Integrated Wall Retrofit Solutions for Commercial Buildings’ Existing Masonry Construction

André Desjarlais, Fellow ASTM
Mugdha Mokashi
Oak Ridge National Laboratory
P.O. Box 2080, Mail Stop 6070, Oak Ridge, Tennessee 37831-6070
Phone: 865-574-0022 • Fax: 865-574-9354 • E-mail: desjarlaisa@ornl.gov

Amy Wylie
Bayer MaterialScience
100 Bayer Road, Building 8, Pittsburgh, Pennsylvania 15205
Phone: 412-777-4593 • E-mail: amy.wylie@bayer.com
**Abstract**

Existing masonry buildings offer a good potential to achieve energy efficiency through improved envelope performance. Conditions such as historic preservation or zoning issues could require masonry walls to be insulated on the interior. However, adding insulation to the interior of an existing masonry wall without proper analysis might result in potential durability issues. The speakers will review best-practice recommendations for energy-efficient retrofit solutions for existing masonry buildings that address thermal performance, air leakage, and moisture management. The best-practice recommendations identified are evaluated through energy modeling, laboratory testing, and field data analysis.

**Speakers**

**André Desjarlais, Fellow ASTM — Oak Ridge National Laboratory**

ANDRÉ DESJARLAIS is program manager for the Building Envelope Research Program at Oak Ridge National Laboratory (ORNL). He has been involved in building envelope and materials research for over 40 years. Desjarlais has been a member of ASTM since 1987 and is past chair of ASTM Committee C16. He now serves as the chairman of ASTM’s Committee on Technical Committee Operations (COTCO). He has been a member of ASHRAE since 1991.

**Amy Wylie — Bayer MaterialScience**

AMY WYLIE is the buildings and transportation platform leader for Bayer Material Science in the Public Sector and Business Growth Services Division. She is currently leading the efforts for government contracts, market intelligence, and market development support for the buildings and transportation areas of the public sector. Wylie is also principal investigator dedicated to the U.S. Department of Energy-funded Consortium for Building Energy Innovation. Her primary responsibilities include integration of roof and envelope systems into whole-building integrated retrofit designs.
INTRODUCTION

A growing concern in the construction industry today is the retrofitting of older buildings by adding thermal insulation on the interior side of masonry walls. Internally insulating existing masonry walls requires effectively evaluating the performance of wall systems with respect to heat, moisture, and air flow across the assembly in order to avoid moisture problems and ensure durability.

Older buildings with brick walls are common in many northern U.S. cities. A study of CoStar data conducted in 2011 (Otto, 2011), funded by the Consortium for Building Energy Innovation (CBEI) for the ten-county region around Philadelphia, indicated that 28% of the existing office buildings have masonry construction. Most of these buildings were built prior to the 1980s and have masonry walls that are uninsulated. These buildings offer a good potential to achieve energy efficiency through effective wall retrofit strategies.

While an ideal solution would be to insulate masonry walls on the exterior, conditions such as historic preservation, space requirement, zoning issues, etc. often require the walls to be insulated on the interior. However, adding insulation to the interior of an existing masonry wall could result in potential moisture and durability issues such as freeze/thaw damage. Effective hygrothermal analysis of retrofit solutions can potentially help ensure improved thermal performance and durability for the existing masonry wall systems.

Energy-efficient retrofits of existing commercial buildings are essential to achieve the Building Technologies Office’s (BTO’s) goal of 50% reduction in overall building energy use by 2030 (EEER, 2014). Standard retrofits such as HVAC and lighting system upgrades provide a limited scope of retrofit and can help achieve only 30% to 40% reduction in energy use for buildings (AIA and RMI, 2013). Consequently, it is essential to use an integrated retrofit approach that addresses the building envelope along with other systems to achieve over 50% reduction in building energy use.

PROJECT BACKGROUND

The Consortium for Building Energy Innovation (CBEI), funded through the Department of Energy (DOE), is a partnership of 14 member organizations, with Pennsylvania State University serving as the project lead. The goal for CBEI is to develop and deploy market-tested pathways to achieve 50% reduction in energy use for existing small- and medium-sized commercial buildings (SMSCB) by 2030. This goal is aligned with BTO’s goal of achieving 50% reduction in overall building energy use by 2030.

