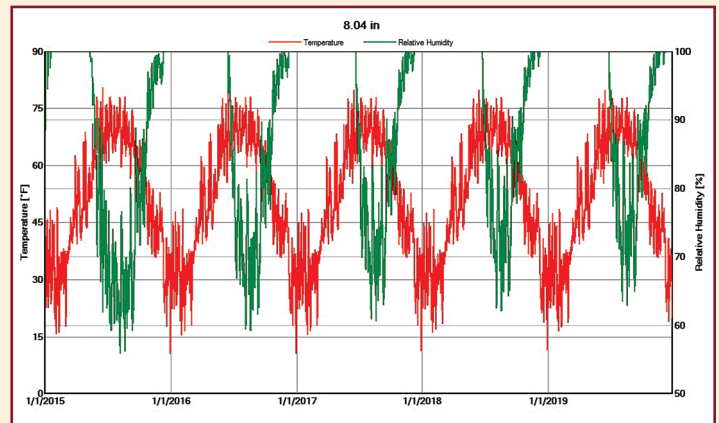


Figure 12 – Temperature and humidity readings at the interior surface of the concrete wall. Condensation occurs when the green line tops out at the 100% RH mark.

finishes and vapor barrier, the wall assembly collected significant moisture content each winter (Figure 11). Figure 12 indicates a significant period of time that condensation can occur (areas indicated by 100% RH each winter) at the interior concrete surface. This includes potential condensation within the mineral wool and metal framing layer.

ASSEMBLY 3:

The wall assembly modeled in Figure 13 has a new thermally broken aluminum curtainwall system with the wall construction consisting of the following components, listed from the exterior:

- 8-in.-thick precast concrete panels
- 2¼ in. SPF
- ½-in. gypsum wall board (painted) on 2-in. metal studs, set minimum 1½ in. off face of precast

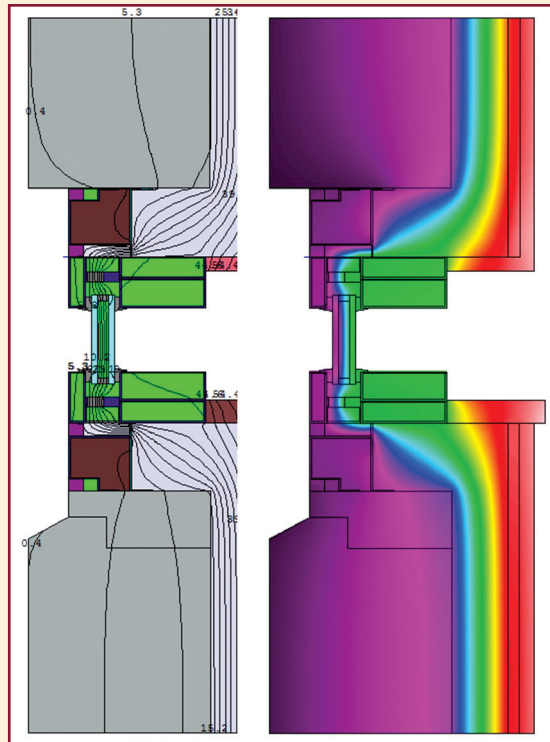


Figure 13 – Two-dimensional image of the existing exterior precast concrete panel wall with new interior spray-applied foam (SPF) insulation, new curtainwall assembly, and new interior finishes.

The new SPF insulation installed to the interior surface of the precast concrete panels provided a thermal barrier between the conditioned interior and the concrete wall panels. Since the product was spray-applied, it could be installed continuously around existing objects and uneven surfaces. One item of concern was the depth of the metal studs. The greater the offset, the less thermal bridging was caused. While modeling the SPF assembly in Figure 14, at ¾ in. of thickness, there was still the potential for RH above 80%, which could cause corrosion of metal items. At a depth of 1½ in., the chance for corrosion was reduced

