Revision to the Residential ACM Calculation for Slab Heat Flow

DRAFT

2008 Residential Building Standards Project

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Summary

This is a change to the Residential Alternative Compliance Methods (RACM)1 calculation procedures for homes with slab on grade construction.

Background

The RACM specifies the algorithms and modeling rules to be used in Alternative Compliance Method computer programs (ACMs) that are certified for use in compliance with the building standards. The 2005 RACM section 4.2.5 specifies that slab heat flows to the outside are modeled using a conductance from the conditioned zone air temperature to a specified monthly ground temperature. The conductance is a function of the slab perimeter length and insulation level as specified in RACM section 3.2.6.

Marc Hoeschele of Davis Energy Group commented on what he sees as defects in this model that "Building America has identified slabs as a key target for improving energy efficiency of new homes. My concern is that Title 24 provide a reasonable approximation of slab performance, both in terms of appropriately valuing slab edge insulation and giving reasonable heat fluxes through the different seasons of the year. I am concerned that the current approach underestimates mid-winter heat losses and overestimates summer and swing season heat losses."[2]

In 2000 Joe Huang led a Lawrence Berkeley National Laboratory team in developing a simplified slab modeling approach for the CEC.[3] This model is based on detailed 2 dimensional heat flow simulations for a range of slab configurations in all 16 of the CEC weather files. Huang's model was developed for use in the nonresidential standards, but has been adapted here for use in the RACM context. The adaptation preserves the slab area and perimeter as the primary user inputs and requires the R-value and depth of the slab edge insulation instead of the slab edge heat loss rate (F2) value.

[1] ACM manual

[2] Email to Bruce Wilcox, Wed, 02 Nov 2005

[3] Huang, J; Bazjanac, V; Winkleman, F. DOE-2 Modeling of Two-dimensional Heat Flow in Underground Surfaces, CEC contract 400-96-017.

Proposed Changes

1. Slab floors shall be modeled using conductances from the bottom of the slab to 3 ground temperatures:
    a. Year: the deep ground set to the annual average of outdoor temperature
    b. Month: the medium depth temperature calculated according to DOE2
    c. Week: shallow ground set to a moving weekly average outdoor temperature

2. The coefficients for the slab cases shall be read from the following table for exterior insulation of the slab edge which will replace the F2 factors in RACM 3.2.6:

	Carpeted					Exposed				
Type	Perim Week	Perim Month	Perim Year	Core Month	Core Year	Perim Week	Perim Month	Perim Year	Core Month	Core Year
R0	0.1157	0.0664	0.0028	0.0517	0.0257	0.2042	0.0797	0.0014	0.0550	0.0258
R5 2'	0.0320	0.0869	0.0103	0.0390	0.0310	0.0639	0.1001	0.0087	0.0421	0.0304
R10 2'	0.0205	0.0874	0.0131	0.0363	0.0322	0.0441	0.1005	0.0116	0.0395	0.0314

Note: the table values have been adjusted from the Huang report to allow application to the outside of the slab.

3. The following will be added to RACM 4.2.5 to specify calculation of the conductances to each temperature from each slab:

The fraction of the slab that is near the perimeter
FracPerim = 2*Perimeter/Area

Week =PerimWeek*Fracperim

Month =Perimmonth*Fracperim+CoreMonth*(1- Fracperim)

Year =PerimYear*Fracperim+CoreYear*(1- Fracperim)

