RAMP DESIGN

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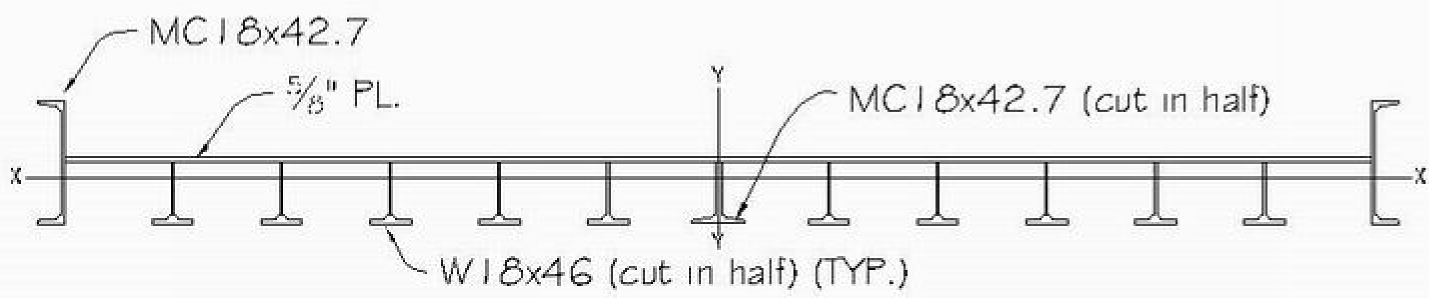
(DISCLAIMER: This worksheet is shared only as an example and should be used with caution.)
(The calculations are not guaranteed to be error free.)

Define the section modulus for ramp section

(section modulus calculated using AutoCAD, see graphic below)

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----------------   REGIONS   ----------------

Area:                      226.6616 sq in
Perimeter:                 833.0722 in
Bounding box:           X: -99.9506  --  99.9504 in
                        Y: -6.8177  --  11.1823 in
Centroid:               X: -0.0003 in
                        Y: 0.0000 in
Moments of inertia:     X: 4216.4402 sq in sq in
                        Y: 800704.1645 sq in sq in
Product of inertia:    XY: -0.1510 sq in sq in
Radii of gyration:      X: 4.3130 in
                        Y: 59.4357 in
Principal moments (sq in sq in) and X-Y directions about centroid:
                        I: 4216.4402 along [1.0000 0.0000]
                        J: 800704.1645 along [0.0000 1.0000]
Elastic section moduli:
  Section modulus (Top)      X: 377.0638
  Section modulus (Bottom)   X: 618.4549
  Section modulus (Right)    Y: 8011.0151
  Section modulus (Left)     Y: 8010.9991
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Smod = section modulus (in^3)

$Smod := 377.0638\,in^3$

Calculate the maximum allowable stress in tension and compression

σu = ultimate tensile strength (ksi)
σy = yield stress (ksi)
FS = safety factor
σall = maximum allowable stress in tension or compression (ksi)

