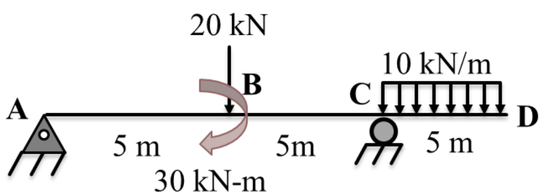
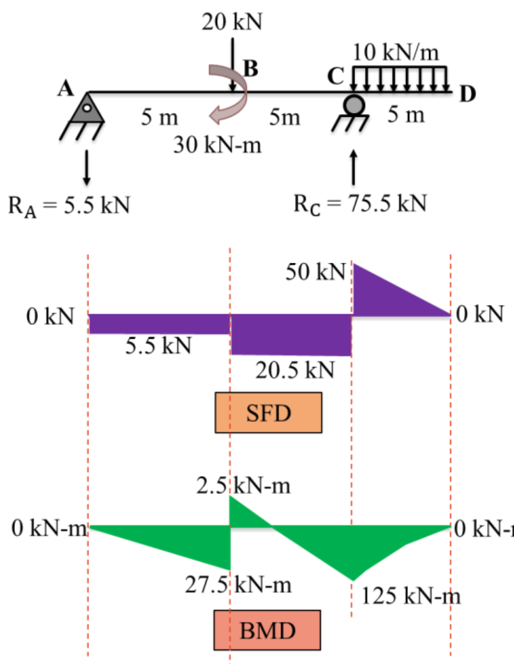
Structural Engineering

Problem-1: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam. [BWDB – 2020]



Solution:



$\sum M_A = 0$

=> $20 \times 5 + 30 + 5 \times 10 \times 12.5 - R_C \times 10 = 0$

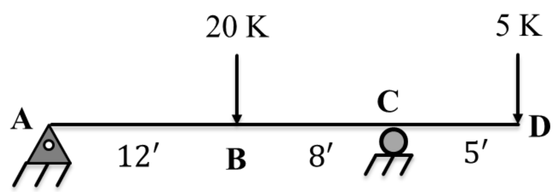
=> $R_C = 18.25$ kN.

$\sum F_y = 0$

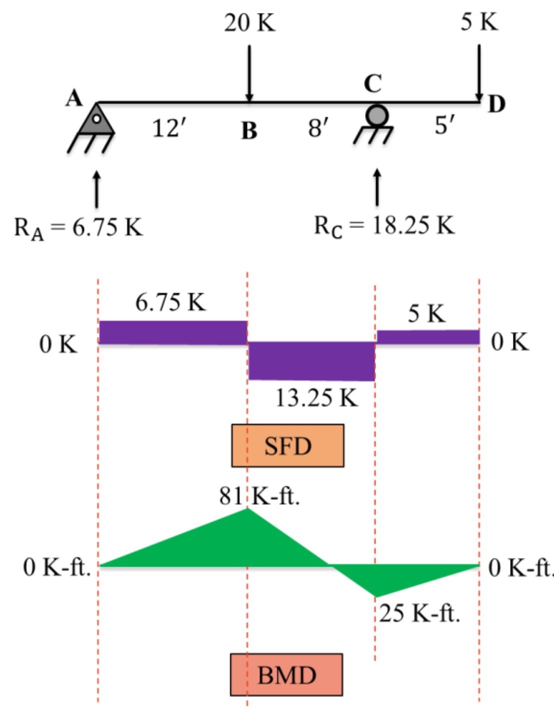
=> $R_A + R_C - 20 - 50 = 0$

=> $R_A = 5.5$ kN.

Problem-2: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam. [EED – 2020]



Solution:



$\sum M_A = 0$

=> $20 \times 12 + 5 \times 25 - R_C \times 20 = 0$

=> $R_C = 18.25$ K.

$\sum F_y = 0$

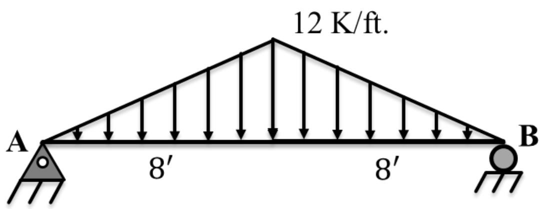
=> $R_A + R_C - 20 - 5 = 0$

=> $R_A = 25 – 18.25 = 6.75$ K.

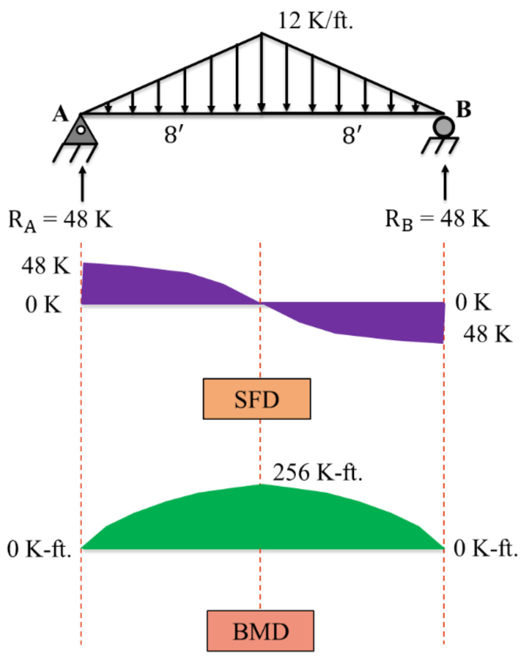
Faruque Abdullah

Practical Engineering

Problem-3: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

=> $0.5 \times 16 \times 12 \times 8 - R_B \times 16 = 0$

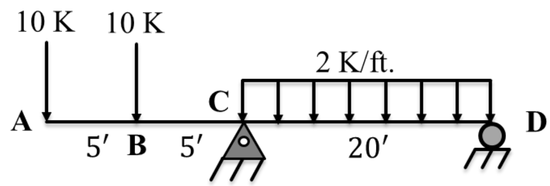
=> $R_B = 48$ kN.

$\sum F_y = 0$

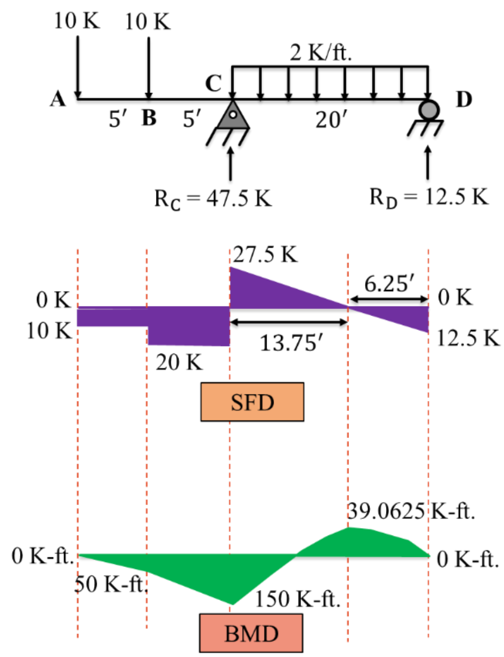
=> $R_A + R_B - 96 = 0$

=> $R_A = 48$ kN.

Problem-4: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

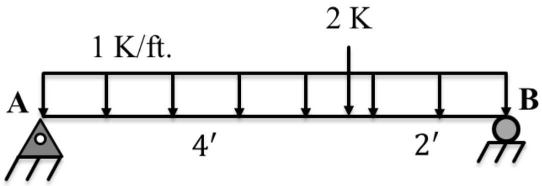
=> $-10 \times 10 - 10 \times 5 + 2 \times 20 \times 10 - R_D \times 20 = 0.$

=> $R_D = 10.5$ K

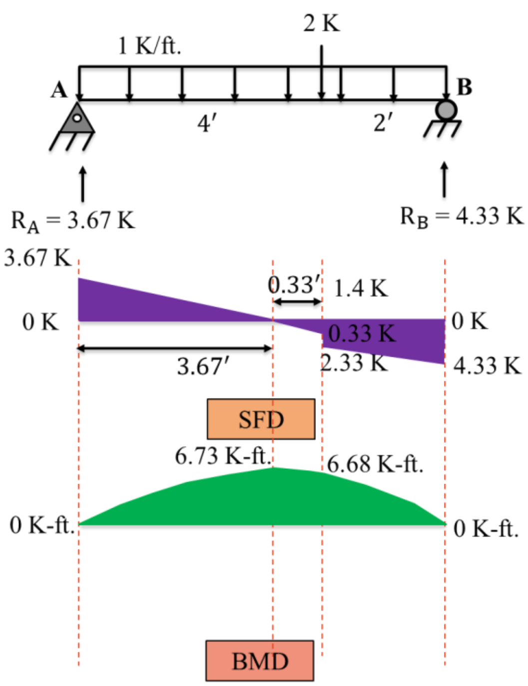
$\sum F_y = 0$

=> $R_C = 47.5$ K.

Problem-5: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

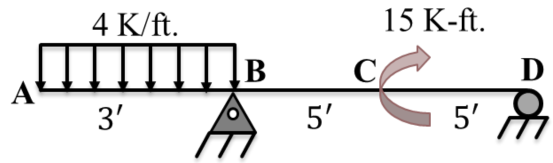
$\Rightarrow 1 \times 6 \times 3 + 2 \times 4 - R_B \times 6 = 0$

$\Rightarrow R_B = 4.33$ K

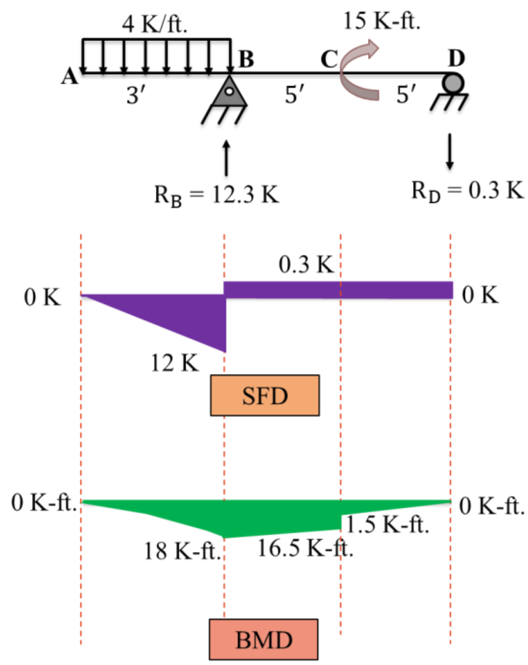
$\sum F_y = 0$

$\Rightarrow R_A = 3.67$ K.

Problem-6: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

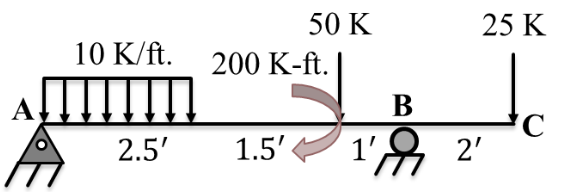
$\Rightarrow - 4 \times 3 \times 1.5 + 15 - R_D \times 10 = 0$

$\Rightarrow R_D = - 0.3$ K

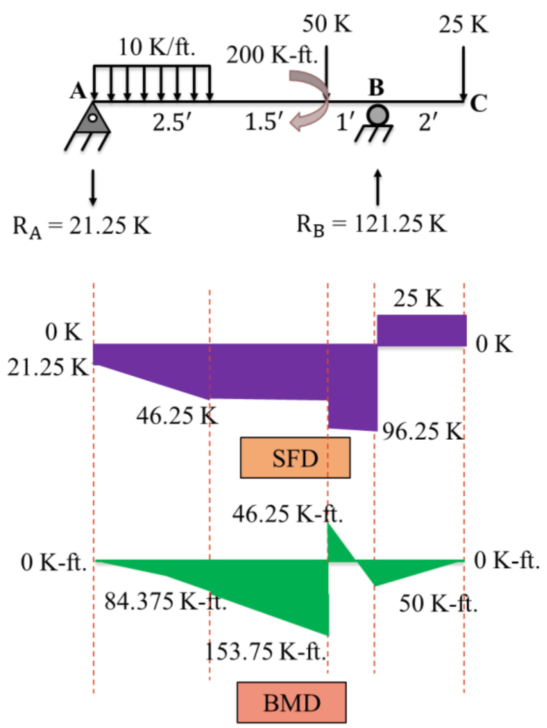
$\sum F_y = 0$

$\Rightarrow R_B = 12.3$ K.

Problem-7: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

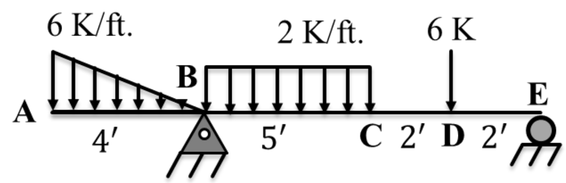
=> 10 x 2.5 x 1.25 + 200 + 50 x 4 + 25 x 7 - R_B x 5 = 0

=> R_B = 120 K

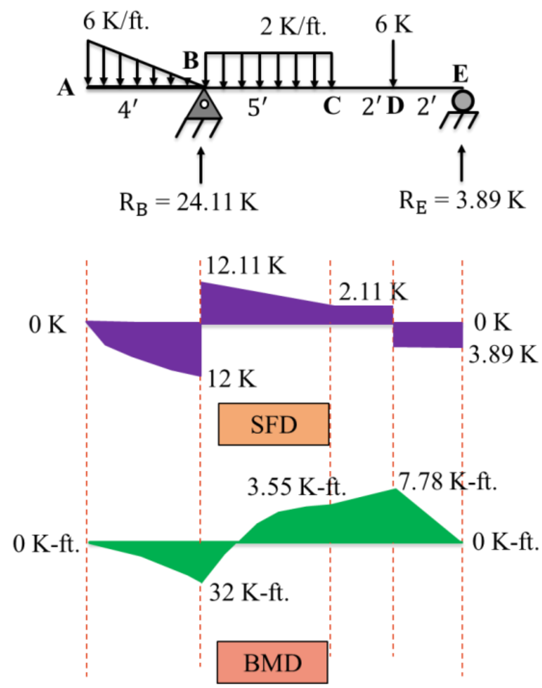
$\sum F_y = 0$

=> R_A = 21.25 K.

Problem-8: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

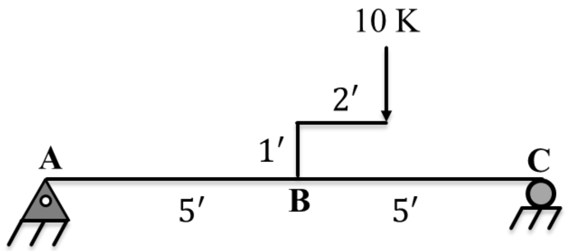
=> - 0.5 x 4 x 6 x $\frac{2}{3}$ x 4 + 2 x 5 x 2.5 + 6 x 7 - R_E x 9 = 0

=> R_E = 3.89 K

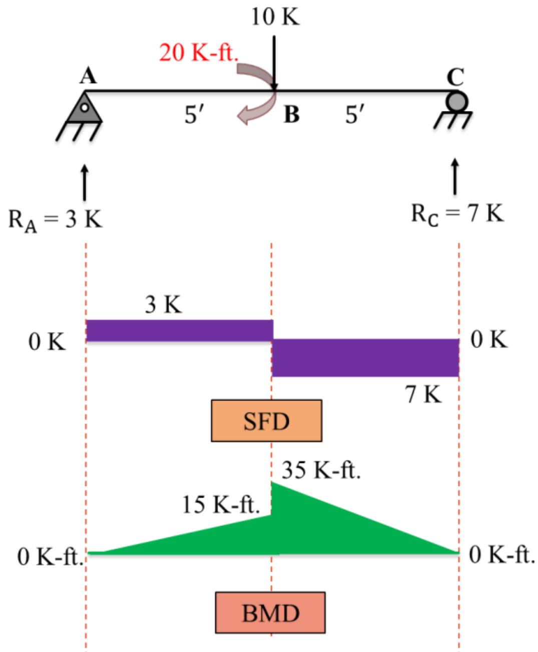
$\sum F_y = 0$

=> R_A = 24.11 K.

Problem-9: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

=> $M_B = 10 \times 2 = 20$ k-ft. [Clockwise]

$\sum M_A = 0$

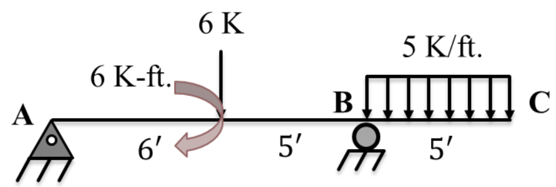
=> $20 + 10 \times 5 - R_C \times 10 = 0$

=> $R_C = 7$ K

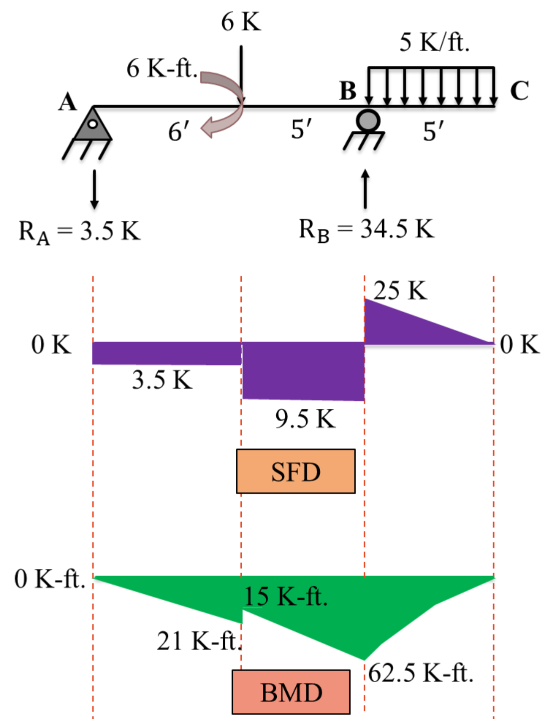
$\sum F_y = 0$

=> $R_A = 3$ K.

Problem-10: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

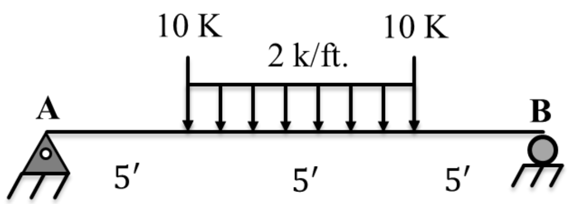
=> $6 + 6 \times 6 + 5 \times 5 \times 13.5 - R_B \times 11 = 0$

=> $R_B = 34.5$ K

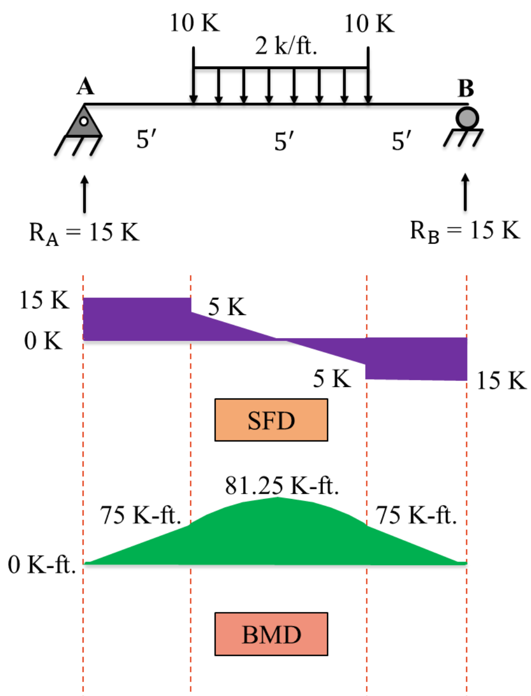
$\sum F_y = 0$

=> $R_A = 3.5$ K.

