Table 2.1 Typical Thermal Properties of Common Building Materials—Design Value[a]

Description	*Density, lb/ft³*	*Conductivity[b] (k), Btu-in./ h-ft²-°F*	*Conductance (C), Btu/ h-ft²-°F*	*Resistance[c] (R)*	
				Per Inch Thickness (1/k), °F-ft²-h/ Btu-in.	*For Thickness Listed (1/C), °F-ft²-h/ Btu*
BUILDING BOARD					
Asbestos-cement board	120	4.0	—	0.25	—
Asbestos-cement board, 0.25 in.	120	—	16.50	—	0.06
Gypsum or plaster board, 0.5 in.	50	—	2.22	—	0.45
Plywood (Douglas fir)	34	0.80	—	1.25	—
Plywood (Douglas fir), 0.375 in.	34	—	2.13	—	0.47
Plywood (Douglas fir), 0.5 in.	34	—	1.60	—	0.62
Plywood (Douglas fir), 0.625 in.	34	—	1.29	—	0.77
Vegetable fiber board					
Sheathing, regular density, 0.5 in.	18	—	0.76	—	1.32
Shingle backer, 0.375 in.	18	—	1.06	—	0.94
Sound deadening board, 0.5 in.	15	—	0.74	—	1.35
Tile & lay-in panels, plain or acoustic	18	0.40	—	2.50	—
0.5 in.	18	—	0.80	—	1.25
0.75 in.	18	—	0.53	—	1.89
Hardboard[e]					
Medium density	50	0.73	—	1.37	—
High-density, service-tempered grade & service grade	55	0.82	—	1.22	—
Particleboard[e]					
Medium density	50	0.94	—	1.06	—
High density	62.5	1.18	—	0.85	—
Underlayment, 0.625 in.	40	—	1.22	—	0.82
Wood subfloor, 0.75 in.	—	—	1.06	—	0.94
BUILDING MEMBRANE					
Vapor—permeable felt	—	—	16.70	—	0.06
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12
Vapor—seal, plastic film	—	—	—	—	Negl.
FINISH FLOORING MATERIALS					
Carpet & fibrous pad	—	—	0.48	—	2.08
Carpet & rubber pad	—	—	0.81	—	1.23
Cork tile, 0.125 in.	—	—	3.60	—	0.28
Terrazzo, 1 in.	—	—	12.50	—	0.08
Tile-asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05
Wood, hardwood finish, 0.75 in.	—	—	1.47	—	0.68
INSULATING MATERIALS					
Blanket and batt[e]					
Mineral fiber, fibrous form processed from rock, slag, or glass					
approx. 3–4 in.	0.4–2.0	—	0.091	—	11
approx. 3.5 in.	1.2–1.6	—	0.067	—	15
approx. 5.5–6.5 in.	0.4–2.0	—	0.053	—	19
approx. 6–7.6 in.	0.4–2.0	—	0.045	—	22
approx. 8.25–10 in.	0.4–2.0	—	0.033	—	30
approx. 10–13 in.	0.4–2.0	—	0.026	—	38
Board and Slabs					
Cellular glass	8.0	0.33	—	3.03	—
Glass fiber, organic bonded	4.0–9.0	0.25	—	4.00	—

