Table IV.12 – Properties of Hollow Unit Masonry Walls

			Partly Grouted with Ungrouted Cells								
			Solid Grout			Empty			Insulated		
Thickness	Type		A			B			C		
		1	U-factor	C-factor	HC	U-factor	C-factor	HC	U-factor	C-factor	HC
12"	LW CMU	2	0.51	0.90	23	0.43	0.68	14.8	0.30	0.40	14.8
	MW CMU	3	0.54	1.00	23.9	0.46	0.76	15.6	0.33	0.46	15.6
	NW CMU	4	0.57	1.11	24.8	0.49	0.84	16.5	0.36	0.52	16.5
10"	LW CMU	5	0.55	1.03	18.9	0.46	0.76	12.6	0.34	0.48	12.6
	MW CMU	6	0.59	1.18	19.7	0.49	0.84	13.4	0.37	0.54	13.4
	NW CMU	7	0.62	1.31	20.5	0.52	0.93	14.2	0.41	0.63	14.2
8"	LW CMU	8	0.62	1.31	15.1	0.50	0.87	9.9	0.37	0.54	9.9
	MW CMU	9	0.65	1.45	15.7	0.53	0.96	10.5	0.41	0.63	10.5
	NW CMU	10	0.69	1.67	16.3	0.56	1.07	11.1	0.44	0.70	11.1
	Clay Unit	11	0.57	1.11	15.1	0.47	0.78	11.4	0.39	0.58	11.4
6"	LW CMU	12	0.68	1.61	10.9	0.54	1.00	7.9	0.44	0.70	7.9
	MW CMU	13	0.72	1.86	11.4	0.58	1.14	8.4	0.48	0.81	8.4
	NW CMU	14	0.76	2.15	11.9	0.61	1.27	8.9	0.52	0.93	8.9
	Clay Unit	15	0.65	1.45	11.1	0.52	0.93	8.6	0.45	0.73	8.6

The walls addressed in this table are rarely used in residential construction, but are common in some types of nonresidential construction. The tables include four types of hollow masonry units: lightweight concrete masonry units (CMU), medium weight CMU, normal weight CMU, and hollow clay masonry units. ASTM C-90 defines these masonry products in more detail.

Masonry used in California must be reinforced to withstand wind loads and earthquakes. This is achieved by installing reinforcing steel and grouting the cells in both a vertical and horizontal direction. Since grouting the cells affects thermal performance, data is provided for three cases: where every cell is grouted, where the cells are partially grouted and the remaining cells are left empty, and where the cells are partially grouted and the remaining cells are filled with perlite or some other insulating material.