Problem-11: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

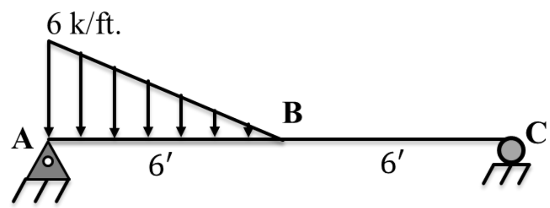
=> $10 \times 5 + 2 \times 5 \times 7.5 + 10 \times 10 - R_B \times 15 = 0$

=> $R_B = 15$ K

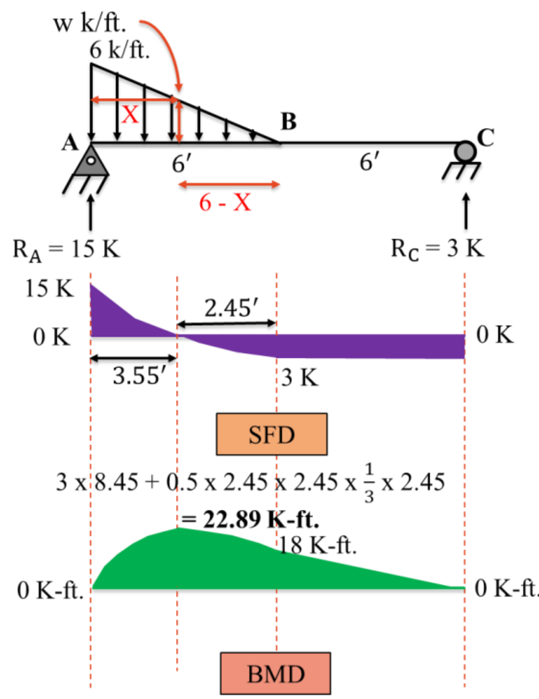
$\sum F_y = 0$

=> $R_A = 15$ kN.

Problem-12: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam. [RPP-2019]



Solution:



$\sum M_A = 0$

=> $0.5 \times 6 \times 6 \times \frac{1}{3} \times 6 - R_C \times 12 = 0$

=> $R_C = 3$ K

$\frac{6}{6} = \frac{w}{(6-x)}$

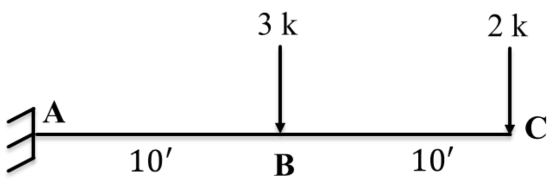
=> $w = (6 - x)$

$V_x = 15 - \frac{1}{2} . [6 + (6-x)] x$

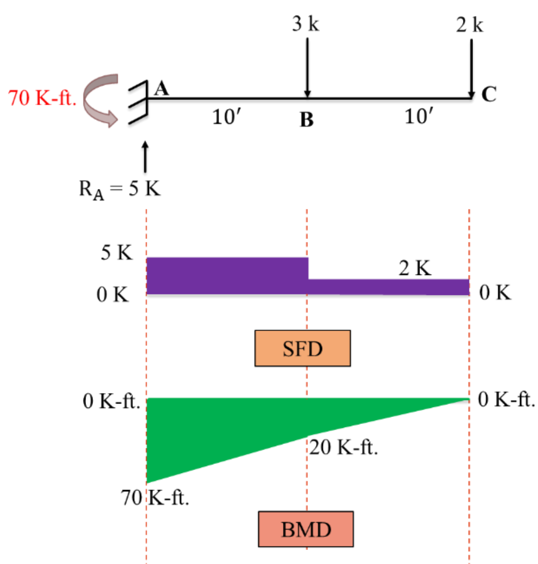
=> $0 = 15 - \frac{12x - x^2}{2}$

=> $x = 3.55'$

Problem-13: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



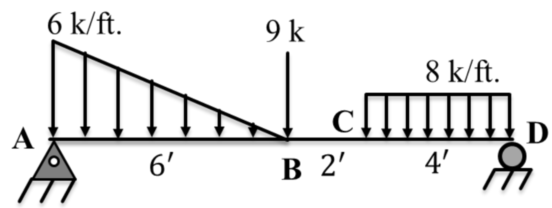
$\sum M_A = 0$

=> $M_A = 3 \times 10 + 2 \times 20 = 70$ k-ft.

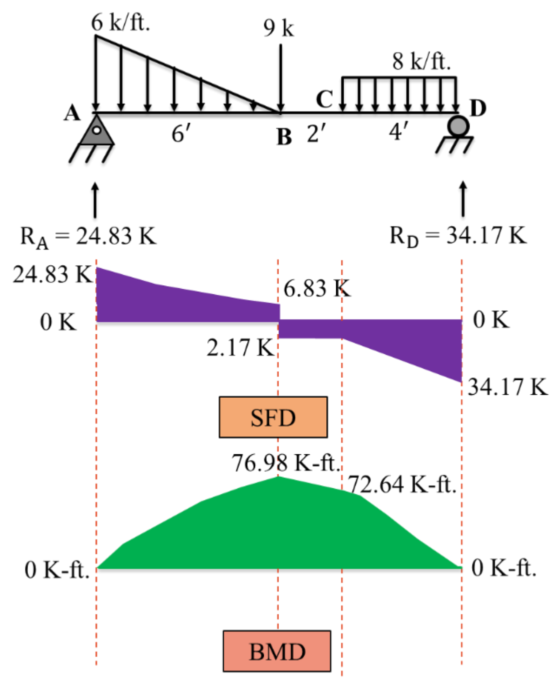
$\sum F_y = 0$

=> $R_A = 3\text{ K} + 2\text{ K} = 5\text{ K}$

Problem-14: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

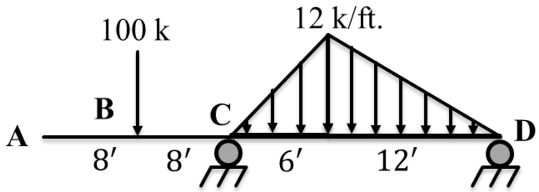
=> $0.5 \times 6 \times 6 \times \frac{1}{3} \times 6 + 9 \times 6 + 8 \times 4 \times 10 - R_D \times 12 = 0$

=> $R_D = 34.17$ K

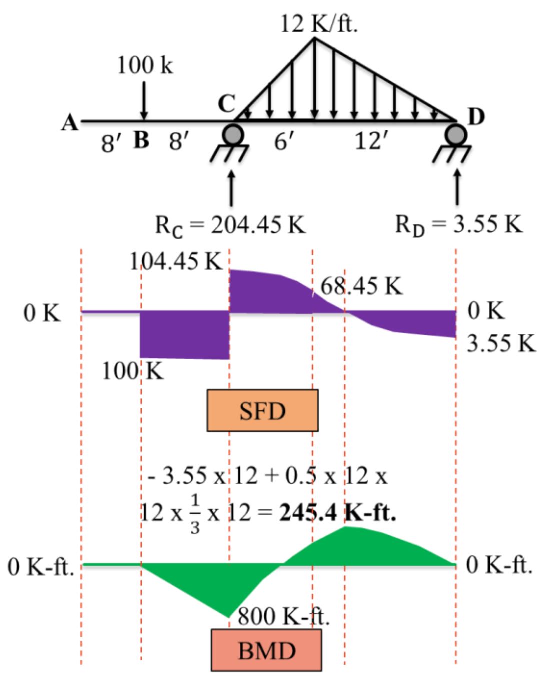
$\sum F_y = 0$

=> $R_A = 24.83$ K.

Problem-15: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_C = 0$

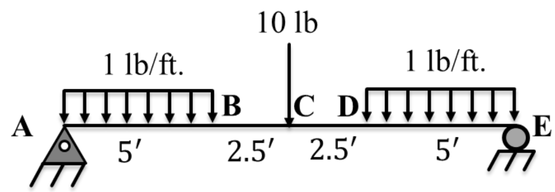
=> $- 100 \times 8 + 0.5 \times 6 \times 12 \times \frac{2}{3} \times 6 + 0.5 \times 12 \times 12 \times (6 + \frac{1}{3} \times 12) - R_D \times 18 = 0$

=> $R_D = 3.55$ K

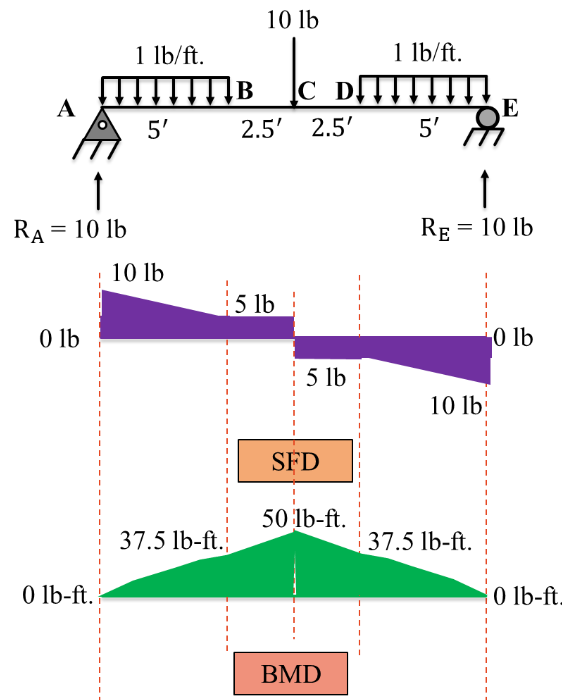
$\sum F_y = 0$

=> $R_C = 204.45$ K.

Problem-16: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

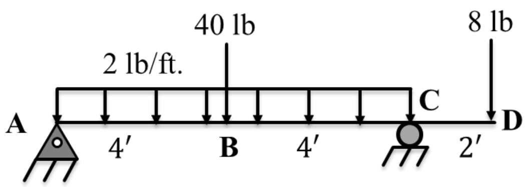
=> $1 \times 5 \times 2.5 + 10 \times 7.5 + 1 \times 5 \times 12.5 - R_E \times 15 = 0$

=> $R_E = 10$ lb

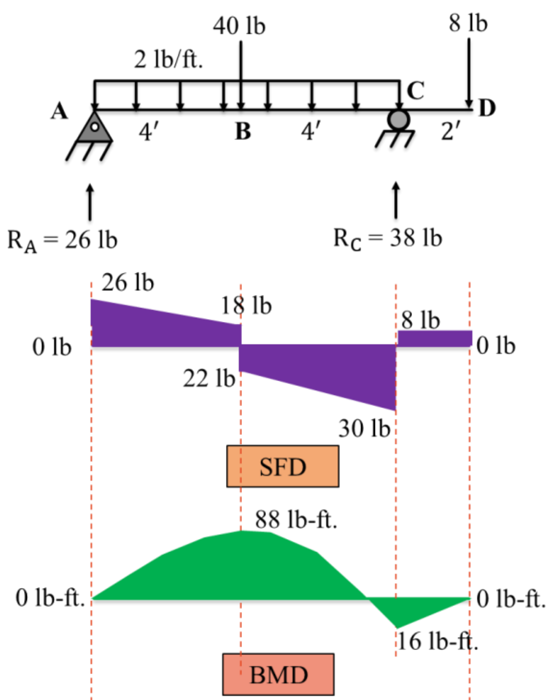
$\sum F_y = 0$

=> $R_A = 10$ K.

Problem-17: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

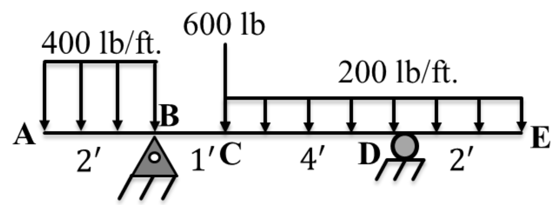
=> 2 x 8 x 4 + 40 x 4 + 8 x 10 - R_C x 8 = 0

=> R_C = 38 lb

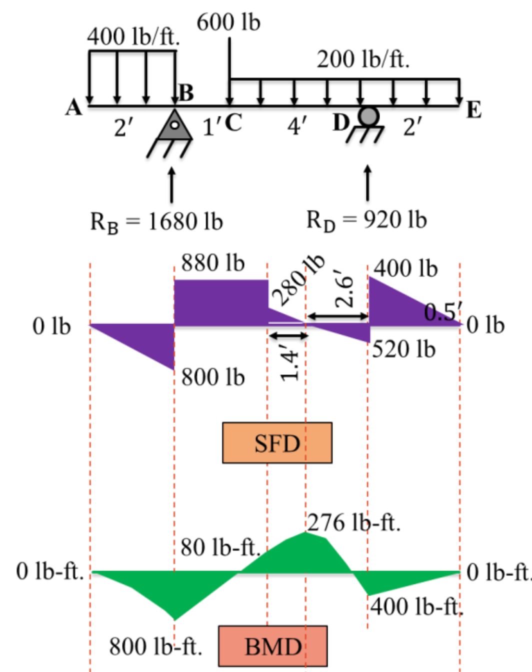
$\sum F_y = 0$

=> R_A = 26 kN.

Problem-18: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

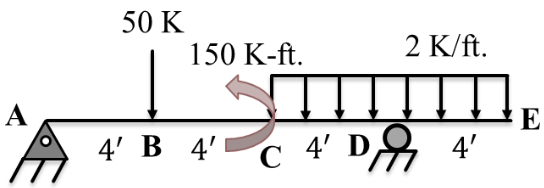
=> - 400 x 2 x 1 + 600 x 1 + 200 x 6 x 4 - R_D x 5 = 0

=> R_D = 920 lb

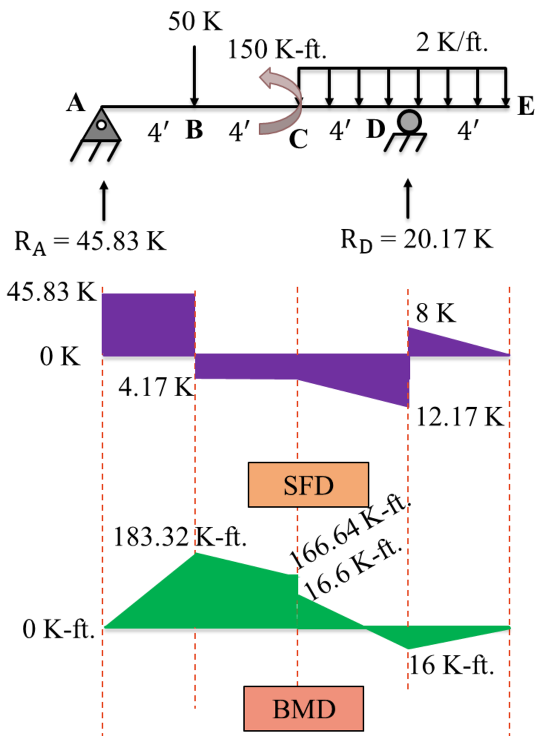
$\sum F_y = 0$

=> R_B = 1680 lb.

Problem-19: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

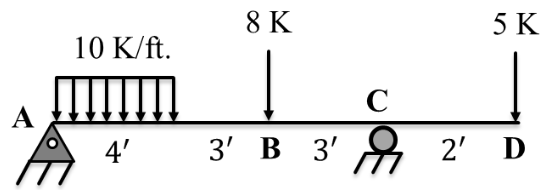
=> 50 x 4 – 150 + 2 x 8 x 12 - R_D x 12 = 0

=> R_D = 20.17 K

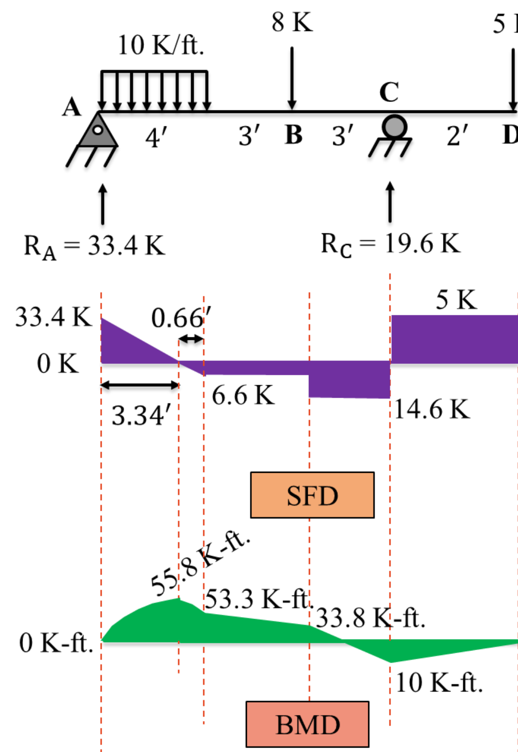
$\sum F_y = 0$

=> R_A = 45.83 K.

Problem-20: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

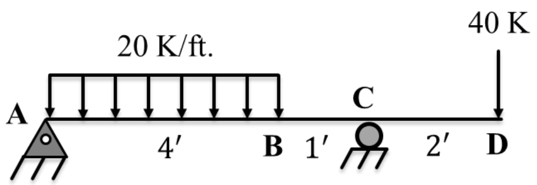
=> 10 x 4 x 2 + 8 x 7 + 5 x 12 - R_C x 10 = 0

=> R_C = 19.6 K

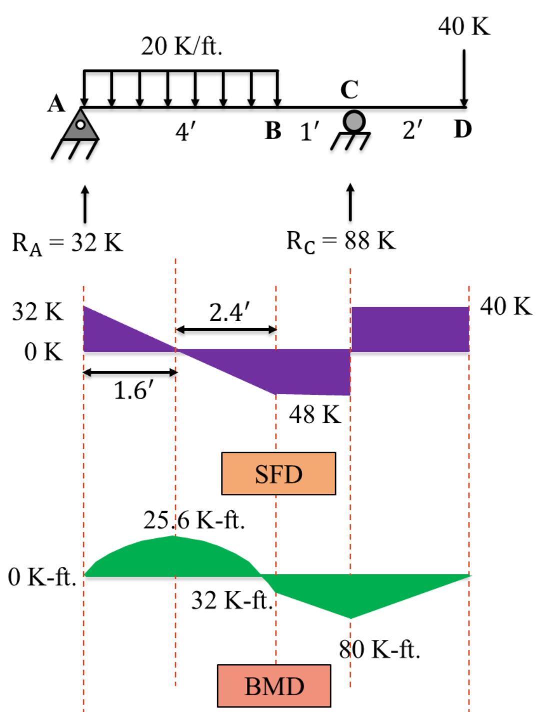
$\sum F_y = 0$

=> R_A = 33.4 K.