Results Comparison with 2005 ACM

Table 1 Comparison of TDV Energy Use

2008 TDV Energy Use (TDV/ft2)															
	2005 R0 Slab Edge Standard					2008 R0 Slab Edge Proposed					Percent Difference Proposed - Standard				
Climate	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total
1	30.8	0.5	0.00	20.4	51.6	31.1	0.5	0.00	20.4	52.0	1%	13%	n/a	0%	1%
2	36.8	15.0	0.00	19.8	71.7	36.4	16.6	0.00	19.8	72.8	-1%	9%	n/a	0%	2%
3	22.4	4.6	0.00	19.8	46.7	22.3	5.3	0.00	19.8	47.4	0%	14%	n/a	0%	1%
4	27.8	6.6	0.00	19.5	53.9	27.7	7.6	0.00	19.5	54.9	0%	13%	n/a	0%	2%
5	21.7	5.2	0.00	19.7	46.6	22.3	5.8	0.00	19.7	47.8	3%	10%	n/a	0%	2%
6	8.6	4.4	0.00	19.1	32.0	8.9	4.9	0.00	19.1	33.0	4%	12%	n/a	0%	3%
7	9.3	5.7	0.00	18.9	33.9	9.6	6.5	0.00	18.9	35.0	4%	13%	n/a	0%	3%
8	11.3	13.3	0.00	18.9	43.5	11.6	14.4	0.00	18.9	44.8	2%	8%	n/a	0%	3%
9	11.8	21.1	0.00	18.7	51.6	12.1	22.6	0.00	18.7	53.5	3%	7%	n/a	0%	3%
10	14.9	32.4	0.00	18.7	66.0	15.3	34.2	0.00	18.7	68.2	2%	5%	n/a	0%	3%
11	32.9	40.8	0.00	19.2	92.9	32.7	42.9	0.00	19.2	94.8	-1%	5%	n/a	0%	2%
12	29.8	25.4	0.00	19.4	74.7	29.5	27.6	0.00	19.4	76.5	-1%	8%	n/a	0%	2%
13	22.8	45.0	0.00	18.7	86.4	23.1	46.6	0.00	18.7	88.4	1%	4%	n/a	0%	2%
14	31.6	45.5	0.00	19.1	96.2	31.6	47.6	0.00	19.1	98.3	0%	4%	n/a	0%	2%
15	4.9	90.9	0.00	17.1	112.9	5.5	92.3	0.00	17.1	114.9	11%	2%	n/a	0%	2%
16	63.9	18.0	0.00	21.0	102.9	66.3	18.6	0.00	21.0	105.9	4%	3%	n/a	0%	3%
Ave	23.8	23.4	0.00	19.3	66.5	24.1	24.6	0.00	19.3	68.0	1%	5%	n/a	0%	2%
CIRB	22.0	25.5	0.00	19.1	66.7	22.2	27.1	0.00	19.1	68.3	1%	6%	n/a	0%	2%

Table one shows the heating cooling, fan and total TDV energy consumption for the 1761 prototype house with no slab insulation calculated using the 2005 and proposed 2008 slab modeling approaches. The absolute differences are generally very small with a statewide CIRB weighted increase in cooling of 6% and an increase of 2% in overall TDV energy consumption.

Table 2 2005 ACM Savings for R-7 Slab Edge Insulation

2008 TDV Energy Use (TDV/ft2)															
	2005 R0 Slab Edge Standard					2005 R7 Slab Edge Proposed					Percent Difference Proposed - Standard				
Climate	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total
1	30.78	0.47	0.00	20.37	51.62	28.63	0.53	0.00	20.37	49.53	-8%	11%	n/a	0%	-4%
2	36.82	15.04	0.00	19.79	71.65	35.36	15.85	0.00	19.79	71.00	-4%	5%	n/a	0%	-1%
3	22.38	4.58	0.00	19.75	46.71	21.25	4.95	0.00	19.75	45.95	-5%	7%	n/a	0%	-2%
4	27.75	6.63	0.00	19.52	53.90	26.64	7.21	0.00	19.52	53.37	-4%	8%	n/a	0%	-1%
5	21.65	5.23	0.00	19.71	46.59	20.58	5.64	0.00	19.71	45.93	-5%	7%	n/a	0%	-1%
6	8.56	4.36	0.00	19.10	32.02	8.09	4.66	0.00	19.10	31.85	-6%	6%	n/a	0%	-1%
7	9.28	5.65	0.00	18.92	33.85	8.81	6.07	0.00	18.92	33.80	-5%	7%	n/a	0%	0%
8	11.32	13.29	0.00	18.86	43.47	10.89	13.87	0.00	18.86	43.62	-4%	4%	n/a	0%	0%
9	11.76	21.14	0.00	18.73	51.63	11.36	21.85	0.00	18.73	51.94	-4%	3%	n/a	0%	1%
10	14.94	32.35	0.00	18.74	66.03	14.45	33.23	0.00	18.74	66.42	-3%	3%	n/a	0%	1%
11	32.91	40.79	0.00	19.21	92.91	31.79	41.76	0.00	19.21	92.76	-4%	2%	n/a	0%	0%
12	29.81	25.43	0.00	19.44	74.68	28.63	26.36	0.00	19.44	74.43	-4%	4%	n/a	0%	0%
13	22.76	44.95	0.00	18.71	86.42	22.03	45.74	0.00	18.71	86.48	-3%	2%	n/a	0%	0%
14	31.60	45.50	0.00	19.14	96.24	30.47	46.43	0.00	19.14	96.04	-4%	2%	n/a	0%	0%
15	4.89	90.87	0.00	17.09	112.85	4.89	90.99	0.00	17.09	112.97	0%	0%	n/a	0%	0%
16	63.93	18.02	0.00	20.96	102.91	63.93	18.02	0.00	20.96	102.91	0%	0%	n/a	0%	0%
Ave	23.82	23.39	0.00	19.25	66.47	22.99	23.95	0.00	19.25	66.19	-4%	2%	n/a	0%	0%
CIRB	22.03	25.54	0.00	19.11	66.67	21.24	26.23	0.00	19.11	66.58	-4%	3%	n/a	0%	0%