Table 2.1 *(Continued)*

Description	*Density, lb/ft³*	*Conductivity[b] (k), Btu-in./ h-ft²-°F*	*Conductance (C), Btu/ h-ft²-°F*	*Resistance[c] (R)* *Per Inch Thickness (1/k), °F-ft²-h/ Btu-in.*	*Resistance[c] (R)* *For Thickness Listed (1/C), °F-ft²-h/ Btu*
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—
	1.5	0.24	—	4.17	—
	2.0	0.23	—	4.35	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—
Mineral fiberboard, wet felted					
Core or roof insulation	16–17	0.34	—	2.94	—
Acoustical tile	18.0	0.35	—	2.86	—
Acoustical tile	21.0	0.37	—	2.70	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—
Cement fiber slabs (shredded wood with Portland cement binder)	25.0–27.0	0.50–0.53	—	2.0–1.89	—
Loose Fill					
Cellulosic insulation (milled paper or wood pulp)	2.3–3.2	0.27–0.32	—	3.70–3.13	—
Perlite, expanded	2.0–4.1	0.27–0.31		3.7–3.3	—
	4.1–7.4	0.31–0.36	—	3.3–2.8	—
	7.4–11.0	0.36–0.42	—	2.8–2.4	—
Mineral fiber (rock, slag or glass)[e]					
approx. 3.75–5 in.	0.6–2.0	—	—	—	11.0
approx. 6.5–8.75 in.	0.6–2.0	—	—	—	19.0
approx. 10.25–13.75	0.6–2.0	—	—	—	22.0
Spray Applied				—	30.0
Polyurethane foam	1.5–2.5	0.16–0.18	—	6.25–5.56	—
Cellulosic fiber	3.5–6.0	0.29–0.34	—	3.45–2.94	—
Glass fiber	3.5–4.5	0.26–0.27	—	3.85–3.70	—
ROOFING					
Asbestos-cement shingles	120	—	4.76	—	0.21
Asphalt roll roofing	70	—	6.50	—	0.15
Asphalt shingles	70	—	2.27	—	0.44
Built-up roofing, 0.374 in.	70	—	3.00	—	0.33
Slate, 0.5 in.	—	—	20.00	—	0.05
Wood shingles, plain & plastic film faced	—	—	1.06	—	0.94
PLASTERING MATERIALS					
Cement plaster, sand aggregate	116	5.0	—	0.20	—
Gypsum plaster:					
Lightweight aggregate, 0.5 in.	45	—	3.12	—	0.32
Lightweight aggregate on metal lath, 0.75 in.	—	—	2.13	—	0.47
Perlite aggregate	45	1.5	—	0.67	—
Sand aggregate	105	5.6	—	0.18	—
Sand aggregate on metal lath, 0.75 in.	—	—	7.70	—	0.13
Vermiculite aggregate	45	1.7	—	0.59	—
MASONRY MATERIALS					
Masonry Units					
Brick, fired clay	150	8.4–10.2	—	0.12–0.10	—
	100	4.2–5.1	—	0.24–0.20	—
				0.40–0.33	—

Table 2.1 *(Continued)*

Description	Density, lb/ft³	Conductivity[b] (k), Btu-in./h-ft²-°F	Conductance (C), Btu/h-ft²-°F	Resistance[c] (R) Per Inch Thickness (1/k), °F-ft²-h/Btu-in.	Resistance[c] (R) For Thickness Listed (1/C), °F-ft²-h/Btu
Concrete blocks					
Normal weight aggregate (sand & gravel)					
8 in., 33–36 lb, 126–136 lb/ft³ concrete,					
2 or 3 cores	—	—	0.90–1.03	—	1.11–0.97
Same with verm.-filled cores	—	—	0.52–0.73	—	1.92–1.37
12 in., 50 lb, 125 lb/ft³ concrete,					
2 cores	—	—	0.81	—	1.23
Lightweight aggregate (expanded shale, clay, slate or slag pumice)					
6 in., 16–17 lb, 85–87 lb/ft³ concrete,					
2 or 3 cores	—	—	0.52–0.61	—	1.93–1.65
Same with perlite-filled cores	—	—	0.24	—	4.2
Same with verm.-filled cores	—	—	0.33	—	3.0
8 in., 19–22 lb, 72–86 lb/ft³					
concrete	—	—	0.32–0.54	—	3.2–1.90
Same with perlite-filled cores	—	—	0.15–0.23	—	6.8–4.4
Same with verm.-filled cores	—	—	0.19–0.26	—	5.3–3.9
12 in., 32–36 lb, 80–90 lb/ft³ concrete,					
2 or 3 cores	—	—	0.38–0.44	—	2.6–2.3
Same with verm.-filled cores	—	—	0.17	—	5.8
Gypsum partition tile					
3 by 12 by 30 in., solid	—	—	0.79	—	1.26
Concretes					
Sand & gravel or stone aggregate concretes	150	10.0–20.0	—	0.10–0.05	—
Lightweight aggregate concretes					—
Expanded shale, clay, or slate;					—
expanded slags; cinders; pumice					—
(with density up to 100 lb/ft³)	100	4.7–6.2	—	0.21–0.16	—
	80	3.3–4.1	—	0.30–0.24	—
	40	1.3	—	0.78	—
Perlite, vermiculite, and					
polystyrene beads	50	1.8–1.9	—	0.55–0.53	—
	30	1.1	—	0.91	—
Foam concretes	120	5.4	—	0.19	–
	80	3.0	—	0.33	—
Foam concretes and cellular					
concretes	40	1.4	—	0.71	—
SIDING MATERIALS (on flat surface)					
Shingles					
Asbestos-cement	120	—	4.75	—	0.21
Wood, plus insulation backer					
board, 0.3125 in.	—	—	0.71	—	1.40
Siding					
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21
Asphalt insulating siding					
(0.5 in. bed)	—	—	0.69	—	1.46
Wood, bevel, 0.5 × 8 in. lapped	—	—	1.23	—	0.81
Aluminum or Steel[g] over sheathing					
Insulating-board backed nominal					
0.375 in.	—	—	0.55	—	1.82

