Framed Exterior Wall Thermal Performance

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Providing compete construction specifications documentation, systems and performance descriptions, and risk and quality advisory services.

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ABSTRACT:
When selecting exterior wall assemblies be sure to consider:
Climate zone.
Framing material.
Insulation R-values.
Need for continuous insulation.
Location of weather barrier membrane, and especially the vapor retarder.
Be sure to know all the codes and standards that affect the exterior wall design and thermal performance.

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KEYWORDS:
Climate zone, continuous insulation, thermal performance, wood framing, steel framing

CODES AND STANDARDS:
ASHRAE 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings, 2004 & 2007
IECC - International Energy Conservation Code, 2006.
LEED Reference Guide for Green Building Design and Construction, 2009
LEED for Homes Reference Guide, 2008

The Problem

The design of exterior walls is affected by requirements from many sources: building code, energy code, and LEED to name a few. The performance specified by one source may not be consistent with the others. And then come the details. It is never quite as simple as it may seem.

This article will explore the prescriptive requirements of the model energy code, ASHRAE 90.1, and LEED for the effect on framed, exterior, above-grade, walls for commercial and residential buildings.

Getting Started

The first step for designing building exterior walls is to determine the climate zone for the building location. The US Department of Energy (DOE) publishes a climate zone map for the United States. The zones range from 1 (warmest) to 8 (coldest). The map also divides the country into A-Moist, B-Dry, and C-Marine areas. A project climate zone is designated by number and letter, 4A for Philadelphia, PA for example. The DOE map is used by the International Energy Conservation Code (IECC) and ASHRAE 90.1 to establish the building envelope requirements based on project location.

To help understand the impact of the IECC and ASHRAE 90.1 refer to the comparative Tables 1, 2, and 3 included in this Tech Tips.

Wood vs. Steel

The framing material selection for the exterior wall affects the wall R-value. Wood is a natural insulator and is treated more favorably by the energy code and standards. Steel is a very good thermal conductor that easily creates thermal bypasses through the wall. Steel stud spacing directly affects the thermal performance. Closer spacing transfers more heat and degrades thermal performance. By ASHRAE 90.1, the effective R-value of insulation installed in metal stud cavities range from 60% of the insulation rated R-value for 24 inch stud spacing to as little as 35% for 16 inch stud spacing (Table 3). Be sure to know the correct effective R-value for metal framed wall assemblies for energy calculations.

To compensate for the thermal conductance of the steel studs, IECC and ASHRAE 90.1 require continuous insulation. Continuous insulation may be the only insulation provided the wall meets the maximum U-value.

IECC Residential

IECC Table 402.1.1 requires a minimum 13 R-value for exterior wood framed walls. The minimum increases to 19 for climate zones 4C, 5, and 6 and minimum 21 for zones 7 and 8. (Table 1) Note that this table addresses wood framed walls, only. Steel framed walls are governed by Table 402.2.4.

When using steel framing, continuous insulation is required regardless of climate zone. IECC makes no distinction as to steel stud spacing to set the required insulation R-values.

IECC Commercial

IECC 2006 gives the option to comply with the code or to comply with ASHRAE 90.1 - 2004 for commercial buildings (Table 2).

IECC Table 502.2(1) requires minimum 13 R-value for wood and metal framed walls. Continuous insulation is required for wood framing only in northern Alaska climate zone 8. Metal framed walls require

continuous insulation for zones 4A and 5 through 8. For both wood and metal framing, only the minimum R-value of the continuous insulation increases as the climate zone gets colder.

ASHRAE 90.1

The thermal performance requirements in ASHRAE 90.1 - 2004 are similar to the IECC requirements with some exceptions. The 2007 edition is more restrictive than the 2004 edition. The 2007 edition will be referenced by the 2009 IECC when it is adopted by local jurisdictions.

Continuous insulation is required for steel framed walls at residential construction beginning in climate zone 3. Climate zone 5 requires continuous insulation for steel framed commercial construction. Zone 6 for residential construction and zone 8 for commercial construction require continuous insulation for wood framed construction.

In addition to insulation R-value, ASHRAE 90.1 specifies a maximum wall assembly U-value. Buildings must meet both requirements.

LEED

LEED 2009 v3.0 is used for new construction, core and shell, and K-12 schools. LEED for Homes v1.0 is used for low-rise one and two family residences.

LEED certification programs rely on ASHRAE 90.1 as the baseline standard to set the project energy use benchmark. Then superior energy performance is measured as a percentage improvement compared to the baseline.

LEED 2009 requires buildings to comply with the ASHRAE 90.1 - 2007 edition. Earlier versions of LEED NC and LEED CS and the current version of LEED for Homes rely on ASHRAE 90.1 - 2004 edition. Projects attempting LEED 2009 certification may be in the position of complying with the latest version of AHRAE 90.1 even though the code may require an earlier edition.

The Effect

Use of continuous insulation in exterior walls started in the United States in Massachusetts as a result of the state energy code. Now its use has spread to the model codes and standards affecting most buildings in cold climates. Exterior wall details are changing. Continuous insulation is installed outboard of the wall sheathing.

