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R-VALUES OF MULTI-WYTHE CONCRETE MASONRY WALLS

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INTRODUCTION

R-values of building components are used to estimate a building's energy consumption under steady-state conditions. In order to estimate a building's actual energy consumption, however, the effects of building design, thermal mass, and climate, among other factors, must be included.

R-value is an estimate of the overall steady-state resistance to heat transfer. It is determined in the laboratory by applying a constant temperature difference across a wall section, then measuring the steady state heat flow through the wall under this condition. For design, calculation methods have been developed to aid in determining R-values of various building systems (ref. 1).

The thermal mass of concrete masonry walls can significantly reduce energy consumption. Thermal mass effects are determined primarily by the properties of the construction materials used, the climate, building type, and the position of the insulation within the wall. Concrete masonry buildings often require significantly lower insulation levels because of thermal mass. Energy codes and standards such as ASHRAE Standards 90.1 and 90.2 (refs. 4, 5) and the *International Energy Conservation Code* (ref. 6) permit concrete masonry walls to have lower R-values than frame wall systems to achieve the same level of energy efficiency.

Concrete masonry cavity walls provide a wide array of options for including insulation to obtain high R-values. Typically, the cavity is insulated with rigid board or with mineral loose-fill insulation. Cavity walls are also built with insulation in the cores of masonry units leaving the entire cavity space open for drainage. In addition, furring with rigid board or mineral fiber batt insulation can be installed on the interior side of the wall to further increase wall R-values.

Placing insulation between two wythes of masonry offers maximum protection for the insulation. High R-values are easily obtainable, since the cavity installation allows a continuous layer of insulation to envelop the masonry. This continuous insulation layer can also reduce heat loss due to air infiltration into the building.

CAVITY WALLS

Typical cavity walls are constructed with a 4, 6, 8, or 12 in. (102, 152, 203, or 305 mm) concrete masonry backup wythe, a 2 to 4½ in. (51 to 114 mm) wide cavity, and a 4 in. (102 mm) masonry veneer. *Building Code Requirements for Masonry Structures* (ref. 3) allows cavity widths up to 4½ in. (114 mm), beyond which a detailed wall tie analysis must be performed.

When placing rigid board insulation in the cavity, a minimum 1 in. (25 mm) clear airspace (2 in. (51 mm) is preferred) between the insulation and the outer wythe is recommended to ensure proper drainage in the event water enters the wall. Perlite and vermiculite loose fills can occupy the entire cavity space since these materials allow water to drain freely through them. For this reason, these insulation materials are typically treated for water repellency. When loose fill insulation is used, screens placed over the weep holes or wicks should be used to contain the fill while allowing water to drain freely out of the weep holes.

R-VALUE TABLES

Table 1 presents R-values of uninsulated concrete masonry cavity walls with 4, 6, 8, and 12 in. (102, 152, 203, and 305 mm) backup wythes and 4 in. (102 mm) concrete masonry veneer. These R-values should be added to the applicable R-values in Tables 2 and 3 to account for cavity insulation and/or interior furring with insulation. Table 4 contains the thermal data used to develop the tables.

As an example, to determine the R-value of a concrete masonry cavity wall with 8 in. (152 mm) 105 pcf (1682 kg/m^3) backup insulated with 2 in. (51 mm) of extruded polystyrene insulation in the cavity, first determine the R-value of the uninsulated wall from Table 1 (4.0 ft$^2 \cdot$hr$\cdot$°F/Btu, 0.70 m$^2 \cdot$K/W), then add the cavity insulation R-value from Table 2 (10 ft$^2 \cdot$hr$\cdot$°F/Btu, 1.8 m$^2 \cdot$K/W), to obtain the total R-value of 14.0 ft$^2 \cdot$hr$\cdot$°F/Btu (2.5 m$^2 \cdot$K/W).

Calculations are performed using the series-parallel (also called isothermal planes) calculation method recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (refs. 1, 8). The method accounts for the thermal bridging that occurs through the webs of concrete masonry units and is briefly described on the following page.

Thermal values for concrete masonry walls are correlated to density, since the thermal conductivity of concrete increases with increasing concrete density. For each density, Table 1 lists a range of R-values as well as a single value, which represents the middle of the range.

A range of thermal values is appropriate for concrete products because the thermal conductivity of concrete cannot always be accurately estimated from density alone. The thermal conductivity of concrete varies with aggregate type(s) used in the concrete mix, the mix design, moisture content, etc.

These published values reflect a compendium of historical data on thermal conductivity of concrete (refs. 1, 9). Locally available products and local conditions may result in thermal values which fall outside of this range. The middle-of-the-range values are presented for use in cases where more accurate values are not available from local manufacturers.