In order to achieve this objective, the consortium targeted a few existing commercial buildings within The Navy Yard in Philadelphia, PA, as demonstration sites to deploy energy-efficient retrofit technologies. One such project (Building A) identified through CBEI was a small two-story commercial building with masonry walls constructed in the early 1940s. An integrated retrofit analysis was conducted for this building, using energy modeling. This analysis looked at an energy-efficient envelope (opaque and glazing), HVAC system, and lighting system retrofit. However, during this period of analysis, the owner decided to change the business strategy, resulting in the decision to not pursue the proposed retrofit.

The analysis conducted through this project helped the team to realize the uncertainty associated with envelope retrofit projects and the difficulty in finding an ideal demonstration facility. The team identified the need to seek a risk-free environment to test wall assemblies to be able to provide validated field results. The intent was to use these field results to help accelerate adoption of envelope retrofit technologies in the market.

The Wall Retrofit Solutions project was funded through CBEI in response to this need. This project utilized the two-story Flexible Research Platform (FRP) at Oak Ridge National Laboratory (ORNL) as a test bed to analyze wall retrofit scenarios for existing commercial buildings with masonry construction built before the 1980s.

The analysis conducted for “Building A” had evaluated a large set of insulation materials. The results of this evaluation were used to narrow down the selection of insulation materials to a few energy-efficient and cost-effective solutions. These selected retrofit solutions then formed the basis of evaluation for the Wall Retrofit Solutions project.

PROJECT DESCRIPTION

The intent of the Wall Retrofit Solutions project was to analyze the best-practice recommendation for an energy-efficient retrofit of existing commercial buildings with masonry construction that addresses improved thermal and moisture performance, along with reduced air infiltration. The metrics established for the identified retrofit packages were to exceed the ASHRAE 90.1 2010 requirement and have a payback of 10-15 years. The target markets for the retrofit solutions were ASHRAE Climate Zones 4 and 5.

A number of wall retrofit scenarios were evaluated through this project against pre-determined critical parameters based on hygrothermal simulations as well as laboratory test evaluations. Two top-performing retrofit solutions were identified based on these evaluations and were then demonstrated on the two-story FRP located at ORNL.

This paper explains the process of evaluation for the wall retrofit scenarios, along with project goals, project approach, and laboratory test results. It also describes the down-selection process for identifying the top-performing retrofit scenarios, the energy savings estimated for these scenarios, as well as issues related to constructability for the two retrofit scenarios demonstrated on the FRP.

Field data are currently being collected.
for the two scenarios installed on the FRP. These data will then be utilized to identify the best-practice recommendation at the end of the project. Although the FRP is a test-bed facility, it is built to represent an existing small-scale commercial building constructed prior to the 1980s. The interior conditions—such as temperature and humidity, along with occupancy—are simulated to represent an actual small-scale commercial building. Since the data collection for the installed retrofit scenarios is ongoing, it is not included in this paper. The collected data will be analyzed at the end of the project (April 2016) and will be disseminated at a later stage. The project team includes different partners representing diverse areas of the retrofit value chain. While the project is funded through CBEi, Covestro LLC (previously known as Bayer MaterialScience LLC), a raw-material supplier, leads the project. ORNL provides third-party verification for the simulation and laboratory evaluations conducted for the different retrofit scenarios. The other market partners on the team include Carlisle Construction Materials (systems supplier) and the Air Barrier Association of America (trade association). The market partners support the project by providing industry expertise for retrofit solutions and will guide the commercialization of the project results.

CBEI has also engaged a technical advisory group (TAG) for this project, which consists of industry experts. The role of the TAG is to provide advice as the project progresses, ensure that the project outcomes are relevant to the market, and confirm that the project meets the set milestones. The TAG members on this project are Fiona Aldous from Wiss, Janney, Elstner Associates, Inc.; Brian Stroik from Tremco Sealants and Waterproofing; and Pat Conway from the International Masonry Institute.

### PROJECT APPROACH

The Wall Retrofit Solutions project evaluated the performance of a number of wall retrofit solutions through multiple stages. A list of wall retrofit scenarios to be evaluated was vetted through industry experts at an expert review. Based on the input received during the expert review, two retrofit solutions were added to the preliminary list, resulting in a finalized list of nine retrofit scenarios to be evaluated through the project.