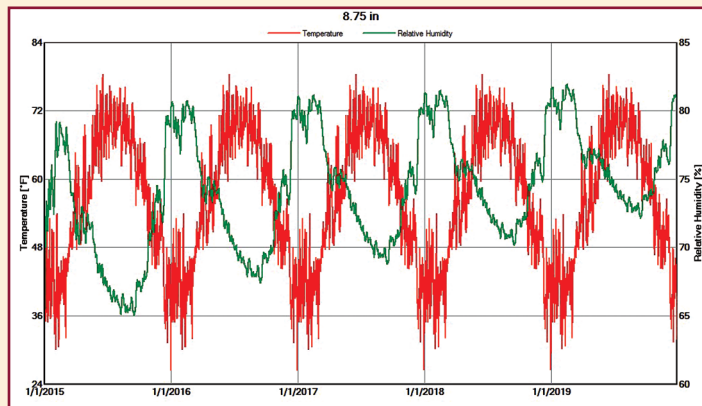


Figure 14 – Temperature and humidity ¾ in. into the SPF. Note several RH readings over 80%.

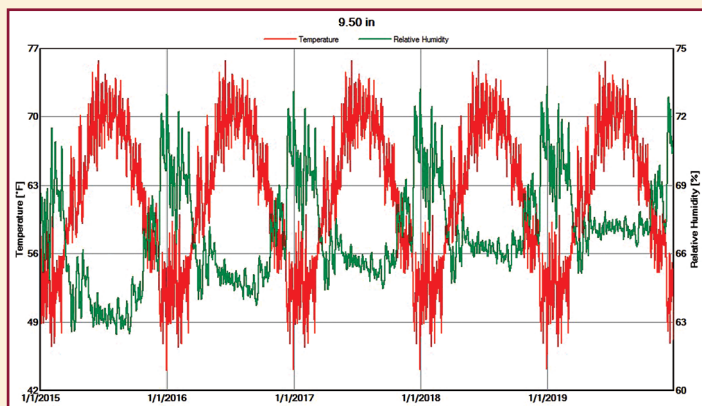


Figure 15 – Temperature and humidity readings 1½ in. into the SPF. Note no RH readings over 80% and very few over 70%.

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WASTE ME

HYDROTECH ROOFS
LEVERAGE MY
POTENTIAL

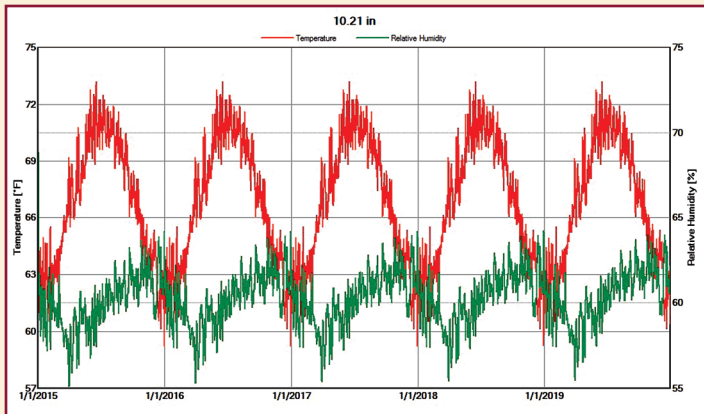


Figure 16 – Temperature and humidity readings at interior face of the SPF. Note low RH readings close to baseline interior RH.

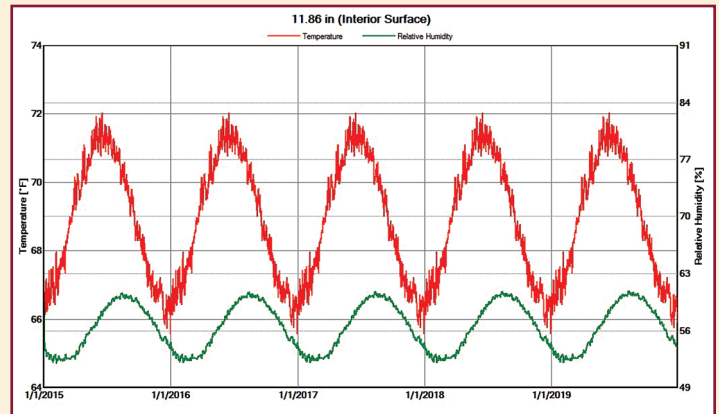


Figure 17 – Temperature and humidity readings at interior face of the gypsum. Note low RH readings close to baseline interior RH and temperatures close to baseline interior temperature range.