Problem-21: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

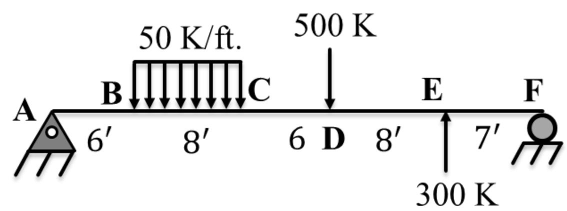
=> (20 x 4) x 2 + 40 x 7 - R_C x 5 = 0

=> R_C = 88 K

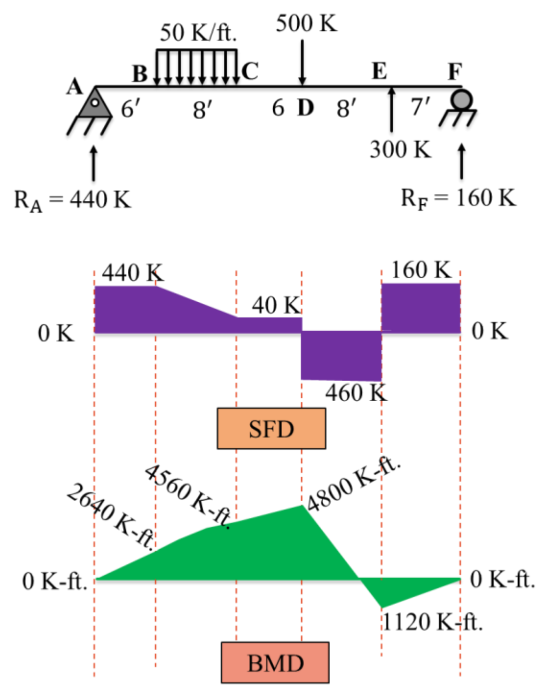
$\sum F_y = 0$

=> R_A = 32 K.

Problem-22: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

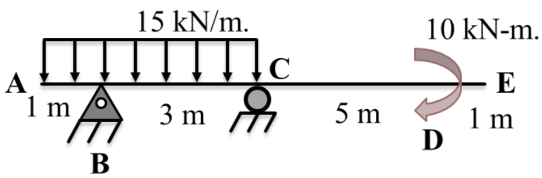
=> 50 x 8 x 10 + 500 x 20 – 300 x 28 - R_F x 36 = 0

=> R_F = 160 K

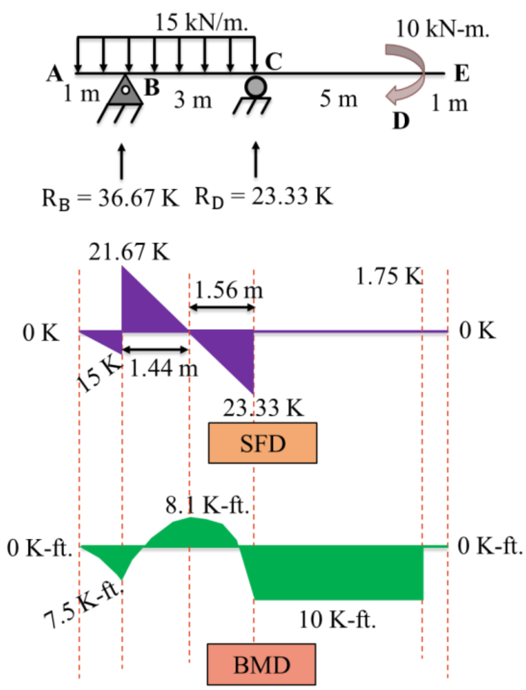
$\sum F_y = 0$

=> R_A = 440 K.

Problem-23: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_C = 0$

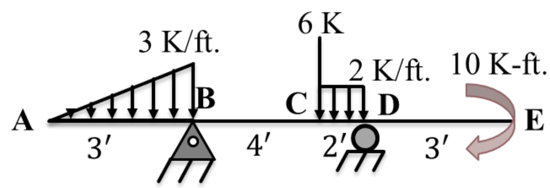
=> - 15 x 4 x 2 + 10 - R_B x 3 = 0

=> R_B = 36.67 K

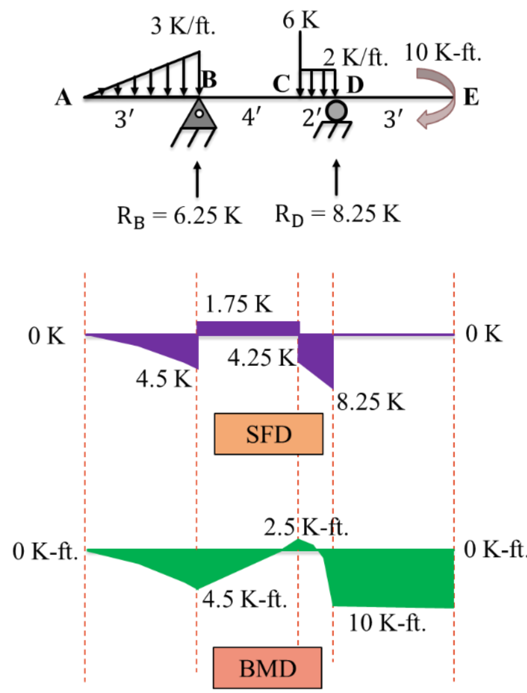
$\sum F_y = 0$

=> R_B = 36.67 K.

Problem-24: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

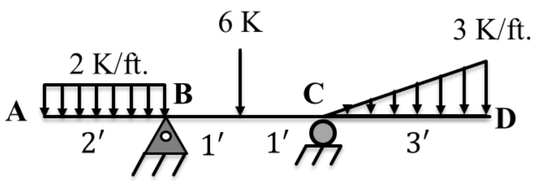
=> - 0.5 x 3 x 3 x $\frac{1}{3}$ x 3 + 6 x 4 + 2 x 2 x 5 + 10 - R_D x 6 = 0

=> R_D = 49.5/6 = 8.25 K

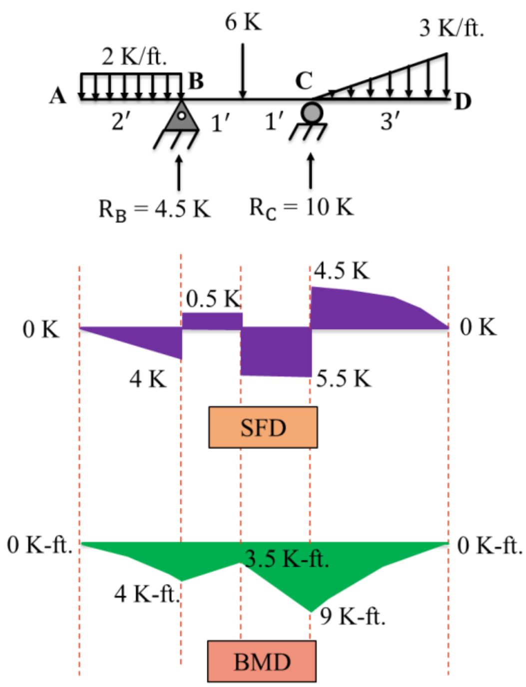
$\sum F_y = 0$

=> R_B = 6.25 K.

Problem-25: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

=> $- 2 \times 2 \times 1 + 6 \times 1 +$

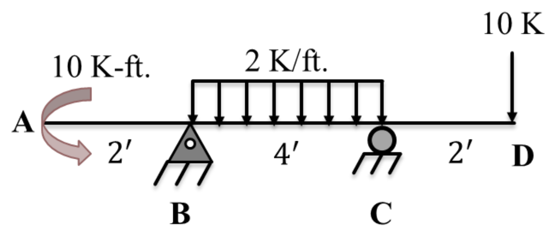
$$0.5 \times 3 \times 3 \times (2 + \frac{2}{3} \times 3) - R_C \times 2 = 0$$

=> $R_C = 20/2 = 10$ K

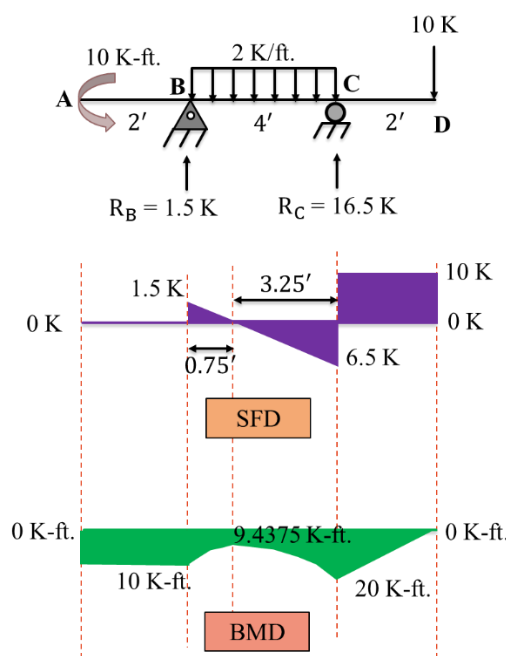
$\sum F_y = 0$

=> $R_B = 4.5$ k.

Problem-26: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

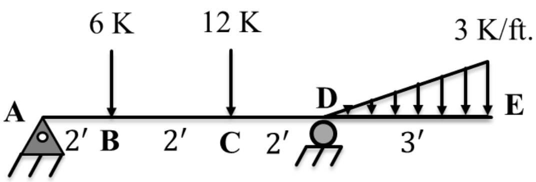
=> $- 10 + 2 \times 4 \times 2 + 10 \times 6 - R_C \times 4 = 0$

=> $R_C = 66/4 = 16.5$ K

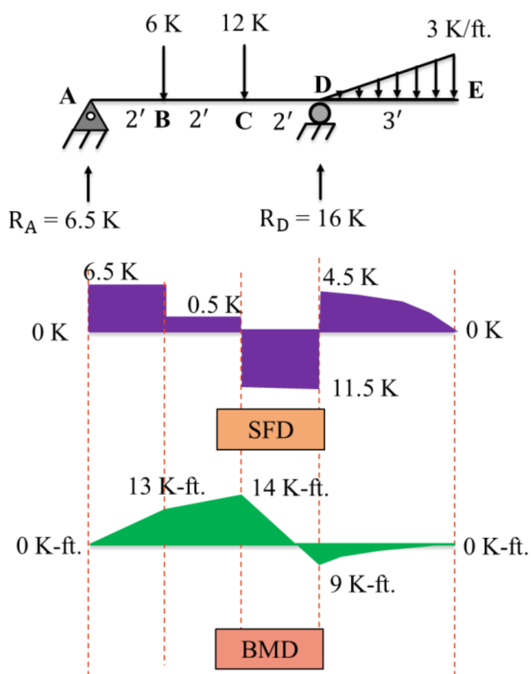
$\sum F_y = 0$

=> $R_B = 1.5$ K.

Problem-27: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

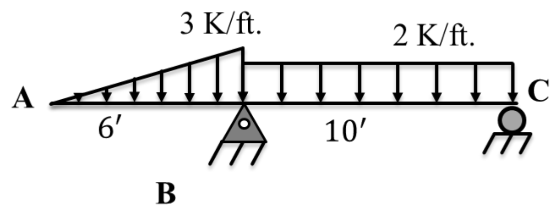
=> $6 \times 2 + 12 \times 4 - 0.5 \times 3 \times 3 \times (6 + \frac{2}{3} \times 3) - R_D \times 6 = 0$

=> $R_D = 16$ K

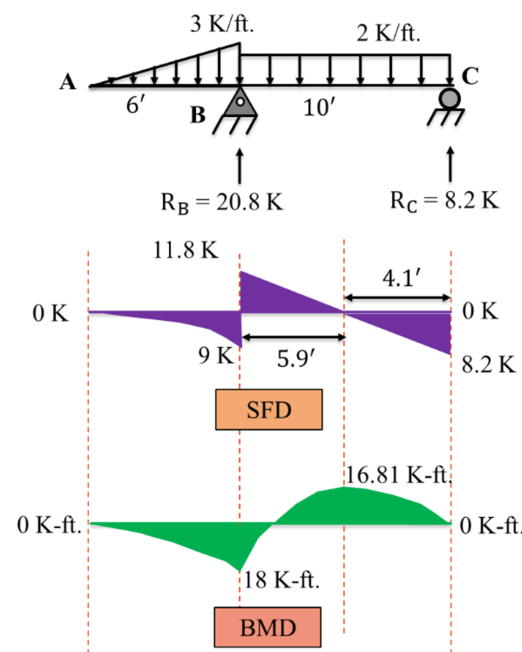
$\sum F_y = 0$

=> $R_A = 6.5$ K.

Problem-28: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

=> $-(0.5 \times 6 \times 3) \times (\frac{1}{3} \times 6) + 2 \times 10 \times 5 - R_C \times 10 = 0$

=> $R_C \times 10 = 82$

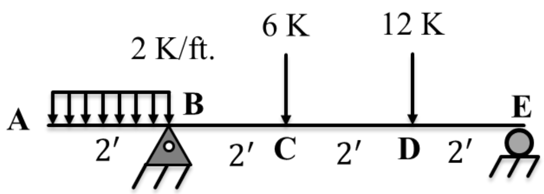
=> $R_C = 82/10 = 8.2$ K

$\sum F_y = 0$

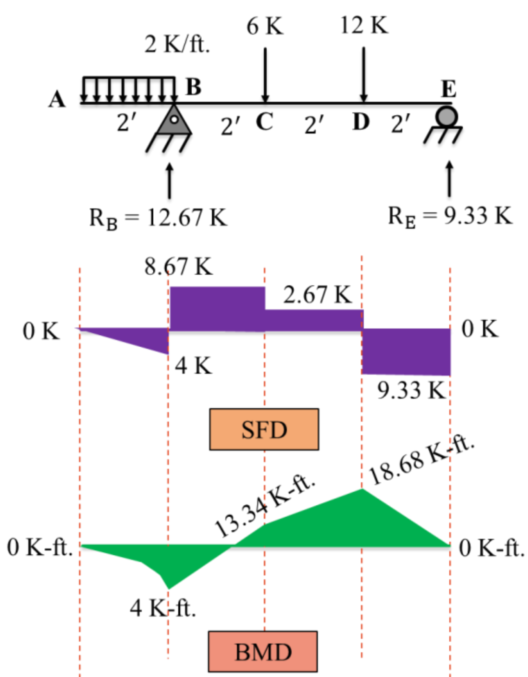
=> $R_B + R_C - 0.5 \times 6 \times 3 - 2 \times 10 = 0$

=> $R_B = 29 - R_C = 29 - 8.2 = 20.8$ K

Problem-29: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_B = 0$

=> - (2 x 2) x 1 + 6 x 2 + 12 x 4 - R_E x 6 = 0

=> R_E x 6 = 34

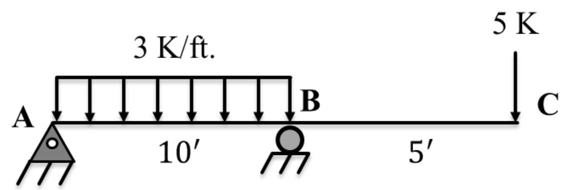
=> R_E = 34/6 = 9.33 K

$\sum F_y = 0$

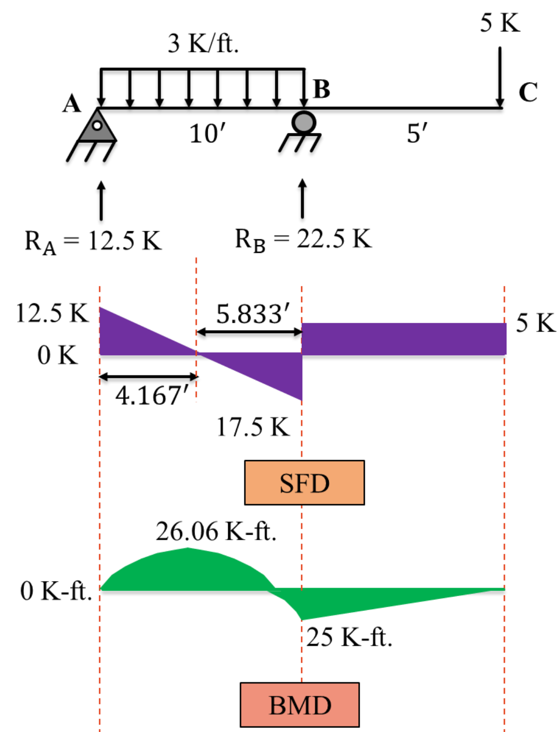
=> R_B + R_E - 2 x 2 - 6 - 12 = 0

=> R_B = 22 - R_E = 22 – 9.33 = 12.67 K

Problem-30: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

=> (3 x 10) x 5 + 5 x (10 + 5) - R_B x 10 = 0

=> R_B x 10 = 150 + 75 = 225

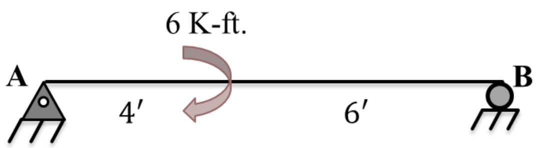
=> R_B = 225/10 = 22.5 K

$\sum F_y = 0$

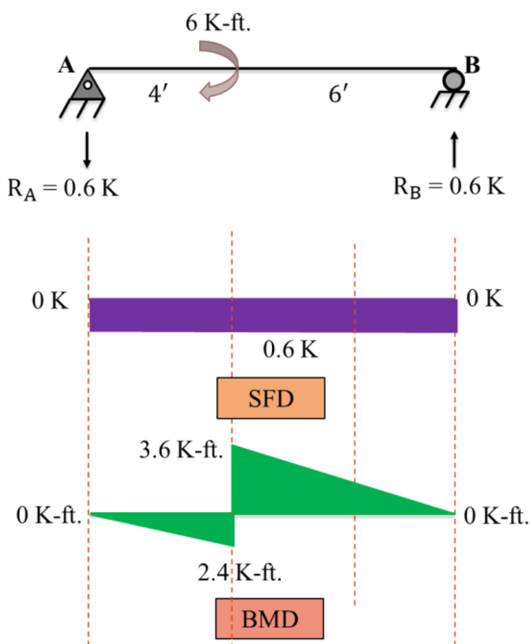
=> R_A + R_B - 3 x 10 - 5 = 0

=> R_A = 35 - R_B = 35 – 22.5 = 12.5 K

Problem-31: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

=> $6 - R_B \times 10 = 0$

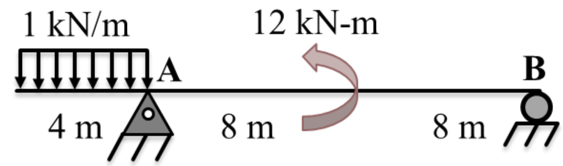
=> $R_B = 6/10 = 0.6$ K.

