WALL RETROFIT SOLUTIONS FOR EXISTING COMMERCIAL BUILDINGS WITH MASONRY CONSTRUCTION

Presented by:

LEARNING OBJECTIVES

Upon completion of this course the student will be able to:

1. Identify the primary reasons for retrofitting masonry walls in older commercial buildings.
2. Describe the evaluation process used to identify the top retrofit solutions for field testing.
3. Identify best practice recommendations for an energy efficient and cost effective retrofit.
4. Analyze potential energy savings and payback periods achievable from a retrofit.

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By Amy Wylie and Andre Desjarlais

WHY A MASONRY WALL RETROFIT?

A growing desire 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. For example, one study indicated that 28% of the existing office buildings in the Philadelphia region 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.

Let's look at a few other reasons a wall retrofit would be desired for commercial buildings with masonry construction.

Standard Component Retrofits Aren't Enough

Standard component retrofits such as HVAC or lighting upgrades present a limited scope for retrofit. This is because greater energy savings can be achieved when envelope retrofits are considered along with standard component retrofits. Integrated retrofits are essential to achieve more than 50% reduction in energy consumption.

Exterior Restrictions Create Demand for Interior Retrofits

An ideal solution would be to insulate masonry walls on the exterior. However, conditions such as historic preservation, space requirements, and zoning issues often require the walls to be insulated on the interior. The problem with adding insulation to the interior of an existing masonry wall is the potential of excess moisture and freeze thaw damage. To avoid this problem, an effective wall retrofit solution can potentially improve thermal performance and durability for the existing masonry wall systems.

Energy Goals Drive Need for Innovative Retrofit Designs

The Department of Energy (DOE) Building Technologies Office (BTO) has a goal to reduce building energy use by 50% by 2030. In turn, this goal drives the need for innovative wall retrofit solutions that will contribute to energy efficiency targets. To meet this need, the Consortium for Building Energy Innovation (CBEI) was formed to develop and deploy market-tested solutions for energy reduction in existing Small and Medium Sized Commercial Buildings (SMSCB). CBEI is a consortium of 14 member organizations funded through the DOE and led by Pennsylvania State University.

Plenty of Opportunities to Retrofit Old Brick Walls in Cold Climates

More than half of existing commercial buildings in the U.S. were built before 1980. This is a concern because a majority of the pre-1980s buildings with masonry construction are located in the northeast region of the U.S. Most of these old masonry walls are un-insulated. This presents a new market opportunity for retrofitting older masonry walls in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) climate zones 4 and 5, which represent a majority of the northeast region of the U.S.

NEED FOR A MASONRY WALL RETROFIT CASE STUDY

While there are good reasons to develop integrated wall retrofit solutions, further studies are needed to evaluate the energy efficiency, cost effectiveness, and long term durability of different retrofit options prior to market deployment.

In order to achieve this objective, the CBEI targeted a few existing commercial buildings within The Navy Yard in Philadelphia as demonstration sites to deploy energy efficient retrofit technologies. One such project identified through the consortium was "Building A," a two-story, small 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. Although the building owner appreciated this analysis, a change in the business strategy resulted in the owner not pursuing 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 field results to accelerate adoption of envelope retrofit technologies in the market.

The "Integrated Wall Retrofit Solutions" project was funded through CBEI in response to this need. This project used 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" 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 down-selected retrofit solutions then formed the basis of evaluation for this project.

PROCESS USED TO EVALUATE POSSIBLE RETROFIT SOLUTIONS

Prior to the field test at the FRP, many wall retrofit scenarios were identified and vetted through an industry expert review. These scenarios were then evaluated against predetermined critical parameters using hygrothermal modeling and industry data. Three top-performing scenarios identified through this evaluation were constructed as mock-up walls and tested in the laboratory at ORNL for thermal performance and air leakage.

The laboratory test evaluations were then used to identify two top-performing scenarios, which were installed on the two-story FRP at ORNL. Field data was collected for one year, and the results were used to further refine the best-practice retrofit recommendations.

Let's take a closer look at the process used during the evaluation period of the "Integrated Wall Retrofit Solutions" project.

Identify and Vet Retrofit Scenarios

An expert review was conducted consisting of building science experts, contractors, and envelope consultants. The industry experts vetted a list of nine retrofit scenarios designed for the baseline wall assembly of the two-story FRP.

