Maintenance + Renovation

Retrofit Put to the Test

Testing shows where a building envelope retrofit succeeds and where opportunities remain.

By Brian H. Neely, AIA, NCARB, CDT, and Joshua T. Hogan, E.I.T., CDT, Gale Associates Inc.

Across the United States, buildings in which people live, work, shop and study use about $200 billion in energy each year. That's a significant portion of the nation's energy-use and carbon footprint.

While the energy efficiency of new buildings has improved dramatically over the past two decades, many older buildings remain substandard in meeting insulation and air-infiltration requirements.

Buildings older than 20 years comprise more than 70 percent of our building stock. Improving their thermal performance offers a great opportunity to conserve energy. A variety of energy upgrades are available for these buildings.

Energy conservation isn't the only reason for retrofitting buildings. Retrofits are often more cost-effective than constructing a new facility. Upgrades can extend building service life, increase asset value and contribute to a

Bottom right: These townhouse-style dorms at a New England university were slated for energy-efficiency upgrades and an update in appearance.
Bottom left: Following their energy-efficiency retrofit, the dorms sport a more traditional New England fiber cement clapboard and shingle palette.
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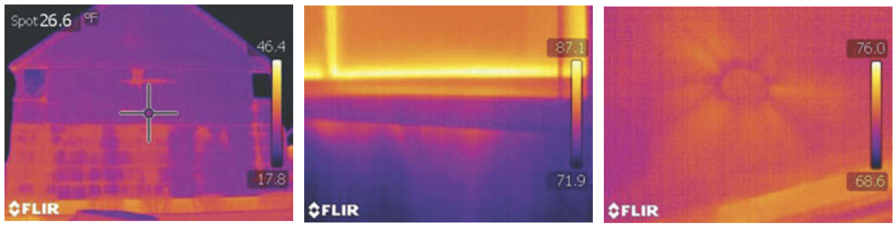

(L to R) -- Infrared thermography shows (1) moisture infiltration from the window, penetration and horizontal sealant joint behind EIFS cladding; (2) air infiltration at an existing windowsill; and (3) air infiltration at a sprinkler pipe penetration.

healthier, more comfortable environment for occupants.

Upgrades can save money, reduce emissions, and provide investment opportunities and jobs.

Existing and retrofitted buildings went head-to-head beginning in 2012 when a New England university began a phased, three-year-upgrade of the building envelopes of three identical, energy-inefficient dormitories. The project's goals included extending the service lives of the buildings and improving energy efficiency, durability and aesthetics, while reducing maintenance requirements.

The work provided an opportunity to measure the change in air infiltration and thermal transfer in the exterior walls, from existing to retrofit. Testing revealed where airtightness was improved by as much as one-third, and where future retrofits might focus.

Damp Dorms

The 1990s student housing complex of townhouse-style buildings experienced high energy use associated with excessive air infiltration, minimal insulation and inefficient thermal glazing. These issues contributed to condensation build-up within the exterior walls, resulting in mold and associated indoor air quality issues.

High energy costs and uncomfortable living conditions were other major factors in the university's decision to retrofit.

The exterior envelopes of the buildings 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 exterior insulation and finishing system (EIFS) with an R-value of 6.

Test cuts reveal unadhered EIFS and deteriorated sheathing and sill plates.

An infrared thermography (IR) scan and destructive test cuts revealed failed EIFS panels had let moisture migrate into the OSB sheathing and fiberglass batt insulation. This moisture infiltration caused deterioration of the OSB sheathing, saturated the fiberglass and contributed to mold growth within the wood stud wall.

On with the New

The university decided to replace the modernist, monolithic EIFS style with a more traditional New England aesthetic. Officials chose a fiber cement clapboard and shingle palette.

The replacement wall system consisted of new plywood sheathing, blown-in cellulose insulation, a self-adhered vapor permeable air barrier, one-inch (2.5-centimeter) rigid insulation and fiber cement siding installed to wood furring. The original aluminum slider windows were replaced with ENERGY STAR-rated, aluminum-clad, double-hung wood windows to match the design aesthetic. The renovation team also replaced the original asphalt shingle roofing and exterior metal doors.