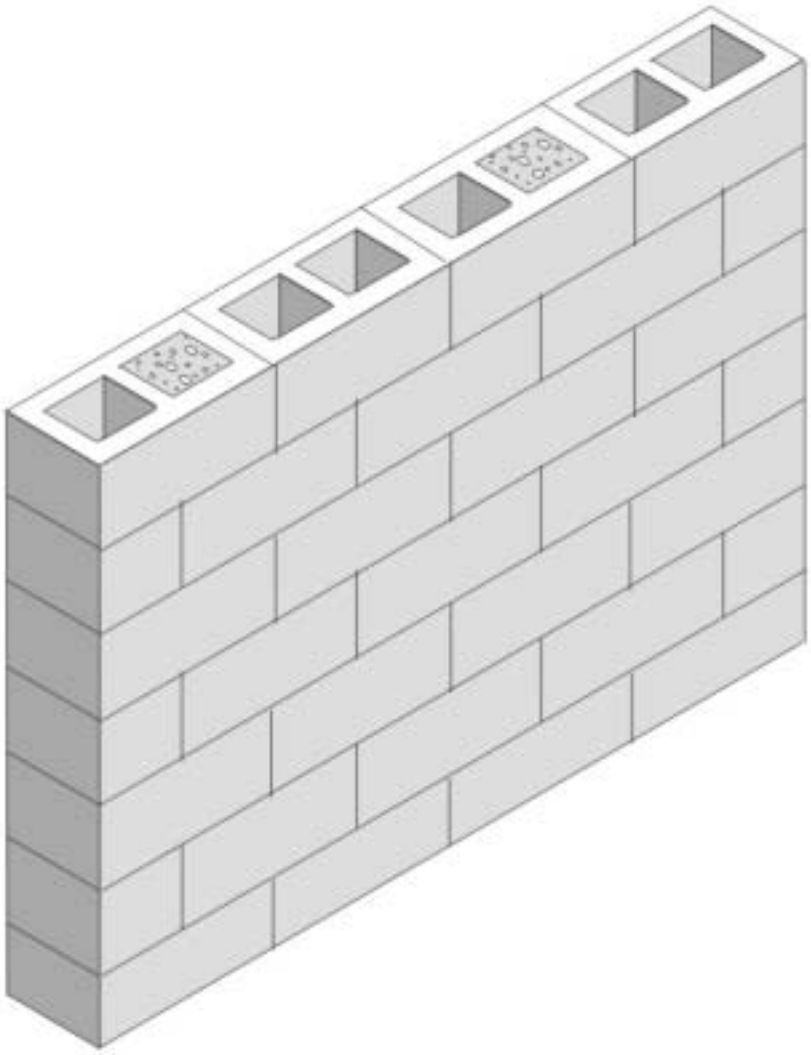

Figure IV.12 – Masonry Wall

For each of these conditions the U-factor, C-factor and heat capacity (HC) is published. There are other properties of mass materials that may be needed in compliance calculations, but these values can be determined from the published data using the procedures in Modeling Constructions in the Nonresidential ACM contained at the end of this appendix.

Assumptions: Data is taken from *Energy Calculations and Data*, CMACN, 1986, Berkeley Solar Group; Concrete Masonry Association of California and Nevada. The density of the CMU material (not counting the grouted or hollow cells) is 105 lb/ft³ for lightweight, 115 lb/ft³ for medium weight and 125 lb/ft³ for normal weight. The density of the clay unit material is 130 lb/ft³. For all four types of masonry units, data is provided for thicknesses of 6 in., 8 in., 10 in., and 12 in. For the partially grouted cases, vertical cells are assumed to be grouted at 32 in. OC. Reinforcing in the horizontal direction is at 48 in. OC. Wall thicknesses given in the table are nominal; actual thicknesses are 3/8 in. less. Insulating material inside unit masonry hollow is assumed to be perlite.

Table IV.13 – Properties of Solid Unit Masonry and Solid Concrete Walls

			Wall Thickness, inches									
			3	4	5	6	7	8	9	10	11	12
Type	**Property**		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
LW CMU	U-Factor		na	0.71	0.64	na	na	na	na	na	na	na
	C-Factor	**1**	na	1.79	1.40	na	na	na	na	na	na	na
	HC		na	7.00	8.75	na	na	na	na	na	na	na
MW CMU	U-Factor		na	0.76	0.70	na	na	na	na	na	na	na
	C-Factor	**2**	na	2.15	1.73	na	na	na	na	na	na	na
	HC		na	7.67	9.58	na	na	na	na	na	na	na
NW CMU	U-Factor		0.89	0.82	0.76	na	na	na	na	na	na	na
	C-Factor	**3**	3.66	2.71	2.15	na	na	na	na	na	na	na
	HC		6.25	8.33	10.42	na	na	na	na	na	na	na
Clay Brick	U-Factor		0.80	0.72	0.66	na	na	na	na	na	na	na
	C-Factor	**4**	2.50	1.86	1.50	na	na	na	na	na	na	na
	HC		6.30	8.40	10.43	na	na	na	na	na	na	na
Concrete	U-Factor		0.96	0.91	0.86	0.82	0.78	0.74	0.71	0.68	0.65	0.63
	C-Factor	**5**	5.22	4.02	3.20	2.71	2.31	1.99	1.79	1.61	1.45	1.36
	HC		7.20	9.60	12.00	14.40	16.80	19.20	21.60	24.00	26.40	28.80

This table provides thermal performance information for solid masonry units and solid concrete walls.

The walls addressed in this table are rarely used in residential construction, but are common in some types of nonresidential construction. The tables include four types of hollow masonry units: lightweight concrete masonry units (CMU), medium weight CMU, normal weight CMU, and hollow clay masonry units. ASTM C-90 defines these masonry products in more detail.

