Whole Wall vs. Cavity R-Values

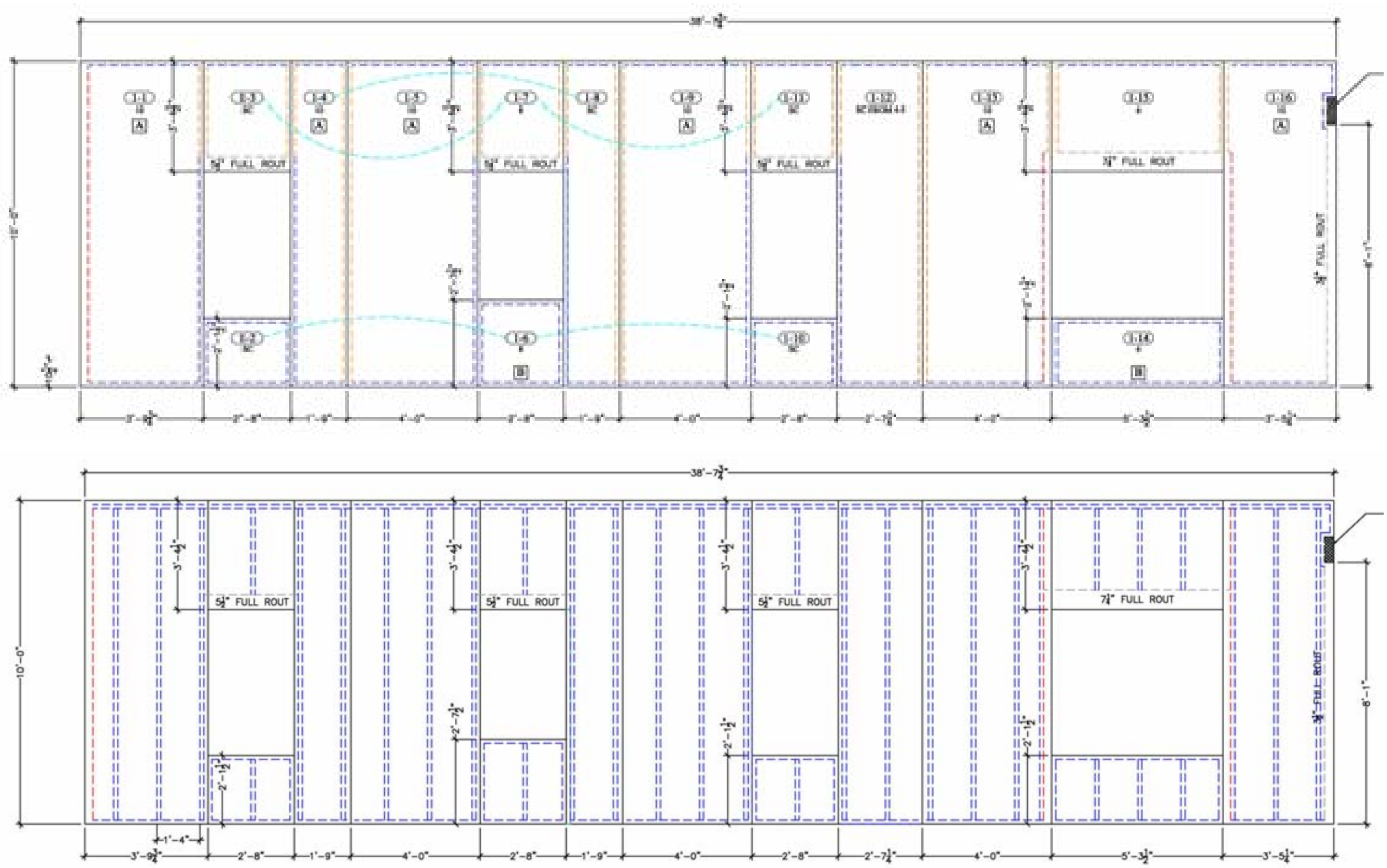
Introduction:

An R-value is a measure of resistance to thermal conduction. Since heat conducts through walls and roofs all over, not just where the insulation is, building heat loss is calculated over the “whole surface”. The problem comes from the fact that most insulations are labeled and sold based on their in-cavity R-value. Additionally, most residential energy codes are written assuming stick framing will be used and only specify the infill R-value. The in-cavity R-value doesn't include the heat that conducts through the stick framing that creates the cavity, usually 2x4, 2x6, 2x8, 2x10, or 2x12 studs and rafters. There is also the portion of the whole surface that is windows or other openings, for the purpose of this discussion we will be using the term “whole wall” which refers to the portion of the whole surface that is not window or door or other penetrations.