Storm and Smoke

The first of the three dorms, or phase 1, completed in summer 2012, got a real-world test after about 18 months, when a

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A retrofitted wall complete with ENERGY STAR-rated, aluminum-clad, double-hung wood windows stands next to an under-construction wall showing the orange air barrier and blue non-structural rigid insulation.


Air infiltration at the renovated first- and second- floor units, N1 and N2, was significantly reduced and was only apparent during testing.

Air-Tightness of Existing (E1, E2) vs. Retrofitted Apartments (N1, N2)

Unit	Volume/sq. ft. (sq. m.)	ACH50 Air exchanges per hour at 50 Pa (ACH50)
E1	4,890 (454)	5.85
N1	4,890 (454)	4.12
E2	5,330 (495)	9.67
N2	5,330 (495)	9.16

Upgrades included a replacement wall system, ENERGY STAR-rated windows, asphalt shingle roofing and exterior metal doors.

Feb. 8 storm knocked out power on campus for three days. The university facilities staff reported that the renovated dormitories were 10 to 15 degrees warmer than the un-renovated dormitories. Insulation upgrades and reduced air infiltration got the credit.

The project team used a blower door test to compare air-infiltration rates at a pair of two-story dormitories, one unchanged and the other newly renovated, in summer 2013. Blower door test ASTM E779-10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization measured the airflow in cubic feet per minute through a single fan to create a 50-pascal (Pa) change in building pressure, or CFM50.

The interior conditioned volume of the first-floor apartment units measured 4,890 cubic feet (138 cubic meters), with a floor area of about 690 square feet (64 square meters). The second-floor apartment units' volume was 5,330 cubic feet (151 cubic meters), with a floor area of about 760 square feet (71 square meters).

A theatrical smoke machine and infrared thermography (IR) also played a role in testing, in accordance with ASTM E1186 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems. They helped identify areas of air infiltration at the un-reno-

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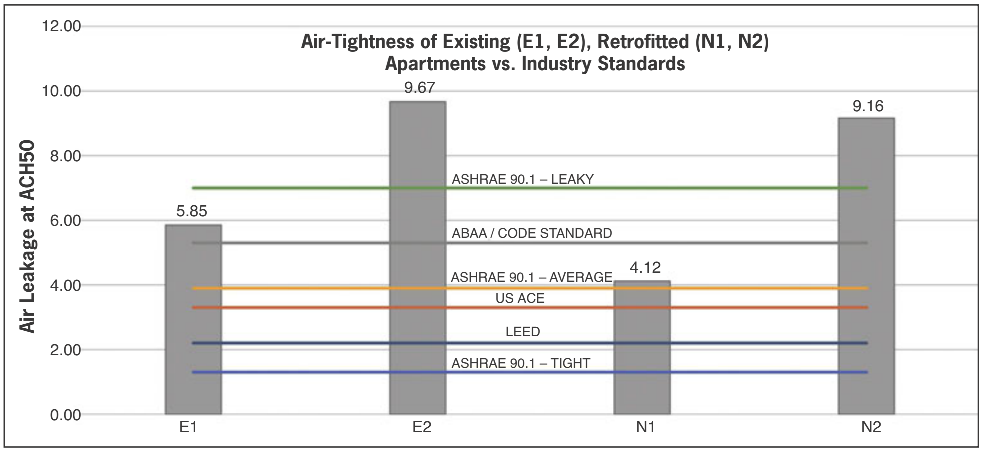

New thermally efficient exterior walls, windows and doors also greatly improved the water-tightness of the building enclosure, reducing the potential for moisture-related issues.

vated first- and second-floor apartments, E1 and E2.

Window perimeters, floor-to-wall transitions and wall and ceiling penetrations showed the most air infiltration. Smoke entering between the first-floor sill plate and foundation filled the room in less than a minute, indicating substantial air leakage in the existing assembly.

