The permissible unit stress in concentrically loaded columns having values of L/r not greater than 130 for silicon steel or 120 for nickel steel may be computed from the following approximate formulas or by the more exact method, using formulas given in Appendix B.

	Silicon steel	Nickel steel
Riveted ends	$20{,}000-0.46\frac{L^2}{r^2}$	$24{,}000-0.66\frac{L^2}{r^2}$
Pin ends	$20{,}000-0.61\frac{L^2}{r^2}$	$24{,}000-0.86\frac{L^2}{r^2}$

For compression on members with values of L/r greater than 130 for silicon steel and 120 for nickel steel, and for compression members of known eccentricity see appendix "B."

Compression in extreme fibers of rolled shapes, girders and built sections, subject to bending, gross rection.

(a) When compression flange is supported laterally its full length by embedment in concrete or by other means	24,000	30,000
(b) *When compression flange is partially supported or is unsupported	$24{,}000-6.67\frac{L^2}{b^2}$	$30{,}000-8.33\frac{L^2}{b^2}$

For values of L/b not to exceed 25 for silicon steel, or 20 for nickel steel,
where L = length, in inches, of unsupported flange between lateral connections, knee braces or other points of support. For continuous beams and girders, L may be taken as the distance from interior support to point of dead load contraflexure if this distance is less than that designated above.
b = flange width in inches.

Compression, splice material, gross section	24,000	30,000
Stress in extreme fibers of pins	36,000	44,000
Shear in plate girder webs, gross section	14,000	17,500
Diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occurs simultaneously	24,000	27,000
Shear in pins	18,000	22,000
Bearing on pins (not subject to rotation)	32,000	40,000
Bearing on milled stiffeners and other parts in contact	36,000	44,000
Bearing on pins subject to rotation (not due to deflection)	16,000	18,000
Bearing on rollers and rockers: Same formulas as in article 3. 4. 2.		

3. 4. 9.—Unit Stresses for Welding.

The allowable unit stresses in pounds per square inch of effective area of weld shall be as given in the current specifications of the American Welding Society for Welded Highway and Railway Bridges.

3. 4. 10.—Bearing on Masonry.

Bearing on granite masonry	800
Bearing on sandstone and limestone masonry	400
Bearing on concrete:	

* Note. Continuous or cantilever beams or girders may be proportioned for negative moment at interior supports for an allowable unit stress 20 per cent higher than permitted by above formula but in no case exceeding allowable unit stress for compression flange supported its full length. If cover plates are used, the allowable stress at the point of cut-off shall be as determined by the formula.

Bridge seats, under hinged rockers and bolsters (not subjected to high edge loading by a deflecting beam, girder, or truss)	1,000
Bridge seats, under bearing plates or non-hinged shoes (subjected to high edge loading by the direct bearing, upon the plate or shoe, of a deflecting beam or girder), average	700

(The above bridge seat unit stresses will apply only where the edge of bridge seat projects at least 3 inches (average) beyond edge of shoe or plate. Otherwise, the unit stresses permitted will be 75 per cent of the above amounts.)

Concrete Structures

3. 4. 11.—Concrete Stresses.

(a) Standard Notations and Assumptions.

L = unsupported length of column, in feet.
D = least dimension of column in feet.
(1) The full dimensions of the concrete section shall be used in the design of tied columns.
(2) The diameter of the outer circumference of the spiral hooping shall be used for the computation of stresses in spiral columns.
(3) For battered columns "D" shall be measured at midheight.
fc = permissible extreme fiber stress in compression.
f'c = unit ultimate compressive strength of concrete as determined by cylinder tests at the age of 28 days.
fe = permissible unit compressive stress in concrete in eccentrically loaded columns.
e = eccentricity of resultant load as measured from the gravity axis.
c = distance from gravity axis to the extreme fiber in compression, measured parallel to the plane of bending.
r = radius of gyration of gross transformed column section in the plane of bending.
K = ratio of the permissible unit concrete compressive stress for axial loading to the permissible unit stress in the extreme fibers of the concrete beams. (See formula in appendix D.)
n = ratio of modulus of elasticity of steel to that of concrete. The value of n, as a function of the ultimate cylinder strength of concrete, shall be assumed as follows:

f'c = 2000–2400	n = 15
= 2500–2900	= 12
= 3000–3900	= 10
= 4000–4900	= 8
= 5000 or more	= 6

p = ratio of cross-sectional area of longitudinal reinforcing bar to the gross area of the concrete section.
p' = ratio of volume of spiral reinforcement to volume of the concrete core.
Coefficients:
Thermal, .000006. Shrinkage, .0004.
f''c = permissible unit compressive stress in concrete when L/D is greater than 12.