They also recommended categorizing the nine retrofit scenarios into three major types of retrofit construction:

Construction Type	Scenario No.	Scenario Description
Retain Existing Wall **with** Existing Insulation	1	Rigid PIR foam board (2") insulation with taped joints installed over existing insulation
Retain Existing Studs **without** Existing Insulation	2	Open-cell spray foam (6") insulation installed within existing studs
	3	Closed-cell spray foam (4.5") insulation within existing studs
Remove Existing Insulation and Studs	4	Blown cellulose (6") insulation
	5	Closed-cell spray foam (3.5") insulation
	6	Hybrid closed-cell spray foam (1.5") insulation and blown-cellulose insulation
	7	Hybrid closed-cell spray foam (2") insulation and blown-cellulose insulation
	8	Rigid PIR foam board (2.5") insulation with a separate air barrier layer
	9	Rigid PIR foam board (2.5") insulation without separate air barrier layer

Industry Expert Vetted Retrofit Scenarios Evaluated During the Project

- Retain existing wall with existing insulation.
- Retain existing studs without existing insulation.
- Remove existing insulation and studs.

The nine retrofit scenarios were designed to address the existing baseline for the FRP, which was built to represent the wall systems of a majority of the pre-1980s commercial buildings in the ten-county region around Philadelphia. The nine scenarios were then used to establish a matrix that allowed the team to evaluate and rank the scenarios according to expert vetted predetermined parameters.

Identify Parameters to Evaluate Retrofit Scenarios and Rank Them

The experts identified six critical evaluation parameters and assigned a weighted percent for each parameter:

- Cost effectiveness—35%
- Moisture management/durability—20%
- Thermal performance—18%
- Air leakage—12%
- Disruptiveness/constructability—9%
- Indoor air quality—6%

The nine retrofit scenarios were then evaluated against the six parameters and compiled in a final performance evaluation matrix to provide the overall performance for each scenario.

The top three scenarios in the matrix were then evaluated through the next stage. The three down-selected wall retrofit scenarios were Scenarios 1, 5, and 8.

Test Key Parameters in the Lab for Energy Modeling

The next stage of the evaluation process was to test the three down-selected scenarios, using constructed mock-up walls, in the laboratory at ORNL for:

- Thermal Performance (in accordance with ASTM C1363)
- Air Leakage (in accordance with ASTM E283)

The results obtained from the laboratory tests were then used as inputs for the energy modeling software to compute the energy savings and payback period for the three down-selected scenarios. The energy savings were computed against two baseline scenarios:

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

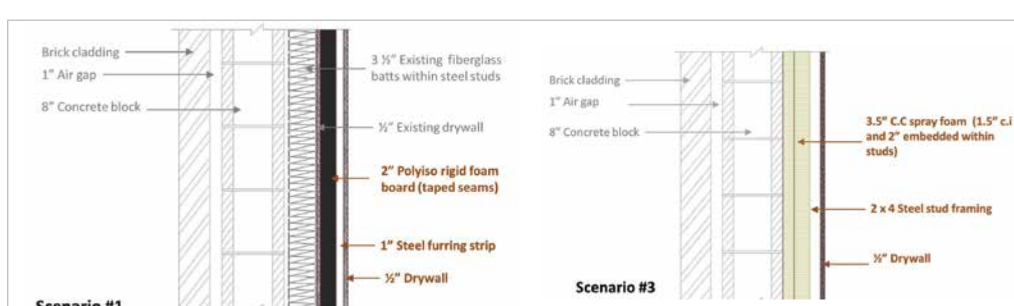
Based on the lab test results, the top two scenarios down-selected for field testing on the FRP at ORNL, were as follows:

- Scenario #1: Rigid PIR foam board (2") insulation with taped joints installed over existing insulation. 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 #5: Closed-cell spray foam (3.5") insulation. This scenario provided maximum energy savings based on laboratory evaluations and was termed as "best recommendation" or "most energy-efficient recommendation."

