NCMA TEK

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STEEL COLUMN FIRE PROTECTION

TEK 7-6
Fire Resistance (2003)

Keywords: calculated fire resistance, columns, equivalent thickness, fire resistance ratings, masonry fire protection, steel column fire protection, thermal properties

INTRODUCTION

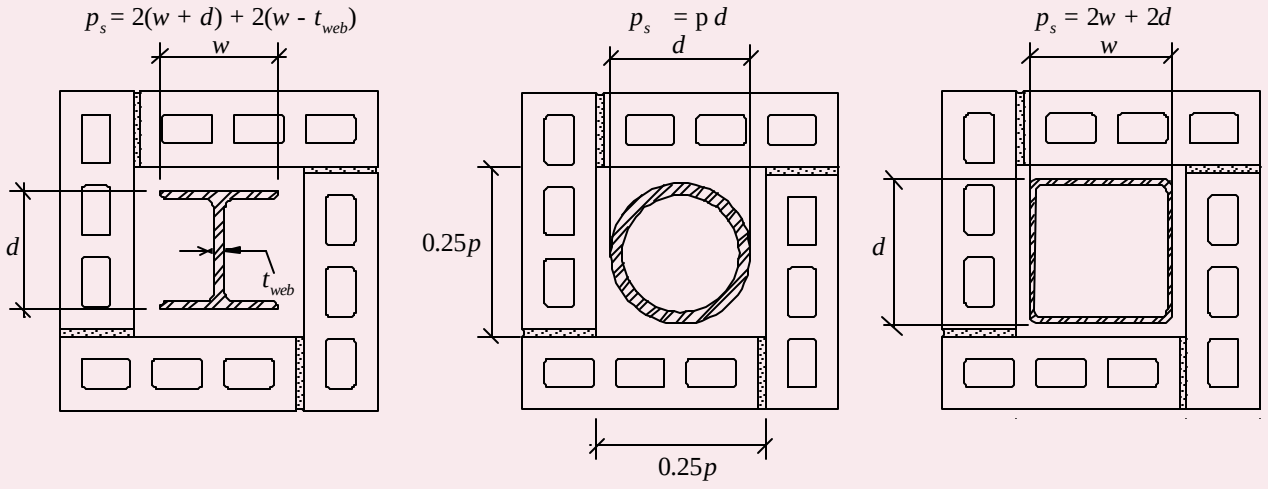
Because of its inherent fire resistant properties, concrete masonry is often used as a non-structural fire protection covering for structural steel columns. Fire endurance of steel column protection is determined as the period of time for the average temperature of the steel to exceed 1000 °F (538 °C), or for the temperature at any measured point to exceed 1200 °F (649 °C) (ref. 6). These criteria depend on the thermal properties of the column cover and of the steel column (ref. 3). Using this technique, an empirical formula was developed for the prediction of the fire endurance of concrete masonry protected steel columns (refs. 2, 4).

$$R^* = 0.401(A_s/p_s)^{0.7} + [0.285(T_{ea}^{1.6}/k^{0.2})][1.0 + 42.7\{(A_s/DT_{ea})/(0.25p + T_{ea})\}^{0.8}] \quad \text{(English units)}$$

$$R^* = 7.13(A_s/p_s)^{0.7} + [0.0027(T_{ea}^{1.6}/k^{0.2})][1.0 + 2.49\text{x}10^7\{(A_s/DT_{ea})/(0.25p + T_{ea})\}^{0.8}] \quad \text{(SI units)}$$

where:

A_s = Cross-sectional area of the steel column, in.^{2} (m^2)
D = Density of the concrete masonry protection, pcf (kg/m^3)
d = Depth of steel column, diameter of pipe column, in. (m)
k = Thermal conductivity of concrete masonry, Btu/hrft·°F (W/mK) (see Table 2)
p = Inner perimeter of concrete masonry protection, in. (mm)
p_s = Heated perimeter of steel, in. (mm)
R = Fire resistance rating of the column assembly, hr
T_{ea} = Equivalent thickness of concrete masonry protection assembly, in. (mm) (see Figure 2)
t_{web} = Thickness of web, in. (m)
W = Average weight of steel column, lb/ft (kg/m)
w = Width of steel column, in. (m)



W shape column | Steel pipe column | Structural tube column

Figure 1—Details of Concrete Masonry Protection for Commonly Used Steel Columns (ref. 1)

*Note: The 2000 International Building Code (IBC) (ref. 7) replaces the first term in the above equation with $0.17(W/p_s)^{0.7}$ (English) and $(1.22(W/p_s)^{0.7})$ (metric) where W is the average weight of the steel column in lb/ft (kg/m). Both forms of the equations yield identical answers.

