H

Properties of Materials

Notes:

1. Properties of materials vary greatly depending upon manufacturing processes, chemical composition, internal defects, temperature, previous loading history, age, dimensions of test specimens, and other factors. The tabulated values are typical but should never be used for specific engineering or design purposes. Manufacturers and materials suppliers should be consulted for information about a particular product.

2. Except when compression or bending is indicated, the modulus of elasticity E, yield stress σ_Y, and ultimate stress σ_U are for materials in tension.

TABLE H-1 WEIGHTS AND MASS DENSITIES

Material	Weight density γ		Mass density ρ	
	lb/ft^3	kN/m^3	slugs/ft^3	kg/m^3
Aluminum alloys	160–180	26–28	5.2–5.4	2,600–2,800
2014-T6, 7075-T6	175	28	5.4	2,800
6061-T6	170	26	5.2	2,700
Brass	520–540	82–85	16–17	8,400–8,600
Bronze	510–550	80–86	16–17	8,200–8,800
Cast iron	435–460	68–72	13–14	7,000–7,400
Concrete				
Plain	145	23	4.5	2,300
Reinforced	150	24	4.7	2,400
Lightweight	70–115	11–18	2.2–3.6	1,100–1,800
Copper	556	87	17	8,900
Glass	150–180	24–28	4.7–5.4	2,400–2,800
Magnesium alloys	110–114	17–18	3.4–3.5	1,760–1,830
Monel (67% Ni, 30% Cu)	550	87	17	8,800
Nickel	550	87	17	8,800
Plastics				
Nylon	55–70	8.6–11	1.7–2.2	880–1,100
Polyethylene	60–90	9.4–14	1.9–2.8	960–1,400
Rock				
Granite, marble, quartz	165–180	26–28	5.1–5.6	2,600–2,900
Limestone, sandstone	125–180	20–28	3.9–5.6	2,000–2,900
Rubber	60–80	9–13	1.9–2.5	960–1,300
Sand, soil, gravel	75–135	12–21	2.3–4.2	1,200–2,200
Steel	490	77.0	15.2	7,850
Titanium	280	44	8.7	4,500
Tungsten	1,200	190	37	1,900
Water, fresh	62.4	9.81	1.94	1,000
sea	63.8	10.0	1.98	1,020
Wood (air dry)				
Douglas fir	30–35	4.7–5.5	0.9–1.1	480–560
Oak	40–45	6.3–7.1	1.2–1.4	640–720
Southern pine	35–40	5.5–6.3	1.1–1.2	560–640

TABLE H-2 MODULI OF ELASTICITY AND POISSON'S RATIOS

Material	Modulus of elasticity E		Shear modulus of elasticity G		Poisson's ratio ν
	ksi	GPa	ksi	GPa	
Aluminum alloys	10,000–11,400	70–79	3,800–4,300	26–30	0.33
2014-T6	10,600	73	4,000	28	0.33
6061-T6	10,000	70	3,800	26	0.33
7075-T6	10,400	72	3,900	27	0.33
Brass	14,000–16,000	96–110	5,200–6,000	36–41	0.34
Bronze	14,000–17,000	96–120	5,200–6,300	36–44	0.34
Cast iron	12,000–25,000	83–170	4,600–10,000	32–69	0.2–0.3
Concrete (compression)	2,500–4,500	17–31			0.1–0.2
Copper and copper alloys	16,000–18,000	110–120	5,800–6,800	40–47	0.33–0.36
Glass	7,000–12,000	48–83	2,700–5,100	19–35	0.17–0.27
Magnesium alloys	6,000–6,500	41–45	2,200–2,400	15–17	0.35
Monel (67% Ni, 30% Cu)	25,000	170	9,500	66	0.32
Nickel	30,000	210	11,400	80	0.31
Plastics					
Nylon	300–500	2.1–3.4			0.4
Polyethylene	100–200	0.7–1.4			0.4
Rock (compression)					
Granite, marble, quartz	6,000–14,000	40–100			0.2–0.3
Limestone, sandstone	3,000–10,000	20–70			0.2–0.3
Rubber	0.1–0.6	0.0007–0.004	0.03–0.2	0.0002–0.001	0.45–0.50
Steel	28,000–30,000	190–210	10,800–11,800	75–80	0.27–0.30
Titanium alloys	15,000–17,000	100–120	5,600–6,400	39–44	0.33
Tungsten	50,000–55,000	340–380	21,000–23,000	140–160	0.2
Wood (bending)					
Douglas fir	1,600–1,900	11–13			
Oak	1,600–1,800	11–12			
Southern pine	1,600–2,000	11–14			