No.	Scenarios	Insulation type and thickness	Cost effectiveness	Moisture management	Thermal performance	Air leakage development	Disruptiveness/ constructability	Indoor air quality	Final ranking
A.	Retain existing wall (w/ existing insulation)								
1	Rigid polyiso foam board over existing insulation	2" rigid polyiso foam board	*high*	*high*	*high*	*low*	*high*	*high*	1st
B.	Retain existing studs (w/o existing insulation)								
2	Open-cell spray foam within existing studs	6" o.c. spray foam	*moderate*	*high*	*low*	*low*	*low*	*high*	
3	Closed-cell spray foam within existing studs	4.5" c.c. spray foam	*moderate*	*high*	*low*	*moderate*	*moderate*	*high*	
C.	Remove existing insulation and studs								
4	Blown-cellulose with a/b	6.0" blown-cellulose	*low*	*poor*	*high*	*high*	*moderate*	*high*	
5	Closed-cell spray foam	3.5" c.c. spray foam	*low*	*high*	*high*	*moderate*	*moderate*	*high*	3rd
6	Hybrid spray foam	2" c.c. SPF + .5" blown-cellulose	*low*	*high*	*high*	*moderate*	*low*	*high*	
7	Hybrid spray foam	1.5" c.c. SPF + 3.5" blown-cellulose	*moderate*	*high*	*high*	*moderate*	*low*	*high*	
8	Rigid polyiso foam board with a/b	2.5" rigid polyiso foam board	*high*	*high*	*moderate*	*high*	*high*	*high*	2nd
9	Rigid polyiso foam board w/o a/b	2.5" rigid polyiso foam board	*high*	*high*	*moderate*	*low*	*high*	*high*	

Final Performance Evaluation Matrix

A wall air and moisture penetration test chamber and a rotatable guarded hot box were used in the laboratory to test full-scale assemblies.



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

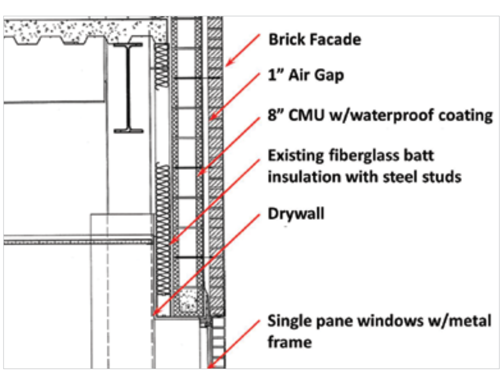
After the laboratory tests were completed, the two top-performing scenarios were installed in the two-story FRP at ORNL to collect field data.

HOW RETROFIT SCENARIOS WERE PUT TO THE TEST IN THE FIELD

After the laboratory tests were completed, the two top-performing scenarios were installed in the two-story FRP at ORNL to collect field data. The purpose of the field test was to analyze the field performance and constructability for both retrofit scenarios.

The baseline wall assembly of the FRP was built to represent the typical wall assembly for a majority of the existing commercial buildings built before 1980.

The FRP is divided into eight zones with four zones on each floor. Each zone has the capability to be monitored separately.



Retrofit scenarios were designed to address the existing baseline for the FRP. The baseline envelope system for the 2-story FRP was built to represent the wall systems of a majority of the pre-1980s commercial buildings in the ten-county region around Philadelphia.

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 #5 closed-cell spray foam (3.5") insulation.
- Northwest zone on the second floor—installed with the cost-effective Scenario #1 rigid PIR foam board (2") insulation with taped joints installed over existing insulation.

QUIZ

1. One of the primary reasons for retrofitting masonry walls in older commercial buildings is that the Department of Energy has a goal to reduce building energy use by ____ by the year 2030.
   a. 10% b. 30%
   c. 50% d. 60%

2. True or False: Another primary reason for retrofitting masonry walls in older commercial buildings is that standard component retrofits, such as HVAC or lighting upgrades, have limited energy savings.

3. The first step in the evaluation process to identify the top integrated wall retrofit solutions for field testing was:
   a. Identify and vet retrofit scenarios b. Identify parameters to evaluate retrofit scenarios
   c. Rank the retrofit scenarios

4. True or False: A total of seven masonry wall retrofit scenarios were identified and vetted through an industry expert review.

5. Of the six critical parameters identified for evaluating the retrofit scenarios, which one was given the heaviest weight, in terms of importance, at 35%?
   a. Thermal performance b. Cost effectiveness
   c. Air leakage

6. True or False: Two key parameters, thermal performance and air leakage, were tested in the laboratory at ORNL to evaluate the top-ranked retrofit scenarios.

7. The baseline wall assembly of the Flexible Research Platform was built to represent the typical wall assembly for a majority of the existing commercial buildings built before _____.
   a. 2010 b. 2000
   c. 1990 d. 1980

8. True or False: Based on field test results, the rigid PIR foam board (2") insulation (with taped joints installed over existing insulations) is a recommended best practice for masonry wall retrofits in older commercial buildings.