(Figure 15). Therefore, we recommended an offset of 1½ in. for the metal studs. The humidity continued to moderate moving towards the interior surface of the room (Figures 16 and 17).

The use of new thermally efficient fenestration and the SPF insulation provided a thermal barrier that maintained a continuous barrier around the interior. The new curtainwall frames were held off the concrete to reduce thermal bridging. While they were warmer than the old windows, they were still the weak location in the assembly. As indicated in Figure 11, when it is below ten degrees outside, the window frames could be expected to be in the low 40s, requiring the interior temperature and humidity to be reduced to 68°F and 30% RH to eliminate any risk of condensation occurring on the aluminum frames.

ASSEMBLY 4:

The wall assembly modeled in Figure 18 had a new thermally broken aluminum curtainwall system with the wall construction consisting of the following components, from the exterior:

- 3-in. exterior insulated finish system (EIFS)
- 8-in.-thick precast concrete panels
- Periodic vertical furring strips
- ½-in. gypsum wall board, painted

Figure 18 represents a new thermally efficient curtainwall assembly installed within the existing punched opening of the precast concrete panel construction. Additionally, a new EIFS had been installed on the exterior surface of the precast concrete panels, and finishes installed on the interiors. EIFS was modeled due to lack of complexity, but a similar exterior insulated cladding system would be expected to perform much the same. Note the thermal conductivity and temperature differentials are now moved towards the exteriors instead of the interiors (Figure 19). When installing an exterior-insulating system, the thermal and moisture issues are shifted out to the exterior insulation

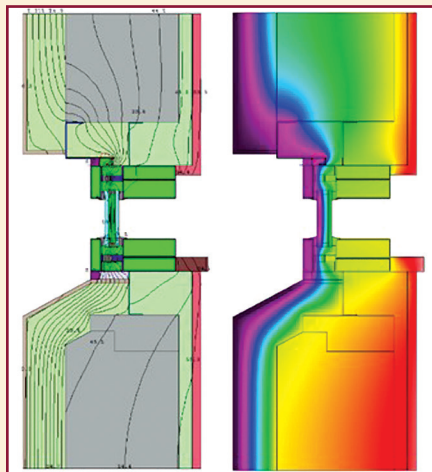


Figure 18 – Existing exterior precast concrete panel wall with new exterior EIFS, new curtainwall assembly, and new interior finishes.

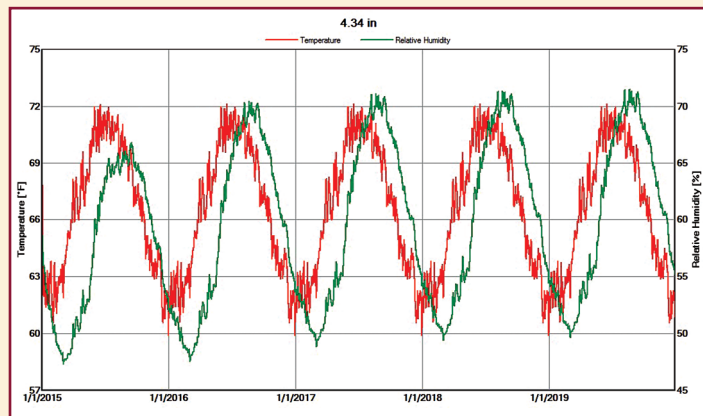


Figure 19 – Temperature and humidity readings at the exterior surface of the precast concrete panel. Note the range of the temperature and RH closely mimics the interior set temperatures.

layer, which is outboard of the drainage plane and structural members. Over the long term, this would provide the longest-lasting assembly. While it may require periodic upkeep to maintain the new exterior cladding, the structure and the interior environment would be isolated from the exterior weather and could be expected to last longer than with an interior option.



Figure 20 – Infrared image highlighting the thermal bridging caused by the metal studs.



Figure 21 – Infrared image indicates air leakage.