TABLE H-3 MECHANICAL PROPERTIES

Material	Yield stress σ_Y		Ultimate stress σ_U		Percent elongation (2 in. gage length)
	ksi	MPa	ksi	MPa	
Aluminum alloys	5–70	35–500	15–80	100–550	1–45
2014-T6	60	410	70	480	13
6061-T6	40	270	45	310	17
7075-T6	70	480	80	550	11
Brass	10–80	70–550	30–90	200–620	4–60
Bronze	12–100	82–690	30–120	200–830	5–60
Cast iron (tension)	17–42	120–290	10–70	69–480	0–1
Cast iron (compression)			50–200	340–1,400	
Concrete (compression)			1.5–10	10–70	
Copper and copper alloys	8–110	55–760	33–120	230–830	4–50
Glass			5–150	30–1,000	0
Plate glass			10	70	
Glass fibers			1,000–3,000	7,000–20,000	
Magnesium alloys	12–40	80–280	20–50	140–340	2–20
Monel (67% Ni, 30% Cu)	25–160	170–1,100	65–170	450–1,200	2–50
Nickel	15–90	100–620	45–110	310–760	2–50
Plastics					
Nylon			6–12	40–80	20–100
Polyethylene			1–4	7–28	15–300
Rock (compression)					
Granite, marble, quartz			8–40	50–280	
Limestone, sandstone			3–30	20–200	
Rubber	0.2–1.0	1–7	1–3	7–20	100–800
Steel					
High-strength	50–150	340–1,000	80–180	550–1,200	5–25
Machine	50–100	340–700	80–125	550–860	5–25
Spring	60–240	400–1,600	100–270	700–1,900	3–15
Stainless	40–100	280–700	60–150	400–1,000	5–40
Tool	75	520	130	900	8
Steel, structural	30–100	200–700	50–120	340–830	10–40
ASTM-A36	36	250	60	400	30
ASTM-A572	50	340	70	500	20
ASTM-A514	100	700	120	830	15

(*Continued*)

TABLE H-3 MECHANICAL PROPERTIES (Continued)

Material	Yield stress σ_Y		Ultimate stress σ_U		Percent elongation (2 in. gage length)
	ksi	MPa	ksi	MPa	
Steel wire	40–150	280–1,000	80–200	550–1,400	5–40
Titanium alloys	110–150	760–1,000	130–170	900–1,200	10
Tungsten			200–600	1,400–4,000	0–4
Wood (bending)					
Douglas fir	5–8	30–50	8–12	50–80	
Oak	6–9	40–60	8–14	50–100	
Southern pine	6–9	40–60	8–14	50–100	
Wood (compression parallel to grain)					
Douglas fir	4–8	30–50	6–10	40–70	
Oak	4–6	30–40	5–8	30–50	
Southern pine	4–8	30–50	6–10	40–70	

TABLE H-4 COEFFICIENTS OF THERMAL EXPANSION

Material	Coefficient of thermal expansion α		Material	Coefficient of thermal expansion α	
	$10^{-6}/°F$	$10^{-6}/°C$		$10^{-6}/°F$	$10^{-6}/°C$
Aluminum alloys	13	23	Plastics		
Brass	10.6–11.8	19.1–21.2	Nylon	40–80	70–140
Bronze	9.9–11.6	18–21	Polyethylene	80–160	140–290
Cast iron	5.5–6.6	9.9–12	Rock	3–5	5–9
Concrete	4–8	7–14	Rubber	70–110	130–200
Copper and copper alloys	9.2–9.8	16.6–17.6	Steel	5.5–9.9	10–18
Glass	3–6	5–11	High-strength	8.0	14
Magnesium alloys	14.5–16.0	26.1–28.8	Stainless	9.6	17
Monel (67% Ni, 30% Cu)	7.7	14	Structural	6.5	12
Nickel	7.2	13	Titanium alloys	4.5–6.0	8.1–11
			Tungsten	2.4	4.3