9. One of the best practice recommendations to retrofit masonry walls is the closed-cell spray foam (3.5") insulation. One reason for this recommendation is that it offers a ______ R-value/inch compared to conventional insulation materials.
   a. low b. medium
   c. high

10. True or False: Estimated payback periods were evaluated for compliance against the previously defined metrics for the integrated masonry wall retrofit project.

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

The FRP, located on the ORNL campus, is a two-story steel superstructure with a footprint of 40' x 40'. The purpose of the FRP is to serve as a mechanism to conduct research, then 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. The wall assembly was finished on the interior side with gypsum board that was painted with a latex paint. This baseline assembly was identified as the typical wall assembly in the 10-county region around Philadelphia for existing commercial buildings (pre-1980s), because buildings in the mid-70s would have had minimum amounts of insulation and, before that time, none at all.

The two top-performing retrofit scenarios, installed on the FRP, served as best practice recommendations for the first field test cycle and subsequent market deployment in ASHRAE climates 4 and 5. Let's take a more in-depth look at each retrofit scenario.

BEST PRACTICE RECOMMENDATION: RIGID PIR FOAM BOARD RETROFIT

As you recall, one of the top-two performing scenarios was Scenario #1, which was the Rigid PIR foam board (2") insulation with taped joints installed over existing insulation. This was designed as an integrated solution that addressed improved thermal performance, reduced air infiltration, and improved durability for the wall assembly.

The high R-value per inch for the PIR foam provided better energy performance at minimized thickness. The low air permeance of the board, along with taped seams and sealed junctions, qualified the material as an air barrier according to the Air Barrier Association of America (ABAA) using the ASTM E2178 materials test method. The foam board, with coated-glass facers, provided a vapor

The overall evaluation of the rigid PIR foam board scenario revealed this to be the most cost-effective option. However, some of the constructability issues need to be considered when evaluating this scenario as a retrofit option for an existing building.

permeance of less than 1 perm, minimizing the risk of interior moisture reaching the cold surface of the masonry block wall. This reduced the potential for moisture accumulation and mold probability.

Installation of this scenario over the existing assembly eliminated the cost of demolishing the existing insulation within the assembly. However, installing a retrofit over the existing assembly requires investigation of the insulation to ensure effective performance. For this project, investigation was not required because the insulation installed for the two-story FRP baseline was relatively new.

The rigid PIR foam board retrofit required installing 2" of rigid PIR foam board with coated-glass facers over the existing drywall (existing wall assembly was retained). Steel furring strips (1") 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 continuous insulation as well as an air and moisture barrier layer. Gypsum board (1/2") installed as the new drywall provided the interior finish for this scenario.

Now let's review the advantages, performance characteristics, cost effectiveness, and constructability of the rigid PIR foam board retrofit solution as used in the field demonstration.

Advantages

As learned from the field testing, the rigid PIR foam board retrofit offers several advantages in the retrofit of existing masonry walls in commercial buildings:

- 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

In the field demonstration, the thermal, thermal barrier, and moisture performance characteristics for the rigid PIR foam board assembly were analyzed.

Thermal Performance—The high R-value/inch for the rigid PIR foam board helps to achieve the desired R-value at reduced thickness. In this project, the 2" 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.

Thermal Barrier Performance—The rigid PIR foam board is required to be separated from interior spaces by a 15-minute thermal barrier. For this project, the 1/2" gypsum board installed on the interior provided the essential thermal barrier.

Moisture Performance—The low air permeance of the rigid PIR foam board along with taped seams and sealed junctions, qualified the material as an air barrier according to ABAA using the ASTM E2178 materials test method. In this case study, the 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.

Cost Effectiveness

The cost estimate for the rigid PIR foam board retrofit scenario for the field test 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. However, the high R-value per inch for the rigid PIR foam board, in comparison to other conventional foam boards, provides better energy performance at minimized thickness. In turn, this results in reduced utility bills and lower payback periods.

Constructability

The parameter of constructability evaluated the ease of construction in terms of time and labor, commercial floor space cannibalized, ability to address critical details effectively, as well as minimum disruptiveness for building occupants. Some of the lessons learned around constructability for the rigid PIR foam board retrofit scenario are as follows:

- This scenario cannibalized 3.5" 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 re-installed over the new drywall.
- The installation of rigid PIR foam 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. Therefore, the presence of any irregularities on the surface of the existing wall can make the installation of this retrofit scenario difficult. Check the manufacturer's recommendations to determine suitable adhesive patterns.
- In order for the rigid PIR foam 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—an area 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 window sills over the additional thickness.

