PLASTICS Takes Improvement to the Wall

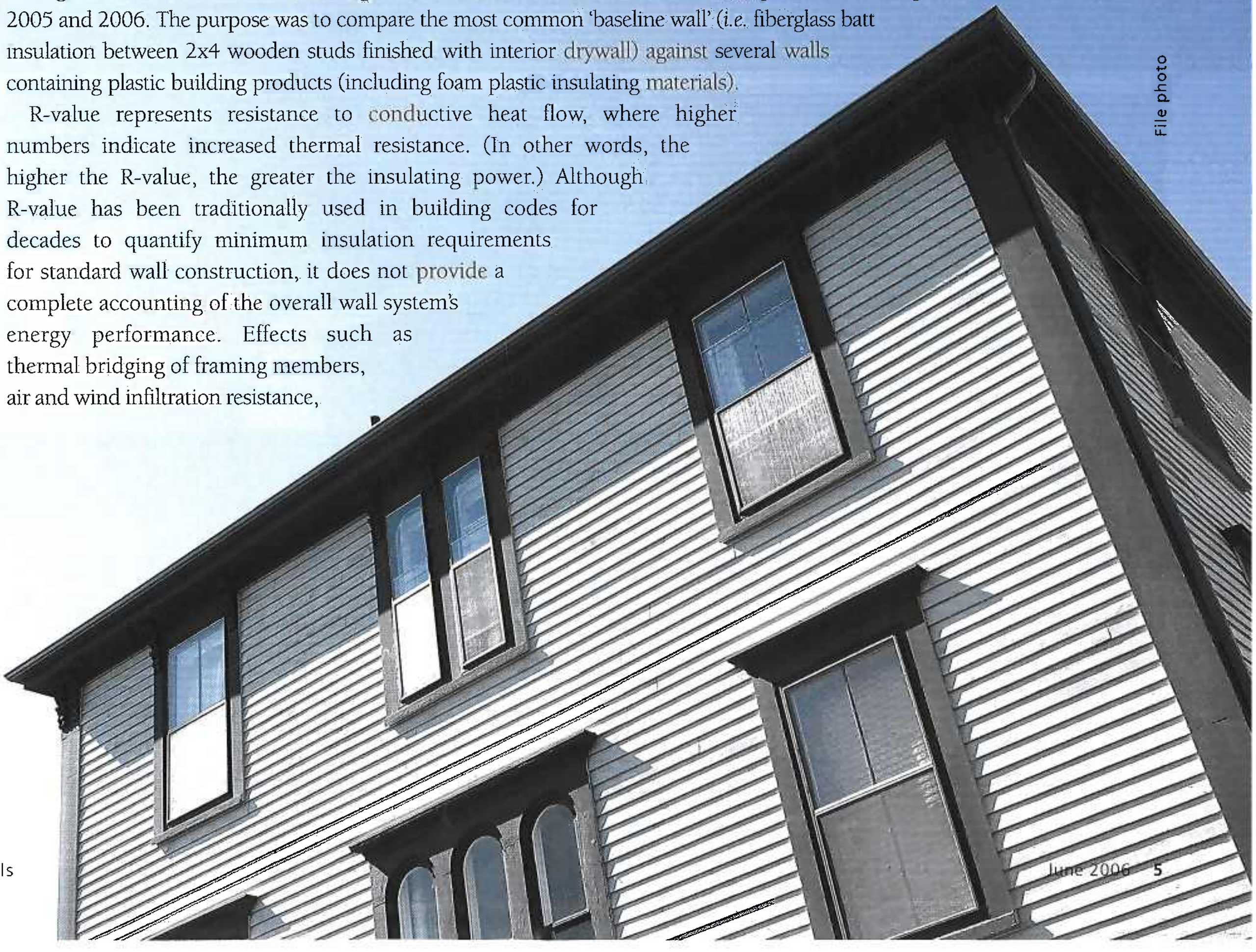
NEW NAHB RESEARCH CENTER WALL STUDY ABOUT HEAT FLOW—R-VALUE NOT THE WHOLE STORY

By Craig Drumheller, NAHB Research Center

> "Plastic building products can reduce heat flow an average of 18 to 25 percent over baseline wall under windy conditions."

In an effort to more realistically quantify the energy performance of a variety of wall system alternatives under simulated 'real-world' conditions, the National Association of Home Builders (NAHB) Research Center, through the labs of Architectural Testing Inc., conducted a series of residential wall panel tests during 2005 and 2006. The purpose was to compare the most common 'baseline wall' (*i.e.* fiberglass batt insulation between 2x4 wooden studs finished with interior drywall) against several walls containing plastic building products (including foam plastic insulating materials).