Air infiltration at the renovated first- and second-floor units, N1 and N2, was significantly reduced and was only apparent during testing. Due to the project's budget-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. The project team observed limited air leakage at the ceiling-to-wall interface and at ceiling penetrations, such as light fixtures and sprinkler heads.

The top-floor units of both dormitories had higher air-infiltration rates due to the original attic/ceiling assemblies, which weren't renovated.

To compare dorm units of varying size, the team divided the CFM50 values recorded during testing by the conditioned interior volume of the respective apartment unit. This formula (when multiplied by 60) calculates the air changes per hour at 50 Pa, or ACH50, which indicates 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.

Un-renovated first-floor unit E1 had a calculated ACH50 of 5.85 (see table on page 34.) Blower door testing confirmed that the building envelope renovations reduced air leakage to an ACH50 of 4.12 at renovated first-floor unit N1.

The difference of 1.73 ACH50 between units E1 and N1 equates to an approximate 30 percent reduction in air infiltration.

Un-renovated second-floor unit E2 had a measured ACH50 of 9.67. The ACH50 improved to 9.16 during blower door testing of renovated second-floor unit N2, equating to a 5 percent reduction in air infiltration.

As noted, the second floor's lesser reduction of 5 percent compared to the first floor's 30 percent resulted from uncontrolled air infiltration through ceiling penetrations, such as sprinkler heads, and into the vented attic space above.

This limited improvement illustrates how important it is for air barriers to be installed fully and continuously.

Measuring Up

To put these results in perspective, it's helpful to hold them up to industry standards.

These standards are authored by organizations such as the Air Barrier Association

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(Above and right) Blower door testing confirmed that the building envelope upgrade reduced energy costs and improved occupant comfort in these dormitories at a New England University.

of America (ABAA), the U.S. Army Corps of Engineers (USACE) and ASHRAE.

The figure on page 36 shows how the ACH50 test results compare to ABAA, USACE and ASHRAE standards.

The reduced ACH50 in unit N1, from 5.85 to 4.12, appears to be below the ABAA's maximum air-infiltration requirement of 5.3 ACH50, although it doesn't meet ASHRAE's "average" standard of 3.9, or its "tight" 1.3 standard.

Unit E2 had a measured ACH50 of 9.67, well above what ASHRAE considers to be a leaky building. The ACH50 improved to a value of 9.16 during blower door testing of N2, still leaky but a little better.

Air-infiltration standards are typically predetermined by the owner and designer, and reflect requirements designated by state or local building codes. The requirements are often based on standards such as those referenced.

A Reason to Retrofit

The blower door testing confirmed the renovation's reduction of air infiltration through the exterior walls, resulting in reduced energy costs and improved occupant comfort.

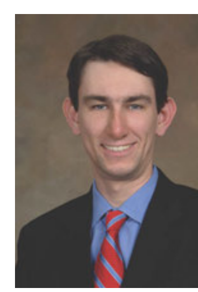
University officials expect further energy savings when the attic and inter-unit leaks are addressed. New thermally efficient exterior walls, windows and doors also greatly improved the water-tightness of the building enclosure, reducing the potential for moisture-related issues and providing a long-lasting assembly.

Building retrofits are an option owners should consider to extend the service life of existing facilities, before investing in new construction. Repairing or replacing building exteriors offers great opportunities for thermal and airtightness upgrades to the building envelope. Diagnostics such as blower door testing and infrared thermography can help identify existing building envelope deficiencies and quantify the envelope performance of a newly retrofitted building.

Performing both pre- and post-retrofit testing can provide valuable information about the success of the retrofitting upgrades, in addition to which areas of the facility may be considered for future retrofit upgrades.

About the Authors

Brian H. Neely, AIA, NCARB, CDT, is a project architect for Gale Associates' Building Envelope Technology Group.



Neely has 13 years of experience in building envelope commissioning, ranging from design period services to construction period services. He has been actively involved with providing peer review and design assistance for new construction projects.

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