The overall evaluation of the rigid PIR foam board scenario revealed this to be the most cost-effective option. However, some of the constructability issues need to be considered when evaluating this scenario as a retrofit option for an existing building.

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 because the space required vacating during installation as well as for a specific period after installation.

BEST PRACTICE RECOMMENDATION: CLOSED-CELL SPRAY FOAM RETROFIT

The other top-performing scenario was Scenario #5, which was the closed-cell spray foam (3.5") insulation option. The closed-cell spray foam served as an air and moisture barrier along with providing thermal insulation.

In this field test, the retrofit required installing 3.5" of closed-cell spray foam on the inner face of bare concrete masonry block. 1.5" of the total 3.5" was installed as continuous insulation over the concrete surface while the remaining 2" 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 (1/2") installed as the new drywall provided the interior finish for this scenario.

Similar to the rigid PIR foam board solution, let's assess the advantages, performance characteristics, cost effectiveness, and constructability of the closed-cell spray foam retrofit option.

Advantages

The field testing demonstrated a few key learning points. The closed-cell spray foam retrofit offers several advantages in the retrofit of existing masonry walls in commercial buildings:

- Provides a seamless, continuous insulation layer.
- High R-value/inch (R 6.5—R7.0/inch) compared to conventional insulation materials.
- Conforms to unusual shapes and configurations such as cracks or construction gaps.
- Seals penetrations and junctions effectively.
- Serves as an air and moisture barrier.

Performance Characteristics

Similar to the rigid PIR foam board field test, the thermal, thermal barrier, and moisture performance characteristics for the closed-cell spray foam retrofit were analyzed.

Thermal Performance—The high R-value/inch 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, which helped to provide a continuous and seamless layer of insulation. Spray foam provided the potential to reduce the thermal bridging effect by encapsulating existing thermal bridges.

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" gypsum board installed on the interior provided the essential thermal barrier for the spray foam retrofit.

Moisture Performance—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 3/4". With a perm rating of less than 1 perm at 1.5", closed-cell spray foam serves as Class II Vapor Retarder. In this project, these characteristics helped minimize the risk of interior moisture reaching the cold surface of the masonry block wall—and ultimately reduced the potential for moisture accumulation and mold probability.

Cost Effectiveness

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

The closed-cell spray foam scenario installed on the FRP provided three functions with one material—thermal insulation, air barrier (minimum 3/4" thickness), and vapor retarder (minimum 1.5" thickness). This eliminated the need for additional materials to address air and moisture infiltration resulting in less labor and less material cost. The spray foam scenario also provided greater energy efficiency resulting in higher energy savings contributing to a lower payback period.

Construction Details	Overall Surface-to-Surface R-value, h.ft²·F/Btu	Air Leakage at 75 Pa., L/s.m²
Baseline	10.1 (w/existing fiberglass batt) & 5.0 (without batt)	2.7 (measured for FRP) & 8.0 (1980 no air barrier default)
Demolish existing insulation + 3.5' C.C. SPF	21.6	0.015
Retain existing insulation + 2" PIR boards with taped seams	20.7	1.8

Measured R-Value & Air Tightness Values

Constructability

Constructability for the installation of closed-cell spray foam was evaluated along with the thermal performance, moisture performance and cost-effectiveness. A few factors that contributed to the ease of construction or the disruptiveness of the closed-cell spray foam retrofit scenario are as follows:

- 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". This offset of 1.5" required the window sill to be extended by 1.5".
- The work area where spray foam was being installed had to be vacated with access restricted to certified personnel wearing appropriate personal protective equipment. The space was ventilated at the air change rate of a minimum 1 ACH. The re-occupancy of the retrofit space was permitted 24 hours after the installation. However, specific re-occupancy time may vary for each project depending on type of material, volume, building size and rate of ventilation. Manufacturer recommendations need to be referred 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 because the space required vacating 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.

