COLUMN DESIGN

Condition #1: when subject only to an axial load acting through the centroidal axis
Condition #2: when subject to combined axial compression and flexure

based on AISC Manual of Steel Construction, Allowable Stress Design, 9th ed.

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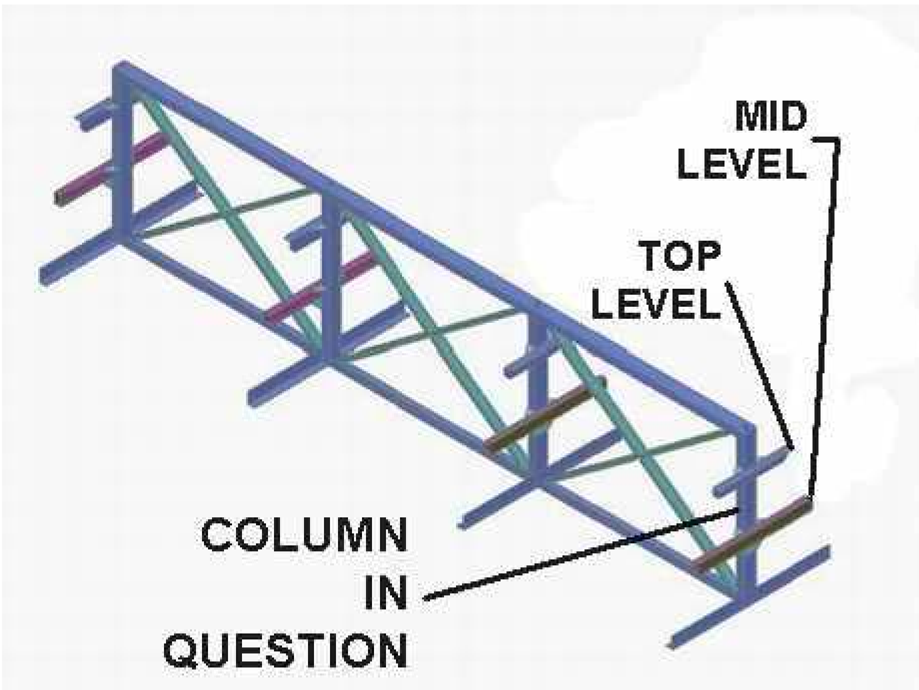
(DISCLAIMER: This worksheet is shared only as an example and should be used with caution. The calculations are not guaranteed to be error free.)



A. COLUMN DESCRIPTION

A.1 Description of rack for storing steel

nc = number of columns
Lt = load on top level, one side only (kips)
Lm = load on mid level, one side only (kips)
dt = distance from rack centerline to load center of gravity on the top level (in)
dm = distance from rack centerline to load center of gravity on the mid level (in)

nc:= 4

Lt:= 31.392 kips

Lm:= 55.664 kips

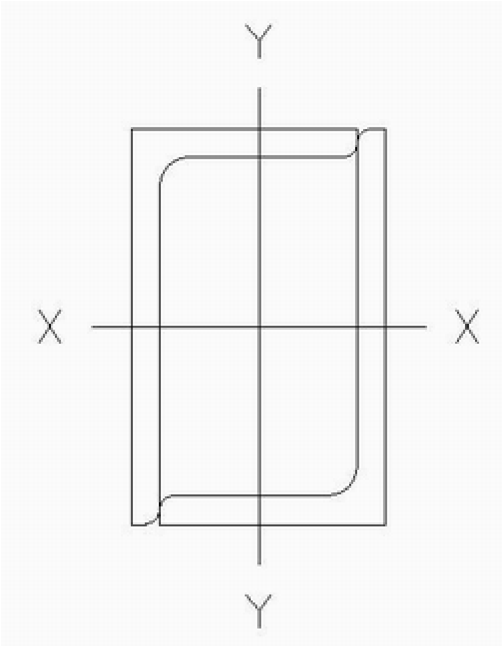
dt:= 11.9853 in

dm:= 17.6421 in

A.2 Start by choosing a preliminary column member size

Two L7x4x1/2 Angles

A.3 List Data for two L7x4x1/2 angles



A = area (in^2)
Ixx = moment of inertia about xx (in^4)
Sxx = section modulus about xx (in^3)
rxx = radius of gyration about xx (in)
Iyy = moment of inertian about yy (in^4)
Syy = section modulus about yy (in^3)
txx = radius of gyration about yy (in)