#### INDUSTRY EXPERT REVIEW

A review by an expert panel, consisting of building science experts, envelope consultants, and contractors was conducted in August 2014 (Table 1). The objectives of the expert review were to:

- Get input on the preliminary list of wall retrofit scenarios to be evaluated through the project
- Identify additional scenarios to be evaluated
- Identify critical parameters and weights for each parameter for evaluating the scenarios

A preliminary list of seven retrofit scenarios was vetted through the industry experts at this review. Based on the input received during the expert review, two retrofit solutions were added to the preliminary list, resulting in a finalized list of nine retrofit scenarios to be evaluated through the project.
next stages of the project (Table 2). These scenarios have been grouped into three categories:
A. Retain existing wall assembly (with insulation).
B. Retain existing studs (without existing insulation).
C. Remove existing insulation and studs.

The experts also identified six critical parameters for evaluating the nine scenarios (Table 3). These retrofit scenarios were designed for the baseline wall assembly for existing commercial buildings with masonry construction built prior to the 1980s (Figure 1).

INITIAL EVALUATION

An extensive evaluation matrix was generated comparing the performance of the nine retrofit scenarios against the identified critical evaluation parameters.

Data for the scenarios for every parameter were obtained from various sources. Construction costs per square foot were obtained from a contractor for each scenario. Moisture management of the scenarios was determined using the WUFi hygrothermal simulation software. The potential for mold growth was analyzed using WUFi Bio modeling. This provided input for the parameter of indoor air quality. Thermal performance of the scenarios was determined using THERM modeling. The data for air leakage for the scenarios were obtained from the ABAA website based on the air leakage rates available for standard wall assemblies. The parameter of constructability considered multiple factors such as interior floor area cannibalized by the retrofit scenarios, the time and labor required, and the ease of construction for each scenario. Industry assumptions were used as data for this parameter.

The data collected from multiple sources for each parameter had different units. As a result, all the data values under the different evaluation parameters were normalized to range from 0 to 1 for the purpose of objective comparison. These normalized data values were applied with the respective weighted percentages identified by the industry experts for each parameter (Table 3). The values for all six critical parameters were then added to achieve the overall weighted percentage for each scenario. A final evaluation matrix, indicating the overall weighted percentages, was generated to provide the ranking for the scenarios.

The evaluation matrix was used to identify the three top-performing retrofit scenarios to be down-selected for the next stage of the project: laboratory test evaluations. Table 4 provides an overview of the performance evaluation of the nine retrofit scenarios with respect to each evaluation parameter. This evaluation was used to down-select the three top-performing scenarios at this stage.

The three top-performing scenarios down-selected from the nine scenarios were:
• Scenario #1: Retain existing interior insulation, steel studs, and dry-

<table>
<thead>
<tr>
<th>No.</th>
<th>Critical Evaluation Parameter</th>
<th>Weighted Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost effectiveness</td>
<td>35%</td>
</tr>
<tr>
<td>2</td>
<td>Moisture management/ durability</td>
<td>20%</td>
</tr>
<tr>
<td>3</td>
<td>Thermal performance</td>
<td>18%</td>
</tr>
<tr>
<td>4</td>
<td>Air leakage</td>
<td>12%</td>
</tr>
<tr>
<td>5</td>
<td>Disruptiveness/ constructability</td>
<td>9%</td>
</tr>
<tr>
<td>6</td>
<td>Indoor air quality</td>
<td>6%</td>
</tr>
</tbody>
</table>

Table 3 – Six critical evaluation parameters identified through the expert review, along with their weighted percent.
wall in the baseline wall assembly; install 2-in. rigid polyisocyanurate (PIR) foam board with taped seams on existing wall.

- **Scenario #2**: Remove existing insulation, steel studs, and drywall in the baseline wall assembly; install 2.5-in. PIR foam board with a separate air barrier layer applied on concrete block wall.

- **Scenario #3**: Remove existing insulation, steel studs, and drywall in the baseline wall assembly; install 3.5-in. closed-cell spray foam with 1.5 in. installed as continuous insulation (c.i.) on concrete block wall.