ENERGY SAVINGS AND PAYBACK PERIODS

Simulations were conducted for Knoxville and Philadelphia using TMY3 weather files for the corresponding locations. Lab-evaluated overall air-to-air thermal resistance of the retrofitted wall samples (ASTM C1363) were used for annual energy simulations to account for the thermal bridging impacts. Air leakage for building assemblies were determined following ASTM E283 procedure. Two levels of assembly R-values and air leakage rates were assumed for the baseline construction. The table to the left shows the thermal resistance and air tightness of the wall assemblies.

To convert from annual cooling load to cooling energy, two levels of equipment coefficient of performance (COP) were considered; 2.9 and 1.93 (derated 1/3rd for aging). Electrical energy cost was used as $0.1031/kWh and $0.0944/kWh and natural gas cost was used as $0.823/Therm and $0.981/Therm for Tennessee and Pennsylvania, respectively[1].

The table below shows the annual energy savings and payback for two locations assuming COP 1.9. The costs per square foot assumed for these payback calculations were $4.35 for Retrofit #1, $9.40 for Retrofit #2 if there was existing cavity insulation, and $7.40 for Retrofit #2 if there was no cavity insulation present. Overall, the annual energy cost savings from the retrofit walls range from $868 to $1041 for Knoxville and $1101 to $1403 for Philadelphia and are shown as percentage savings in the Table.

The PIR field test data indicated a 10% improvement in payback period versus earlier

Retrofit No.	Scenario	Thermal Performance (based on field data)		Knoxville				Philadelphia			
				Performance measured against baseline without existing insulation (R-5)		Performance measured against baseline with existing insulation (R-10)		Performance measured against baseline without existing insulation (R-5)		Performance measured against baseline with existing insulation (R-10)	
		R-value (IP units)	U-value (IP units) Yearly HVAC Energy Savings	Yearly HVAC Energy Savings	Payback Period, Years	Yearly HVAC Energy Savings	Payback Period	Yearly HVAC Energy Savings	Payback Period, Years	Yearly HVAC Energy Savings	Payback Period, Years
1	PIR over existing assembly	20.7	0.048	NA	NA	24%	16	NA	NA	33%	12
2	CC SPF over concrete block wall	21.6	0.046	31%	22	25%	32	41%	17	29%	27

Proven Energy Savings & Payback Periods for the Two Scenarios in Two Climate Zones calculations based on simulated values. The spray foam retrofit measured results were very similar to the simulated values, so the payback period did not change. The PIR retrofit would be appropriate for both climate zones, while the spray foam retrofit has more realistic payback periods for the colder side of climate zone 4 and zone 5. Both retrofit paybacks would continue to improve as the location of the retrofit migrated further north.

SUMMARY

With the support of funding from the CBEI, several scenarios were identified, evaluated, and tested to determine the top two performing retrofit solutions for masonry walls in commercial buildings. One recommended best practice is to retain existing interior insulation, steel studs, and drywall in the existing wall assembly. Then install 2" rigid PIR foam board with taped seams and junctions over the existing wall. The other recommended best practice is to remove the existing interior insulation, steel studs, and drywall. Then install 3.5" of closed-cell spray foam with 1.5" continuous insulation on the concrete block wall and the remaining 2" between the steel studs.

The one year field data collection for both of these scenarios is now complete. Both approaches were effective for reducing heating and cooling costs versus a baseline wall assembly representative of many of the under-insulated commercial buildings in the U.S., with energy cost savings ranging from 24– 41%. The PIR retrofit would be appropriate for both climate zones, while the spray foam retrofit has more realistic payback periods for the colder side of climate zone 4 and zone 5. Both retrofit paybacks would continue to improve as the location of the retrofit migrated further north.

The rigid PIR foam board scenario evaluated as a retrofit installed over an existing assembly was identified as the most cost-effective retrofit scenario. However, this scenario is dependent on the condition of the existing insulation and is applicable only if the existing insulation is in effective condition to be retained.

The closed-cell spray foam scenario was identified as the most energy-efficient retrofit. This also requires the tear down of existing insulation within the assembly, which can be an added cost in terms of time and labor.

The objective of the "Integrated 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.

Integrated retrofits which address building envelope requirements, along with 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 "Integrated Wall Retrofit Solutions" project used 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 evaluation conducted through the project compared the two integrated retrofit solutions based on cost, energy performance, and constructability. This information will provide the industry with guidelines for best practice retrofit recommendations and help building owners and design professionals make informed decisions regarding the most suitable retrofit option for their buildings. ■

FOOTNOTE

1 http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_sum/html/sum_pr_com.html&sid=US