METAL-STUD FRAMED WALLS

Unlike masonry and concrete walls, metal stud-framed walls have less moisture storage capacity than wood-framed or masonry walls, so the margin for error is drastically smaller. In this case, the addition of or lack of a vapor retarder is more critical. Continuous exterior insulation is preferred to reduce thermal bridging caused by metal studs (Figure 20). Older metal-stud buildings typically have minimal exterior continuous insulation. For instance, continuous insulation was not a code requirement until the adoption of the 2006 International Energy Conservation Code. Older walls experience significant overall insulation R-value loss due to the thermal bridging caused by the metal studs, reducing effective R-values to 55% of the stated value on the label.⁵

For instance, an R-15 batt installed within a 3½-in. stud wall results in an effective R-value of only R-6.4, while an R-21 batt installed within a 6-in. stud has an

effective R-value of R-7.4.⁶ By increasing the exterior insulation, the thermal barrier shifts outward, as does the potential dew point. Depending on the new cladding being utilized, you can move to an assembly closer to those now used in new construction. These assemblies consist of an exterior cladding and air space, continuous insulation, an air and vapor barrier, exterior sheathing, metal stud walls, and existing interior finish. The removal and replacement of the exterior sheathing allows the engineer to review the condition of the metal studs and the existing batt insulation. The moisture-damaged insulation and deteriorated studs will likely require replacement. If the existing stud cavity insulation is not removed, a thermal analysis should be performed to confirm that the dew point will remain outboard of the air and vapor barrier. A vapor-permeable barrier is another consideration.

On a recent project involving an international corporation’s headquarters, the exterior siding was found to be in poor condition and near the end of its useful life. During the design phase, an infrared (IR) survey indicated significant air leakage and thermal bridging (Figure 21). To address these issues, the proposed wall assembly included a vapor-permeable air barrier, exterior continuous insulation, and a fiber cement wallboard to replicate the traditional New England clapboard style of the original building (Figure 22).

Since the project maintained the existing interior finishes and exterior sheathing, the existing batt insulation remained in place. This required using a vapor-permeable air barrier to allow drying potential inwards and outwards. A continuous layer of rigid insulation was installed outboard of the new air barrier. Vertical furring was added to provide a venting cavity behind the siding. When insulating the exterior in this manner, it is important to provide additional blocking around the windows to accommodate the thickness of the



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Figure 22 – Exterior wall assembly under construction.

insulation. Additional considerations are needed with regard to the fastening of the furring and siding to comply with wind loading.

WOOD-FRAMED STRUCTURES

Wood-framed structures are similar to metal studs except there is significantly less thermal bridging through the wood framing. Using an air barrier can significantly increase the efficiencies of these structures by reducing air movement and moisture transport within the wall assembly. The addition of continuous insulation helps improve the overall performance of the assembly. After an existing university student housing complex (circa early 1990s) in southern New England experienced a blow-off of its EIFS, an evaluation of the exterior wall assembly

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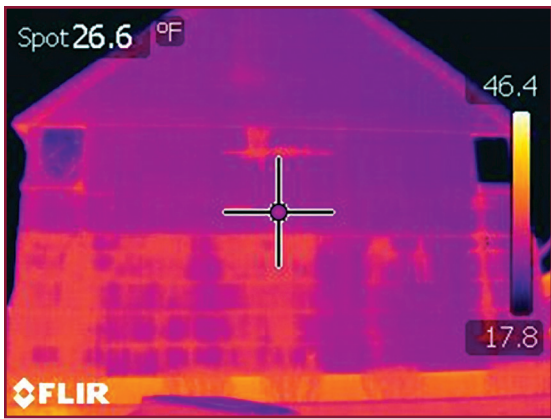


Figure 23 – Infrared image indicating wet and damaged EIFS.

found increased energy use associated with elevated rates of air infiltration, minimal amounts of insulation, and inefficient thermal glazing. These issues contributed to condensation build-up within the exterior walls, resulting in the development of mold and associated indoor air quality issues. The high energy usage, aesthetics, and occupant comfort were also major factors in the university's decision to retrofit the envelope.