LABORATORY TEST EVALUATIONS

The three scenarios down-selected through the initial evaluation process were constructed as mock-up walls and tested in the laboratory at ORNL for:

- Thermal performance, in accordance with ASTM C1363 (Figure 2)
- Air leakage (in accordance with ASTM E283 (Figure 3)

The intent of constructing and testing mock-up walls was to utilize the laboratory test results to evaluate the performance of the three scenarios and to validate the initial simulated data for these down-selected scenarios.

The results obtained from the thermal performance and air leakage laboratory tests were utilized as inputs for the energy modeling software to compute the energy savings and payback period for the three down-selected scenarios. The energy savings have been computed against two baseline scenarios:

1. Baseline 1: ("Baseline without existing insulation") having an air leakage of 8 L/s·m² (1.6 cfm/ft²) without any existing insulation (baseline R-value: R-5)
2. Baseline 2: ("Baseline with existing insulation") having an air leakage of 8 L/s·m² (1.6 cfm/ft²) and existing fiberglass batt insulation within steel studs (Baseline R-value: R-11)

Table 5 highlights the performance of the three scenarios against the laboratory tests. In the case of the "Baseline without existing insulation," Scenario 1 was deemed not applicable, as this scenario relies on retaining existing insulation in the assembly.

The laboratory test evaluations for the three scenarios were compared against the previously defined metrics for the project. Two top-performing scenarios, based on these laboratory test results, were then down-selected for demonstration on the FRP at ORNL. These two top-performing retrofit scenarios were:

**Scenario #1:**
Retain existing interior insulation, steel studs, and drywall; install 2-in. rigid PIR foam board with taped seams over existing wall (Figure 4).

Although this scenario was the most cost-effective, it is dependent on the condition of the existing insulation. Therefore, this scenario was termed as “good recommendation” or “most cost-effective recommendation.”

**Scenario #2:**
Remove existing interior insulation, steel studs, and drywall; install 3.5 in. of closed-cell spray foam with 1.5 in. c.i. on the concrete block wall (Figure 5).

This scenario provided maximum energy

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario</th>
<th>R-value (IP units)</th>
<th>U-value (IP units)</th>
<th>Air leakage for assembly (L/s·m²)</th>
<th>Performance measured against baseline without existing insulation (R-5)</th>
<th>Performance measured against baseline with existing insulation (R-11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PIR over exist. ins.</td>
<td>20.7*</td>
<td>0.048</td>
<td>1.8</td>
<td>N/A</td>
<td>30%</td>
</tr>
<tr>
<td>2</td>
<td>PIR w/ separate a/b</td>
<td>17.6</td>
<td>0.056</td>
<td>0.28</td>
<td>31%</td>
<td>17 yrs</td>
</tr>
<tr>
<td>3</td>
<td>C.c SPF</td>
<td>21.6</td>
<td>0.046</td>
<td>0.015</td>
<td>41%</td>
<td>16 yrs</td>
</tr>
</tbody>
</table>

Table 5 – Laboratory test evaluations for the three down-selected retrofit scenarios.

('Assumption: Existing insulation is in effective condition.)
savings based on laboratory evaluations and was termed as “best recommendation” or “most energy-efficient recommendation.”

FIELD DEMONSTRATIONS

The two down-selected retrofit scenarios identified through the laboratory test evaluations were demonstrated on the two-story FRP at ORNL to collect actual field data. The field data collection took place over three seasons and concluded in February 2016. The field data will be used to validate the initial estimations and the laboratory test evaluations for the retrofit scenarios.

TWO-STORY FLEXIBLE RESEARCH PLATFORM

The FRP, located on ORNL campus, is a two-story steel superstructure with a footprint of 40 x 40 ft. This steel superstructure was designed to accommodate many different wall systems, such as masonry, insulated precast concrete panels, or metal studs with sheathing and an exterior insulation and finish system (EIFS) (Figure 6). The purpose of the FRP is to serve as a mechanism to conduct research and develop and deploy new energy-efficient retrofit technologies. The structure provides an opportunity for installing multiple research cycles in which a number of retrofit options can be tested for their performance.

CBEI was one of the primary industry partners for the first cycle of envelope research on the FRP. In 2011, CBEI supported the installation of the baseline envelope structure for the FRP.