Table 1—Fire Resistance of Con

W SHAPE COLUMNS

Column size	Concrete masonry density, pcf	Minimum required equivalent thickness of concrete masonry protection assembly, T_{ea}, in. Fire resistance rating, hr 1	2	3	4	Column size	Concrete masonry density, pcf	Minimum required equivalent thickness of concrete masonry protection assembly, T_{ea}, in. Fire resistance rating, hr 1	2	3	4
W 14 x 82	80	0.74	1.61	2.36	3.04	W 10 x 68	80	0.72	1.58	2.33	3.01
	100	0.89	1.85	2.67	3.40		100	0.87	1.83	2.65	3.38
	110	0.96	1.97	2.81	3.57		110	0.94	1.95	2.79	3.55
	120	1.03	2.08	2.95	3.73		120	1.01	2.06	2.94	3.72
W 14 x 68	80	0.83	1.70	2.45	3.13	W 10 x 54	80	0.88	1.76	2.53	3.21
	100	0.99	1.95	2.76	3.49		100	1.04	2.01	2.83	3.57
	110	1.06	2.06	2.91	3.66		110	1.11	2.12	2.98	3.73
	120	1.14	2.18	3.05	3.82		120	1.19	2.24	3.12	3.90
W 14 x 53	80	0.91	1.81	2.58	3.27	W 10 x 45	80	0.92	1.83	2.60	3.30
	100	1.07	2.05	2.88	3.62		100	1.08	2.07	2.90	3.64
	110	1.15	2.17	3.02	3.78		110	1.16	2.18	3.04	3.80
	120	1.22	2.28	3.16	3.94		120	1.23	2.29	3.18	3.96
W 14 x 43	80	1.01	1.93	2.71	3.41	W 10 x 33	80	1.06	2.00	2.79	3.49
	100	1.17	2.17	3.00	3.74		100	1.22	2.23	3.07	3.81
	110	1.25	2.28	3.14	3.90		110	1.30	2.34	3.20	3.96
	120	1.32	2.38	3.27	4.05		120	1.37	2.44	3.33	4.12
W 12 x 72	80	0.81	1.66	2.41	3.09	W 8 x 40	80	0.94	1.85	2.63	3.33
	100	0.91	1.88	2.70	3.43		100	1.10	2.10	2.93	3.67
	110	0.99	1.99	2.84	3.60		110	1.18	2.21	3.07	3.83
	120	1.06	2.10	2.98	3.76		120	1.25	2.32	3.20	3.99
W 12 x 58	80	0.88	1.76	2.52	3.21	W 8 x 31	80	1.06	2.00	2.78	3.49
	100	1.04	2.01	2.83	3.56		100	1.22	2.23	3.07	3.81
	110	1.11	2.12	2.97	3.73		110	1.29	2.33	3.20	3.97
	120	1.19	2.23	3.11	3.89		120	1.36	2.44	3.33	4.12
W 12 x 50	80	0.91	1.81	2.58	3.27	W 8 x 24	80	1.14	2.09	2.89	3.59
	100	1.07	2.05	2.88	3.62		100	1.29	2.31	3.16	3.90
	110	1.15	2.17	3.02	3.78		110	1.36	2.42	3.28	4.05
	120	1.22	2.28	3.16	3.94		120	1.43	2.52	3.41	4.20
W 12 x 40	80	1.01	1.94	2.72	3.41	W 8 x 18	80	1.22	2.20	3.01	3.72
	100	1.17	2.17	3.01	3.75		100	1.36	2.40	3.25	4.01
	110	1.25	2.28	3.14	3.90		110	1.42	2.50	3.37	4.14
	120	1.32	2.39	3.27	4.06		120	1.48	2.59	3.49	4.28

[a] in. x 25.4 = mm

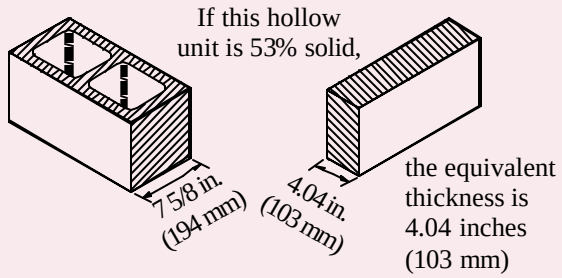
asonry Protected Steel Columns[a]