Masonry used in California must be reinforced to withstand wind loads and earthquakes. This is achieved by installing reinforcing steel and grouting the cells in both a vertical and horizontal direction. Since grouting the cells affects thermal performance, data is provided for three cases: where every cell is grouted, where the cells are partially grouted and the remaining cells are left empty, and where the cells are partially grouted and the remaining cells are filled with perlite or some other insulating material.

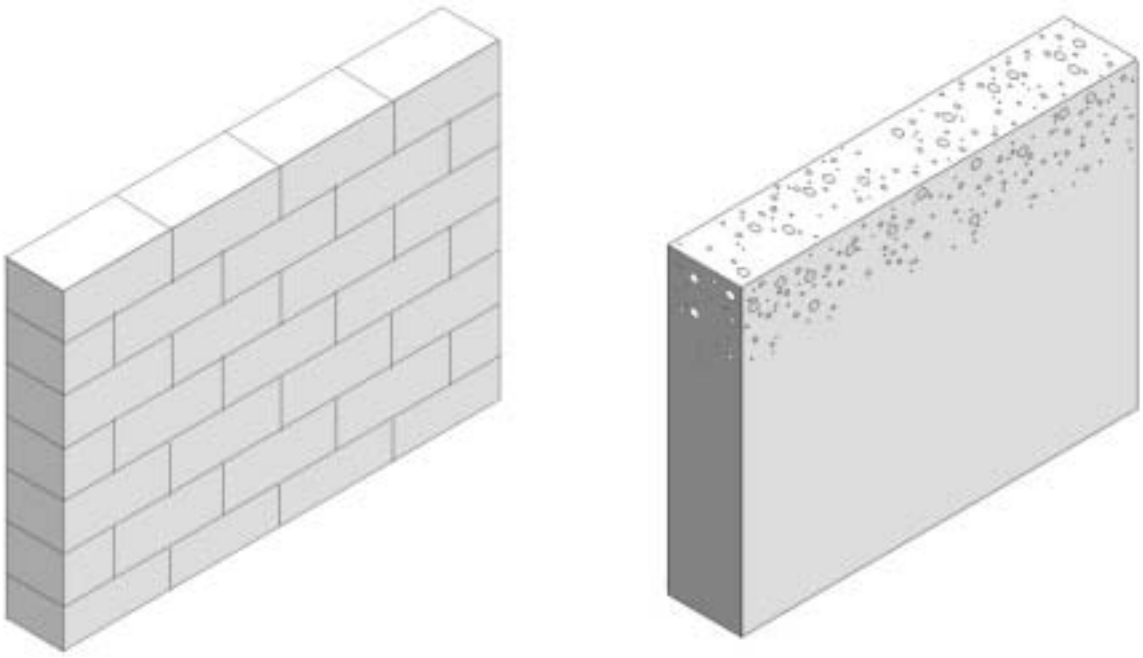

Figure IV.13 – Solid Unit Masonry (left) and Solid Concrete (right) Walls

For each of these conditions the U-factor, C-factor and heat capacity (HC) is published. There are other properties of mass materials that may be needed in compliance calculations, but these values can be determined from the published data using the procedures in Modeling Constructions in the Nonresidential ACM contained at the end of ACM Joint Appendix IV.

When insulation is added to the outside of masonry walls and/or when the inside is furred and insulated, the performance data in this table may be adjusted using Equation IV-4 and Equation IV-5.

Assumptions: Data is taken from *Energy Calculations and Data*, CMACN, 1986, Berkeley Solar Group; Concrete Masonry Association of California and Nevada. The density of the CMU material is 105 lb/ft^3 for lightweight, 115 lb/ft^3 for medium weight and 125 lb/ft^3 for normal weight. The density of the clay unit material is 130 lb/ft^3 and the density of the concrete is 144 lb/ft^3. For all four types of masonry units, data is provided for thicknesses of 3 in., 4 in., and 5 in. ASTM C-90 provides more information on the classification of masonry walls.

