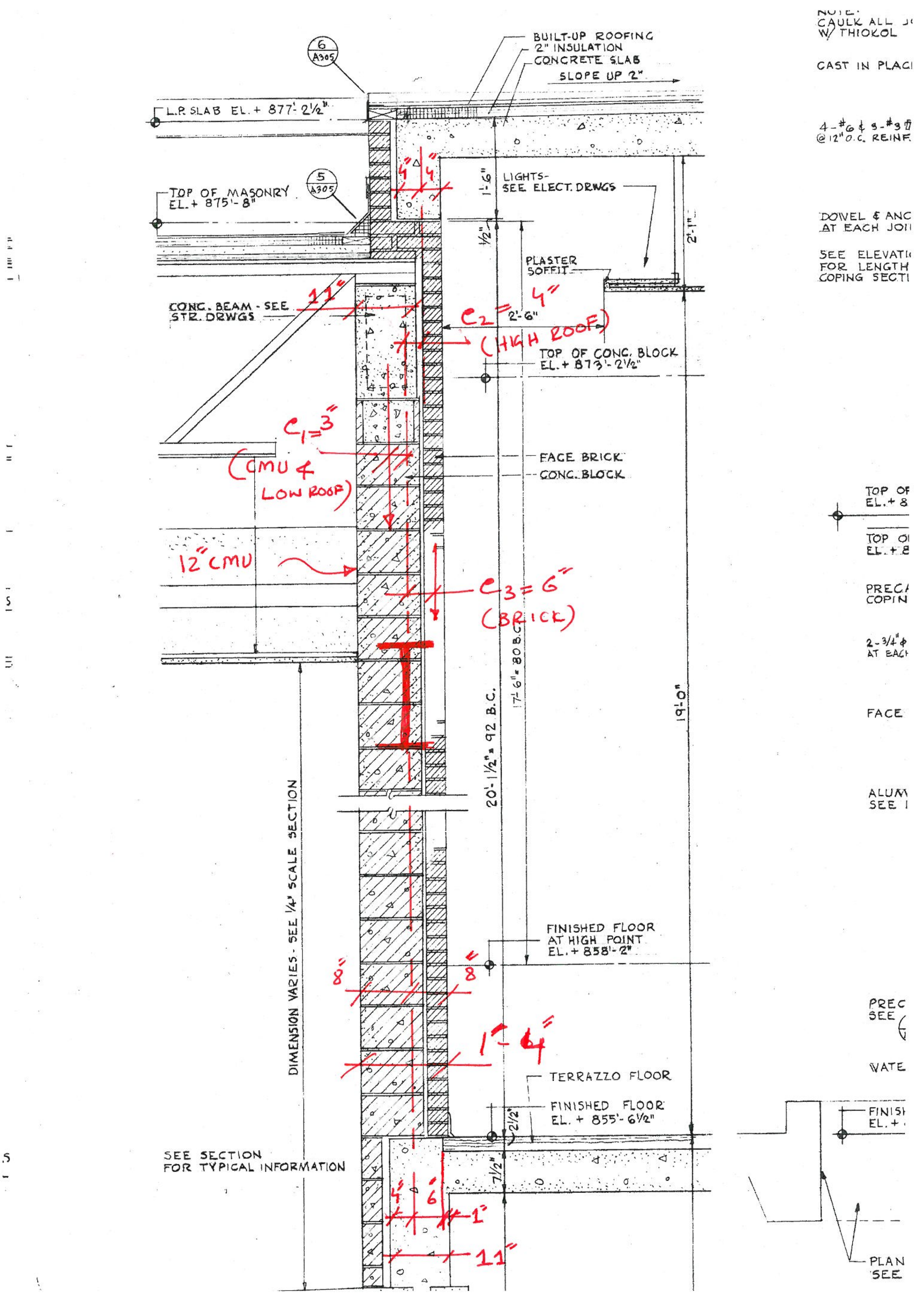


NOTE:
CAULK ALL J
W/ THIOKOL
CAST IN PLAC
4-#6 & 3-#3
@12" O.C. REINF.
DOWEL & ANC
AT EACH JOI
SEE ELEVATI
FOR LENGTH
COPING SECTI
TOP OF
EL.+ 8
TOP O
EL.+ 8
PREC
COPIN
2-3/4"
AT EAC
FACE
ALUM
SEE
PREC
SEE
WATE
FINISH
EL.+
PLAN
SEE
6
A305
5
A305
BUILT-UP ROOFING
2" INSULATION
CONCRETE SLAB
SLOPE UP 2"
L.R. SLAB EL. + 877'-2½"
TOP OF MASONRY
EL.+ 875'-8"
LIGHTS-
SEE ELECT. DRWGS
1'-6"
½"
2'-1"
PLASTER
SOFFIT
CONC. BEAM - SEE
STR. DRWGS
2'-6"
TOP OF CONC. BLOCK
EL.+ 873'-2½"
FACE BRICK
CONC. BLOCK
20'-1½" = 92 B.C.
17'-6" = 80 B.C.
19'-0"
DIMENSION VARIES - SEE ¼" SCALE SECTION
FINISHED FLOOR
AT HIGH POINT
EL. + 858'-2"
TERRAZZO FLOOR
FINISHED FLOOR
EL. + 855'-6½"
2½"
7½"
SEE SECTION
FOR TYPICAL INFORMATION
4"
4"
11"
e_2 = 4"
(HIGH ROOF)
e_1 = 3"
(CMU & LOW ROOF)
12" CMU
e_3 = 6"
(BRICK)
8"
8"
1'-4"
4"
6
1"
11"

USS
STEEL DESIGN MANUAL
1981

CHAPTER 7
Torsion

(COPIED 5/11/84)

7.1 Introduction

A torsional moment applied to opposite ends of a member causes each cross section of the member to rotate. As illustrated in Figure 7.1, if the member is a round bar or tube, each cross section rotates in its own plane without warping, and the resistance to torsion is provided by the shear stresses, which are proportional to the distance from the centroid. However, if a member with a non-circular cross section is subjected to the same torsional moment, the cross sections not only rotate but also deform non-uniformly in the longitudinal directions so that plane transverse sections do not remain plane after twisting. This latter deformation, known as "warping," is illustrated in Figure 7.2 for a rectangular bar. If the warping is not restrained, resistance to torsion is due to a distribution of shear stress known as "St. Venant torsion." If warping *is* restrained, additional direct shear stresses due to bending of the component parts of the section are superposed on the St. Venant shear stresses and add effectively to the torsional resistance. Bending of the component parts also induces longitudinal direct stresses that may require consideration in design.

