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Energy Efficiency Through Airtight Design

Envelope airtightness is an area of building science that suffers from a disconnect in how it is discussed during design and planning versus how it is delivered and measured in the field.

This whitepaper explores how to merge these efforts to deliver well-sealed buildings that support a project's performance goals and promote occupant well-being.

ABOVE
Art Rutkin Elementary School boasts a Target Air Leakage Rate of just 0.15 cfm/sf at 1.57psf.

ABOUT THE AUTHOR

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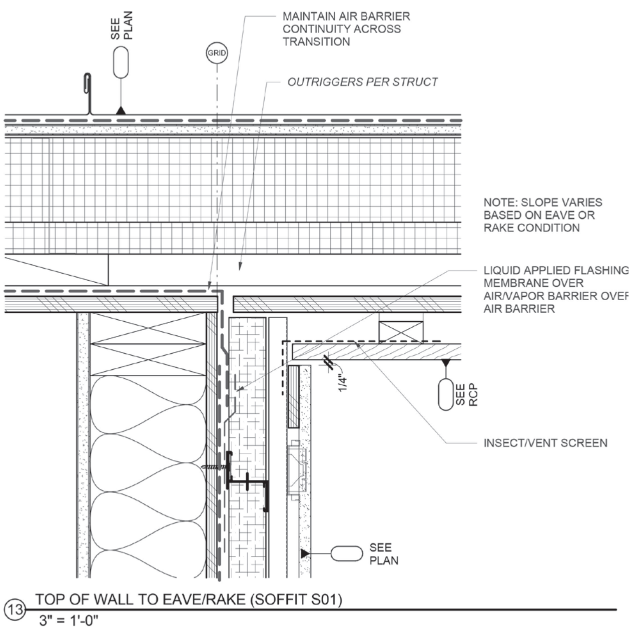
Unwanted air leakage, also known as infiltration and exfiltration, can account for a third of a structure's heating system size.

Leaky buildings can significantly increase energy use, especially in colder climates. In recent years, Bora has made concerted efforts to reduce the amount of conditioned air leaking from our buildings, and continues to learn from each project experience. **Designing airtight buildings requires clear communication with the mechanical system designer and energy modeler, careful detailing of the building envelope, and persistent attention and testing through the construction process.**

MATERIALS AND DETAILING

During design, the necessary materials and details are carefully documented to achieve tight building envelopes. This essentially requires drawing a continuous line around all six sides of the building enclosure–ground floor, roof, and walls–and zooming into each transition and penetration to verify that this line is unbroken. This air barrier line consists of



ABOVE Roof-to-wall intersection showing air barrier continuity

materials, membranes, transition membranes, sealants and other components that are capable of blocking airflow. These components must either be fully supported by a substrate or able to span whatever gaps exist, and need to withstand building movements, resist damage from UV light, and be compatible with adjacent materials.

Of course, the air barrier system is only one component of the building enclosure. This exterior skin must also serve as a thermal and moisture barrier, allow for the passage of fresh air and daylight, and be durable and attractive. We study the latest building science, work with building envelope consultants, apply the lessons of past projects, and evaluate the constraints of each site, program, and budget to design energy-saving building envelopes.

LEFT Mockup testing at Earl Boyles Childhood Education Center.

RIGHT Final whole-building testing identified detailing improvements that helped the project exceed PAE's airtightness goal.

CONSTRUCTION AND TESTING

To achieve its goals good documentation must be followed by proper execution. During the construction phase architects therefore insist on thorough submittals, coordination of trades, and testing to the specified criteria. Contractors often submit shop drawings specific to trade, but a good air barrier assembly is dependent on the overlapping scopes of the different trades; among them the concrete installer, waterproofer, framer, sheathing installer, window and door installer, roofer, flashing fabricator, and air barrier applicator. We find it most effective to gather the critical representatives of each of these trades in a preconstruction meeting during the submittal review and mockup phase to collectively address any issues up front.

Testing usually starts with a six-sided mockup featuring conditions representative of typical and challenging portions of the building such as openings, parapets, overhangs, deep sills, and movement joints. These tests frequently uncover weaknesses in the detailing or implementation that can be addressed to ensure best practices are followed on the actual building. Partial building tests can verify that construction is progressing properly. Whole-building testing can confirm the building meets the target air leakage rate--a critical step when the mechanical system is especially sensitive to airtightness.

The goal: to keep conditioned air in and cold air out to ensure happy, healthy occupants.