Table IV.14 – Properties of Concrete Sandwich Panels

Percent Concrete Web	Steel Penetrates Insulation	Performance Factor		Insulation Thickness (R-value)				
				1.5 (7.0)	**2.0 (9.3)**	**3.0 (14.0)**	**4.0 (18.6)**	**6.0 (27.9)**
				A	**B**	**C**	**D**	**E**
0%	No	U-factor		0.122	0.095	0.066	0.051	0.034
		C-factor	**1**	0.136	0.104	0.070	0.053	0.035
		HC		16.13	16.13	16.13	16.13	16.13
	Yes	U-factor		0.164	0.128	0.091	0.070	0.048
		C-factor	**2**	0.190	0.144	0.099	0.074	0.050
		HC		16.13	16.13	16.13	16.13	16.13
10%	No	U-factor		0.476	0.435	0.345	0.286	0.217
		C-factor	**3**	0.800	0.690	0.488	0.377	0.267
		HC		16.53	16.66	16.93	17.20	17.74
	Yes	U-factor		0.500	0.435	0.357	0.303	0.227
		C-factor	**4**	0.870	0.690	0.513	0.408	0.282
		HC		16.53	16.66	16.93	17.20	17.74
20%	No	U-factor		0.588	0.556	0.476	0.417	0.333
		C-factor	**5**	1.176	1.053	0.800	0.645	0.465
		HC		16.93	17.20	17.74	18.28	19.35
	Yes	U-factor		0.588	0.556	0.476	0.417	0.333
		C-factor	**6**	1.176	1.053	0.800	0.645	0.465
		HC		16.93	17.20	17.74	18.28	19.35

This table provides U-factors, C-factors, and heat capacity (HC) data for concrete sandwich panels. Concrete sandwich panels, as the name suggests, consist of two layers of concrete that sandwich a layer of insulation. The wall system can be constructed in the field or in a factory. One method of field construction is where the wall panels are formed in a flat position using the concrete floor slab of the building as the bottom surface. After the panel has set, it is hoisted with a crane into its final vertical position.

Both the percent of concrete web and the percent steel are factors in determining the thermal performance of walls. The insulation layer in this type of concrete sandwich panel generally does not extend over the entire surface of the wall. To provide structural integrity, a certain portion of the wall is solid concrete, which ties together the two concrete layers. This portion is known as the concrete web. The thermal performance of concrete sandwich panels depends on the percent of the wall that is concrete web. Data is provided for concrete webs representing 0%, 10% and 20% of the opaque wall surface. In some cases, the concrete layers are tied together by structural steel that penetrates the insulation layer. Data is provided for the case where this steel is present and for cases where it is not.