The baseline assembly for the envelope was concrete block masonry with brick veneer on the outside and fiberglass batt insulation (~R-11) embedded within steel studs on the inside of the concrete block wall (Figure 1). This baseline assembly was identified as the typical wall assembly for existing commercial buildings (pre-1980s) in the 10-county region around Philadelphia based on data available through CBEC2003 and CoStar 2011 (study funded by CBEI; Otto, 2011).

The two retrofit scenarios, installed on the FRP, serve as the first research cycle for envelope retrofit solutions.

FIELD TEST SETUP

The two-story FRP is divided into eight zones: four zones on each floor. Each zone has the capability to be monitored as an individual space.

The two retrofit scenarios, down-selected for field demonstration through this project, were installed in two of the eight zones in the FRP. The chosen zones were:

- Northwest zone on the first floor, installed with the energy-efficient scenario/spray foam retrofit scenario.
- Northwest zone on the second floor, installed with the cost-effective scenario.
nario/rigid PIR foam board retrofit scenario.

Similarly oriented zones and interior climates were chosen to generate similar baseline conditions for both scenarios.

RETROFIT INSTALLATION

This section describes the installation of the two down-selected scenarios on the FRP. Each retrofit scenario section describes the retrofit assembly components, the benefits of the thermal insulation selected, the performance characteristics for the assembly, and the constructability issues.

PIR FOAM BOARD RETROFIT

The rigid PIR foam board retrofit required installing 2 in. of rigid PIR foam board with coated-glass facers over the existing drywall (retain existing wall assembly). Steel 1-in. furring strips were installed over the rigid foam board to support the installation of the new drywall. The rigid foam board layer was installed with taped seams and sealed junctions and penetrations, thus serving as c.i., as well as an air and moisture barrier layer. Gypsum board (½ in.) installed as the new drywall provided the interior finish for this scenario (Figure 4).

The advantages associated with the PIR foam board are:

- High R-value/inch (R-6.0/inch) compared to conventional foam board insulations
- Can serve as an air barrier material due to low air permeance (as long as seams are taped and junctions are sealed)
- Has a moisture-resistant foam core
- Designed for use as continuous insulation

Performance Characteristics

The performance characteristics for the rigid PIR foam board assembly are:

**Thermal and moisture performance.**

The high R-value/inch for the rigid PIR foam board helps to achieve the desired R-value at reduced thickness. In this case, the 2-in. rigid foam board installed as a continuous insulation layer over existing thermally bridged insulation (~R-11) provided an overall R-value of R-20.7 for the assembly.

The low air permeance of PIR foam board, along with taped seams and sealed junctions, qualified the material as an air barrier according to ASTM E2178. Rigid foam board with coated-glass facers having a vapor permeance of less than 1 perm helped minimize the risk of interior moisture reaching the cold surface of the masonry block wall. This reduced the potential for moisture accumulation and mold probability.

**Thermal Barrier**

Rigid PIR foam board is required to be separated from interior spaces by a 15-minute thermal barrier. For this project, the ½-in. gypsum board installed on the interior provided the essential thermal barrier.

**Cost Effectiveness**

The high R-value per inch for the PIR rigid foam board (in comparison to other conventional foam boards) provides better energy performance at minimized thickness, resulting in reduced utility bills, contributing to lower payback periods.

The cost estimate for the rigid PIR foam board retrofit scenario for this project did not take into account the cost that would be needed to investigate the existing insulation in the assembly in order to ensure its effective performance.

The energy modeling conducted for this scenario (R-20.7), based on the laboratory test evaluations, estimated a payback period of 14 years against a baseline assembly that has existing insulation (R-11). However, the energy data collected through the post-retrofit stage will be utilized to calculate a more realistic payback period for this scenario.

**Constructability for the Rigid PIR Foam Board Retrofit Scenario Installed on the FRP**

The parameter of constructability evaluated the ease of construction for the retrofit scenario in terms of time and labor, commercial floor space cannibalized, ability to address critical details effectively, and minimum disruption for building occupants. Some of the factors related to constructability for the rigid PIR foam board scenario are:

- This scenario cannibalized 3.5 in. of interior commercial floor space since it was installed over the existing assembly.
- The installation of this scenario is dependent on the condition of existing insulation and requires time and money to conduct forensic investigation of the existing insulation within the assembly. This investigation was not conducted for this project, and estimation for the investigation was not included in the costing of the project.