$A := 10.5537 \ in^2$

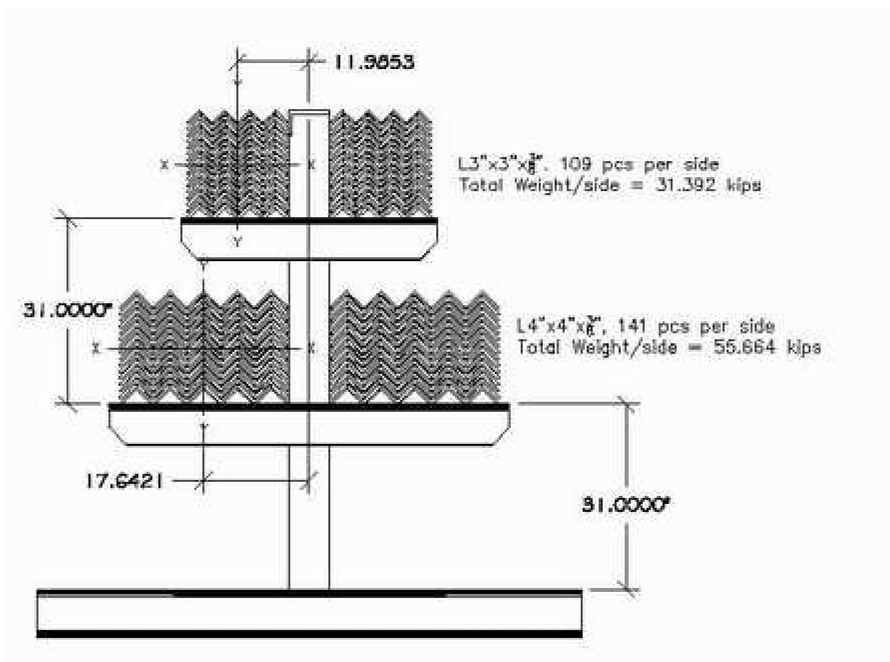
$Ixx := 65.9523 \ in^4$ $\quad$ $Iyy := 31.8431 \ in^4$

$Sxx := 18.8435 \ in^3$ $\quad$ $Syy := 14.1525 \ in^3$

$rxx := 2.4998 \ in$ $\quad$ $ryy := 1.7370 \ in$

B. CONDITION #1: RACK FULLY LOADED, AXIAL FORCE APPLIED THROUGH CENTROIDAL AXIS

from CHAPTER E - COLUMNS AND OTHER COMPRESSION MEMBERS



B.1 Calculate Cc

E = modulus of elasticity (ksi)
Fy = yield stress (ksi)

$Fy := 36 \ ksi$ $\quad$ $E := 29000 \ ksi$

$$Cc := \sqrt{\frac{2 \cdot \pi^2 \cdot E}{Fy}}$$

$Cc = 126.0993$

B.2 Estimate the effective-length factor and calculate Kl/r

K = effective-length factor
l = length of column (in)
r = radius of gyration (in)

$K := 2.1$ $\quad l := 69$ in <-- Note: The value of the length of the column is conservative since the majority of the load is actually applied much lower on the column

$r := ryy$ $\quad r = 1.737$ in

$$\frac{K \cdot l}{r} = 83.4197$$

B.3 Calculate the allowable stress

Fa = allowable stress from axial loading

if $\frac{K \cdot l}{r} > Cc$

$$Fa := \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{K \cdot l}{r}\right)^2}$$

else

$$Fa := \frac{\left(1 - \left(\frac{\left(\frac{K \cdot l}{r}\right)^2}{2 \cdot Cc^2}\right)\right) \cdot Fy}{\frac{5}{3} + \frac{3 \cdot \left(\frac{K \cdot l}{r}\right)}{8 \cdot Cc} - \frac{\left(\frac{K \cdot l}{r}\right)^3}{8 \cdot Cc^3}}$$