$ksi := 1000\,psi$

$\sigma u := 58\,ksi$ $\quad \sigma y := 36\,ksi$ $\quad FS := 3.0$

$\sigma all := \frac{\sigma y}{FS}$ $\quad \sigma all = 12\,ksi$

Calculate the maximum allowable moment

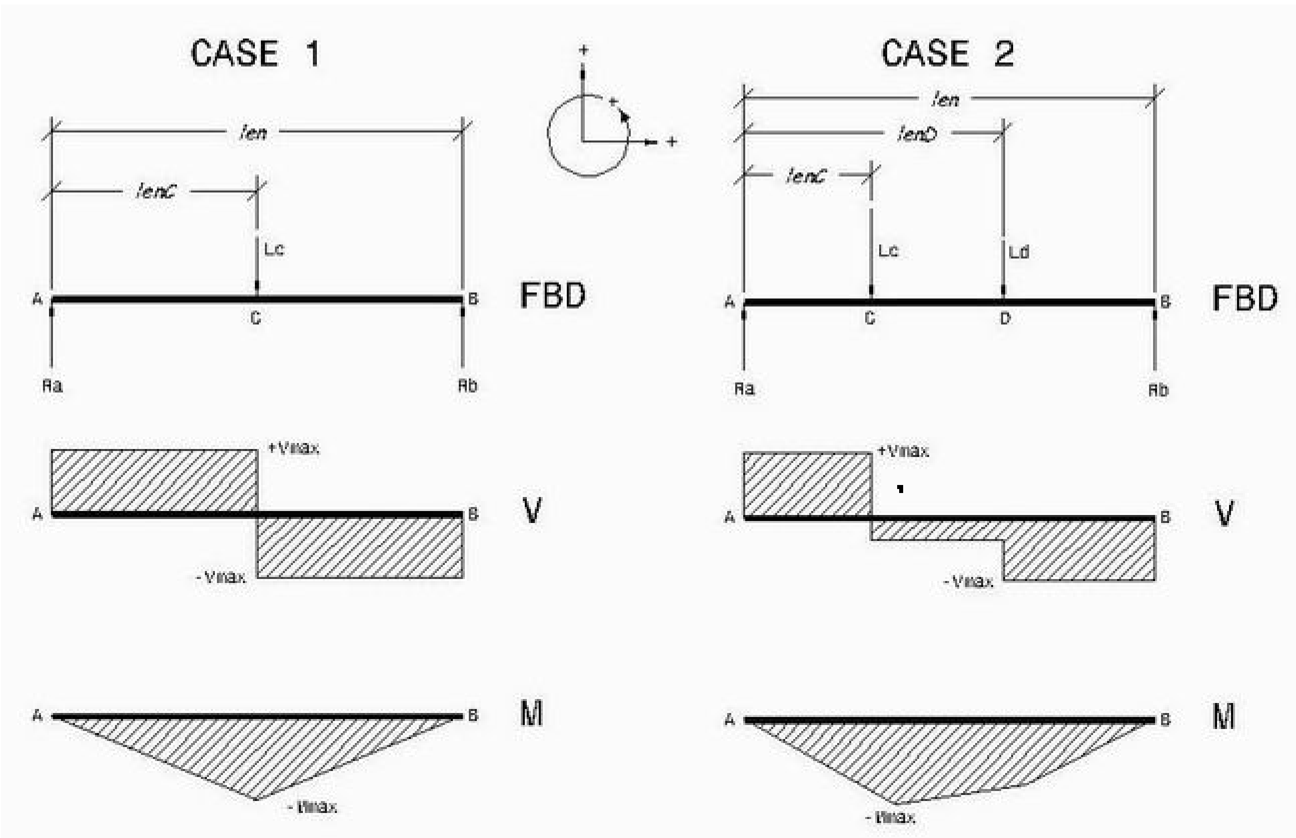
Mall = maximum allowable moment (ft*lb)

Mall:= Smod· σall

Mall= $3.7706 \cdot 10^{5}$ *ft lbf*

FBD, V, and M diagrams

CASE 1 = front axle of large forklift on ramp
CASE 2 = both axles of smaller fully-loaded forklift on ramp



CASE 1: front axle of unloaded large forklift on ramp

Calculate Bending Moment:

len = length of the ramp (ft)
lenC = distance from A to C, the point of application of Load C (ft)
Lc = load at C (kips)
Rb = reaction at B (kips)
Ra = reaction at A (kips)
posVmax = maximum positive shear (+kips)
negVmax = maximum negative shear (-kips)
Mmax = maximum bending moment (ft*lb)

len:= 21 *ft*   lenC:= 10.5 *ft*

Lc:= 67.739 *kip*   Note: actual front axle load for unloaded Hyster H1050HDS

Calculate the reactions at A and B:

$Rb := \frac{Lc \cdot lenC}{len}$ $Rb = 33.8695\ kip$

$Ra := Lc - Rb$ $Ra = 33.8695\ kip$

Calculate the maximum shear forces:

$posVmax := Ra$ $posVmax = 33.8695\ kip$

$negVmax := Rb$ $negVmax = 33.8695\ kip$

Calculate the maximum bending moment:

$Mmax := posVmax \cdot (lenC)$

$Mmax = 3.5563 \cdot 10^{5}\ ft\ lbf$

Compare maximum bending moment to allowable bending moment:

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if Mall > Mmax
  result := "Pass"
else
  result := "Fail"
```

result = "Pass"

Calculate Max Deflection:

E = modulus of elasticity (ksi)
I = moment of inertia about horizontal centroidal axis (in^4)
ymax = maximum deflection (in)

Define modulus of elasticity and moment of inertia values:

$E := 29000\ ksi$ $I := 4216.4402\ in^{4}$

Calculate the maximum deflection:

if $lenC \le \frac{len}{2}$

$ymax := \frac{-Lc \cdot lenC}{3 \cdot E \cdot I \cdot len} \cdot \left(\frac{len^{2} - lenC^{2}}{3}\right)^{\frac{3}{2}}$

else

$lenC := len - lenC$

$ymax := \frac{-Lc \cdot lenC}{3 \cdot E \cdot I \cdot len} \cdot \left(\frac{len^{2} - lenC^{2}}{3}\right)^{\frac{3}{2}}$

<-- Note: lenC must be less than half the total length (len)

$ymax = -0.1847\ in$

CASE 2 : both axles of smaller fully-loaded forklift on ramp

Calculate Bending Moment:

Lc = load at C , which is the larger of the two loads (kips)
Ld = load at D (kips)
wheelbase = the distance between the wheels on the forklift (in)
len = length of the ramp (ft)
lenC = distance from A to C, the point of application of Load C (ft)
lenD = distance from A to D, the point of application of Load D (ft)
Rb = reaction at B (kips)
Ra = reaction at A (kips)
posVmax = maximum positive shear (+kips)
negVmax = maximum negative shear (-kips)
Mmax = maximum bending moment (ft*lb))

$Lc := 64.282\ kip$ $Ld := 4.475\ kip$

$wheelbase := 129.9\ in$

Note: data shown corresponds to a loaded Hyster H300HD

$len := 20\ ft$ $lenC := 9\ ft$ $lenD := lenC + wheelbase$ $lenD = 19.825\ ft$

Calculate the reactions at A and B:

$$Rb := \frac{Lc \cdot lenC + Ld \cdot lenD}{len} \qquad Rb = 33.3627\ kip$$

$$Ra := Lc + Ld - Rb \qquad Ra = 35.3943\ kip$$

Calculate the maximum shear forces:

$$posVmax := Ra \qquad posVmax = 35.3943\ kip$$

$$negVmax := Rb \qquad negVmax = 33.3627\ kip$$

Calculate the maximum bending moment:

$$Mmax := posVmax \cdot lenC$$

$$Mmax = 3.1855 \cdot 10^{5}\ ft\ lbf$$

Recalculate allowable bending moment using yield strength

$$Mall := Smod \cdot \sigma all$$

$$Mall = 3.7706 \cdot 10^{5}\ ft\ lbf$$

Compare maximum bending moment to allawable bending moment:

```
if Mall > Mmax
  result := "Pass"
else
  result := "Fail"
```

result = "Pass"

Calculate Max Deflection:

E = modulus of elasticity (ksi)
I = moment of inertia about horizontal centroidal axis (in^4)
ymaxC = maximum deflection at C from load C only (in)
xC = position of maximum deflection (ft) measured from point A
θa = angle of deflection at A from load D only (radians)
yD = deflection at xC from load D only (in)
ymax = maximum deflection (in)

Define modulus of elasticity and moment of inertia:

$E := 29000\ ksi$ $\qquad$ $I := 4216.4402\ in^4$

Calculate the maximum deflection at C from load C only:

$$ymaxC := \frac{-Lc \cdot lenC}{3 \cdot E \cdot I \cdot len} \cdot \left(\frac{len^2 - lenC^2}{3} \right)^{\frac{3}{2}} \qquad ymaxC = -0.1494\ in$$

Calculate the position of the point of maximum deflection:

$$xC := len - \left(\frac{len^2 - lenC^2}{3} \right)^{\frac{1}{2}} \qquad xC = 9.6882\ ft$$

Calculate the angle of deflection at A from load D only:

$$\theta a := \left(\frac{(-Ld) \cdot lenD}{6 \cdot E \cdot I \cdot len} \right) \cdot (2 \cdot len - lenD) \cdot (len - lenD) \qquad \theta a = -3.0739 \cdot 10^{-6}$$

Calculate the reaction at A if only load D existed:

$$Ra := \frac{Ld \cdot (len - lenD)}{len} \qquad Ra = 0.0392\ kip$$

Calculate the deflection at xC if only load D existed:

if $xC > lenD$

$$yD := \theta a \cdot xC + \frac{Ra \cdot xC^3}{6 \cdot E \cdot I} - \frac{Ld}{6 \cdot E \cdot I} \cdot (xC - lenD)^3$$

else

$$yD := \theta a \cdot xC + \frac{Ra \cdot xC^3}{6 \cdot E \cdot I}$$

$yD = -2.7351 \cdot 10^{-4}\ in$

Due to the principle of superposition deflections "ymaxC" and "yD" may be added to obtain the total maximum deflection at xC:

$ymax := yD + ymaxC$

$ymax = -0.1497\ in$

References:

Mechanics of Materials, 2nd ed. by Beer and Johnson, pg. 446-48
Formulas for Stress and Strain, 5th ed. by Roark and Young, pg. 96-97