$\sum F_y = 0$

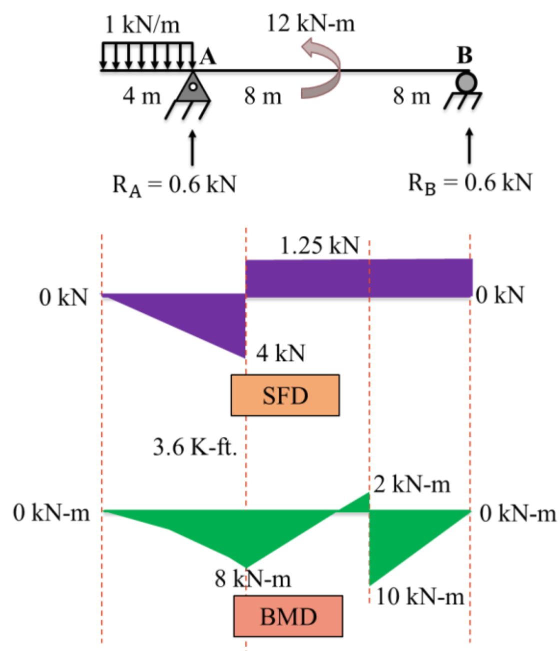
=> $R_A + R_B + 0.6 = 0$

=> $R_A = -0.6$ K.

Problem-32: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



$\sum M_A = 0$

=> $-4 \times 1 \times 2 - 12 - R_B \times 16 = 0$

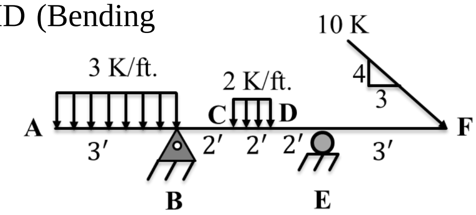
=> $R_B = -20/16 = -1.25$ kN.

$\sum F_y = 0$

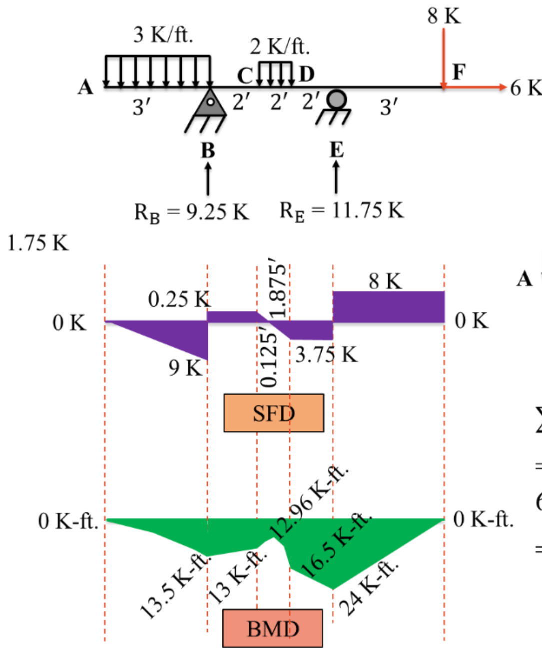
=> $R_A + R_B - 4 = 0$

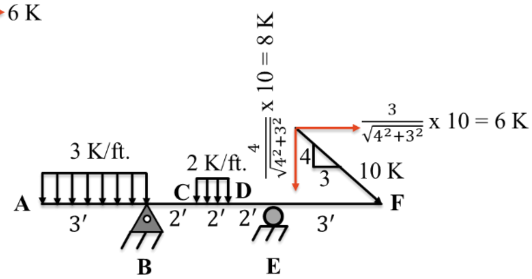
=> $R_A = -5.25$ kN.

Problem-33: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



Solution:



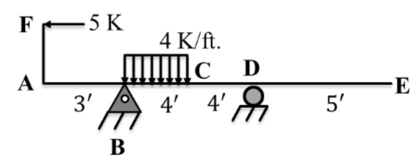


$\sum M_B = 0$

=> - 3 x 3 x 1.5 + 2 x 2 x 3 + 8 x 9 - R_E x 6 = 0

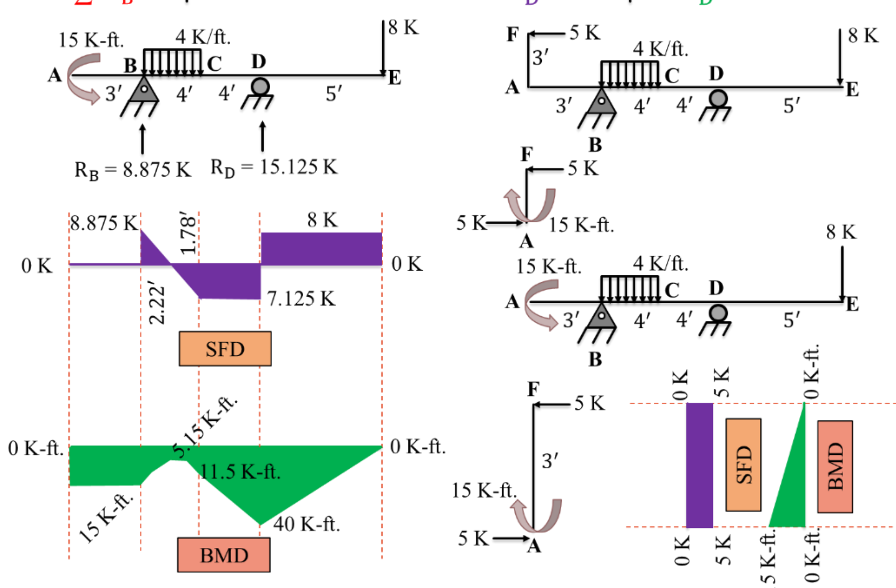
=> R_E = 11.75 K

Problem-34: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.

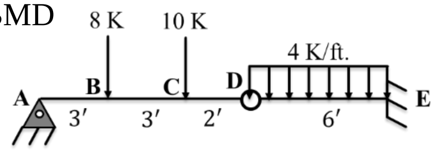


Solution:

$\sum M_B = 0$ | => - 15 + 4 x4 x 2 + 8 x 13 - R_D x 8 = 0 | => R_D = 15.125 K

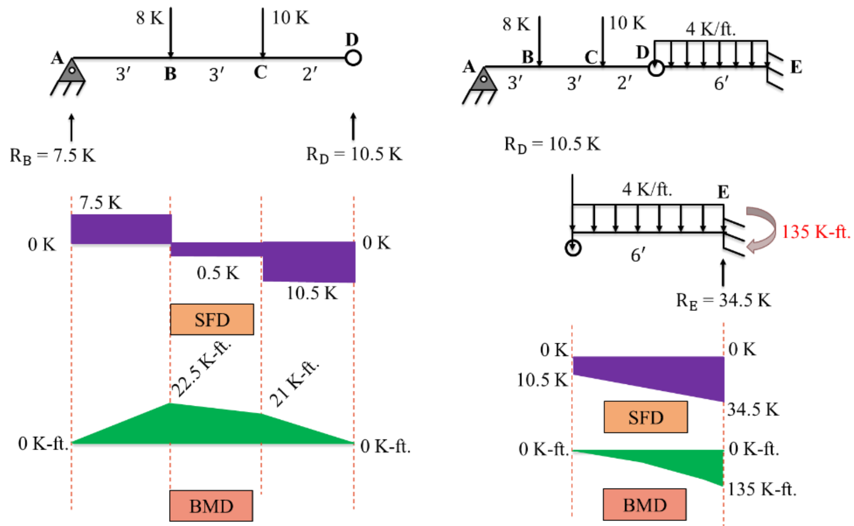


Problem-35: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.

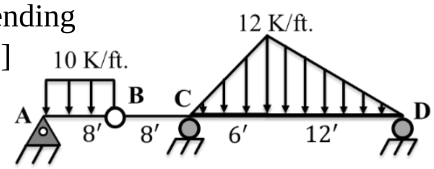


Solution:

$\sum M_A = 0$ | => $8 \times 3 + 10 \times 6 - R_D \times 8 = 0$ | => $R_D = 10.5$ K

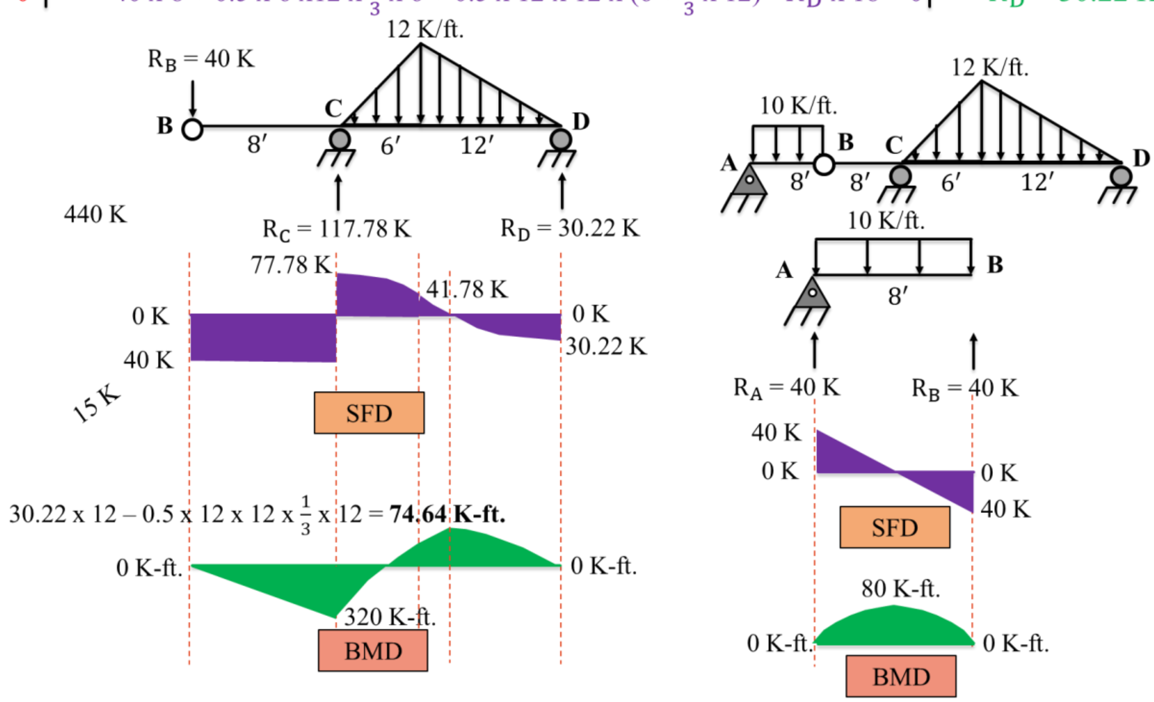


Problem-36: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam. [Janata Bank – 2017]

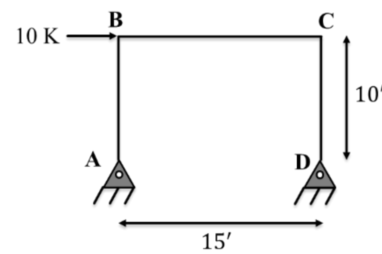


Solution:

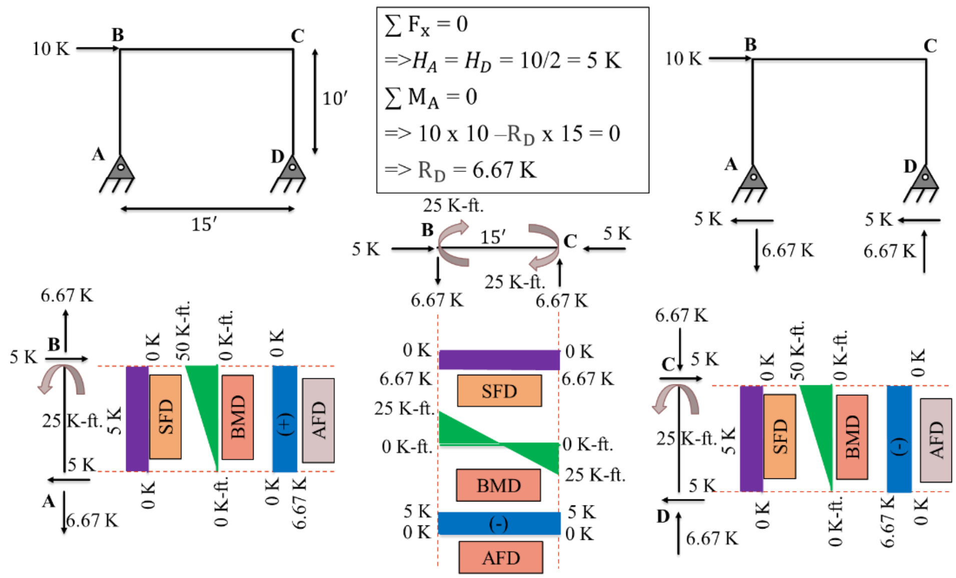
$\sum M_C = 0$ | => $- 40 \times 8 + 0.5 \times 6 \times 12 \times \frac{2}{3} \times 6 + 0.5 \times 12 \times 12 \times (6 + \frac{1}{3} \times 12) - R_D \times 18 = 0$ | => $R_D = 30.22$ K



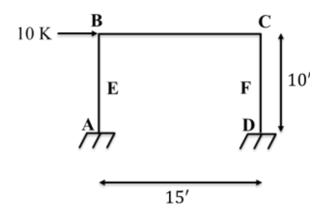
Problem-37: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



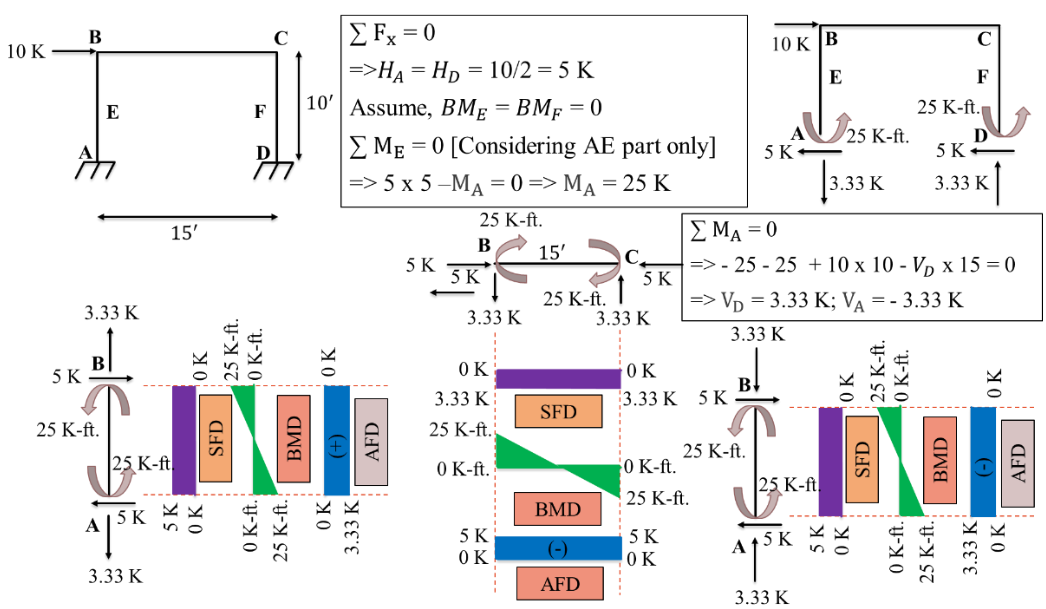
Solution:



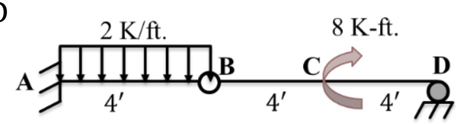
Problem-38: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



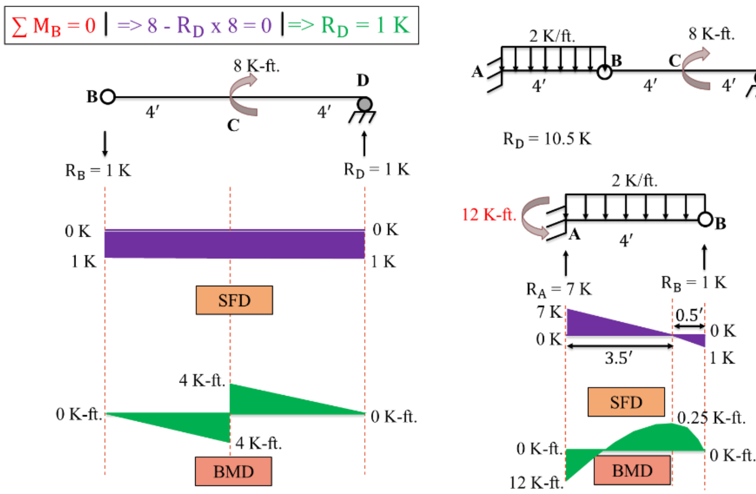
Solution:



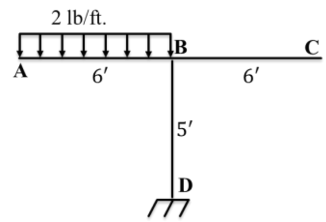
Problem-39: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



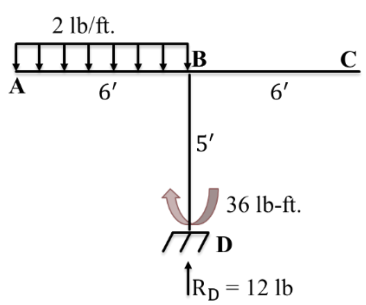
Solution:



Problem-40: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



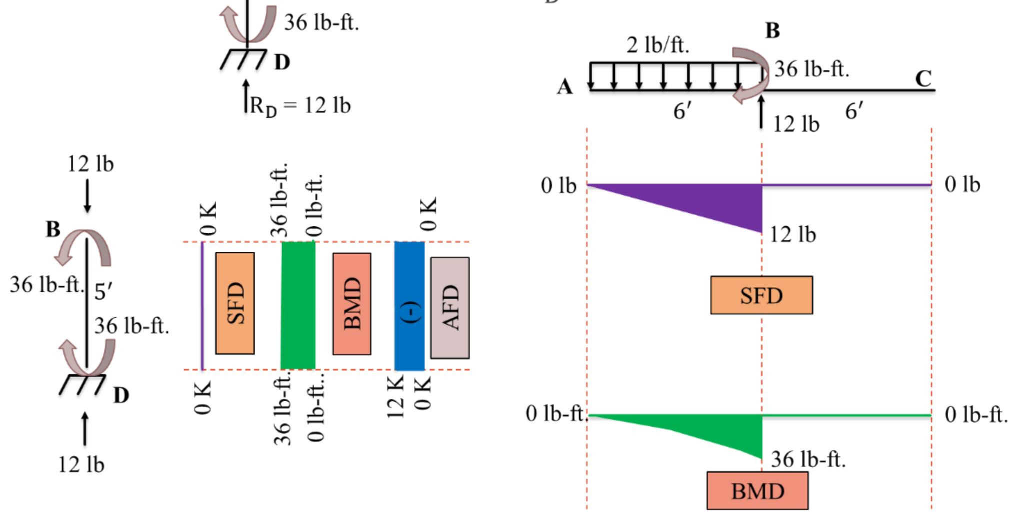
Solution:



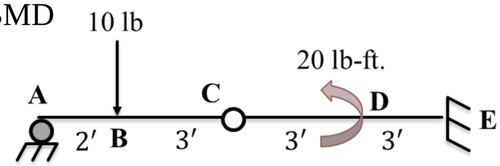
$\sum M_D = 0$

$\Rightarrow - 2 \times 6 \times 3 + M_D = 0$

$\Rightarrow M_D = 36$ lb-ft.