The exterior envelopes of the existing townhouse-style dormitory complex consisted of fiberglass batt insulation, installed within wood-framed stud walls and overlaid with oriented strand board (OSB) sheathing. The OSB sheathing was overlaid with an EIFS, with a total R-value of 6. An IR thermography scan (Figure 23) and destructive test cuts revealed that the failure of the existing EIFS panels had allowed moisture to migrate into the OSB sheathing and fiberglass batt insulation. This moisture infiltration resulted in deterioration of the OSB sheathing and saturation of the fiberglass, allowing mold growth within the wood stud wall.

A WUFI analysis was performed of the EIFS wall assembly (Figure 24) and the new proposed wall assembly (Figure 25), which consisted of new plywood sheathing, blown-in cellulose insulation, a self-adhered vapor-permeable air barrier, 1-in. rigid insulation, and fiber cement siding installed to wood furring.

The EIFS wall had a higher interior RH range of 35% to 73%, while the proposed wall assembly was 35% to 67%. It should be noted that the real failure of the existing wall assembly was due to poor detailing and poor installation. Several details allowed the flow of bulk water behind the EIFS cladding, which acted as a partial vapor barrier. The moisture deteriorated the OSB sheathing and foam adhesive, leading to the blow-off of the exterior finish, which initiated the project. During construction, further damages were uncovered, including significant deterioration of wood-framing members and mold growth on the sheathing and fiberglass batt insulation.

AIR BARRIERS

With any renovation of an exterior wall, confirming existing deficiencies and including repairs to the existing or the installation of a new air barrier are critical. As an example, the renovation noted under the wood-framed assembly was performed on three duplicate-style dorms over a three-year period, which provided a unique opportunity to perform an energy comparison between the existing and renovated dormitories.

Phase 1, completed in the summer of 2012, allowed for the first real-world test of the enclosure's performance when, on February 8, 2014, a storm knocked out power on campus for three days and the

university's facilities staff reported that the renovated dormitories were 10 to 15 degrees warmer than the unrenovated dormitories. This improved occupant comfort was associated with insulation upgrades and reduced air infiltration.

Blower-door testing was performed to measure the air infiltration rates at typical townhouse units within the existing and newly renovated dormitory complexes. The blower-door test, ASTM E779-10, measured the airflow in cubic feet per minute through a single fan to create a 50 Pascal (Pa) change in building pressure, or CFM50. During the performance of blower-door testing, additional tests utilizing a theatrical smoke machine and IR thermography, in accordance with ASTM E1186, were executed to aid in identifying areas of air infiltration. At the existing building, visible areas of air infiltration were identified by smoke movement and IR thermographic anomalies. The most prolific areas of air infiltration were observed at window perimeters, floor-to-wall transitions, and at wall/ceiling penetrations. The smoke entering between the first floor sill plate and foundation filled the room in less than one minute, indicating substantial air leakage in the existing assembly.

Air infiltration at the renovated units was significantly reduced and was only visible during testing. Due to the limited scope and the construction of the existing wall framing, the new air barrier could not be sealed at the ceiling-to-wall connections, where it abuts the underside of the roof trusses. Limited air leakage was observed at the ceiling-to-wall interface and at ceiling penetrations, such as existing light fixtures and sprinkler heads. The top floor unit has higher air infiltration rates due to the original attic/ceiling assembly, which was not

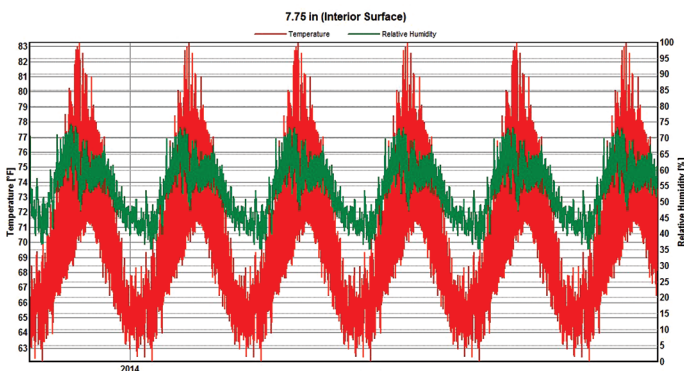


Figure 24 – Temperature and humidity readings at the interior gypsum sheathing at the existing wall assembly.