This construction provides some distinct advantages. Air, moisture, and vapor resistant weather barrier membranes can be a single material installed directly to the wall sheathing. This helps keep buildings dry and allows the membrane and the insulation to be continuous.

The new construction also raises some new issues about fastening exterior wall finishes to the framing, penetrating the weather barrier, and locating the vapor retarder correctly. Some material manufacturers limit the distance between their material and the fastening substrate. The wall finish could rely on many fasteners that will penetrate the weather barrier, presumably breeching the effectiveness at resisting air, water, and vapor penetration. Placing the vapor retarder at the correct location may require analysis to ensure condensation will not occur inside the weather barrier and will not damage the construction.

Additional controls may be needed to ensure fasteners hit their mark and are not backed out after missing the substrate, leaving a hole in the weather barrier. Elastic weather barrier membranes may need to be selected so they will self-seal or gasket when penetrated by fasteners.

Conclusion

Be sure to know all the codes and standards that affect the exterior wall design and thermal performance. The prescriptive methods shown in the codes and standards are not the only way to comply. Alternative solutions are permitted by IECC and ASHRAE 90.1 when the resulting energy use is no greater than when complying with the prescriptive method.

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The following tables are provided as a convenience for thermal performance comparison purposes only.

Table 1 - Residential Thermal Performance for Exterior Above Grade Framed Walls

Codes & Standards	Framing	Climate Zone Minimum R-values[a,b] and Maximum U-values								
		1A,B	2A,B	3A,B,C	4A,B	4C	5A,B,C	6A,B	7	8
IECC (2006)[c]	Wood	R13 U0.082	R13 U0.082	R13 U0.082	R13 U0.082	R19 R13+5 U0.030	R19 R13+5 U0.030	R19 R13+5 U0.026	R21 U0.026	R21 U0.026
	Steel	R13+5 R15+4 R21+3 U0.082	R13+5 R15+4 R21+3 U0.082	R13+5 R15+4 R21+3 U0.082	R13+5 R15+4 R21+3 U0.082	R13+9 R19+8 R25+7 U0.030	R13+9 R19+8 R25+7 U0.030	R13+9 R19+8 R25+7 U0.026	R13+10 R19+9 R25+8 U0.026	R13+10 R19+9 R25+8 U0.026
ASHRAE 90.1 (2004)[d]	Wood	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13+3.8 U0.064	R13+7.5 U0.051	R13+7.5 U0.051
	Steel	R13 U0.124	R13 U0.124	R13+3.8 U0.084	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+10 U0.055
ASHRAE 90.1 (2007)[d]	Wood	R13 U0.089	R13 U0.089	R13 U0.089	R13+3.8 U0.064	R13+3.8 U0.064	R13+7.5 U0.051	R13+7.5 U0.051	R13+7.5 U0.051	R13+15.6 U0.036
	Steel	R13 U0.124	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+15.6 U0.042	R13+18.8 U0.037

a. For R-values expressed as RX+X, the second number in the expression is the R-value required for the continuous insulation.
b. Where multiple R-values are shown on separate lines, any one of the values is permitted to be used.
c. IECC applies to R-3 buildings as well as R-2 and R-4 buildings 3-stories or less as defined by the International Building Code.
d. ASHRAE 90.1 does not apply to single family homes, multi-family facilities 3-stories or less, and mobile and modular homes.

Table 2 - Commercial Thermal Performance for Exterior Above Grade Framed Walls

Codes & Standards	Framing	Climate Zone Minimum R-values[a] and Maximum U-values								
		1A,B	2A,B	3A,B,C	4A,B	4C	5A,B,C	6A,B	7	8
IECC (2006)	Wood	R13	R13	R13	R13	R13	R13	R13	R13	R13+7.5
	Steel	R13	R13	R13	R13	R13+3.8	R13+3.8	R13+3.8	R13+7.5	R13+7.5
ASHRAE 90.1 (2004)	Wood	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13+7.5 U0.051
	Steel	R13 U0.124	R13 U0.124	R13 U0.124	R13 U0.124	R13 U0.124	R13+3.8 U0.084	R13+3.8 U0.084	R13+7.5 U0.064	R13+7.5 U0.064
ASHRAE 90.1 (2007)	Wood	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13 U0.089	R13+3.8 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064
	Steel	R13 U0.124	R13 U0.124	R13+3.8 U0.084	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.064	R13+7.5 U0.051	R13+7.5 U0.051	R13+15.6 U0.036

a. For R-values expressed as RX+X, the second number in the expression is the R-value required for the continuous insulation.

Table 3 - Steel Stud Cavity Insulation R-values[a] and U-values[b]

Stud Depth	16 inch Spacing			24 inch Spacing		
3.5 inches	R11(5.5) U0.132	R13(6.0) U0.124	R15(6.4) U0.118	R11(6.6) U0.116	R13(7.2) U0.108	R15(7.8) U0.102
6 Inches	R19(7.1) U0.109	R21(7.4) U0.106		R19(8.6) U0.094	R21(9.0) U0.090	

a. The R-value in parentheses is the effective R-value of the batt insulation rated R-value, without any continuous insulation.
b. U-values include both air films, 3/4 inch stucco, 5/8 inch gypsum sheathing, and 5/8 inch interior gypsum board.