R-value represents resistance to conductive heat flow, where higher numbers indicate increased thermal resistance. (In other words, the higher the R-value, the greater the insulating power.) Although R-value has been traditionally used in building codes for decades to quantify minimum insulation requirements for standard wall construction, it does not provide a complete accounting of the overall wall system's energy performance. Effects such as thermal bridging of framing members, air and wind infiltration resistance,



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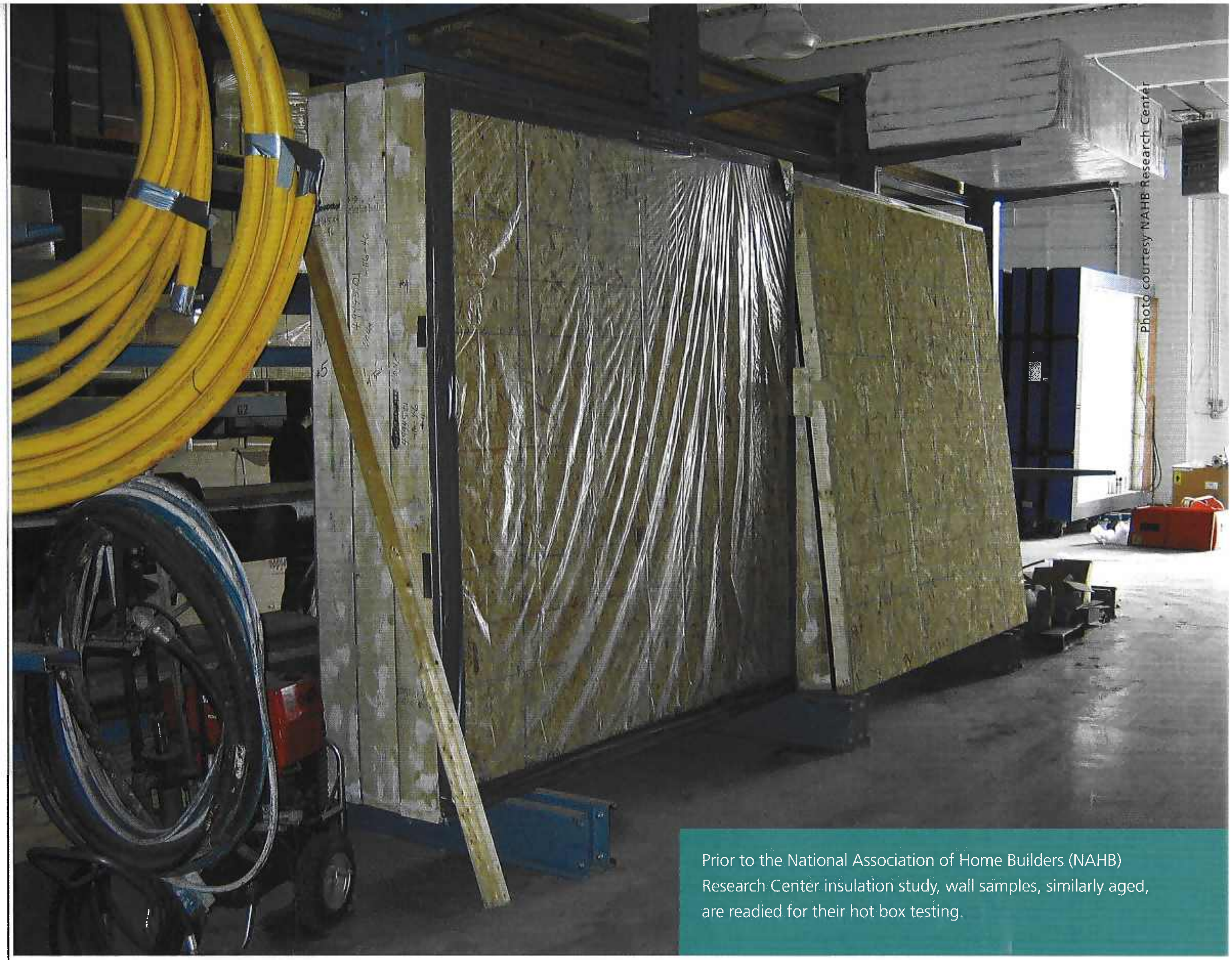

Photo courtesy NAHB Research Center

Prior to the National Association of Home Builders (NAHB) Research Center insulation study, wall samples, similarly aged, are readied for their hot box testing.

and stack effect on the building shell under normal, 'real-world' operating conditions are not considered in the R-value.

This study is unique in its evaluation of overall wall system performance. It was designed to characterize the energy consequences of wall construction and insulation material choices under simulated wind pressure conditions. To more accurately represent various climates and 'real-world' conditions, each wall system was tested under two conditions:

- in a 'static state' condition with no additional atmospheric wind pressures at one outdoor temperature; and
- with a 24-km/h (15-mph) 'wind loading' at three different outdoor temperatures.

