MULTIFAMILY PERFORMANCE PROGRAM

Technical Topic – Existing Buildings

Calculating the U-value of a Surface

Summary

Proper characterization of the building envelope is critical to any energy reduction plan that includes changes in insulation. This Tech Tip describes how to calculate the effective U-value of a building assembly and discusses de-rating insulation.

Calculating the Effective U-Value of a Building Assembly

Many people are more familiar with R-values than with U-values because insulation comes labeled with R-value ratings. R-value expresses the resistance to heat transfer. The U-value is the rate of heat transfer per unit area per degree of temperature difference, and is the inverse of the R-value. That is, U=1/R and R=1/U.

If different cross-sections through a building assembly such as a wall, roof, or floor have different R-values, the effective R-value for that surface must be calculated by first calculating the U value of each different cross-section. TREAT and eQuest offer libraries with R-values for different building surfaces. Here is how those R-values are calculated for a wood frame stucco wall with nominal 2” x 4” framing, 3.5” fiberglass batt insulation.

The R-value at a cross-section through the insulation is higher than the R-value of the insulation itself:

Material	R value[1]
Outside air film	0.17
Stucco	0.08
Gypsum board	0.56
Batt insulation (nominal rating)	11.00
Gypsum board	0.56
Inside air film	0.68
Total R	13.05
U value	0.08

The R-value of a cross-section at the framing is lower than the R-value of the insulation.

According to Oak Ridge National Laboratory, framing factors such as studs, wall/wall (corners), wall/roof, wall/floor, wall/door, and wall/window connections typically occupy 10% to 40% of the wall area.

Material	R value[1]
Outside air film	0.17
Stucco	0.08
Gypsum board	0.56
3.5” wood (nominal 2” x 4”)	4.38
Gypsum board	0.56
Inside air film	0.68
Total R	6.43
U value	0.16

[1] R-values for insulation and building materials can be found in ASHRAE Fundamentals as well as many sources on the Internet.

Calculating the U-value of a Surface

Assume (per ASHRAE 90.1-2004) that the studs, plates, sills and headers are 25% of the total area of a wood-framed wall, while the cavity insulation is 75% of the total area.

The effective U-value of this wall assembly would be calculated as:

Effective U-value = (0.75 x 0.08) + (0.25 x 0.16) = 0.1

The effective R-value for the wall assembly is 1/0.1 = 10, lower than the nominal R-value of the insulation.

ASHRAE Standard 90.1-2004 contains a series of tables that show the effective R-value of different wall, roof, and floor assemblies, including both cavity and continuous insulation. If you are considering a building whose construction is not described in the TREAT or eQuest libraries or the ASHRAE Standard 90.1-2004 tables, you can calculate its R-value using the procedure described previously. ASHRAE Fundamentals contains R-values for many building materials; these values are also widely available on the Internet.

Metal Wall Studs

The attached table, reproduced from ASHRAE Standard 90.1-2004, Appendix A presents measured R-values for wall insulation installed between steel framing. Metal wall studs present a special situation because of metal's high thermal conductivity and because of the vertical orientation of the studding. To calculate the overall U value for a wall with metal studs, use the R-value from this table and add the R-values of the rest of the wall assembly (e.g. masonry, interior gypsum board, interior and exterior airfilms), using the procedure described previously.

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity (in.)	Actual Depth of Cavity (in.)	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on center	Effective Framing/Cavity at 24 in. on center
Empty cavity, no insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

This information is provided as a summary to the Technical Topics discussion in November 2008

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In comparison to metal studs in walls, metal framing members in roofs and floors cause little reduction in R-value. The table below excerpts ASHRAE Standard 90.1-2004, Appendix A, Table A9.2A.

Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on center)

Rated R-value of Insulation	Framing/Cavity R-Value
11.00	10.01
19.00	16.34
38.00	28.12
55	36.85

De-Rating Insulation in Existing Buildings

Gaps in insulation increase heat loss. Using the procedure described on the previous page, gaps of 2.5% increase heat loss by 4% while gaps equal to 5% of the insulation area increase heat loss by 12%.

BPI's Building Analyst and Shell & Envelope courses include a table showing how the effective R-value of batt insulation is reduced by gaps and other installation imperfections. This table indicates larger effects from gaps than can be explained by conduction alone. The BPI table is being reviewed for potential revision and should not be used for guidance until further notice.

The BPI table may have been intended to show the effects of factors that are not included in the calculations above. For example, convective airflows inside the cavity can increase heat loss when air moves over exposed uninsulated surfaces such as gaps in the insulation.[2] Additional factors that impact the effectiveness of insulation include:

- Wind-washing: air moving through fibrous insulation can accelerate heat loss.
- Gaps in insulation increase the likelihood of condensation within the building cavity. Fibrous insulation loses its R-value when wet.
- The R-value of batt insulation is reduced when the insulation is compressed. Appendix A of ASHRAE 90.1-2004 rates R-19 batt insulation at R-18 when it is compressed into a nominal 6" wall cavity (nominal 2" x 6" studs are actually 1.5" x 5.5").

A small number of studies have evaluated the effects of poor installation practices on insulation value. In general, researchers who have studied these effects, including of compressed areas and gaps of up to 6%, have measured 10% to 20% increases in U-value. Exaggerated de-rating of the existing insulation can lead to unreasonable expectations about the benefits of adding more insulation and might cause you to fall short of your energy conservation goal. If you choose to de-rate the R-value of insulation in an existing building, be prepared to justify your decision by documenting your observations of gaps, voids, moisture, or airflows.

[2] Gaps in insulation are areas in which the building envelope is intact but insulation is missing. Gaps in the building envelope that allow air to leak into or out of the conditioned space must be addressed by air sealing before additional insulation can be effective.