TARGET SETTING AND COMMUNICATION

A building's targeted airtightness rate should be established at the onset of a project in collaboration with the mechanical engineer and energy modeler. This can be challenging, however, because the language, criteria, and units of measurement for HVAC system design and energy modeling are often not the same as those used in building envelope testing. For example, the typical blower-door test for a commercial building, ASTM E779, measures air leakage rates in cfm/sf of exterior enclosure at an air pressure of 1.57 psf (75 Pascals), while mechanical engineers and energy models often use the volumetric measurement of air changes per hour (ACH) at 50 Pascals. There is no direct translation between these values.

Given that most building codes lack specific minimum air leakage rates, Bora has used the following emerging standards as a starting point for setting project targets:

- **Washington State 2009 Energy Code Non-Mandatory Rate:** 0.4 cfm/sf at 75 pa (mandatory in Oregon following update to ASHRAE 90.1-2019 in late 2021)

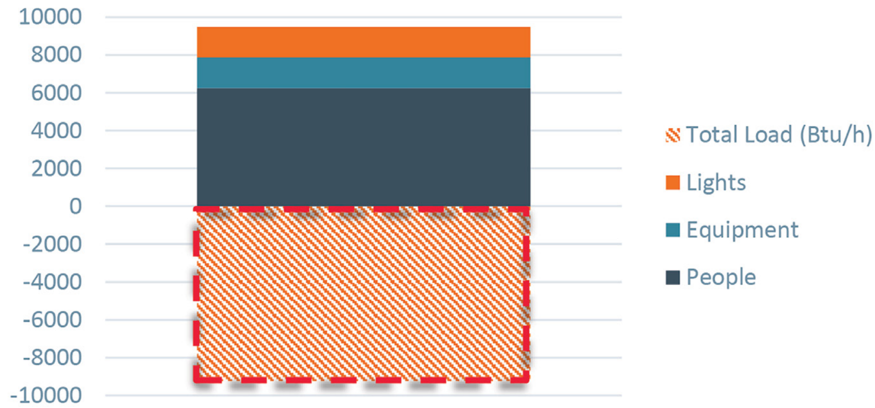
- **US Army Corp of Engineers (USACE) Requirement:** 0.25 cfm/sf at 75 pa

However, some engineers and modelers rely on past experience or energy program defaults to establish targets. This can result in overestimating leakage by as much as 800 percent. To save up-front costs and be able to make an accurate prediction of a building's energy performance, it is necessary for the modeler and engineer to match the level of airtightness to which the building envelope will be designed and built -- in the same units that will be used to test it.

Having everyone use the same terminology and units of measurement is therefore crucial to implementing a successful airtight strategy. For our Earl Boyles Childhood Education Center project, PAE designed a mechanical system that relied on balancing the heating load with internal heat gains. This required a robust envelope, and Bora specified an air leakage rate of 0.25 cfm/sf at 1.57 psf (the USACE standard). The building was detailed accordingly, lessons learned on the mockup were applied to the building, and whole-building testing revealed a leakage rate of 0.131.

BELOW Whole-building testing resulted in an air leakage rate of 0.107 cfm/sf at 1.57 psf for Creekside Community High School, a net-zero-energy project.

RIGHT
Other than on early mornings and exceptionally cold days, the heating load at Earl Boyles Childhood Education Center is sufficiently met with internal heat gains.



EARL BOYLES CHILDHOOD EDUCATION CENTER HEATING LOAD

For our net-zero-energy Creekside Community High School project (shown on prior page), Glumac took a different HVAC system approach, but one that also required an airtight building. Our design incorporated lessons learned from Earl Boyles, followed by mockup and partial building testing and extreme diligence during construction for this design-bid-build project. Enough confidence in the final result at Earl Boyles led us to specify a slightly tighter enclosure at Creekside. The result of whole-building testing ended up exceeding our target, with a measured air leakage rate of 0.107 cfm/sf at 1.57 psf.

Paying attention to detail in the design and construction phases, mockups and testing, as well as thorough communication with the mechanical engineer and energy modeler, should consistently result in buildings that keep conditioned air in and cold air out. This due diligence should also mitigate the expense of oversized HVAC systems and save energy and money throughout the life of the building. Combined with well-designed, intentional ventilation strategies for fresh indoor air and a quality thermal barrier, these are the buildings that will support comfortable, happy, and healthy occupants. ●

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