The values in Table 1 are based on an ungrouted backup wythe. However, the addition of grout to a hollow concrete masonry backup wythe does not significantly affect the overall R-value of an insulated cavity wall. For example, the R-value of a cavity wall with 8 in. (203 mm) ungrouted 105 pcf (1682 kg/m^3) backup and 2 in. (51 mm) of perlite in the cavity is 9.3 hr·ft^2·°F/Btu (1.72 m^2·K/W). When the backup wythe is grouted solid, the R-value becomes 8.8 hr·ft^2·°F/Btu (1.67 m^2·K/W), a decrease of about 5 percent.

Table 1—R-Values of Uninsulated Cavity Walls With 4 in. Concrete Masonry Veneer (ft^2·hr·°F/Btu)[a]

Nominal thickness of backup, in.	Density of concrete used in concrete masonry backup unit (pcf): 85		95		105		115		125		135	
	range	mid	range	mid	range	mid	range	mid	range	mid	range	mid
4	3.8-4.1	3.9	3.7-4.0	3.8	3.6-3.9	3.7	3.5-3.8	3.6	3.4-3.7	3.5	3.3-3.6	3.4
6	4.1-4.3	4.2	3.9-4.2	4.0	3.8-4.1	3.9	3.7-3.9	3.8	3.5-3.8	3.7	3.4-3.7	3.5
8	4.2-4.5	4.4	4.1-4.4	4.2	3.9-4.2	4.0	3.8-4.1	3.9	3.7-4.0	3.8	3.6-3.9	3.7
10	4.3-4.7	4.5	4.2-4.5	4.3	4.0-4.3	4.1	3.8-4.2	4.0	3.8-4.0	3.8	3.6-4.0	3.8
12	4.4-4.8	4.6	4.2-4.6	4.4	4.1-4.4	4.2	4.0-4.3	4.1	3.8-4.2	4.0	3.7-4.0	3.8

[a] (ft^2·hr·°F/Btu)(0.176) = m^2·K/W. Includes a minimum 1 in. (25 mm) nonreflective air space. Mortar joints are assumed to be 3/8 in. (9.5 mm) thick, with full mortar bedding on 4 in. (102 mm) units, and face shell bedding on hollow backup units.

Table 2—R-Values of Cavity Insulation[a]

Insulation type	Insulation thickness, in.	R-value (hr·ft^2·°F/Btu)
Vermiculite loose fill	1	1.3
	2	3.6
	3	5.8
	4 1/2	9.3
Perlite loose fill	1	2.2
	2	5.3
	3	8.4
	4 1/2	13.1
Extruded polystyrene[b]	1	5.0
	1 1/2	7.5
	2	10.0
	2 1/2	12.5
	3	15.0
	3 1/2	17.5
Polyisocyanurate[c]	1	8.7
	1 1/2	12.3
	2	15.8
	2 1/2	19.3
	3	22.8
	3 1/2	26.3

[a] These values should be added to the values presented in Table 1 to achieve the total R-value of an insulated cavity wall.
[b] A minimum 1 in. (25 mm) nonreflective air space is included in the values in Table 1.
[c] Values adjusted to include a 1 in. (25 mm) reflective air space.

Table 3—R-Values of Finish Systems[a]

System:	R-value (hr·ft^2·°F/Btu)	
1/2 in. gypsum board on furring	1.4	
1/2 in. foil-faced gypsum board on furring	2.9	
Wood furring, insulation, and 1/2 in. gypsum wallboard:	**Spacing of furring strips: 16 in. o.c.**	**24 in. o.c.**
3/4 in. extruded polystyrene[b]	5.2	5.2
3/4 in. polyisocyanurate[c]	8.0	8.1
1 1/2 in. extruded polystyrene[b]	8.9	8.9
1 1/2 in. polyisocyanurate[c]	13.2	13.4
R-11 mineral fiber batt	9.6	10.2
R-13 mineral fiber batt	10.8	11.6
R-15 mineral fiber batt	11.9	12.9
R-19 mineral fiber batt	15.9	16.9
R-21 mineral fiber batt	17.1	18.3
Metal furring, insulation, and 1/2 in. gypsum wallboard[d]:		
R-11 mineral fiber batt	6.0	7.1
R-13 mineral fiber batt	6.5	7.7
R-15 mineral fiber batt	6.9	8.3
R-19 mineral fiber batt	7.6	9.1
R-21 mineral fiber batt	7.9	9.5

[a] Values should be added to those presented in Table 1 to achieve the total R-value of a cavity wall with a finish applied.
[b] Values include a 3/4 in. (19 mm) nonreflective air space.
[c] Values include a 3/4 in. (19 mm) reflective air space.
[d] Values from ref. 4, Appendix A.