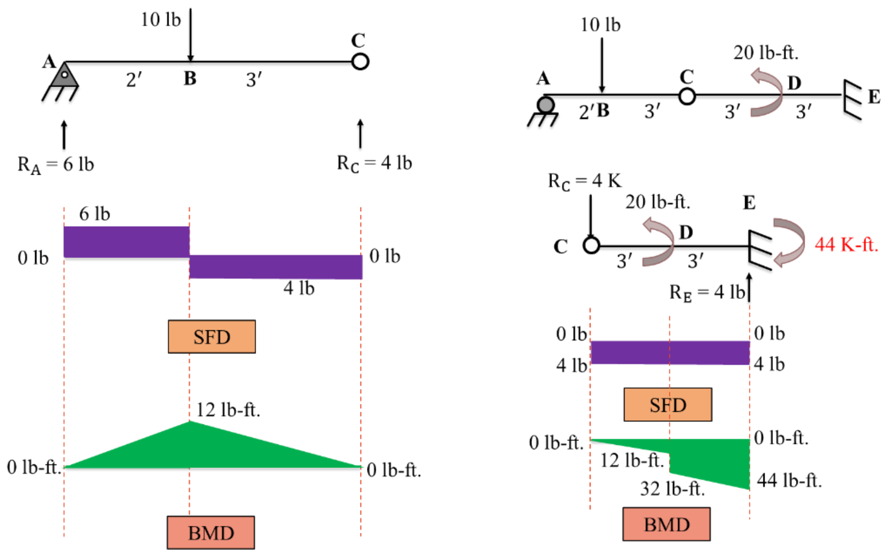


Problem-41: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.

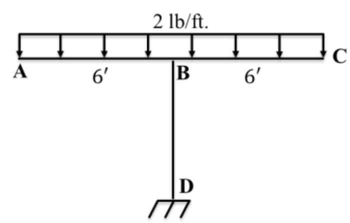


Solution:

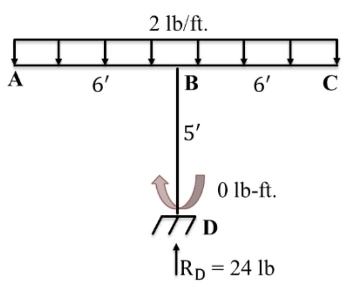
$\sum M_A = 0$ | => 10 x 2 - R_C x 5 = 0 | => R_C = 4 lb



Problem-42: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



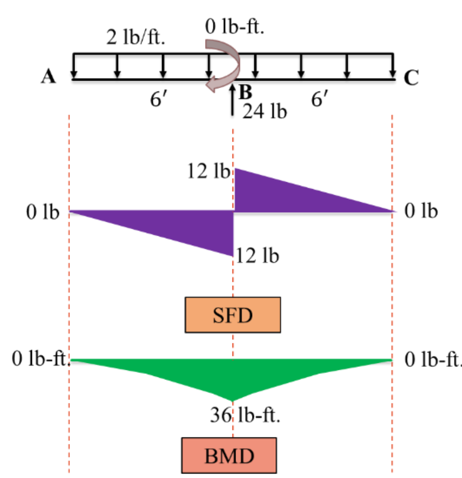
Solution:

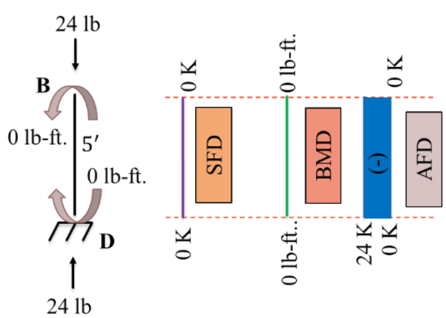


$\sum M_D = 0$

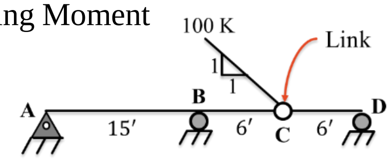
=> - 2 x 6 x 3 + 2 x 6 x 3 + M_D = 0

=>M_D= 0 lb-ft.

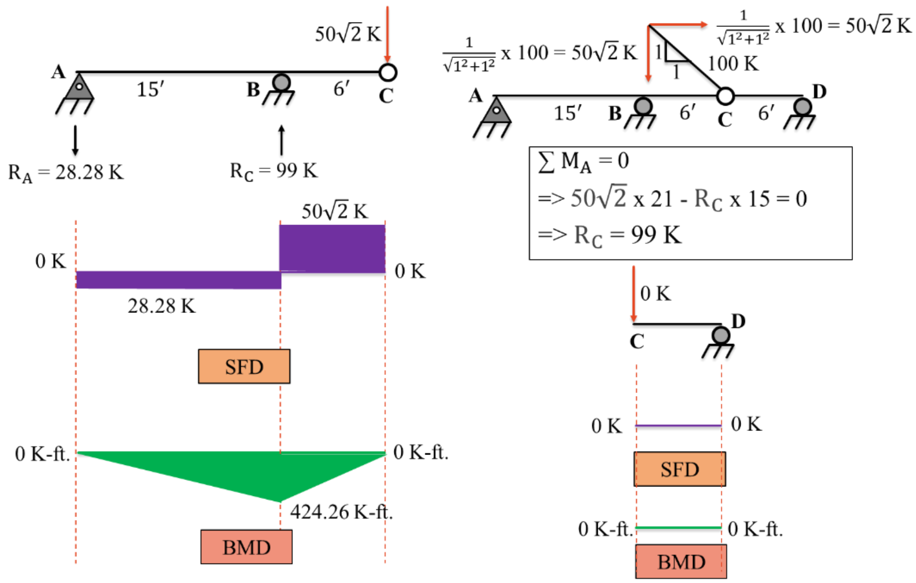




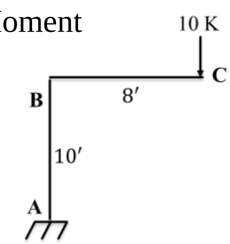
Problem-43: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



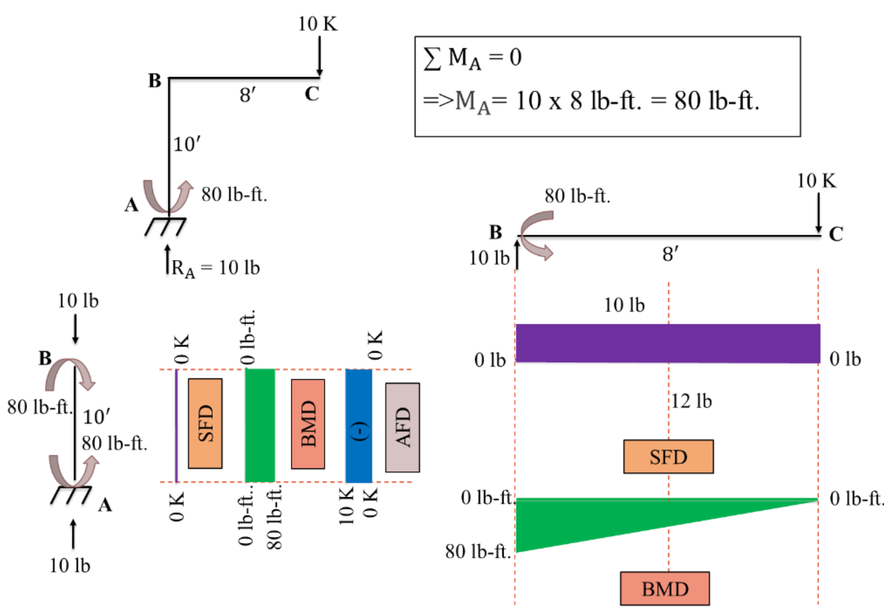
Solution:



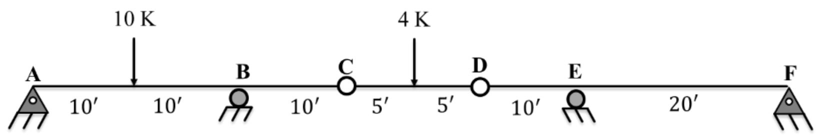
Problem-44: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.



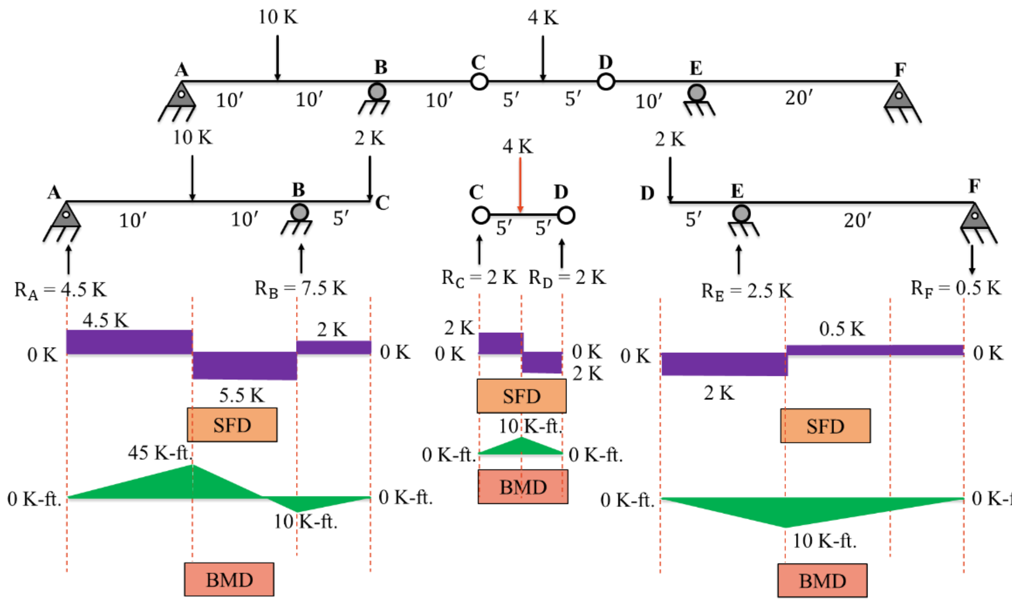
Solution:



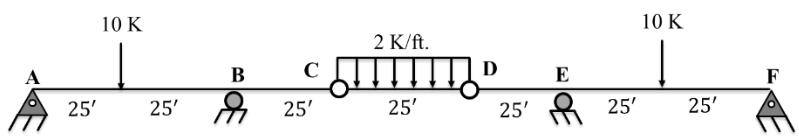
Problem-45: Draw SFD & BMD.



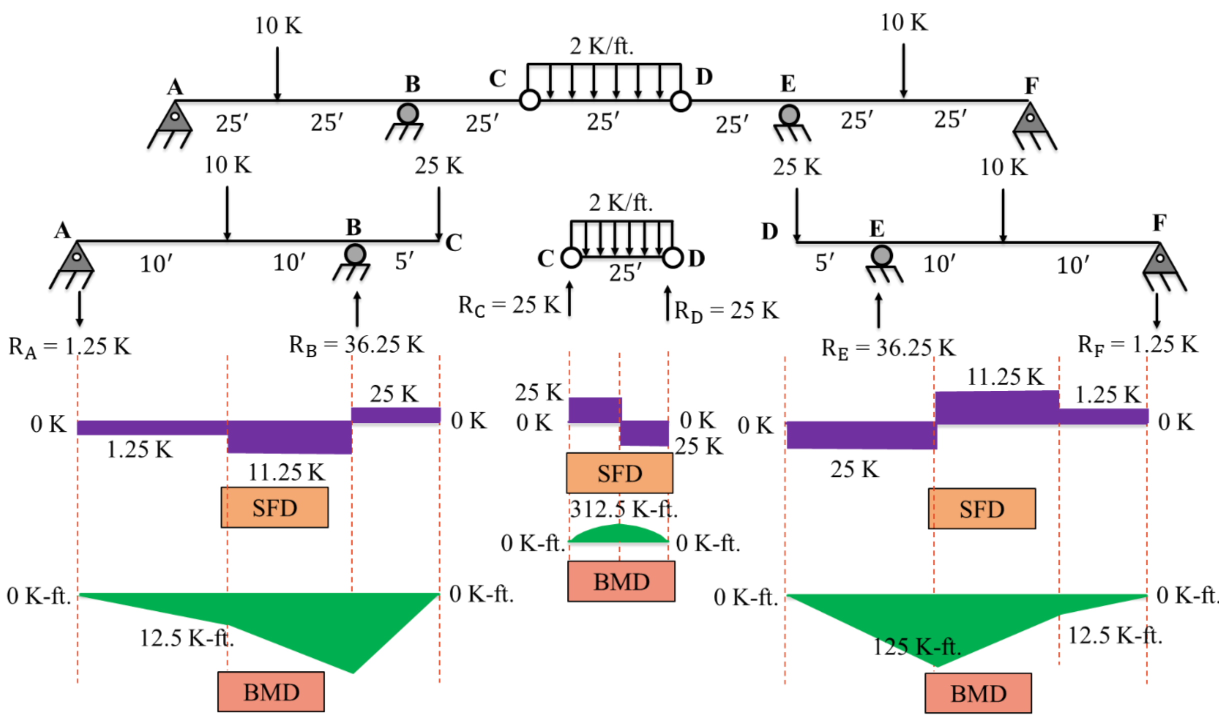
Solution:



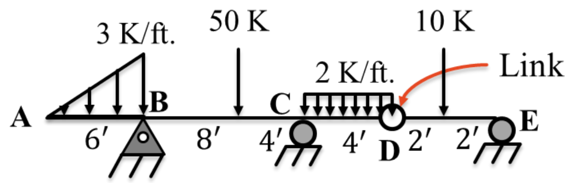
Problem-46: Draw SFD & BMD.



Solution:

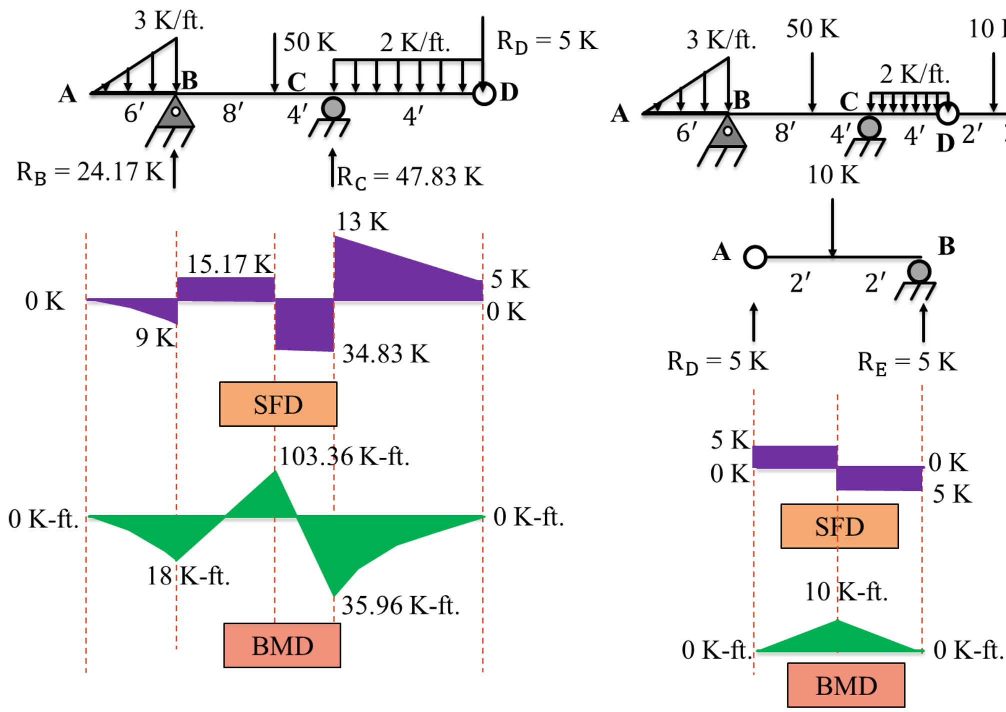


Problem-47: Find the SFD (Shear Force Diagram) & BMD (Bending Moment Diagram) of the following beam.

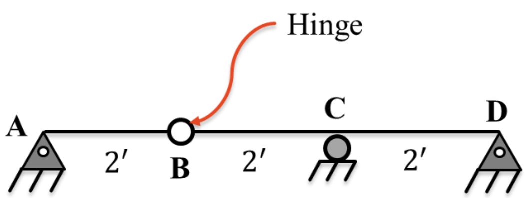


Solution:

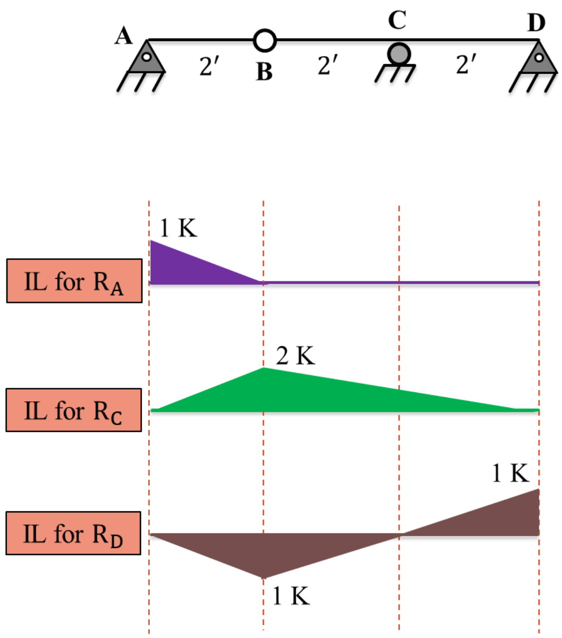
$\sum M_B = 0$ | => $- 0.5 \times 6 \times 3 \times \frac{1}{3} \times 6 + 50 \times 8 + 2 \times 4 \times 14 + 5 \times 16 - R_C \times 12 = 0$ | => $R_C = 47.83$ K



Problem-48: Draw the IL diagram of R_A, R_C & R_D for the following structure due to a point loading.