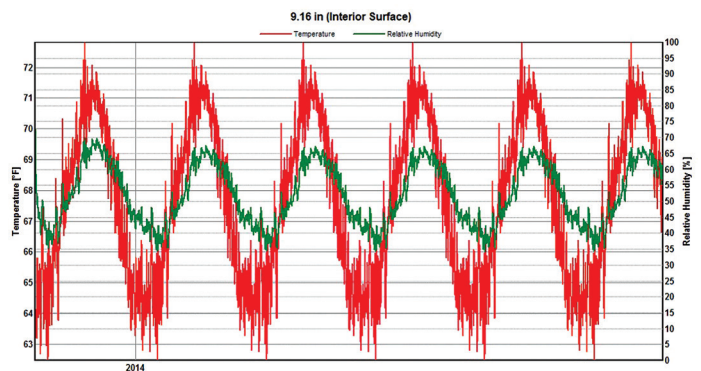


Figure 25 – Temperature and humidity readings at the interior gypsum sheathing at the proposed wall assembly.

renovated, nor was an air barrier provided at the ceiling plane.

To compare dorm units of varying size, the CFM50 values recorded during testing were divided by the unit's volume to identify how many times per hour the entire volume of air in the unit is replaced when the building envelope is subjected to a 50 Pa pressure.

Figure 26 shows the air exchanges per hour at a test pressure of 50 Pa (ACH50), which were recorded during blower-door testing performed at the four dormitory units. A difference of 1.73 ACH50 was calculated between units N1 and E1, which equates to an approximate 30% reduction in

air infiltration. A difference of 5.87 ACH50 was calculated between N2 and E2, which equates to an approximate air infiltration reduction of 61%.

There are several standards used to determine acceptable rates of air infiltration. Air infiltration standards for new con-

struction are typically predetermined by the owner and designer, and reflect requirements designated by state or local building codes. These standards include associations such as the Air Barrier Association of America (ABAA), the U.S. Army Corps of Engineers (USACE), and The American

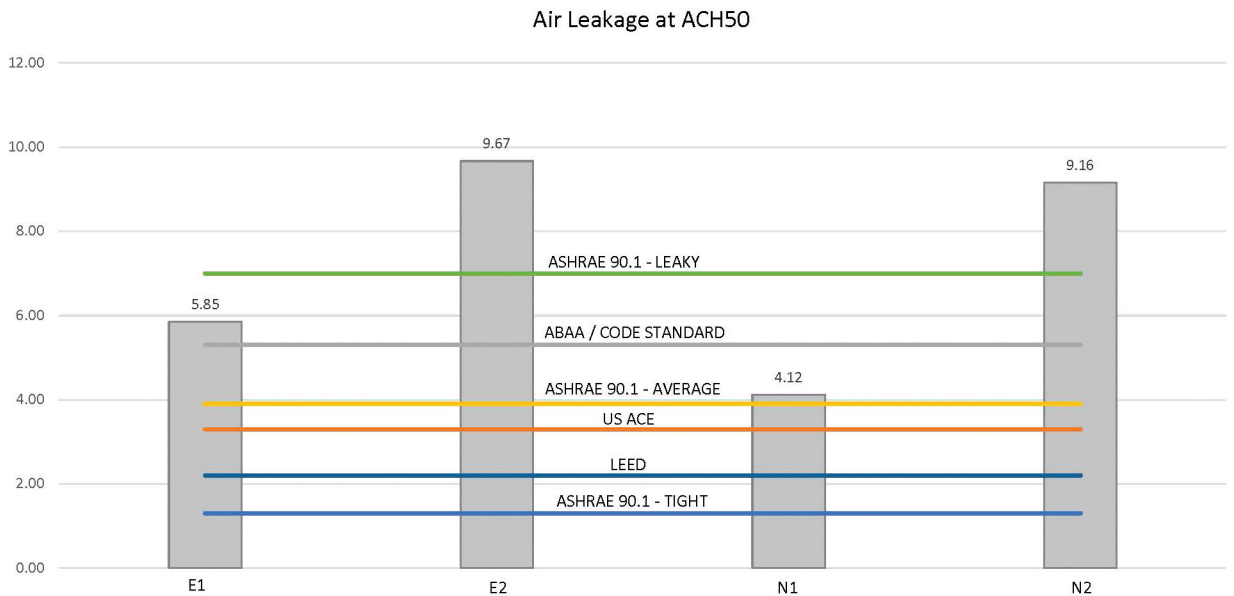


Figure 26 – Graph of industry air change levels and test results.