- Installing new retrofit components over the existing wall made it difficult to judge the position of existing cables and wires running behind the drywall.
- Electrical receptacles on the face of the existing drywall had to be pulled out and reinstalled over the new drywall.
- The installation of rigid PIR board required great care to ensure that the board is firmly in contact with the existing wall assembly. Any gaps between the board and the wall can permit convective loops transporting moisture and heat. The presence of any irregularities on the surface of the masonry can make the installation of this retrofit scenario difficult. It is important to refer to manufacturers’ recommendations to determine suitable adhesive patterns.
- In order for the rigid PIR boards to serve as the air and moisture barrier, the seams and penetrations had to be taped effectively and the junction areas sealed. Maintaining the air and moisture seal for the insulation layer was challenging in critical areas (such as behind perimeter ceiling beams), which were not readily accessible.
- The installation of new retrofit components over the existing wall assembly resulted in increased wall thickness, which required addressing details such as extending windowsills over the additional thickness.

The rigid PIR foam board scenario is the most cost-effective option; however, these are some of the constructability issues that need to be considered when evaluating this scenario as a retrofit option for an existing building.

CLOSED-CELL SPRAY FOAM RETROFIT

This retrofit scenario required installing 3.5 in. of closed-cell spray foam on the inner face of bare concrete masonry block. Of the total 3.5 in., 1.5 in. was installed as c.i. over the concrete surface, while the remaining 2 in. was embedded within the steel studs.
The closed-cell spray foam layer also served the function of an air and moisture barrier, along with providing continuous insulation. Gypsum board (½ in.) installed as the new drywall provided the interior finish for this scenario (Figure 5).

The advantages associated with closed-cell spray foam are:
- Provides a seamless c.i. layer
- High R-value/in. (R-6.5 to R-7.0/in.) compared to conventional insulation materials
- Conforms to unusual shapes and configurations, thus filling cracks or construction gaps and sealing penetrations and junctions effectively
- Serves as air and moisture barrier

Performance Characteristics

The performance characteristics for closed-cell spray foam assembly are:

Thermal and moisture performance.

The high R-value/in. for spray foam provides the desired R-value at reduced thickness. This scenario installed on FRP provided an overall R-value of R-22.10 for the assembly.

Application of spray foam eliminated the need for fasteners for installation, thus providing a continuous and seamless layer of insulation. Spray foam provided the potential to reduce the thermal bridging effect by encapsulating existing thermal bridges.

The spray foam layer in this retrofit scenario also served the function of an integral air and vapor barrier. Closed-cell spray foam is considered air-impermeable at a minimum thickness of ⅝ in. With a perm rating of less than 1 perm at 1.5 in., closed-cell spray foam serves as a Class II vapor retarder. These characteristics helped minimize the risk of interior moisture reaching the cold surface of the masonry block wall, thus reducing the potential for moisture accumulation and mold probability for this scenario.

Thermal Barrier

Closed-cell spray foam insulation is required to be separated from interior spaces by a 15-minute thermal barrier. For this project, the ½-in. gypsum board installed on the interior provided the essential thermal barrier for the spray foam retrofit.

Cost Effectiveness

The closed-cell spray foam scenario installed on the FRP provided three functions with one material: thermal insulation, air barrier (minimum ¾-in. thickness), and vapor retarder (minimum 1.5-in. thickness). This eliminated the need for additional materials to address air and moisture infiltration, resulting in less labor and material cost. The spray foam scenario also provided greater energy efficiency resulting in higher energy savings and contributing to a lower payback period.

The cost estimate for the closed-cell spray foam retrofit scenario included the cost of installation of spray foam, demolition cost for tear-down of existing fiberglass batts and drywall within the existing assembly, offsetting the steel studs from the face of the concrete block wall, and installing new drywall.

The energy modeling conducted for this scenario (R-22.10), based on laboratory test evaluations, estimated a payback period of 16 years against a baseline assembly without any existing insulation (R-5), and 25 years against a baseline assembly with existing insulation (R-11). However, the energy data collected through the post-retrofit stage of the project will be utilized to calculate a more realistic payback period for this scenario.