Solution:



Load on A

$R_A = 1$ k

$R_C = 0$ K

$R_D = 0$ K

Load on B

$R_A = 0$ k

$R_C = 2$ K

$R_D = -1$ K

Load on C

$R_A = 0$ k

$R_C = 1$ K

$R_D = 0$ K

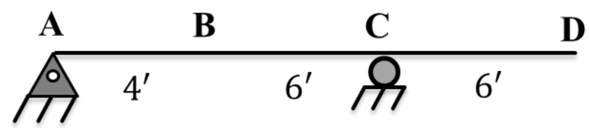
Load on D

$R_A = 0$ k

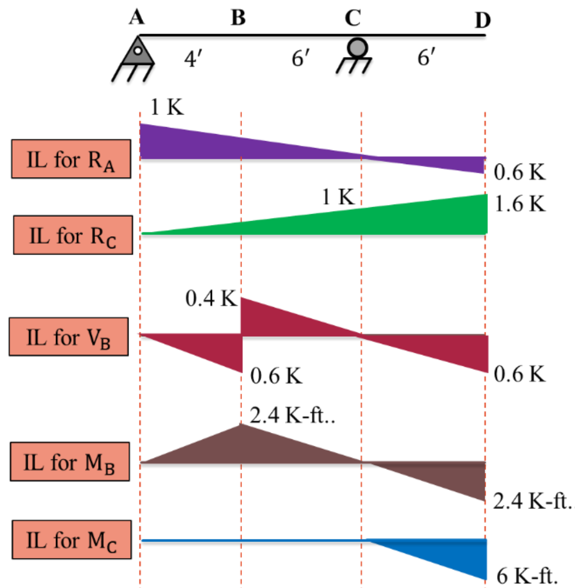
$R_C = 0$ K

$R_D = 1$ K

Problem-49: Draw the IL diagram of R_A, R_C, V_B, M_B & M_C for the following structure due to a point loading.



Solution:



Load on A

$R_A = 1$ K

$R_C = 0$ K

Load on B

$R_A = 0.6$ K

$R_C = 0.4$ K

Load on C

$R_A = 0$ K

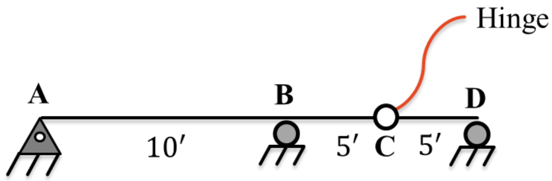
$R_C = 1$ K

Load on D

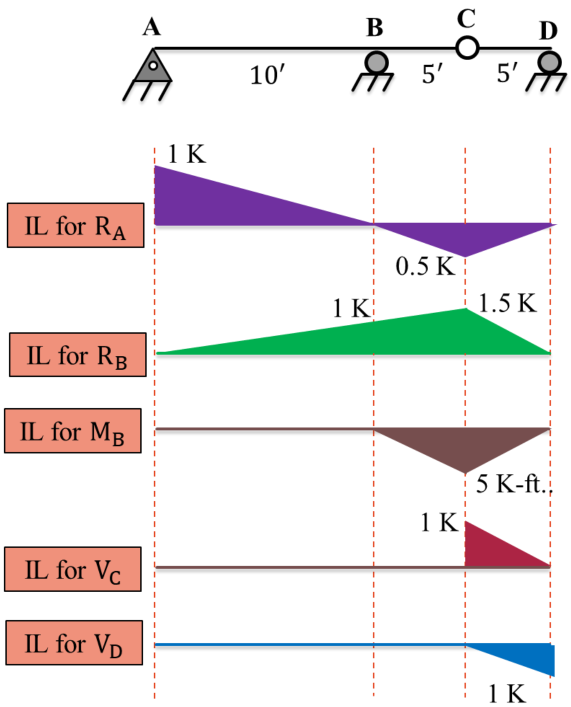
$R_A = -0.6$ K

$R_C = 1.6$ K

Problem-50: Draw the IL diagram of R_A, R_B, M_B, V_C & V_D for the following structure due to a point loading.



Solution:



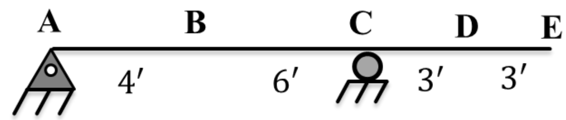
Load on A
R_A = 1 K
R_B = 0 K
R_D = 0 K

Load on B
R_A = 0 K
R_B = 1 K
R_D = 0 K

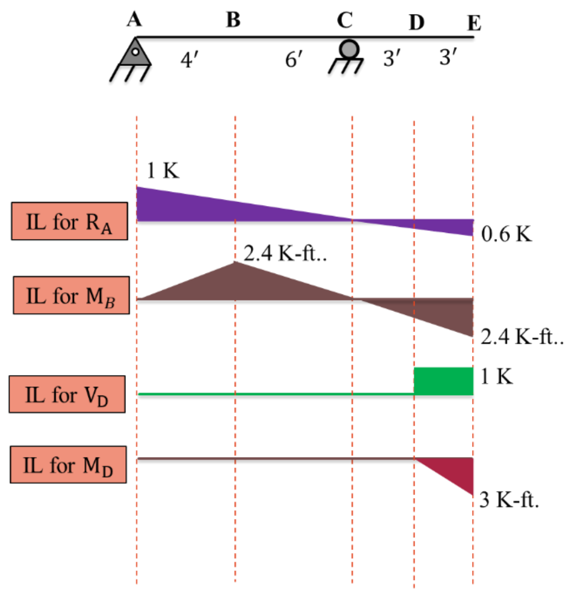
Load on C
R_A = - 0.5 K
R_B = 1.5 K
R_D = 0 K

Load on D
R_A = 0 K
R_B = 0 K
R_D = 1 K

Problem-51: Draw the IL diagram of R_A, M_B, V_D & M_D for the following structure due to a point loading.



Solution:



Load on A
R_A = 1 K
R_C = 0 K

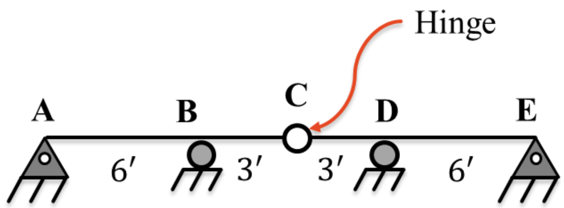
Load on B
R_A = 0.6 K
R_C = 0.4 K

Load on C
R_A = 0 K
R_C = 1 K

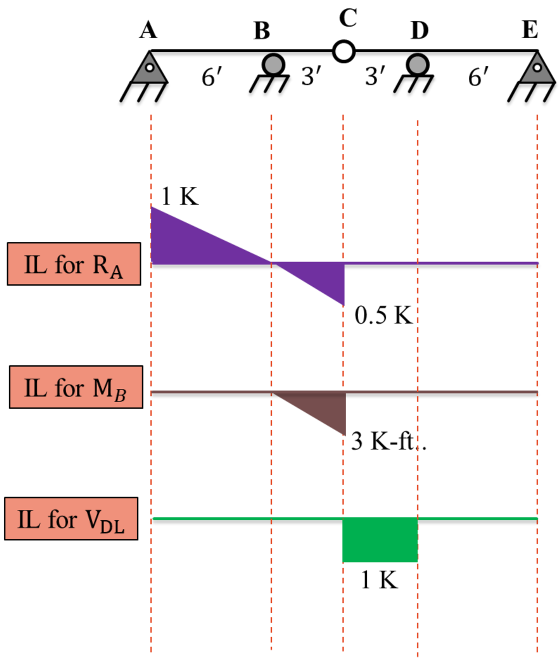
Load on D
R_A = - 0.3 K
R_C = 1.3 K

Load on E
R_A = - 0.6 K
R_C = 1.6 K

Problem-52: Draw the IL diagram of R_A, M_B & V_{DL} for the following structure due to a point loading.



Solution:



Load on A

$R_A = 1$ K

$R_B = 0$ K

Load on B

$R_A = 0$ K

$R_B = 1$ K

Load on C

$R_A = - 0.5$ K

$R_B = 1.5$ K

$R_D = 1.5$ K

$R_E = - 0.5$ K

Load on D

$R_D = 1$ K

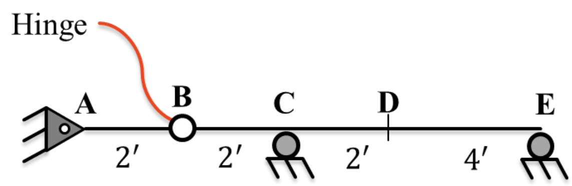
$R_E = 0$ K

Load on E

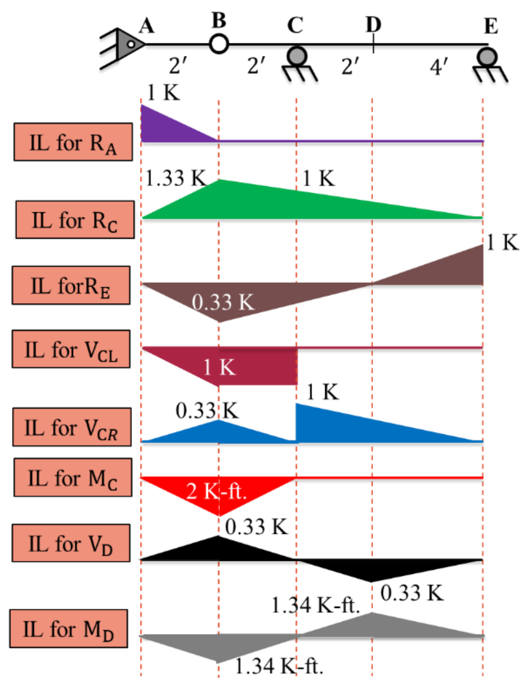
$R_D = 0$ K

$R_E = 1$ K

Problem-53: Draw the IL diagram of R_A, R_C, R_E, V_{CL}, V_{CR}, M_C, V_D & M_D for the following structure due to a point loading.



Solution:



Load on A

$R_A = 1$ K

$R_C = 0$ K

$R_E = 0$ K

Load on B

$R_A = 0$ K

$R_C = 1.33$ K

$R_E = - 0.33$ K

Load on C

$R_A = 0$ K

$R_C = 1$ K

$R_E = 0$ K

Load on D

$R_A = 0$ K

$R_C = 0.67$ K

$R_E = 0.33$ K

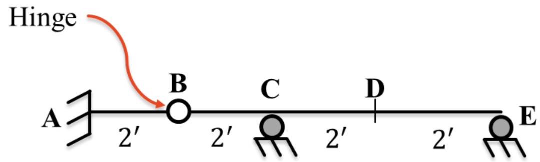
Load on E

$R_A = 0$ K

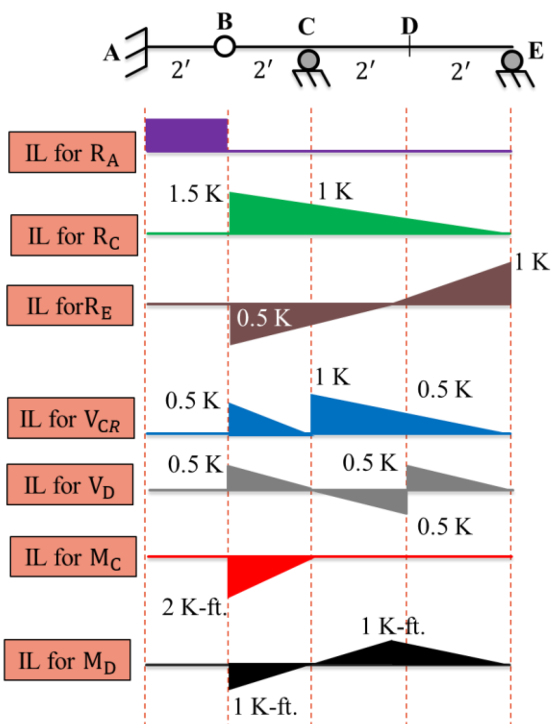
$R_C = 0$ K

$R_E = 1$ K

Problem-54: Draw the IL diagram of R_A, R_C, R_E, V_{CR}, M_C, V_D & M_D for the following structure due to a point loading.



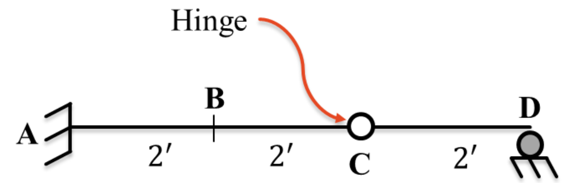
Solution:



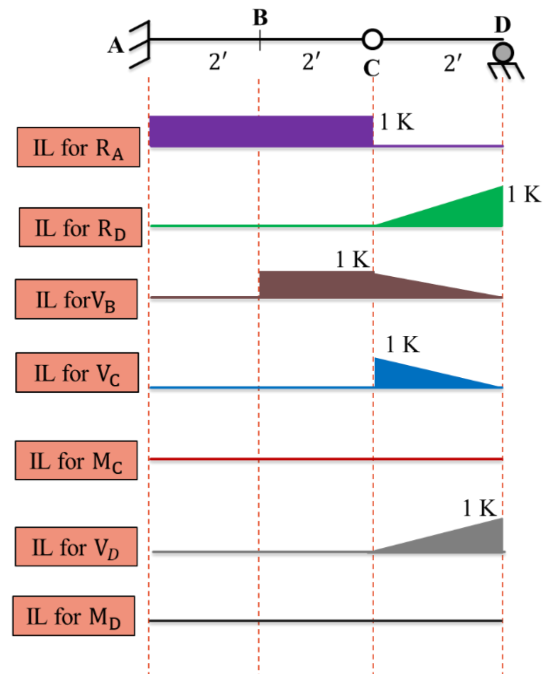
Load on A	Load on B (L)	Load on B (R)
$R_A = 1$ K	$R_A = 1$ K	$R_A = 0$ K
$R_C = 0$ K	$R_C = 0$ K	$R_C = 1.5$ K
$R_E = 0$ K	$R_E = 0$ K	$R_E = -0.5$ K

Load on C	Load on D	Load on E
$R_A = 0$ K	$R_A = 0$ K	$R_A = 0$ K
$R_C = 1$ K	$R_C = 0.5$ K	$R_C = 0$ K
$R_E = 0$ K	$R_E = 0.5$ K	$R_E = 1$ K

Problem-55: Draw the IL diagram of R_A, R_D, V_B, V_C, M_C, V_D & M_D for the following structure due to a point loading.



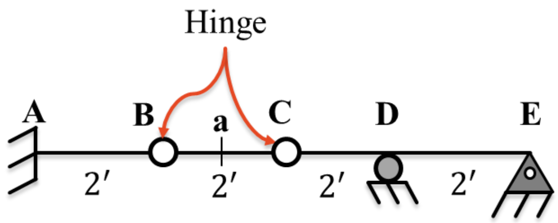
Solution:



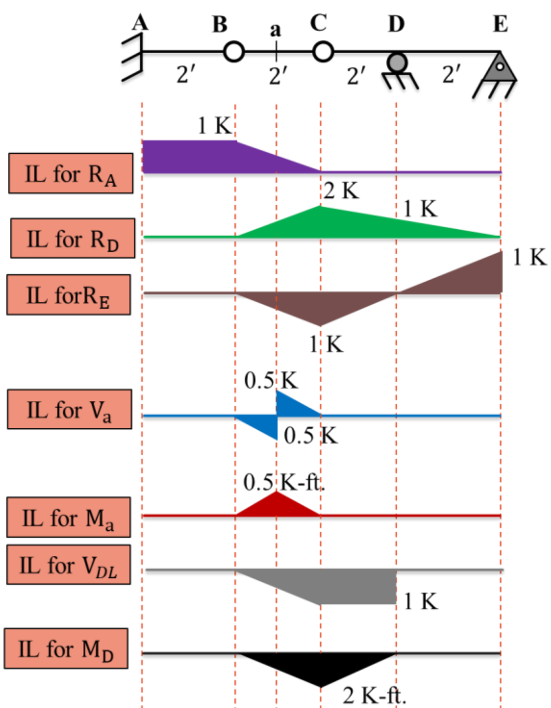
Load on A	Load on B
$R_A = 1$ K	$R_A = 1$ K
$R_D = 0$ K	$R_D = 0$ K

Load on C	Load on D
$R_A = 1$ K	$R_A = 0$ K
$R_D = 0$ K	$R_D = 1$ K

Problem-56: Draw the IL diagram of R_A, R_D, R_E, V_a, M_a, V_{DL} & M_D for the following structure due to a point loading.



Solution:

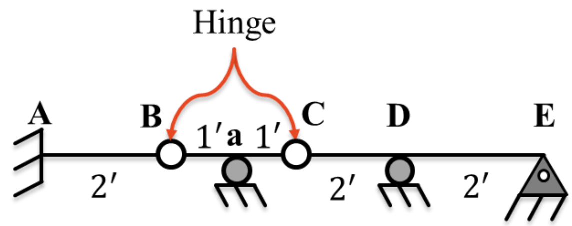


Load on A	Load on B
$R_A = 1$ K	$R_A = 1$ K
$R_D = 0$ K	$R_D = 0$ K
$R_E = 0$ K	$R_E = 0$ K

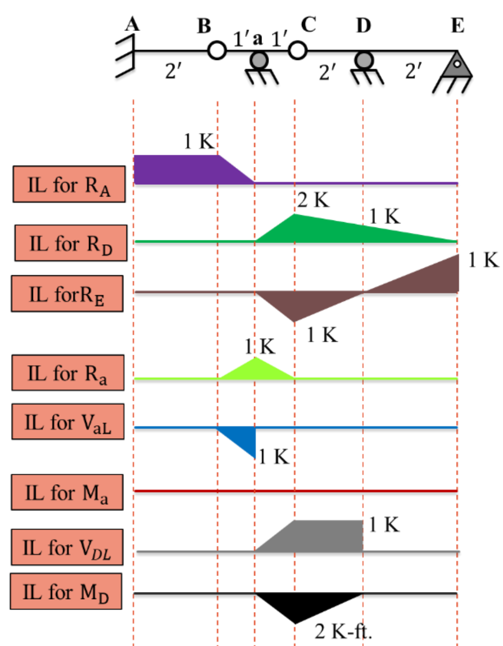
Load on a	Load on C
$R_A = 0.5$ K	$R_A = 0$ K
$R_D = 1.5$ K	$R_D = 2$ K
$R_E = -0.5$ K	$R_E = -1$ K

Load on D	Load on E
$R_A = 0$ K	$R_A = 0$ K
$R_D = 1$ K	$R_D = 0$ K
$R_E = 0$ K	$R_E = 1$ K

Problem-57: Draw the IL diagram of R_A, R_D, R_E, R_a, V_{aL}, M_a, V_{DL} & M_D for the following structure due to a point loading.