Table 2.1 *(Continued)*

Description	Density, lb/ft³	Conductivity[b] (k), Btu-in./h-ft²-°F	Conductance (C), Btu/h-ft²-°F	Resistance[c] (R) Per Inch Thickness (1/k), °F-ft²-h/Btu-in.	Resistance[c] (R) For Thickness Listed (1/C), °F-ft²-h/Btu
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96
Architectural (soda-lime float) glass	158	6.9	—	—	—
WOODS (12% moisture content)					
Hardwoods					
Oak	41.2–46.8	1.12–1.25	—	0.89–0.80	—
Birch	42.6–45.4	1.16–1.22	—	0.87–0.82	—
Maple	39.8–44.0	1.09–1.19	—	0.92–0.84	—
Ash	38.4–41.9	1.06–1.14	—	0.94–0.88	—
Softwoods					
Southern pine	35.6–41.2	1.00–1.12	—	1.00–0.89	—
Douglas fir–larch	33.5–36.3	0.95–1.01	—	1.06–0.99	—
Southern cypress	31.4–32.1	0.90–0.92	—	1.11–1.09	—
Hem–fir, spruce–pine–fir	24.5–31.4	0.74–0.90	—	1.35–1.11	—
West Coast woods, cedars	21.7–31.4	0.68–0.90	—	1.48–1.11	—
California redwood	24.5–28.0	0.74–0.82	—	1.35–1.22	—

[a] Values are for a mean temperature of 75°F (24°C). Representative values for dry materials are intended as design (not specification) values for materials in normal use. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

[b] To obtain thermal conductivities in Btuh-ft-°F, divide the *K*-factor by 12 in./ft.

[c] Resistance values are the reciprocals of *C* before rounding off *C* to two decimal places.

[d] Does not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an air space, see Tables 2.3 and 2.6 for insulating value of an air space with the appropriate effective emittance and temperature conditions of the space.

[e] Conductivity varies with fiber diameter. Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed here.

[f] Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

[g] Values for metal siding applied over flat surfaces vary widely.

Source. Data reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, from the 1993 *ASHRAE Handbook—Fundamentals.*

common insulating material and a common construction material. See also Table 2.2 for a summary of the terms that relate to heat transfer by conduction.

2.3 Convection

As described in Section 1.8, convection is a heat transfer mechanism that relies on fluid flow to carry the heat from one place to another. Although convective currents can occur in any fluid, convective heat transfer in building work is caused by air movement. The basic natural, or free convective flow is illustrated in Figure 1.5. (Forced convection, as illustrated in Figure 1.6, is not under discussion here.) This same natural convection occurs at a cold window in a heated room. See Figure 2.3 *(a)*. The cold outside air reduces the temperature of the inside surface of the window (by conduction). This in turn cools the layer of air immediately adjacent to the window, making it heavier than the warm room air. As a result, it drops towards the floor and is replaced by warm room air. This air in turn is cooled and falls, thus creating a convective air current, as shown. (For this reason, heaters are placed below windows—to reheat the cold air dropping from them. This practice prevents what can be a quite strong and unpleasant cold "draft" on a cold day from a single-glazed window.)