The whole wall R-value is calculated by finding the area of the whole wall that is cavity and the area that is framing and averaging their respective R-values (the math actually requires that it is the average of the reciprocals of the R-value called the U-value). Obviously the proportion of the whole surface that is framing varies depending on many factors, including: amount and layout of windows, type of deck construction and depth of floor deck, Stud spacing (16” or 24”), ect… In order to accurately compare SIPs, with their much smaller proportion of framing to insulation, we need to know the framing factor (percentage of the whole wall area that is framing) of the conventional framing and of the SIPs.

Finding Framing Factors:

Oak Ridge National Labs (ORNL) has done a fair amount of testing of various wall types to determine actual whole wall R-values. In ORNL’s testing Dr. Jan Kosny used data from a study by ASHREA in 2003 that showed that the average stick framed house had a 25% framing factor, though they noted that a 2002 study by Enermodal Engineering for California Energy Commission found the framing factor to be 27%. ORNL also has done testing of SIPs, however the SIP testing was done of a clear wall section with framing only on the edges. While SIPs don’t have any framing in a clear wall area, even in timber frame construction they do require some framing around windows. In structural SIP applications there is framing in corners, around windows, and at floor decks. In order to accurately compare SIP R-values with conventional framing we need a direct comparison of SIP framing factors and conventional framing factors.



We decided to use sample SIP walls and compare an actual framing factor for the same wall SIP vs. conventional framing. In the image above blue and red dashed lines show the locations of framing, while orange is the spline joints between panels (no thermal bridge), and the grey lines are insulated headers (no thermal bridge). Insulated Headers are assumed to be the same between systems and therefore neglected from calculations, though in reality often the headers of a conventional wall would be solid not insulated. In this particular wall the windows are 15% of the whole surface. The SIP framing factor was 8% and the conventional framing factor was 21%, a difference of 13%. In other wall comparisons done the same way the difference between SIP framing factor and the conventional framing factor ranged between 10% and 20% with SIPs always having the lower framing factor. The more windows there are the smaller the difference in the framing factors and the deeper the floor decks the bigger the difference. All the comparisons were done with structural panel buildings, in buildings where the SIPs are the secondary structure (timber frames and steel frames) the framing factors for SIPs are much smaller, comparable to double framed conventional walls.

Paul Malko Technical Director at Foard Panel, Inc.
Phone: 800-644-8885 • *Fax*: 603-256-6902 • www.foardpanel.com
PO Box 185 • 53 Stow Dr. • West Chesterfield, NH 03466

Comparison Charts:

Using the 8% and 21% framing factor for the above wall as representative of typical framing factors we have created the following charts to easily compare SIPs with both conventional framing whole wall and Building Code center of cavity numbers.

R-Value Comparison Table
Foard Panel SIPs vs. Conventional Stick Built

Wall Thickness		Fiberglass	Cellulose	EPS SIP	NEO SIP	XPS SIP	PIR SIP
2x4 stud or 4 ½" SIP	Center of Cavity	R-11	R-13	R-15	R-18	R-19	R-23
	Whole Wall	R-9	R-11	R-14	R-17	R-18	R-21
2x6 stud or 6 ½" SIP	Center of Cavity	R-17	R-20	R-23	R-27	R-29	R-34
	Whole Wall	R-15	R-17	R-22	R-25	R-27	R-32
2x8 stud or 8 ¼" SIP	Center of Cavity	R-23	R-26	R-29	R-36	R-38	R-44
	Whole Wall	R-20	R-22	R-27	R-34	R-36	R-41
2x10 stud or 10 ¼" SIP	Center of Cavity	R-29	R-33	R-37	R-45	R-48	R-56
	Whole Wall	R-25	R-28	R-35	R-42	R-45	R-52
2x12 stud or 12 ¼" SIP	Center of Cavity	R-35	R-40	R-45	R-54	R-58	R-67
	Whole Wall	R-30	R-34	R-42	R-51	R-54	R-63
14" I-joist or 15" SIP	Center of Cavity	R-43	R-50	R-56	R-67	R-72	R-82
	Whole Wall	R-37	R-43	R-53	R-63	R-67	R-77
16" I-joist or 17" SIP	Center of Cavity	R-49	R-57	R-63	R-77	R-82	R-93
	Whole Wall	R-42	R-49	R-59	R-72	R-77	R-87

Table 1 - Whole Surface R-Values for Standard Wall Thicknesses

Fiberglass Batt R-value for 1"=3 Cellulose Batt R-value for 1"=3.5 Wood R-Value for 1" =1.1

