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Pacific Northwest NATIONAL LABORATORY

Residential Slab Component Calculations

Technical Brief

December 2018

ZT Taylor

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Contents

Background

This study was conducted by Pacific Northwest National Laboratory (PNNL) in support of the U.S. Department of Energy (DOE) Building Energy Codes Program (BECP). BECP was founded in 1993 in response to the *Energy Policy Act of 1992*, and fulfills several key functions specified under federal statute and related to building energy codes. Section 307 of ECPA, as amended, requires DOE to periodically review the technical and economic basis of the voluntary building energy codes, such as the International Energy Conservation Code (IECC) and Standard 90.1, and participate in the industry process for review and modification, including seeking adoption of all technologically feasible and economically justified energy efficiency measures. (42 U.S.C. 6836(b)) Section 304(a) of ECPA, as amended, also directs DOE to review published editions of the IECC and Standard 90.1, and issue a determination as to whether the revised edition would increase energy efficiency in residential and commercial buildings, respectively.

PNNL supports this mission by evaluating concepts being considered for future code updates, conducting technical reviews and analysis of potential changes and their associated impacts, including energy savings analysis, cost-effectiveness analysis, and providing guidance on how changes can be more readily adopted by states and localities. This helps to ensure successful implementation of advancing technologies, construction practices, and related industry standards, and encourages building practices that are proven affordable and efficient.

This technical brief represents a compilation of relevant information on a specified concept. An overview of the concept is presented, followed by supporting technical analysis, related research and recommended code language. Additional context may also be provided, such as known consideration in previous model code development, state code proceedings, or incorporation in existing codes or standards. Each brief is intended as a resource for interested and affected stakeholders, particularly those charged with considering impacts of proposed code updates. Further technical assistance may be available from PNNL to adapt content to the needs of individual states or municipalities, such as specific building types, climate weightings, or utility rates.

Learn more at www.energycodes.gov.

1.0 Residential Slab-on-Grade Component Calculations for Compliance Tradeoffs

Residential building energy codes that are based on any version of the International Energy Conservation Code (IECC) typically allow compliance to be demonstrated in several ways, one of which is a component tradeoff approach whereby prescriptive requirements for some building components may be relaxed in trade for corresponding improvements in other components. Calculations for this component tradeoff are based on maintaining a maximum overall building UA value, which is the sum across all building envelope components of the product of each component's U-factor (conductance) and area. For slabs on grade, the component UA is based on an F-factor rather than a U-factor and is multiplied by the slab-edge perimeter length rather than slab area.

The IECC does not give explicit instruction on calculating slab F-factors, relying instead on external materials such as ASHRAE's Handbook of Fundamentals. Slab insulation is usually required only around the perimeter of the slab, but the 2018 IECC added a new requirement for full under-slab insulation of heated slabs. It is not clear, even using the ASHRAE reference, how to calculate F-factors for such slabs.

1.1 Summary

This technical brief investigates potential clarifying text to be added to residential energy codes to make component tradeoff calculations involving slab-on-grade insulation easier for code users.

1.2 Technical Considerations

Why is this provision needed?

Current code includes requirements for slab and floor R-values and floor U-factor. It does not include F-factors for heated or unheated slabs. This is important as 2018 IECC added a new requirement for full under-slab insulation of heated slabs.

How does the proposed measure compare to what's required in current codes?

The text presented here does not change a code's requirements in any way; it merely adds clarifying text showing one good source of slab F-factors as a function of insulation R-value and depth. There is no additional cost and no energy impact.

The recommended code-change text refers to Appendix A of ASHRAE Standard 90.1, where precomputed F-factors are tabulated for various combinations of slab insulation placement and R-value, but any F-factor source consistent with the ASHRAE Handbook of Fundamentals may be used.

1.3 Sample Code Language

The suggested code language is presented in this section.

Sample code language is outlined below based on the current 2018 IECC. Similar language can also be adapted to state and local codes that are based on the IECC or contain similar provisions.

Add definition to R202 as follows:

***F*-FACTOR (THERMAL TRANSMITTANCE).** The perimeter heat loss factor for *slab-on-grade floors* (Btu/h·ft·°F) [W/(m·K)].