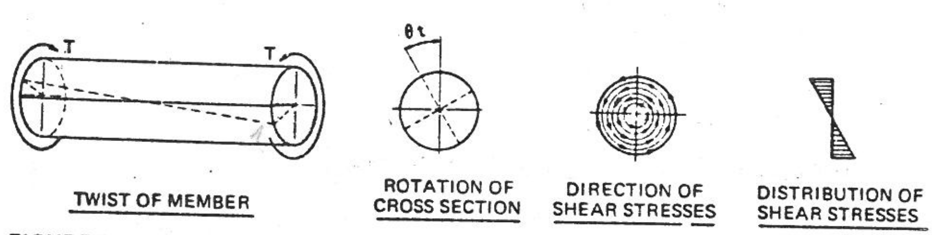


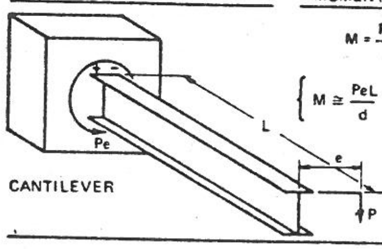
FIGURE 7.1 ROUND BAR IN TORSION

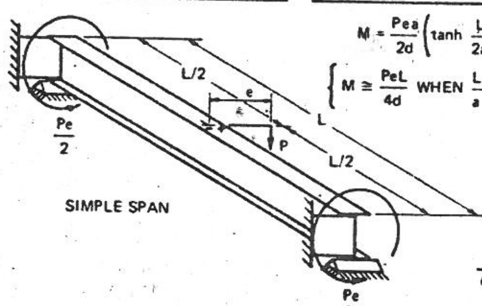
Solutions for six sets of conditions are given in Figures 7.9 and 7.10. The solutions are in terms of hyperbolic functions, which can be found in mathematics handbooks, and the torsional flange bending constant "a" given by

$$a = \sqrt{EC_w/JG} = d/2\sqrt{EI_y/JG} \qquad (7.18)$$

G = 11,200 ksi

where C_w is a torsional warping constant.* Values of both C_w and J are tabulated in the AISC Manual[2]; values of "a" can be easily calculated for most rolled beam sections. Equations for the maximum total angle of twist are given in the Figures 7.9 and 7.10.

LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
 CANTILEVER	$M = \frac{Pea}{d}\left(\tanh \frac{L}{a}\right)$ $\left\{ M \cong \frac{PeL}{d} \text{ WHEN } \frac{L}{a} \le 0.30 \right\}$	$\theta_T = \frac{Pea}{JG}\left(\frac{L}{a} - \tanh \frac{L}{a}\right)$

LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
 SIMPLE SPAN	$M = \frac{Pea}{2d}\left(\tanh \frac{L}{2a}\right)$ $\left\{ M \cong \frac{PeL}{4d} \text{ WHEN } \frac{L}{a} \le 0.60 \right\}$	$\theta_T = \frac{Pea}{2JG}\left(\frac{L}{2a} - \tanh \frac{L}{2a}\right)$

$$\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

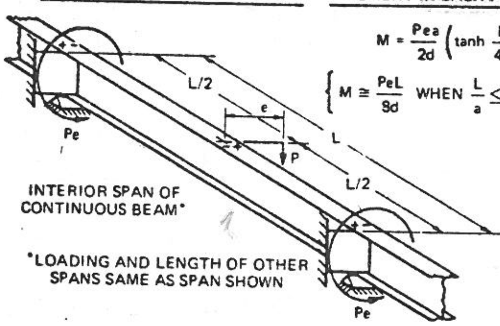
LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
 INTERIOR SPAN OF CONTINUOUS BEAM* *LOADING AND LENGTH OF OTHER SPANS SAME AS SPAN SHOWN	$M = \frac{Pea}{2d}\left(\tanh \frac{L}{4a}\right)$ $\left\{ M \cong \frac{PeL}{9d} \text{ WHEN } \frac{L}{a} \le 1.20 \right\}$	$\theta_T = \frac{Pea}{JG}\left(\frac{L}{4a} - \tanh \frac{L}{4a}\right)$

FIGURE 7.9 MAXIMUM LATERAL BENDING MOMENT AND TOTAL ANGLE OF TWIST FOR BEAMS IN TORSION FROM CONCENTRATED LOADS

*Equations for C_W for various cross sections are given in Reference 4 where the symbol Γ replaces C_W. Values for most shapes are also tabulated in the AISC Manual.

s 7.9 and 7.10. The ch can be found in g constant "a" given

G **(7.18)**

ues of both C_w and J are an be easily calculated for ximum total angle of twist

MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS

$$\theta_T = \frac{Pea}{JG}\left(\frac{L}{a} - \tanh\frac{L}{a}\right)$$

MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS

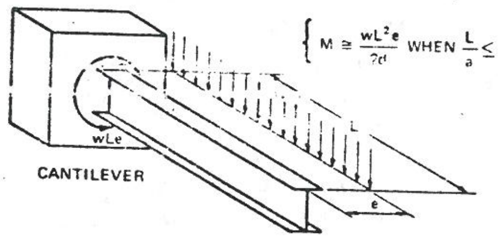
$$\theta_T = \frac{Pea}{2JG}\left(\frac{L}{2a} - \tanh\frac{L}{2a}\right)$$

AXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS

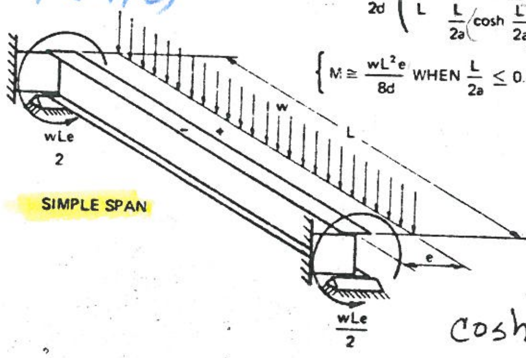
$$\theta_T = \frac{Pea}{JG}\left(\frac{L}{4a} - \tanh\frac{L}{4a}\right)$$

AND TOTAL ANGLE OF D LOADS

ference 4 where the symbol the AISC Manual.

LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
	$M = \frac{wLea}{d}\left(\tanh\frac{L}{a} + \frac{1}{\frac{L}{a}\cosh\frac{L}{a}} - \frac{a}{L}\right)$ $\left\{M \cong \frac{wL^2e}{2d} \text{ WHEN } \frac{L}{a} \le 0.30\right\}$	$\theta_T = \frac{wLea}{JG}\left(\frac{L}{2a} - \tanh\frac{L}{a} - \frac{1}{\frac{L}{a}\cosh\frac{L}{a}} + \frac{a}{L}\right)$

$\frac{k}{in} \cdot in^2 \cdot \frac{in}{in}$

LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
$M/(Sy/2)$ $<0.75 \times 50$ 	$M = \frac{wLea}{2d}\left(\frac{2a}{L} - \frac{1}{\frac{L}{2a}\cosh\frac{L}{2a}}\right)$ $\left\{M \cong \frac{wL^2e}{8d} \text{ WHEN } \frac{L}{2a} \le 0.60\right\}$	$\theta_T = \frac{wLea}{2JG}\left(\frac{L}{4a} - \frac{2a}{L} + \frac{1}{\frac{L}{2a}\cosh\frac{L}{2a}}\right)$

T = END TORQUE

$= \frac{\omega Le}{2}$

$$M = \frac{Ta}{d}\left[\frac{2a}{L} - \frac{1}{\frac{L}{2a}\cosh\frac{L}{2a}}\right]$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

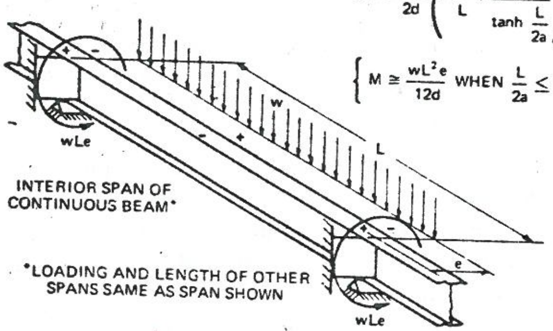
LOAD AND SUPPORT CONDITIONS	MAXIMUM LATERAL BENDING MOMENT IN EACH FLANGE	MAXIMUM TOTAL ANGLE OF TWIST AT END OF CANTILEVER AND AT MIDSPAN OF OTHER BEAMS
	$M = \frac{wLea}{2d}\left(-\frac{2a}{L} + \frac{1}{\tanh\frac{L}{2a}}\right)$ $\left\{M \cong \frac{wL^2e}{12d} \text{ WHEN } \frac{L}{2a} \le 0.60\right\}$	$\theta_T = \frac{wLea}{2JG}\left(\frac{L}{4a} - \tanh\frac{L}{4a}\right)$

FIGURE 7.10 MAXIMUM LATERAL BENDING MOMENT AND TOTAL ANGLE OF TWIST FOR BEAMS IN TORSION FROM UNIFORM LOADS