Wall Thickness (Nominally Meets Code) Comparison Table
Foard Panel SIPs vs. Conventional Stick Built

Center of Cavity	Standard Wall Thickness Needed to Achieve Desired Center-of Cavity Code					
R-Value	Fiberglass	Cellulose	*EPS SIP*	*NEO SIP*	*XPS SIP*	PIR SIP
R-13	4 ½"	4 ½"	4 ½"	4 ½"	4 ½"	4 ½"
R-19	6 ½"	6½"	6 ½"	4 ½"	4 ½"	4 ½"
R-22	8 ¼"	8 ¼"	6 ½"	6 ½"	6 ½"	4 ½"
R-30	10 ½"	10 ¼"	8 ¼"	6 ½"	6 ½"	6 ½"
R-35	12¼"	12¼"	10 ¼"	8 ¼"	8 ¼"	6 ½"
R-38	15"	15"	10 ¼"	8 ¼"	8 ¼"	6 ½"
R-40	15"	12¼"	10 ¼"	8 ¼"	8 ¼"	8 ¼"
R-49	17"	15"	12 ¼"	10 ¼"	10 ¼"	8 ¼"
R-60	21"	19"	15"	12 ¼"	12 ¼"	10 ¼"
R-70	25"	21"	17"	15"	15"	12 ¼"

Table 2 – This table provides the wall thicknesses required to meet the same whole wall R-value as a conventional wall with the given center of cavity number. The thicknesses listed are the standard SIP sizes not the stud or insulation thickness. These are only suggestions, based on our understanding of building codes and actual thermal performance, all final assessments are made by local building code officials.

Paul Malko Technical Director at Foard Panel, Inc.
Phone: 800-644-8885 • *Fax*: 603-256-6902 • www.foardpanel.com
PO Box 185 • 53 Stow Dr. • West Chesterfield, NH 03466

The data in the Tables 1 & 2 was calculated using the following method:

Heat loss is simply calculated by the following simple equation:

$HL = U*A*\Delta T$ **Equation 1**

Where HL = Heat Loss (BTU/hr)

U = U-value is equivalent to 1/R (typically for windows & doors)

R = R-value is equivalent to 1/U (typically used for walls & roofs)

A = Surface area (square feet)

ΔT = Temperature difference between inside & outside (deg F)

If we add up all of the areas and their associated U-and R-values we'd get:

$HL= (U*A_{Window} + A_{Framing}/R_{Framing} + A_{Insulation}/R_{Insulation})*\Delta T$ **Equation 2**

For our work we are not dealing with the windows at all so we are only finding the Heat Loss of the clear wall not the whole surface. In most buildings the portion of heat loss through the window area is greater than the portion lost through the wall.

$HL_{Wall} = (A_{Framing}/R_{Framing} + A_{Insulation}/R_{Insulation})*\Delta T$ **Equation 3**

Most of the time we do not want to spend the time to find the actual surface areas of all these pieces so we us percentages. One can think of this as if the whole surface area was 1 square foot and each area is only portion of it. For the purpose of our work we used SIP framing factor of 8% (insulation 92%) and conventional framing factor of 21% (insulation 79%).

To convert from center of cavity to whole-surface R-values the other we take Equation 3, hold heat loss and T constant and assume we're calculating for 1 square foot of area resulting in:

$HL_{Wall}=(A_{Framing}/R_{Framing}+A_{Insulation}/R_{Insulation})\ \Delta T = (A_{WW}/R_{WW})\ \Delta T$ **Equation 4**

$(A_{Framing}/R_{Framing}+A_{Insulation}/R_{Insulation}) = (A_{WW}/R_{WW})$ **Equation 5**

For Conventional:

$A_{Framing}$ = 0.21 = 21% of the wall area is wood

$A_{Insulation}$ = 0.79 = 79% of wall area that is infill insulation

A_{WW} = 1 = 100% of the wall is the whole wall surface area

R_{stud} = 1.1R/in x 5.5in = R6.6 = R-value of wood times the depth of a 2x6

R_{insul} = R-19 typical insulation for 5.5” stud bay (I actually calculated R-17 for fiber glass batts and R-20 for Cellulose batts including one layer of ½” OSB)

R_{WW} = Whole Wall Surface R-value

So $1/(0.21/6.6+0.79/19)=$ R-14 **Equation 6**

This method matches common energy engineering practices and the results correlate well with Dr. Kosny's guarded hot box testing.

Paul Malko Technical Director at Foard Panel, Inc.
Phone: 800-644-8885 • *Fax*: 603-256-6902 • www.foardpanel.com
PO Box 185 • 53 Stow Dr. • West Chesterfield, NH 03466