STRUCTURAL TUBE COLUMNS

Tube nominal size, in.	Concrete masonry density, pcf	Minimum required equivalent thickness of concrete masonry protection assembly, T_{ea}, in. Fire resistance rating, hr 1	2	3	4
4 x 4	80	0.93	1.90	2.71	3.43
1/2 in. wall	100	1.08	2.13	2.99	3.76
thickness	110	1.16	2.24	3.13	3.91
	120	1.22	2.34	3.26	4.06
4 x 4	80	1.05	2.03	2.84	3.57
3/8 in. wall	100	1.20	2.25	3.11	3.88
thickness	110	1.27	2.35	3.24	4.02
	120	1.34	2.45	3.37	4.17
4 x 4	80	1.21	2.20	3.01	3.73
1/4 in. wall	100	1.35	2.40	3.26	4.02
thickness	110	1.41	2.50	3.38	4.16
	120	1.48	2.59	3.50	4.30
6 x 6	80	0.82	1.75	2.54	3.25
1/2 in. wall	100	0.98	1.99	2.84	3.59
thickness	110	1.05	2.10	2.98	3.75
	120	1.12	2.21	3.11	3.91
6 x 6	80	0.96	1.91	2.71	3.42
3/8 in. wall	100	1.12	2.14	3.00	3.75
thickness	110	1.19	2.25	3.13	3.90
	120	1.26	2.35	3.26	4.05
6 x 6	80	1.14	2.11	2.92	3.63
1/4 in. wall	100	1.29	2.32	3.18	3.93
thickness	110	1.36	2.43	3.30	4.08
	120	1.42	2.52	3.43	4.22
8 x 8	80	0.77	1.66	2.44	3.13
1/2 in. wall	100	0.92	1.91	2.75	3.49
thickness	110	1.00	2.02	2.89	3.66
	120	1.07	2.14	3.03	3.82
8 x 8	80	0.91	1.84	2.63	3.33
3/8 in. wall	100	1.07	2.08	2.92	3.67
thickness	110	1.14	2.19	3.06	3.83
	120	1.21	2.29	3.19	3.98
8 x 8	80	1.10	2.06	2.86	3.57
1/4 in. wall	100	1.25	2.28	3.13	3.87
thickness	110	1.32	2.38	3.25	4.02
	120	1.39	2.48	3.38	4.17

STEEL PIPE COLUMNS

Pipe nominal size, in.	Concrete masonry density, pcf	Minimum required equivalent thickness of concrete masonry protection assembly, T_{ea}, in. Fire resistance rating, hr 1	2	3	4
4	80	1.26	2.25	3.07	3.79
Standard	100	1.40	2.45	3.31	4.07
0.237 in. wall	110	1.46	2.55	3.43	4.21
thickness	120	1.53	2.64	3.54	4.34
4	80	1.12	2.11	2.93	3.65
Extra strong	100	1.26	2.32	3.19	3.95
0.337 in. wall	110	1.33	2.42	3.31	4.09
thickness	120	1.40	2.52	3.43	4.23
4	80	0.80	1.75	2.56	3.28
Double extra	100	0.95	1.99	2.85	3.62
strong	110	1.02	2.10	2.99	3.78
0.674 in. wall	120	1.09	2.20	3.12	3.93
thickness					
5	80	1.20	2.19	3.00	3.72
Standard	100	1.34	2.39	3.25	4.00
0.258 in. wall	110	1.41	2.49	3.37	4.14
thickness	120	1.47	2.58	3.49	4.28
5	80	1.04	2.01	2.83	3.54
Extra strong	100	1.19	2.23	3.09	3.85
0.375 in. wall	110	1.26	2.34	3.22	4.00
thickness	120	1.32	2.44	3.34	4.14
5	80	0.70	1.61	2.40	3.12
Double extra	100	0.85	1.86	2.71	3.47
strong	110	0.91	1.97	2.85	3.63
0.750 in. wall	120	0.98	2.08	2.99	3.79
thickness					
6	80	1.14	2.12	2.93	3.64
Standard	100	1.29	2.33	3.19	3.94
0.280 in. wall	110	1.36	2.43	3.31	4.08
thickness	120	1.42	2.53	3.43	4.22
6	80	0.94	1.90	2.70	3.42
Extra strong	100	1.10	2.13	2.98	3.74
0.432 in. wall	110	1.17	2.23	3.11	3.89
thickness	120	1.24	2.34	3.24	4.04
6	80	0.59	1.46	2.23	2.92
Double extra	100	0.73	1.71	2.54	3.29
strong	110	0.80	1.82	2.69	3.47
0.864 in. wall	120	0.86	1.93	2.83	3.63
thickness					



Equivalent Thickness = 0.53 x 7 5/8 in. = 4.04
(Equivalent Thickness = 0.53 x 194 mm = 103 mm)

Figure 2—Determining Equivalent Thickness

Table 2—Thermal Conductivity of Concrete Masonry Units (ref. 4)

Density, *D*, pcf (kg/m³)	Thermal conductivity[a], *k*, Btu/hr·ft·°F (W/mK)
80 (1282)	0.207 (0.358)
85 (1362)	0.228 (0.394)
90 (1442)	0.252 (0.436)
95 (1522)	0.278 (0.481)
100 (1602)	0.308 (0.533)
105 (1682)	0.340 (0.588)
110 (1762)	0.376 (0.650)
115 (1842)	0.416 (0.720)
120 (1922)	0.459 (0.749)
125 (2003)	0.508 (0.879)
130 (2083)	0.561 (0.971)
135 (2163)	0.620 (1.073)
140 (2243)	0.685 (1.186)
145 (2323)	0.758 (1.312)
150 (2403)	0.837 (1.449)

[a] oven dry thermal conductivity at 70 °F (21 °C)

Calculating Equivalent Thickness

Equivalent thickness is calculated by multiplying the average percentage of net area (percent solid) of a unit by the actual width of the unit (Figure 2). The average net area, in percent, is determined in accordance with *Standard Methods of Sampling and Testing Concrete Masonry Units*, ASTM C 140 (ref. 4).

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