Testing showed all the wall systems performed similarly (within the statistical accuracy of the testing apparatus) under no-wind conditions. Of course, all walls under wind conditions performed less well than with no wind. Nonetheless, once simulated 'real-world' wind loading was applied, the wall systems with plastic building products performed between 14 and 29 percent better, with performance, relative to the baseline wall, increasing as the outside temperature rose. This indicates air infiltration plays an important role in the

Table 1
Panel Study Parameters

Interior finish	Insulation*	Sheathing	Weather barrier
12.7-mm ($^{1}/_{2}$-in.) gypsum	R-13 KFB (88.9 mm [3.5 in.])	11-mm ($^{7}/_{16}$-in.) OSB	None
$^{1}/_{2}$-in. gypsum	R-13 KFB (3.5 in.)	$^{7}/_{16}$-in. OSB	House wrap
$^{1}/_{2}$-in. gypsum	54 mm (2.1 in.) of spray foam insulation R-13	$^{7}/_{16}$-in. OSB	None
$^{1}/_{2}$-in. gypsum and OSB	Net R-15 SIP (92 mm [3 $^{5}/_{8}$ in.])	$^{7}/_{16}$-in. OSB	None
$^{1}/_{2}$-in. gypsum	R-13 KFB (3.5 in.)	$^{1}/_{2}$-in. rigid foam board ~R-3.3	Tape

* Nominal R-values • OSB = oriented strand board • KFB = kraft-faced fiberglass batt • SIP = structural insulated panel

thermal performance of a wall system in 'real-world' conditions.

This study addressed the net effect of temperature and wind pressure differences across a variety of residential walls, comparing them to the most common 'stick and batt' wall construction. The testing shows how a wall assembly would be expected to perform thermally while actually in use.

The test protocol was designed so the performance tests would be equitable for all the wall assemblies; additionally, the testing process was designed in such a manner to be repeatable. No two walls are made of exactly uniform materials due to factors such as wood warping, oriented strand board (OSB) thickness variations, and nail placement.

As such, special effort was made to ensure framing leakage through OSB-sheathed walls was both reasonable and consistent (ASTM International E 283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*). Also, benchmarking was performed on each wall sample. The R-value of each individual material was tested (ASTM C 518, *Standard Test Method for Steady-state Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*, at 24 C [75 F] mean temperature) and from the material test results, a theoretical whole wall R-value was calculated for each wall that became its benchmark.

The benchmark was then compared to the actual whole wall test results at Architectural Testing Inc. of York, Philadelphia (ASTM C 1363, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*). The ratio of actual performance of a wall system over a wall's benchmark became the basis of comparison between the wall types. This enabled reasonable comparison of walls with differing R-values. This method fairly handicaps walls of various R-values to capture differences in performance of a wall system under different conditions. Conditions were representative of both typical and extreme 'real-world' conditions in various climates.

Five wall types were assembled for whole-wall thermal testing. Plastic building products such as building wrap, spray-in-place foam insulation, rigid foam plastic insulation, and structural insulated panels (SIPs) of foam plastic were compared to the baseline wall's benchmark construction (Table 1). Note: the R-value of spray polyurethane foam (SPF) may degrade after installation. Generally, most degradation

The spray foam wall pictured here is being constructed for testing. Each wall's components were individually tested for thermal performance.

Photo courtesy NAHB Research Center

One of the wall products tested in the study was the structural insulated panel (SIP), which typically comprises expanded or extruded polystyrene (EPS or XPS) or polyisocyanurate (polyiso) rigid foam insulation sandwiched between two structural skins or oriented strand board (OSB).