R-VALUE CALCULATION

For estimating R-values of concrete masonry walls, the series-parallel calculation method is recommended (refs. 1, 8). The series-parallel calculation treats the block as a series of thermal layers, as illustrated in Figure 1. The face shells form continuous outer layers, which are in series with the layer containing webs and cores. The webs and cores form parallel paths for heat flow within this thermal layer. The total R-value, R_T, of the block is the sum of the R-values of each layer, as outlined below. Note: When the core is partially filled (i.e. when using insulation inserts), break the core into multiple layers.

$$R_T = R_i + \frac{R_f R_m}{a_f R_m + a_m R_f} + \frac{R_w R_c}{a_c R_w + a_w R_c} + R_a + R_v + R_o$$

where:

- a_c = fractional web area, Figure 1, Section A-A
- a_f = fractional face shell area, Figure 1, elevation
- a_m = fractional mortar joint area, Figure 1, elevation
- a_w = fractional core area, Figure 1, Section A-A
- R_a = thermal resistance of cavity
- R_c = thermal resistance of cores
- R_f = thermal resistance of both face shells, r_c x ($2t_{fs}$)
- R_i = thermal resistance of inside air surface film
- R_m = thermal resistance of mortar joint, r_m x ($2t_{fs}$)
- R_o = thermal resistance of outside air surface film
- R_T = total thermal resistance of wall
- R_v = thermal resistance of veneer
- R_w = thermal resistance of concrete webs, r_c x t_w
- r_c = thermal resistivity of concrete
- r_m = thermal resistivity of mortar
- t_{fs} = face shell thickness
- t_w = length of concrete webs

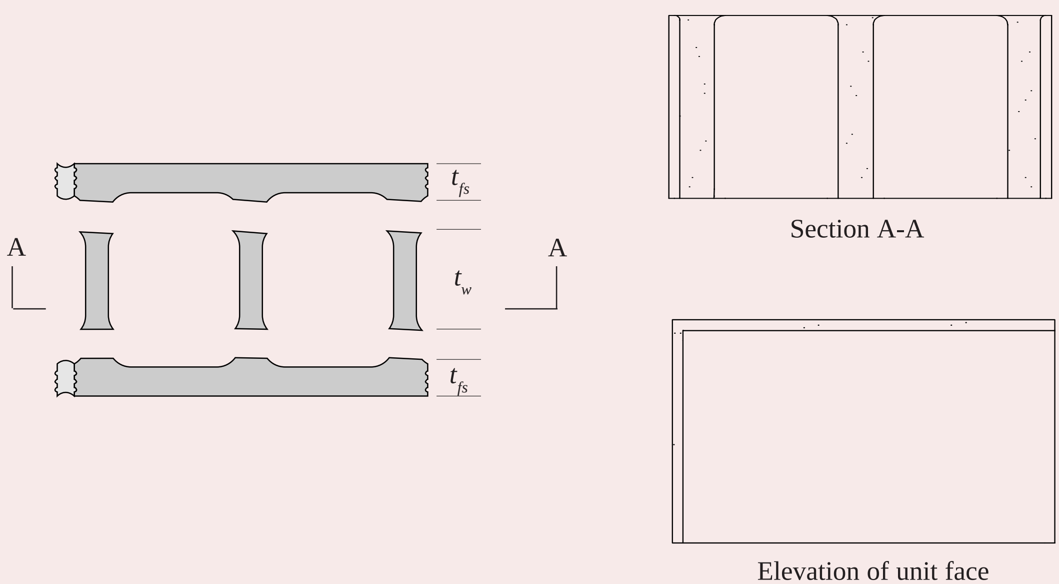

Figure 1—Thermal Model of Concrete Masonry Units for R-Value Calculation

Table 4—Thermal Data Used to Develop Tables

Material:	Thermal resistivity (hr·ft^2·°F/Btu·in)
Vermiculite	2.27
Perlite	3.13
Extruded polystyrene	5.00
Cellular polyisocyanurate, gas-impermeable facer	7.04
Concrete:	
85 pcf	0.23-0.34
95 pcf	0.18-0.28
105 pcf	0.14-0.23
115 pcf	0.11-0.19
125 pcf	0.08-0.15
135 pcf	0.07-0.12
Mortar	0.20

Material:	R-value (hr·ft^2·°F/Btu)
1/2 in. gypsum wallboard	0.45
Surface air films:	
inside	0.68
outside	0.17
Air spaces:	
nonreflective	0.97
reflective	2.67
4 in. concrete masonry exterior wythe	0.84

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