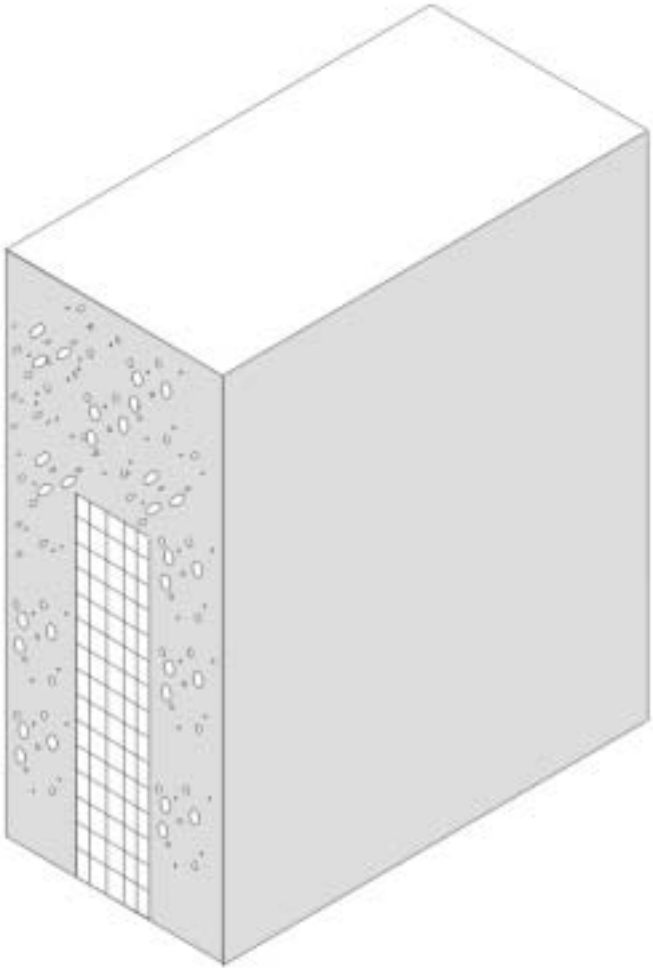

Figure IV.14 – Concrete Sandwich Panel

Other properties of mass materials such as density, conductivity, specific heat and wall weight may be needed in compliance calculations and these properties may be determined from the published data using the procedures in Modeling Constructions in the Nonresidential ACM contained at the end of this ACM Joint Appendix IV.

Values from this table may be combined with values from Table IV.14 when a furring layer is added to the inside of the wall and/or continuous insulation is added to the outside of the wall. Adjustments for additional layers shall follow the procedure of Equation IV-4 and Equation IV-5.

Assumptions. U-factors include an inside air film of 0.68 and an exterior air film of 0.17. Conductivity of the concrete is assumed to be 0.215 Btu/h-ºF-f, density is 150 lb/ft³, the thickness of each side of the sandwich panel is 0.5 ft. The data was calculated by Construction Technologies Laboratories, Inc. and published in the Thermal Mass Handbook, Concrete and Masonry Design Provisions Using ASHRAE/IESNA 90.1-1989, National Codes and Standards Council of the Concrete and Masonry Industries, 1994.

Table IV.15 – U-factors for Spandrel Panels and Glass Curtain Walls

			Rated R-value of Insulation							
			None	R-4	R-7	R-10	R-15	R-20	R-25	R-30
Frame Type	**Spandrel Panel**		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Aluminum without Thermal Break	Single glass pane, stone, or metal panel	**1**	0.558	0.331	0.287	0.265	0.244	0.233	0.226	0.221
	Double glass with no low-e coatings	**2**	0.442	0.310	0.277	0.259	0.241	0.231	0.224	0.220
	Triple or low-e glass	**3**	0.377	0.294	0.268	0.253	0.238	0.229	0.223	0.219
Aluminum With Thermal Break	Single glass pane, stone, or metal panel	**4**	1.012	0.935	0.920	0.912	0.905	0.902	0.899	0.897
	Double glass with no low-e coatings	**5**	0.973	0.928	0.917	0.910	0.904	0.901	0.899	0.897
	Triple or low-e glass	**6**	0.951	0.922	0.914	0.909	0.903	0.900	0.898	0.897
Structural Glazing	Single glass pane, stone, or metal panel	**7**	0.514	0.271	0.224	0.200	0.178	0.166	0.158	0.153
	Double glass with no low-e coatings	**8**	0.390	0.249	0.213	0.194	0.175	0.164	0.157	0.152
	Triple or low-e glass	**9**	0.321	0.231	0.204	0.188	0.172	0.162	0.156	0.151
No framing or Insulation is Continuous	Single glass pane, stone, or metal panel	**10**	0.558	0.173	0.114	0.085	0.060	0.046	0.037	0.031
	Double glass with no low-e coatings	**11**	0.442	0.160	0.108	0.082	0.058	0.045	0.037	0.031
	Triple or low-e glass	**12**	0.377	0.150	0.104	0.079	0.057	0.044	0.036	0.031

This table has U-factors for the spandrel section of glass and other curtain wall systems. Design factors that affect performance are the type of framing, the type of spandrel panel and the R-value of insulation.

Four framing conditions are considered in the table. The first is the common case where standard aluminum mullions are used. Standard mullions provide a thermal bridge through the insulation, reducing its effectiveness. The second case is for metal framing members that have a thermal break. A thermal break frame uses a urethane or other non-metallic element to separate the metal exposed to outside conditions from the metal that is exposed to interior conditions. The third case is for structural glazing or systems where there is no exposed mullion on the interior. The fourth case is for the condition where there is no framing or the insulation is continuous and uninterrupted by framing. The continuous insulation section of the table may be used for any situation where the insulation is continuous, including framed curtain walls, metal spandrel panels or other situations.