Photo courtesy American Plastics Council

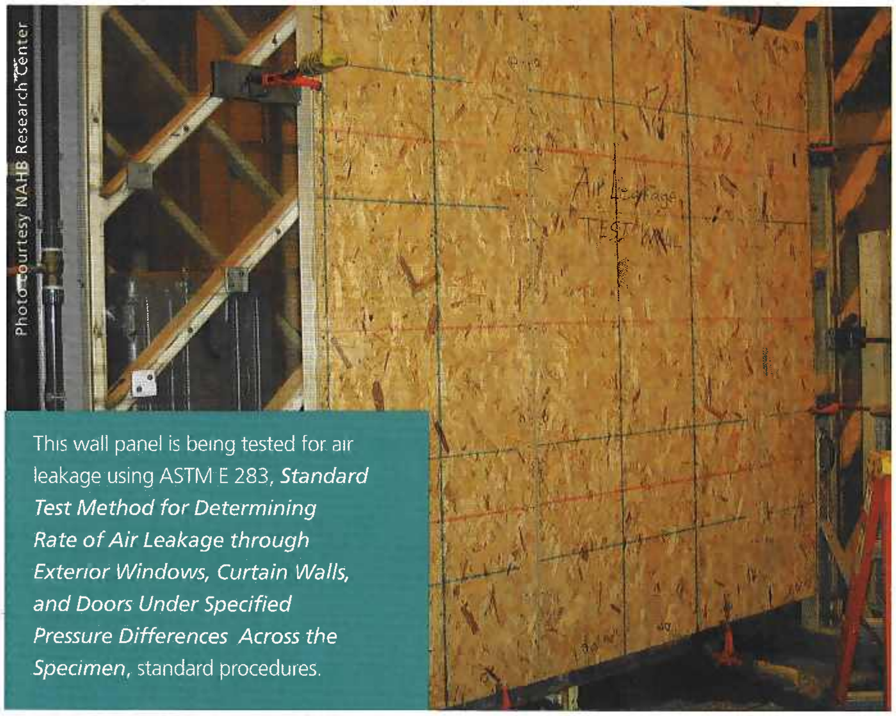

Photo courtesy NAHB Research Center

This wall panel is being tested for air leakage using ASTM E 283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*, standard procedures.

Joints were sealed and holes drilled to control air leakage in all oriented OSB-sheathed panels to a consistent level.

Photo courtesy American Plastics Council

occurs within the first couple of months after application. To account for this possible change, the SPF panels tested were warehoused nearly a year prior to the study.

The tested baseline wall represented the most common wall construction used in home building today (NAHB Research Center): a 2.4-m (8-ft) high, 101.6-mm (4-in.) overall thickness, wood-stud-framed wall with studs spaced 406.4 mm (16 in.) on-center (oc), sheathed with OSB, R-13 kraft-faced fiberglass batt (KFB) insulation, and 12.7-mm (0.5-in.) drywall covering the inside. Furthermore, best installation practices and the manufacturers' specifications were used. Individual insulation products were thermally characterized through alternate testing to validate the overall wall and material performance designations.

Since each plastic-insulated wall performed better than the baseline under windy conditions, it was concluded the supposed performance values based on traditional R-value measurements and calculations are not a complete indicator of how well a wall system will resist the loss or gain of energy.

Summary

This laboratory testing clearly demonstrated the benefits of using plastic building products (including plastic foam insulation) by showing significantly improved energy performance of residential wall systems under 'real-world,' wind-loaded conditions at various temperatures, compared to the baseline wall construction, as specified below.

No wind and moderate temperature (static state)
When there is no wind at 21 C (70 F) inside and –4 C (25 F) outside, all wall systems performed similar to their expected calculated benchmark. Compared to a typical batt insulation baseline, wall systems with plastic building products had a heat flow reduction of only three percent (not statistically significant).

Wind and extremely cold temperature
Under a 24-km/h (15-mph) wind pressure, at 70 F inside and a temperature of –26 C (–15 F) outside, plastic building products and foam plastic-insulated wall panel systems reduced heat flow an average of 18 percent better than the baseline.

Wind and moderate temperature
Under a 15-mph wind, at 70 F inside and a temperature of 25 F outside, the performance results changed significantly. The wall systems with plastic building products overall reduced heat flow an average of 20 percent better than the baseline.

Wind and extremely hot temperature
Under a 15-mph wind, at 70 F inside and a temperature of 46 C (115 F) outside, wall systems with plastic building products reduced heat flow an average of 25 percent better than the baseline. One panel sample performed 29 percent better in this category.

Conclusion

An important finding is all the walls containing plastic building products performed similarly to the baseline wall with respect to reducing heat flow in the 'no-wind' conditions. Interestingly, though, when 'real-world' wind conditions were applied, the research found all wall systems with plastic building products performed similarly better than the baseline. It also found that, as the temperature changed, all wall systems with plastic building products performed similarly better as a group to the baseline wall at each new temperature level.

An important implication of this research indicates in order for a typical (*i.e.* stick and batt) wall to meet the performance of a 'plastic' wall under windy conditions, it would need to perform at least 15 percent better. This is equivalent to upgrading the wall insulation from R-13 to R-15. As mentioned earlier, the higher the R-value, the greater the insulating power. (Design professionals should ask an insulation seller for a fact sheet on R-values.) Nonetheless, without considering changes in air infiltration between the batt types, this means approximately 85 percent more fiberglass material would need to be inserted in the same 88.9-mm (3.5-in.) cavity to achieve similar performance results to plastic building products in this study, according to the NAHB Research Center. ○

About the Author

Craig Drumheller is a senior engineer with the National Association of Home Builders (NAHB) Research Center.