$Fa = 14.9703$ ksi

B.4 Calculate the allowable loading that corresponds to the allowable stress calculated above and compare to the actual load

La = allowable load (kips)
la = actual load (kips)
nc = number of columns
Lt = load on top level, one side only (kips)
Lm = load on mid level, one side only (kips)

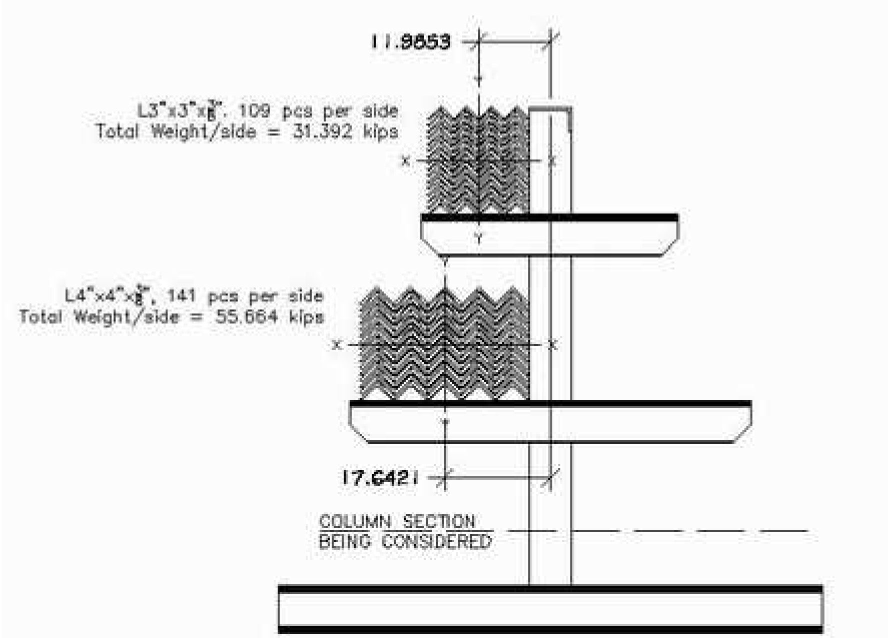
$La := Fa \cdot A$ $\quad La = 157.9923$ kips

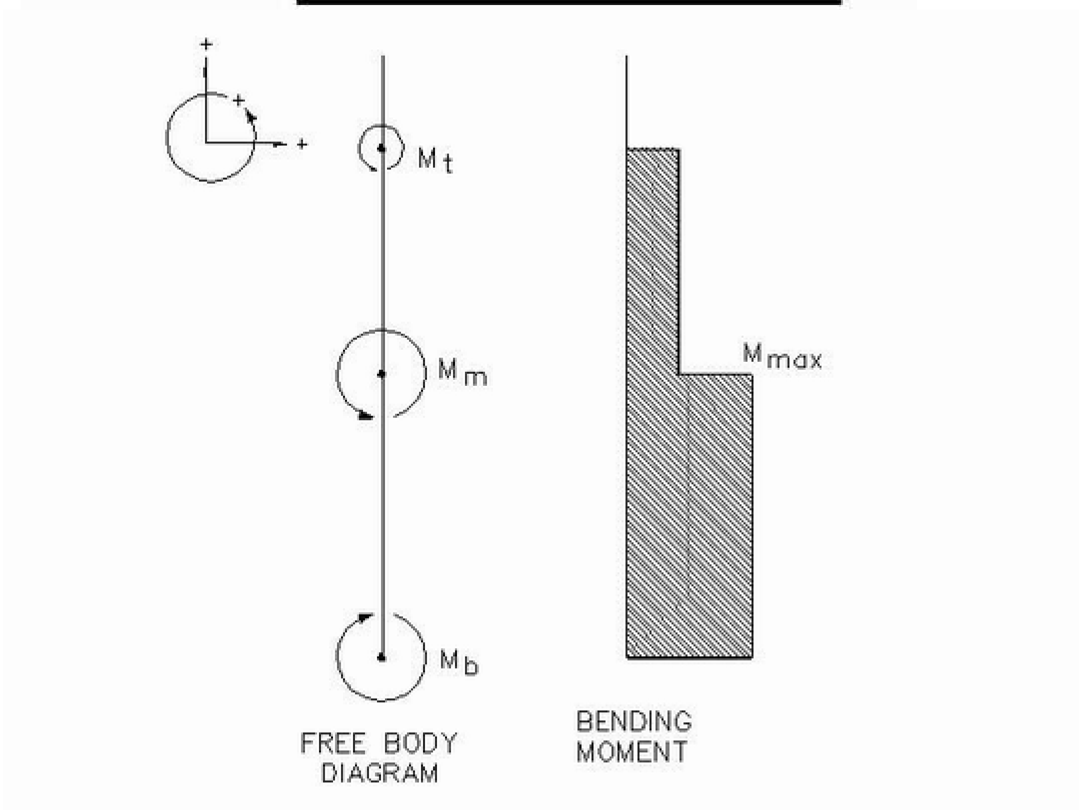
$$la := \left(\frac{Lt}{nc}\right) \cdot 2 + \left(\frac{Lm}{nc}\right) \cdot 2$$