(b) Strength of Concrete.

The proportions for concrete mixes specified in Art. 2. 4. 5 were selected on the basis of meeting the following minimum requirements for strength for 28 day cylinders for the various classes of concrete here recognized.

Class of Concrete	Minimum Compressive Strength at 28 days
A or A(AE)	3,000
B or B(AE)	2,200
C or C(AE)	1,500
X or X(AE)	3,000
Y or Y(AE)	3,000

The basic value used in design under these specifications is 3,000 pounds per sq. in. at 28 days and if another value is used it shall be substantiated by test data and stipulated on the plans, along with the resultant allowable stresses. In no case shall the ultimate strength upon which allowable stresses are based exceed 4,500 pounds per sq. in.

Allowable Stresses

(c) Flexure.

		Values if f'c = 3000
Extreme fiber in compression	fc = 0.4 f'c	1200
Extreme fiber in tension, plain concrete, primarily in footings	fc = .03 f'c	90
Extreme fiber in tension, reinforced concrete	None	

(d) Shear.

Beams without web reinforcement:		
Longitudinal bars not anchored or plain concrete footings	.02 f'c	60
Longitudinal bars anchored	.03 f'c	90
Beams with web reinforcement	.075 f'c	225
Horizontal shear in shear-keys between slab and steam of T-Beams	0.10 f'c	300

(e) Bond on Piles (in Seals).

Timber, steel or concrete piles, 10 lbs. per square inch. (Providing the pile has the resistance to the pull thereby induced.)

(f) Bearing on Bridge Seats.

Refer to article 3. 4. 10.

(g) Columns—

Flexure and Direct Stress

	Value if f'c = 3000
(1) Axially loaded piers and pedestals with L/D equal to or less than 3.	fc = .25f'c.....750
(2) Axially loaded columns with L/D from 3 to 12 inclusive, reinforced with longitudinal bars:	
With lateral ties	$fc = .25f'c\left[1+(n-1)p\right]$
Spirally reinforced	$fc=(.25+12p')f'c\left[1+(n-1)p\right]$
(3) Axially loaded columns with L/D greater than 12.	$f''c=\left(1.33-\frac{L}{36D}\right)fc$
(4) Eccentrically loaded columns	
With L/D equal to or less than 12	$fe=fc\frac{1+\frac{ec}{r^2}}{1+K\frac{ec}{r^2}}$
With L/D greater than 12	$fe=f''c\frac{1+\frac{ec}{r^2}}{1+K\frac{ec}{r^2}}$

Values of fe, when L/D is equal to or less than 12, are given in the diagram, appendix D. For values of fe, when L/D is greater than 12, apply the factor f"c/fc to the values given in the diagram.

3. 4. 12.—Reinforcement.

	Structural Grade	Intermediate* Hard * Rail Steel * Grade
Steel Reinforcement:		
Tension in flexural members	18,000	20,000
Tension in web reinforcement	18,000	20,000
Compression: "n" times the compression in the surrounding concrete.		
Bond, Deformed bars:		
Straight or hooked ends, exclusive of top bars:		
(1) In beams, slabs, one-way footings	.10 f'c (maximum 350)	.10 f'c (maximum 350)
(2) In two-way footings	.08 f'c (maximum 280)	.08 f'c (maximum 280)
Top bars—Bars near top of beams and girders having more than 12 inches of concrete under the bars	.06 f'c (maximum 210)	.06 f'c (maximum 210)

Note: The above allowable bond stresses shall be reduced for footings as provided under the item "Reinforcement," Article 3. 5. 2 (f).

* According to article 4. 5. 1, it is required that the grade of reinforcement steel shall be either "Structural" or "Intermediate," unless otherwise stipulated. In the event allowable stresses for "Intermediate Grade" steel are used, it is necessary to modify article 4. 5. 1 by special provision, to require that "Intermediate Grade" steel be furnished. The grade required should also be noted on the plans.