Table 2 shows the savings for R-7 slab insulation calculated using the 2005 ACM procedure. On a statewide basis there is no savings.

Table 3 Proposed 2008 ACM Savings for R-7 Slab Edge Insulation

2008 TDV Energy Use (TDV/ft2)															
	2008 R0 Slab Edge Standard					2008 R7 Slab Edge Proposed					Percent Difference Proposed - Standard				
Climate	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total	Heat	Cool	Fan	DHW	Total
1	31.12	0.54	0.00	20.37	52.03	29.43	0.60	0.00	20.37	50.40	-6%	10%	n/a	0%	-3%
2	36.41	16.60	0.00	19.79	72.80	34.56	16.85	0.00	19.79	71.20	-5%	1%	n/a	0%	-2%
3	22.33	5.32	0.00	19.75	47.40	21.01	5.45	0.00	19.75	46.21	-6%	2%	n/a	0%	-3%
4	27.74	7.63	0.00	19.52	54.89	26.39	7.75	0.00	19.52	53.66	-5%	2%	n/a	0%	-2%
5	22.27	5.79	0.00	19.71	47.77	21.16	5.97	0.00	19.71	46.84	-5%	3%	n/a	0%	-2%
6	8.91	4.94	0.00	19.10	32.95	8.27	5.10	0.00	19.10	32.47	-8%	3%	n/a	0%	-1%
7	9.63	6.47	0.00	18.92	35.02	9.02	6.53	0.00	18.92	34.47	-7%	1%	n/a	0%	-2%
8	11.60	14.37	0.00	18.86	44.83	10.96	14.52	0.00	18.86	44.34	-6%	1%	n/a	0%	-1%
9	12.13	22.62	0.00	18.73	53.48	11.43	22.78	0.00	18.73	52.94	-6%	1%	n/a	0%	-1%
10	15.25	34.21	0.00	18.74	68.20	14.35	34.31	0.00	18.74	67.40	-6%	0%	n/a	0%	-1%
11	32.67	42.92	0.00	19.21	94.80	30.85	42.99	0.00	19.21	93.05	-6%	0%	n/a	0%	-2%
12	29.49	27.58	0.00	19.44	76.51	27.74	27.74	0.00	19.44	74.92	-6%	1%	n/a	0%	-2%
13	23.06	46.59	0.00	18.71	88.36	21.66	46.39	0.00	18.71	86.76	-6%	0%	n/a	0%	-2%
14	31.58	47.57	0.00	19.14	98.29	29.70	47.36	0.00	19.14	96.20	-6%	0%	n/a	0%	-2%
15	5.50	92.34	0.00	17.09	114.93	5.04	91.30	0.00	17.09	113.43	-9%	-1%	n/a	0%	-1%
16	66.25	18.64	0.00	20.96	105.85	63.30	18.85	0.00	20.96	103.11	-5%	1%	n/a	0%	-3%
Ave	24.12	24.63	0.00	19.25	68.01	22.80	24.66	0.00	19.25	66.71	-6%	0%	n/a	0%	-2%
CIRB	22.18	27.06	0.00	19.11	68.34	20.91	27.10	0.00	19.11	67.12	-6%	0%	n/a	0%	-2%

Table 3 shows the savings for R-7 slab insulation calculated using the proposed 2008 ACM procedure. The statewide savings are now 2% of TDV energy. Savings are largest in climate zone 1 and 16, the 2 heating dominated climates.