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Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). ASHRAE indicates that buildings with “average” air leakage have an approximate ACH50 of 3.9, “tight” of 1.3, and “leaky” of 7.0 or higher. Unit E2 had a calculated ACH50 of 9.67, which, by ASHRAE standards, is considered “leaky.” Blower-door testing confirmed that the addition of an air barrier to the exterior walls was able to reduce air leakage to an ACH 3.80, which is just below “average.” Figure 26 shows how the ACH50 values recorded during testing compare to ABAA, USACE, and ASHRAE standards.

Building retrofits are an option that should be considered by many owners to extend the service life of existing facilities, as opposed to new construction. Renovations that involve the repair or replacement of the building exterior offer a great opportunity to perform thermal and airtightness upgrades to the building envelope. Diagnostic methods, such as blower-door testing and IR thermography, can help identify existing building envelope deficiencies, as well as quantify the envelope performance of a newly retrofitted building. Performing both pre- and post-retrofit testing can provide valuable information regarding the success of the retrofitting upgrades, in addition to which area(s) of the facility may be considered for future retrofit upgrades. 

REFERENCES

1. This is in response to the U.S. Department of Energy’s Better Building Challenge.
2. The WUFI program was developed by the Fraunhofer Institute of Building Physics in Germany.

The program has become an industry standard for vapor-drive analysis, as it includes the most recent understanding of building physics and employs historic weather patterns for specific project locations. It is important to note that while significantly advanced compared to traditional “static state” calculations, the WUFI software has limitations. The program’s calculations are based on intact building components (i.e., the insulation layers are tight together with no voids or gaps, and vapor barriers are continuous, etc.). Additionally, not all of the building material properties provided by WUFI are consistent with the materials used in the United States, and as no physical testing of in-place materials occurred, some substitutions of the specified materials had to be made with comparable materials. Gale performed redundant modeling that identifies the general patterns of the roof or wall assemblies’ behaviors.

3. At this time, WUFI does not have terra cotta in its material library; therefore, a solid masonry wall constructed of historical brick was utilized in the setup for all three cases.
4. Heatlok SPF by Demilec was utilized for this application. A review of the Demilec literature and speaking with a Demilec technical representative indicates that a 1-in.-thick Demilec application is sufficient to act as both an air barrier and an insulator. Furthermore, Demilec can act as a

vapor barrier. A 1¼-in. application of Demilec results in a vapor permeability of 1 perm, and the perm rating consequently decreases with additional thickness of the insulation.

5. Jan Kosny, Jeffrey E. Christian, and André O. Desjarlais, “Improving Energy Performance of Steel Stud Walls; Steel Framing Can Perform as Well as Wood.” Oak Ridge National Laboratory, Buildings Technology Center. 2006.
6. ASHRAE 90.1 – 2013, TABLE A3.3.3.1 Assembly U-Factors for Steel Frame Walls.



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RCI Interface Seeks Project Profiles

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RCI Interface is particularly interested in submission of project profile articles concerning unique building envelope projects. Profiles should be 1500 to 2500 words with five to 15 high-quality photos and should describe a building issue that is diagnosed or solved or an unusual building or condition worked on in the course of a building envelope consultant’s work. Submit articles to Executive Editor Kristen Ammerman, kammerman@rci-online.org.

AIA TO VOTE ON ADDITION TO CODE OF ETHICS BANNING SEXUAL HARASSMENT

A resolution calling for an amendment to the American Institute of Architects’ (AIA’s) code of ethics would include a provision requiring members to ensure that their workplaces are “environments of mutual respect and equitable treatment, free of abusive behavior and harassment,” according to ENR. Delegates at AIA’s annual meeting in June passed the resolution by a vote of 4,272 for, 13 against, and 136 abstentions.

The board of directors must ratify the resolution before it becomes effective.

— ENR