Constructability for the Closed-Cell Spray Foam Retrofit Scenario Installed on the FRP

Constructability for the installation of closed-cell spray foam was evaluated, along with the thermal moisture performance and cost-effectiveness. A few factors contributing to the ease of construction or the disruptiveness of the closed-cell spray foam retrofit scenario are listed below:
- The installation of closed-cell spray foam required a certified spray foam contractor.
- The advantage of the closed-cell spray foam providing thermal insulation as well as serving as an air and moisture barrier eliminated the need to involve multiple trades for the installation of different materials.
- The high R-value/inch helped to save on interior commercial floor space consumed by the retrofit scenario.
- Closed-cell spray foam helped to effectively address critical details (such as inaccessible cracks and voids) with minimum labor.

Additional labor was needed to offset steel studs from the concrete block wall by 1.5 in. This offset of 1.5 in. required the windowsill to be extended by 1.5 in.

The work area where spray foam was being installed had to be vacated with access restricted to certified personnel wearing appropriate personal protective equipment (PPE). The space was ventilated at a minimum rate of 1 air change per hour (ACH). The reoccupancy of the retrofit space was permitted 24 hours after the installation. However, specific reoccupancy time may vary for each project, depending on type of material, volume, building size, and rate of ventilation. Manufacturer recommendations need to be referred to for individual projects.

The spray foam retrofit provided benefits in terms of effective air sealing and ease of application. However, the installation of this scenario disrupted the building activity in terms of requiring vacating the space during installation, as well as for a specific period after installation. These are some factors related to constructability that need to be considered for the closed-cell spray foam retrofit scenario.

NEXT STEPS

The next stage of the project is focused on collecting field data for the two retrofit scenarios demonstrated on the FRP at ORNL. The field data collection spanned three seasons (up to February 2016). The two demonstrated scenarios will be evaluated based on their field performance to identify the best-practice retrofit recommendation. A final report will be generated at the end of the project, highlighting the field performance, simulation analysis, and laboratory test evaluations for the best-practice retrofit recommendation. The data for the identified best-practice recommendation will be disseminated to the industry through conferences in the spring of 2016, as well as through industry association websites. The team intends to work with market partners Carlisle Construction Materials and the Air Barrier Association of America to utilize market channels available through these organizations in order to disseminate the project findings to the industry.
CONCLUSION

The objective of the Wall Retrofit Solutions project, funded through the CBEi, was to identify best-practice retrofit recommendations for internally insulating existing commercial buildings with masonry construction built prior to the 1980s. The intent was to help improve energy efficiency for existing buildings, which will then support the BTO’s goal of achieving 50% reduction in overall building energy use by 2030 (EERE, 2014).

Integrated retrofits that address building envelope, HVAC, and lighting systems are essential to achieve over 50% reduction in energy use for buildings. However, the uncertainties related to envelope retrofits pose a barrier to the adoption of envelope retrofit technologies in the market. The Wall Retrofit Solutions project utilized the two-story FRP at ORNL as an experimental facility to evaluate and demonstrate best-practice retrofit recommendations for existing commercial buildings with masonry construction. The goal of the project was to provide validated field data to help overcome some of the uncertainties associated with envelope retrofits.

The project identified a list of retrofit scenarios to be evaluated by vetting these scenarios through an expert review consisting of industry experts. The performance of these scenarios was evaluated against critical parameters identified by the industry experts. This evaluation was used to down-select three top-performing scenarios that were then constructed as mock-up walls and tested in the laboratory at ORNL. The two top-performing scenarios further down-selected, based on laboratory test results, were:

1. Retain existing interior insulation, steel studs, and drywall in the existing wall assembly; install 2-in. rigid PIR foam board with taped seams over existing wall.
2. Remove existing interior insulation, steel studs, and drywall; install 3.5 in. of closed-cell spray foam with 1.5 in. c.i. on the concrete block wall.

These two down-selected scenarios were installed on the FRP at ORNL to be evaluated through the final stage of the project—the field demonstration. The field data collection for these scenarios is ongoing. This final stage of evaluation will compare the actual field performance of the two demonstrated scenarios to identify the best-practice retrofit recommendation for internally insulating existing commercial buildings with masonry construction built prior to the 1980s, located in ASHRAE Climate Zones 4 and 5. The final results of the field performance for the two demonstrated scenarios will be disseminated when available.

REFERENCES