Modify Table R402.1.4 as follows:

TABLE R402.1.4
EQUIVALENT *U*-FACTORS AND *F*-FACTORS [a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR [b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	UNHEATED SLAB *F*-FACTOR	HEATED SLAB[d] *F*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.084	0.197	0.064	0.360	0.73	1.03	0.477
2	0.40	0.65	0.030	0.084	0.165	0.064	0.360	0.73	1.03	0.477
3	0.32	0.55	0.030	0.060	0.098	0.047	0.091[c]	0.73	1.03	0.136
4 except Marine	0.32	0.55	0.026	0.060	0.098	0.047	0.059	0.54	0.68	0.065
5 and Marine 4	0.30	0.55	0.026	0.060	0.082	0.033	0.050	0.54	0.68	0.055
6	0.30	0.55	0.026	0.045	0.060	0.033	0.050	0.48	0.68	0.055
7 and 8	0.30	0.55	0.026	0.045	0.057	0.028	0.050	0.48	0.68	0.055

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.
b. Mass walls shall be in accordance with Section R402.2.5. Where more than half the insulation is on the interior, the mass wall *U*-factors shall not exceed 0.17 in Climate Zone 1, 0.14 in Climate Zone 2, 0.12 in Climate zone 3, 0.087 in Climate zone 4 except Marine, 0.065 in Climate Zone 5 and Marine 4, and 0.057 in Climate Zones 6 through 8.
c. In warm-humid locations as defined by Figure R301.1 and Table R301.1, the basement wall *U*-factor shall not exceed 0.360.
d. *F*-factors for heated slabs correspond to the configuration described by footnote (d) of Table R402.1.2.

Modify Sections R402.1.4 and R402.1.5 as follows:

R402.1.4 *U*-factor or *F*-factor alternative. An assembly with a *U*-factor or *F*-factor equal to or less than that specified in Table R402.1.4 shall be an alternative to the *R*-value in Table R402.1.2.

R402.1.5 ~~Total UA~~ Component performance alternative. Where the proposed total *building thermal envelope* thermal conductance ~~UA, the sum of *U*-factor times assembly area,~~ is less than or equal to the required total *building thermal envelope* thermal conductance using ~~UA resulting from multiplying the *U*-~~ factors in Table R402.1.4, ~~by the same assembly area as in the proposed *building*~~ the *building* shall be considered to be in compliance with Table R402.1.2. The ~~UA calculation~~ total thermal conductance shall be ~~performed~~ determined in accordance with Equation 4-1. Proposed *U*-factors and slab-on-grade *F*-factors shall be taken from ANSI/ASHRAE/IES Standard 90.1 Appendix A or determined using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. In addition to ~~UA~~ total thermal conductance compliance, the SHGC requirements shall be met.

$$(U_pA + F_pP) \leq (U_r A + F_rP)$$ **(Equation 4-1)**

where:

U_pA = the sum of proposed *U*-factors times the assembly areas in the proposed *building*
F_pP = the sum of proposed *F*-factors times the slab-on-grade perimeter lengths in the proposed *building*
U_rA = the sum of *U*-factors in Table R402.1.4 times the same assembly areas as in the proposed *building*
F_rP = the sum of *F*-factors in Table R402.1.4 times the same slab-on-grade perimeter lengths as in the proposed *building*

Remaining equations and equation references to be renumbered.

Modify Section R402.2.10 as follows:

R402.2.10 Slab-on-grade floors. Slab-on-grade floors in contact with the ground with a floor surface within 24 ~~less than 12~~ inches (~~305~~ 600 mm) above or below grade shall be insulated in accordance with Table R402.1.2. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table R402.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the *building*. Insulation extending away from the *building* shall be protected by pavement or by not less than 10 inches (254 mm) of soil. The top edge of the insulation installed between the *exterior wall* and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the *exterior wall.* Slab-edge insulation is not required in jurisdictions designated by the *code official* as having a very heavy termite infestation.

Modify reference in Chapter 6 as follows:

ANSI/ASHRAE/IES Standard 90.1-2016—Energy Standard for Buildings Except Low-rise Residential Buildings

C401.2, Table C402.1.3, Table C402.1.4, C406.2, Table C407.6.1, C502.1, C503.1, C504.1, R402.1.5

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