Solution:

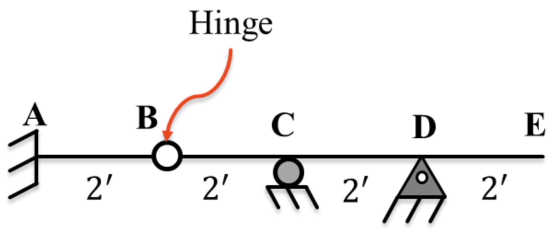


Load on A	Load on B
$R_A = 1$ K	$R_A = 1$ K
$R_D = 0$ K	$R_D = 0$ K
$R_E = 0$ K	$R_E = 0$ K
$R_a = 0$ K	$R_a = 0$ K

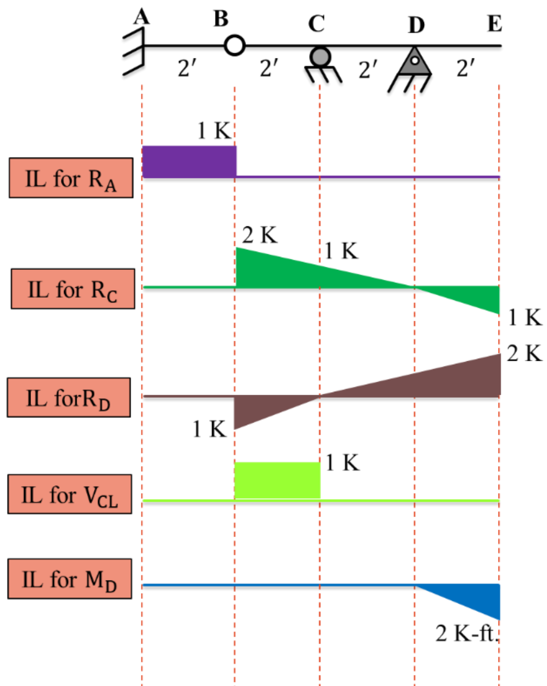
Load on a	Load on C
$R_A = 0$ K	$R_A = 0$ K
$R_D = 0$ K	$R_D = 2$ K
$R_E = 0$ K	$R_E = -1$ K
$R_a = 1$ K	$R_a = 0$ K

Load on D	Load on E
$R_A = 0$ K	$R_A = 0$ K
$R_D = 1$ K	$R_D = 0$ K
$R_E = 0$ K	$R_E = 1$ K
$R_a = 0$ K	$R_a = 0$ K

Problem-58: Draw the IL diagram of R_A, R_C, R_D, V_{CL} & M_D for the following structure due to a point loading.



Solution:



Load on A
$R_A = 1$ K
$R_C = 0$ K
$R_D = 0$ K

Load on B (L)
$R_A = 1$ K
$R_C = 0$ K
$R_D = 0$ K

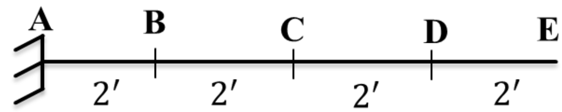
Load on B (R)
$R_A = 0$ K
$R_C = 2$ K
$R_D = -1$ K

Load on C
$R_A = 0$ K
$R_C = 1$ K
$R_D = 0$ K

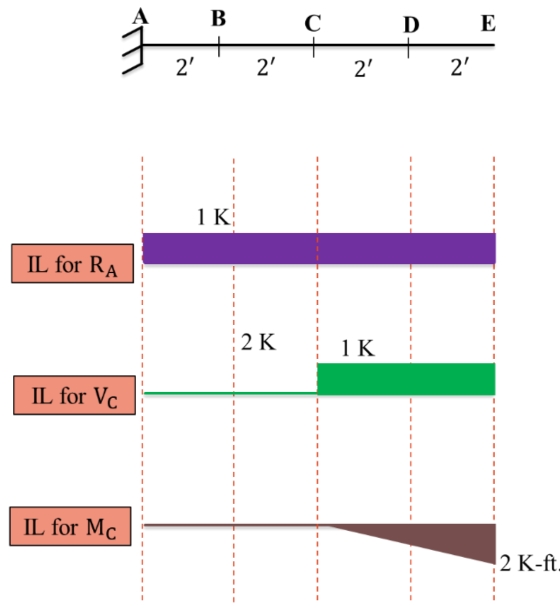
Load on D
$R_A = 0$ K
$R_C = 0$ K
$R_D = 1$ K

Load on E
$R_A = 0$ K
$R_C = -1$ K
$R_D = 2$ K

Problem-59: Draw the IL diagram of R_A, V_C & M_C for the following structure due to a point loading.



Solution:



Load on A
$R_A = 1$ K

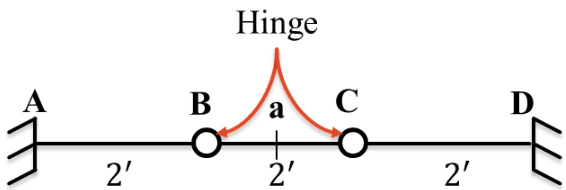
Load on B
$R_A = 1$ K

Load on C
$R_A = 1$ K

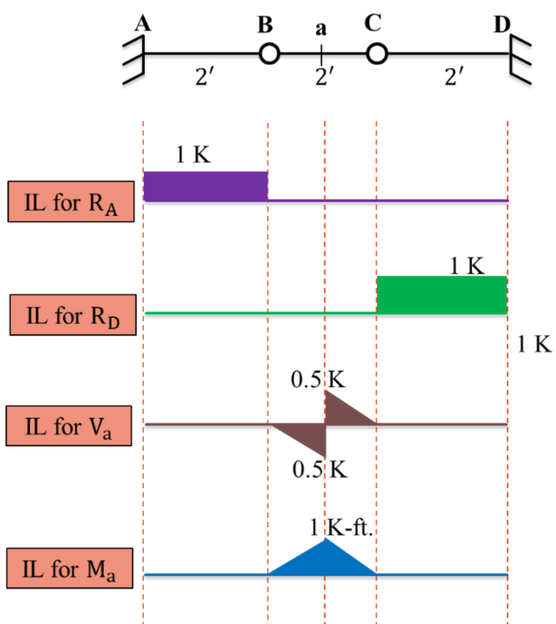
Load on D
$R_A = 1$ K

Load on E
$R_A = 1$ K

Problem-60: Draw the IL diagram of R_A, R_D, V_a & M_a for the following structure due to a point loading.



Solution:



Load on A
$R_A = 1$ K
$R_D = 0$ K

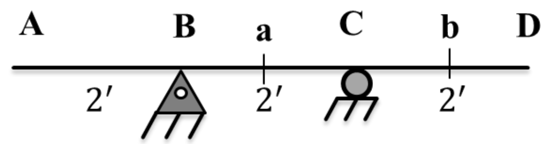
Load on B
$R_A = 1$ K
$R_D = 0$ K

Load on a
$R_A = 0.5$ K
$R_D = 0.5$ K

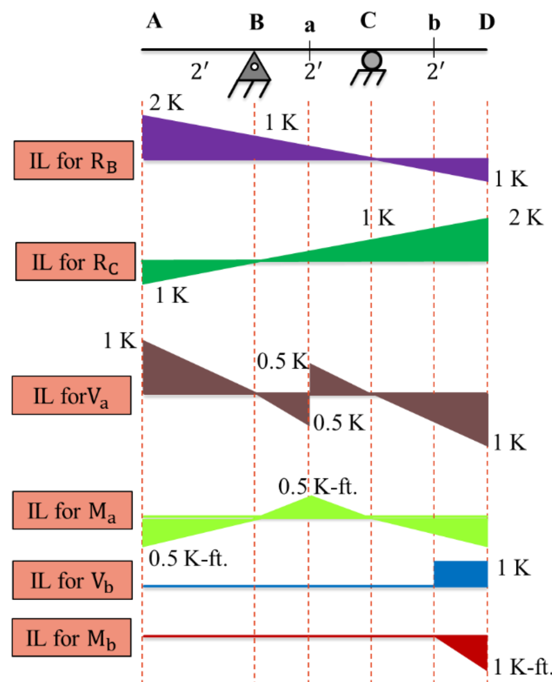
Load on C
$R_A = 0$ K
$R_D = 1$ K

Load on D
$R_A = 0$ K
$R_D = 1$ K

Problem-61: Draw the IL diagram of R_B, R_C, V_a, M_a, V_b & M_a for the following structure due to a point loading.



Solution:



Load on A
$R_B = 2$ K
$R_C = -1$ K

Load on B
$R_B = 1$ K
$R_C = 0$ K

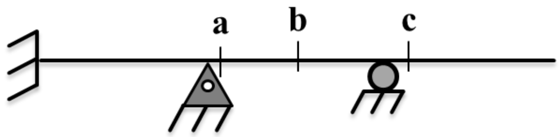
Load on a
$R_B = 0.5$ K
$R_C = 0.5$ K

Load on C
$R_B = 0$ K
$R_C = 1$ K

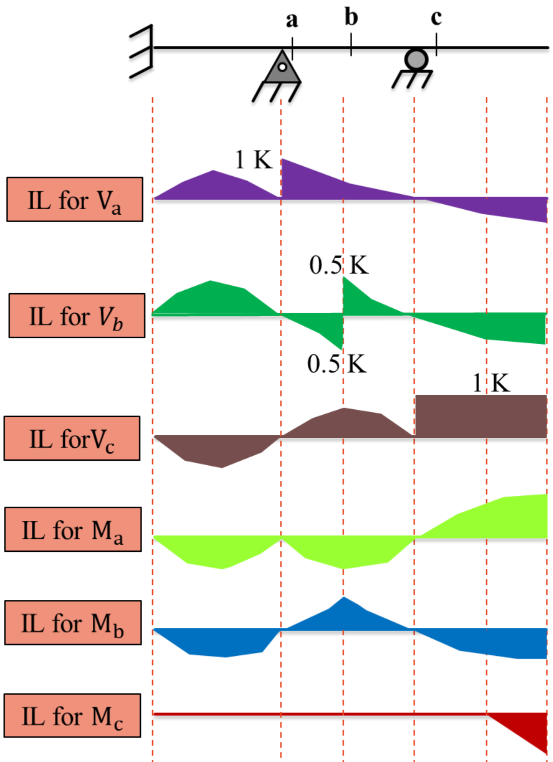
Load on b
$R_B = -0.5$ K
$R_C = 1.5$ K

Load on D
$R_B = -1$ K
$R_C = 2$ K

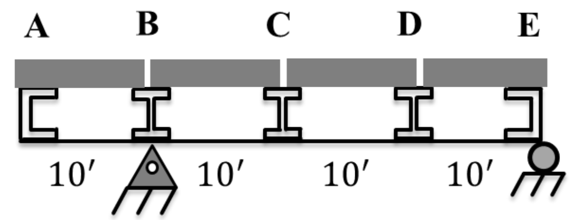
Problem-62: Draw the IL diagram of V_a, V_b, V_c, M_a, M_b & M_c for the following structure due to a point loading.



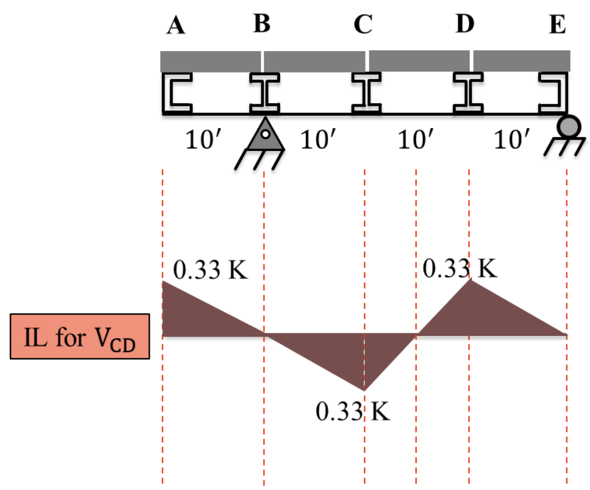
Solution:



Problem-63: Draw the IL diagram for the shear force at panel CD.



Solution:



Load on A

$R_B = 1.33$ K

$R_E = -0.33$ K

Load on B

$R_B = 1$ K

$R_E = 0$ K

Load on C

$R_B = 0.67$ K

$R_E = 0.33$ K

Load on D

$R_B = 0.33$ K

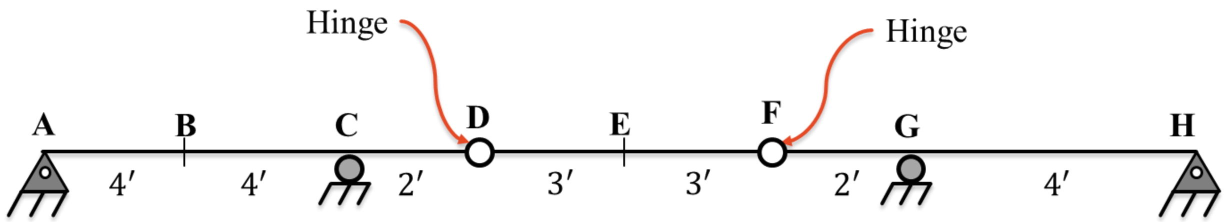
$R_E = 0.67$ K

Load on E

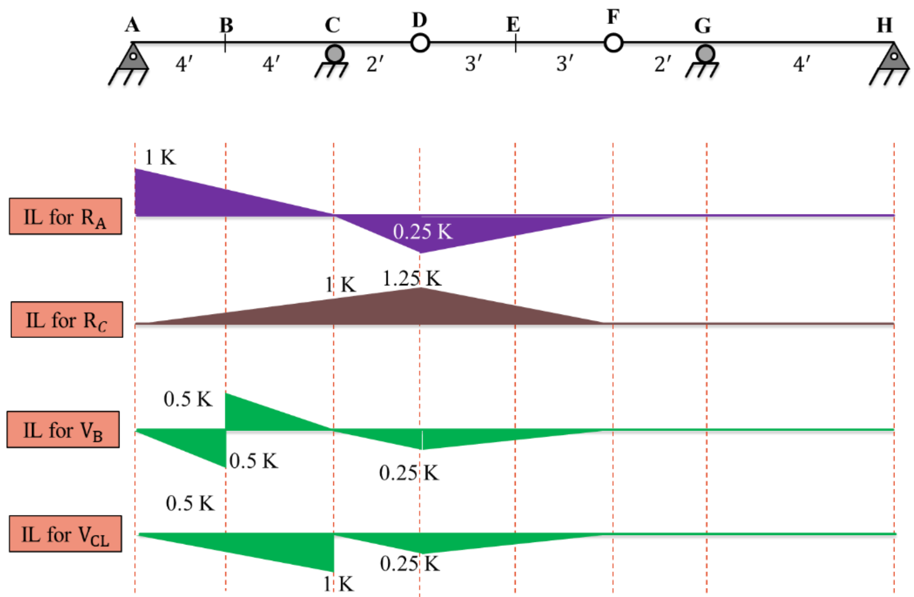
$R_B = 0$ K

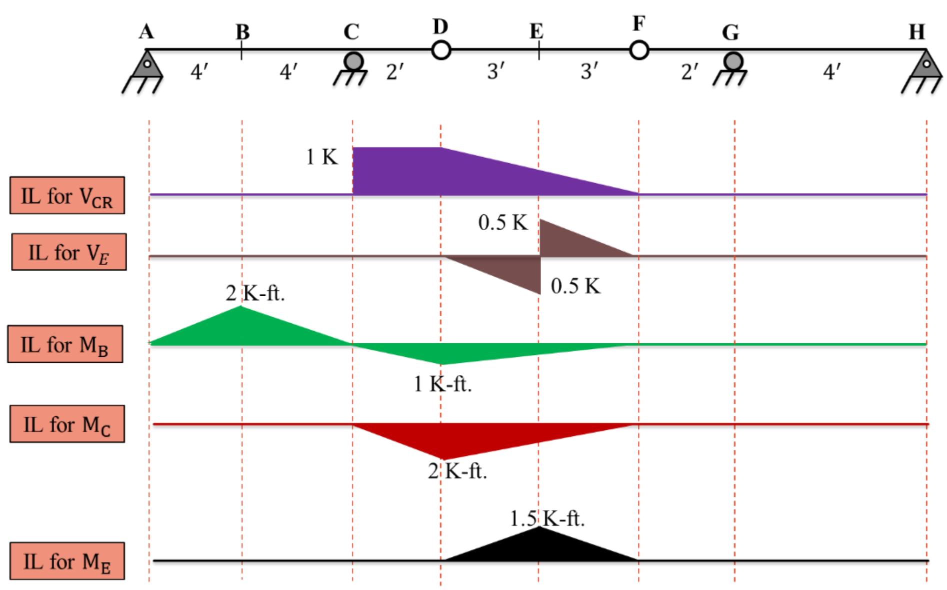
$R_E = 1$ K

Problem-64: Draw the IL diagram of R_A, R_C, V_B, V_{CL}, V_{CR}, V_E, M_B, M_C & M_E for the following structure due to a point loading.

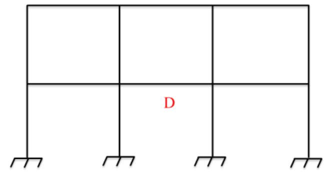


Solution:

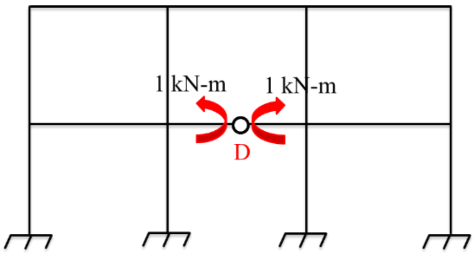


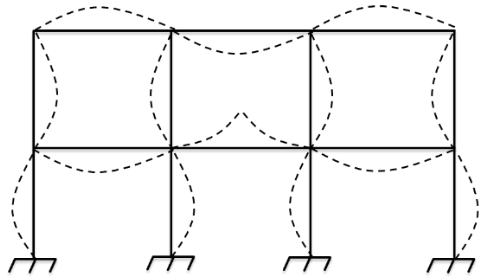


Problem-65: Draw qualitative IL diagram for the following building frame at point D for moment and show the loading diagram for maximum positive and negative moment.