$la = 43.528$ kips <-- OK if less than $La = 157.9923$ kips

C. CONDITION #2: RACK FULLY LOADED ON ONE SIDE ONLY

from CHAPTER H, SECTION H.1 - COMBINED STRESSES





C.1 Calculate the compressive bending stress

Mt = bending moment from load
on top level (kip-in)

Mm = bending moment from load
on mid level (kip-in)

Mmax = maximum bending moment (kip-in)

fb = maximum computed compressive
bending stress (ksi)

Sxx = section modulus around axis xx (in^3)

Fb = allowable bending stress that
would be permitted if bending moment
alone existed (ksi)

nc = number of columns

Lt = load on top level, one
side only (kips)

Lm = load on mid level, one
side only (kips)

dt = distance from rack center-
line to load center of
gravity on the top
level (in)

dm = distance from rack center-
line to load center of
gravity on the mid
level (in)

$Mt := \left(\frac{Lt}{nc}\right) \cdot dt$ $Mt = 94.0606$ kip-in

$Mm := \left(\frac{Lm}{nc}\right) \cdot dm$ $Mm = 245.5075$ kip-in

$Mmax := Mt + Mm$ $Mmax = 339.5681$ kip-in

$Fb := 0.60 \cdot Fy$ $Fb = 21.6$ ksi   (for a noncompact section)

$fb := \frac{Mmax}{Sxx}$ $fb = 18.0204$ ksi   <-- OK if less than $Fb = 21.6$ ksi

C.2 Calculate Fe

Fe = Euler stress divided by a factor of safety (ksi)
E = modulus of elasticity (ksi)
K = effective-length factor in the plane of bending
l = unbraced length in the plane of bending (in)
rxx = radius of gyration in the plane of bending (in)

$$Fe := \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{K \cdot l}{rxx}\right)^2} \qquad Fe = 44.4452 \text{ ksi}$$

C.3 Determine Cm

$Cm := 1.0$

C.4 Calculate fa/Fa

la = actual axial load (kips)
fa = computed axial stress (ksi)
Fa = axial compressive stress that would be permitted if axial force alone existed (ksi)

nc = number of columns
Lt = load on top level, one side only (kips)
Lm = load on mid level, one side only (kips)

$la := \left(\frac{Lm}{nc}\right) + \left(\frac{Lt}{nc}\right)$ $la = 21.764$ kips

$fa := \frac{la}{A}$ $fa = 2.0622$ ksi

$\frac{fa}{Fa} = 0.1378$

C.5 Determine whether axial and bending stresses are within allowable limits

$$\text{if } \frac{fa}{Fa} \le 0.15$$

$$cv1 := \frac{fa}{Fa} + \frac{fb}{Fb}$$

$$cv2 := 1$$

else

$$cv1 := \frac{fa}{0.6 \cdot Fy} + \frac{fb}{Fb}$$

$$cv2 := \frac{fa}{Fa} + \frac{Cm \cdot fb}{\left(1 - \frac{fa}{Fe}\right) \cdot Fb}$$

$cv1 = 0.972$ <-- OK if less than or equal to 1.0

$cv2 = 1$ <-- OK if less than or equal to 1.0