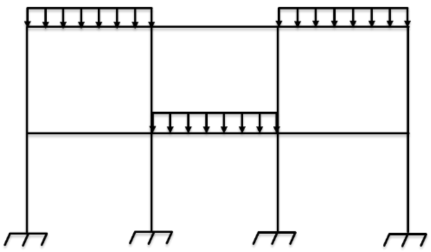


Solution:

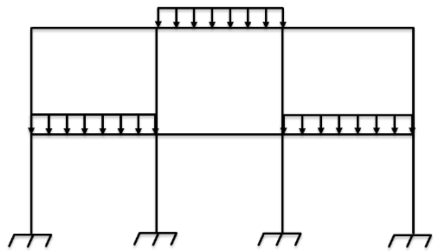




Influence Line for M_D

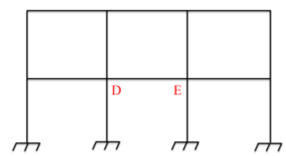


Loading For Maximum Positive Moment

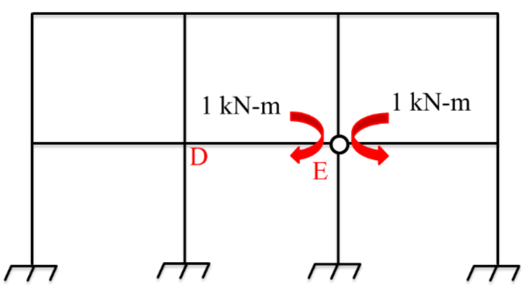


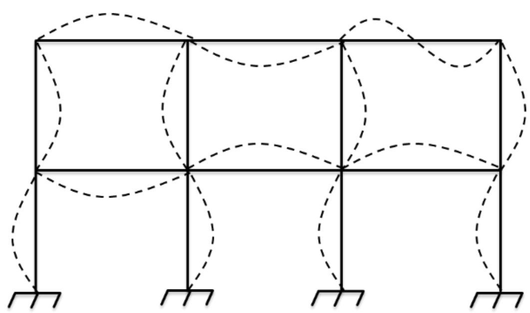
Loading For Maximum Negative Moment

Problem-66: Draw qualitative IL diagram for the following building frame at right end of DE beam for moment and show the loading diagram for maximum positive and negative moment.

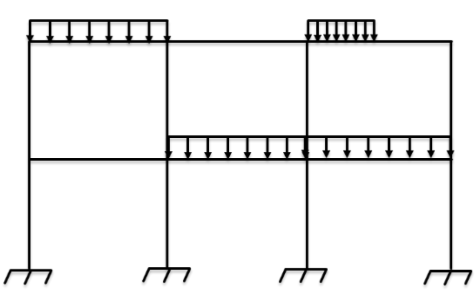


Solution:

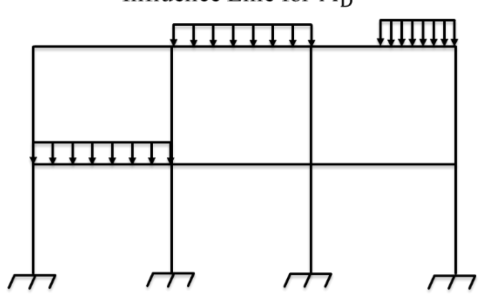




Influence Line for M_D

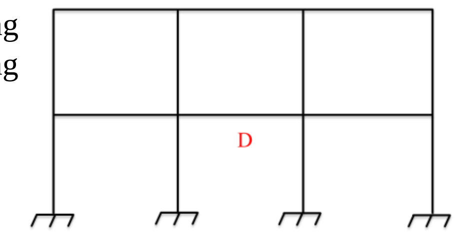


Loading For Maximum Positive Moment

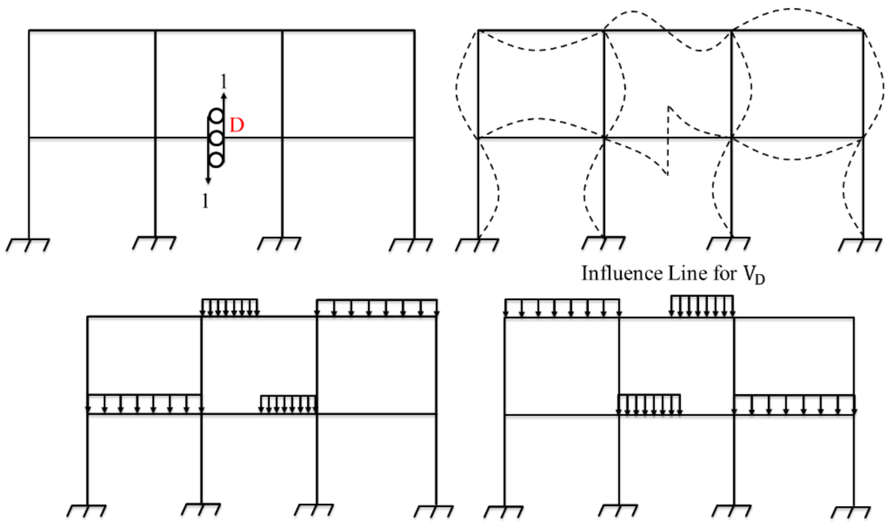


Loading For Maximum Negative Moment

Problem-67: Draw qualitative IL diagram for the following building frame at point D for shear and show the loading diagram for maximum positive and negative shear.



Solution:

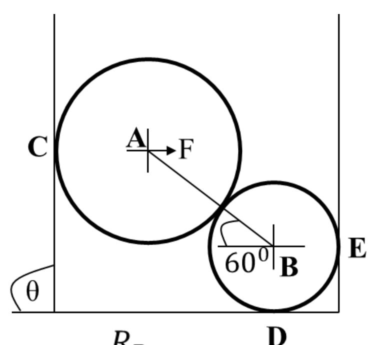


Loading For Maximum Positive Shear

Loading For Maximum Negative Shear

Problem-68: Two spheres are at rest against smooth surface sphere A weighs 3200 lb and spheres B weighs 400 lb. Let, F = 1000 lb and θ = 90^0. Find the reaction C, D & E.

Solution: For FBD of weigh A:

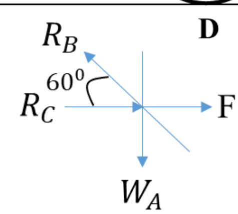


$\sum F_y = 0$

$\Rightarrow R_B \sin 60^0 - W_A = 0 \Rightarrow R_B = \frac{3200}{\sin 60^0} = 3695.04$ lb.

$\sum F_x = 0$

$\Rightarrow R_C + R_B \cos 60^0 + F = 0 \Rightarrow R_C = 847.52$ lb.



For FBD of weigh B:

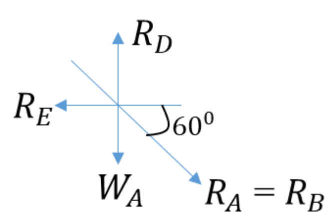
$\sum F_x = 0$

$\Rightarrow R_A \cos 60^0 - R_E = 0 \Rightarrow R_E = 1847.52$ lb.

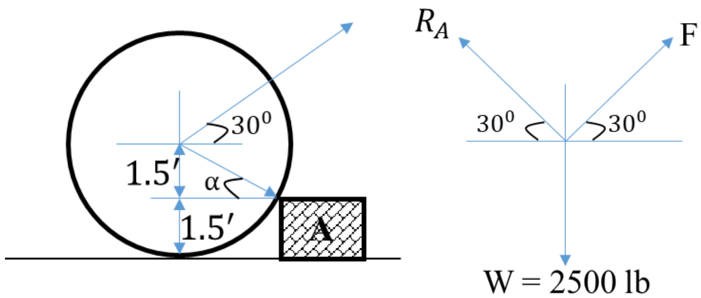
$\sum F_y = 0$

$\Rightarrow R_D - W_B - R_A \sin 60^0 + F = 0$

$\Rightarrow R_D = 3600$ lb.



Problem-69: A 2000 lb wheel is acted upon by a force F, which end to pull the wheel over the obstruction at A. At the instant the wheel is about to move, the pressure between the wheel and the ground is zero. Find the value of F.



Solution: $\sin\propto = 1.5/3 = 1/2$

$\therefore \quad \alpha = 30^0.$

$\sum F_x = 0$

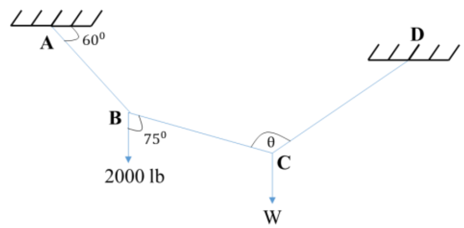
$\Rightarrow R_A \cos30^0 = F\cos30^0 \Rightarrow R_A = F$

$\sum F_y = 0$

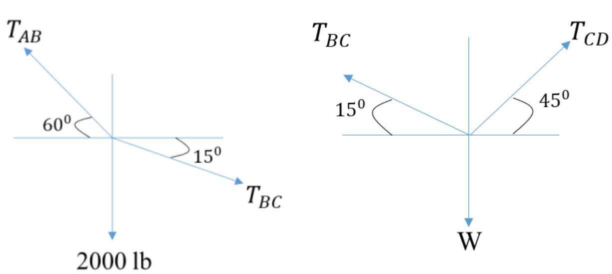
$\Rightarrow R_A \sin\theta + F\sin30^0 = 2500$

$\Rightarrow R_A = F = 2500$ lb

Problem-70: Two weights are suspended from a flexible cable as shown in figure. $\Theta = 120^0$, determine the internal forces and the weight W.



Solution: Using Lami's theorem:



$$\frac{T_{AB}}{\sin75^0} = \frac{T_{BC}}{\sin150^0} = \frac{2000}{\sin135^0}$$

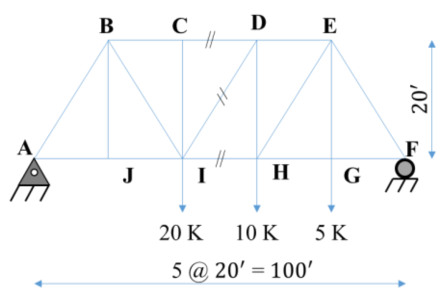
$\Rightarrow T_{AB} = 2732.05$ lb & $T_{BC} = 1414.21$ lb.

Again using Lami's theorem:

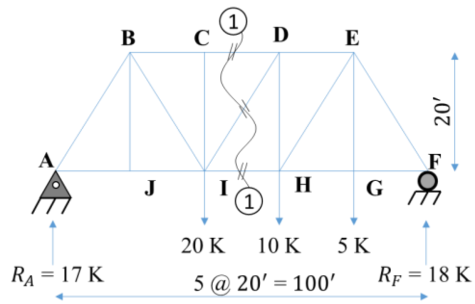
$$\frac{T_{CD}}{\sin105^0} = \frac{W}{\sin120^0} = \frac{T_{BC}}{\sin135^0}$$

$\Rightarrow T_{CD} = 1932$ lb & W = 1732 lb.

Problem-71: Determine forces in member CD, ID & IH.



Solution: Taking a section along the line 1 – 1.



$\sum M_D = 0$

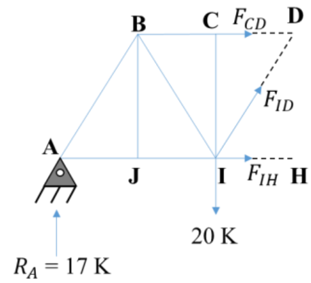
=> 17 x 60 - F_{IH} x 20 – 20 x 20 = 0

=> F_{IH} = 31 K (T).

$\sum M_I = 0$

=> 17 x 40 - F_{CD} x 20 = 0

=> F_{CD} = 34 K (C).

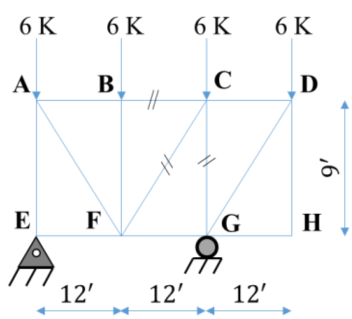


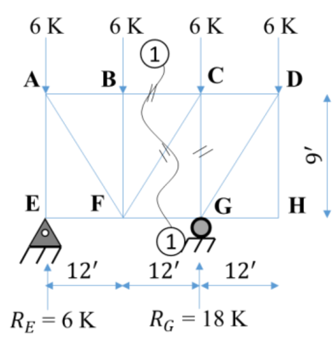
$\sum F_y = 0$

=> 17 – 20 + F_{ID} x $\frac{20}{\sqrt{20^2+20^2}}$ = 0

=> F_{ID} = 4.24 K (T).

Problem-72: Find forces in member BC, CF & CG.





Solution: $\sum M_F = 0$

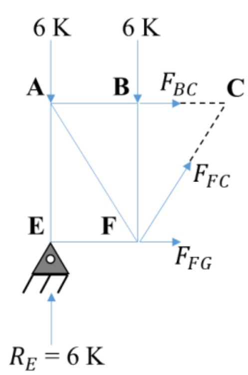
=> 6 x 12 – 6 x 12 + F_{BC} x 9 = 0

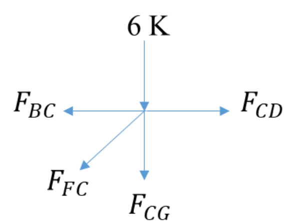
=> F_{BC} = 0 K.

$\sum F_y = 0$

=> 6 + 6 – 6 - F_{FC} x $\frac{9}{\sqrt{9^2+12^2}}$ = 0

=> F_{FC} = 10 K (T).



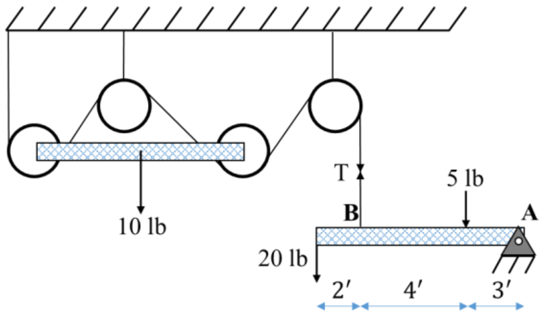


$\sum F_y = 0$

=> 6 + F_{CG} + F_{FC} x $\frac{9}{\sqrt{9^2+12^2}}$ = 0

=> F_{CG} = - 12 K (C).

Problem-73: Find tension in the cable.

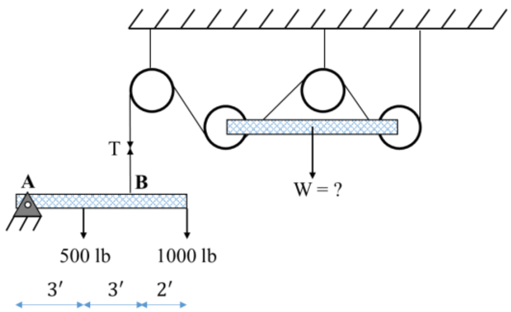


Solution: 4T = 10

=> T = 2.5 lb.

=> R_A = - 2.5 + 5 + 20 = 22.5 lb.

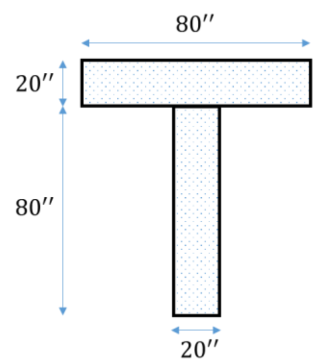
Problem-74: If the reaction at A is 83.33 lb, then what is the weight, W?



Solution: $R_B = R_A$ + 500 + 1000 = 1583.33 lb.

W = $4R_B$ = 4 x 1583.33 = 6333.2 lb.

Problem-75: Find centroid, moment of inertia of the following structure.



Solution: $\bar{X} = 0$

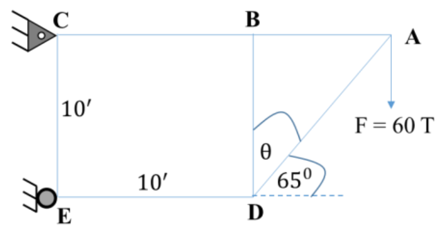
$$\bar{Y} = \frac{20 \ x \ 80 \ x \ 40 + 20 \ x \ 80 \ x \ 90}{1600 \ x \ 2} = 65''$$

$$I_X = \frac{20 \ x \ 80^3}{12} + 1600 \text{ x } (65 - 40)^2 + \frac{80 \ x \ 20^3}{12} + 1600 \text{ x } (90 - 65)^2$$

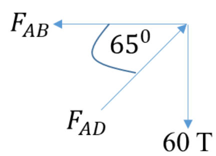
$$= 2.91 \text{ x } 10^6 \ in^4$$

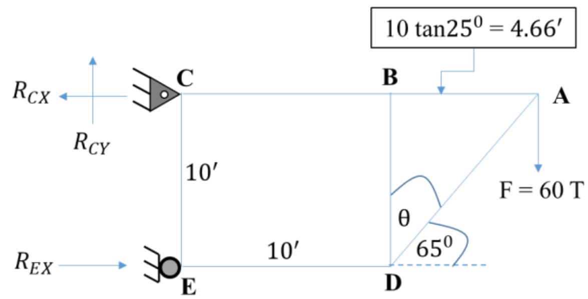
$$I_y = \frac{20 \ x \ 80^3}{12} + \frac{80 \ x \ 20^3}{12} = 9.01 \text{ x } 10^5 \ in^4.$$

Problem-76: As shown in figure below in the truss, F = 60 T and θ = 25^0. Find the external reactions and the force in member AB & AD.



Solution: - $R_{EX} = R_{CX}$ & R_{CY} = 60T





$\sum F_x = 0$

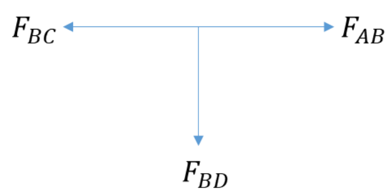
=> F_{AD} cos65^0 = F_{AB}

=> F_{AB} = 27.98T (T).

$\sum F_y = 0$

=> F_{AD} sin65^0 = 60

=> F_{AD} = 66.2T (C).

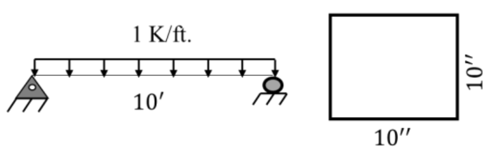


$\sum F_x = 0$

=> $F_{AB} = F_{BC}$ = 27.98T

=> R_{CX} = - R_{EX} = 27.98T (T).

Problem-77: Find out the maximum bending and shearing stress for the following structures.



Solution: Maximum shear, V = $\frac{wl}{2} = \frac{1 \ x \ 10}{2}$ = 5 k

Maximum moment, M = $\frac{wl^2}{8} = \frac{1 \ x \ 10^2}{8}$ = 12.5 k-ft.

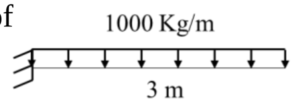
Now, Q = $A'\bar{Y}$ = (b x $\frac{d}{2}$) x $\frac{d}{4}$ = 10 x $\frac{10}{2}$ x $\frac{10}{4}$ = 125 in^3

I = $\frac{10 \ x \ 10^3}{12}$ = 8333.33 in^4; b = 10 inch; c = 10/2 = 5 inch.

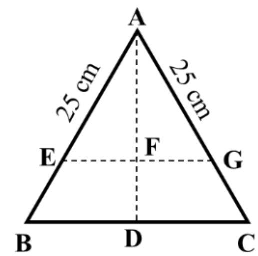
Bending stress, $\sigma_{max} = \frac{MC}{I} = \frac{12.5 \ x \ 12 \ x \ 5}{833.33}$ = 0.9 k/in^2 = 130 k/ft^2.

Shear stress, $\tau_{max} = \frac{VQ}{Ib} = \frac{5\,x\,125}{833.33\,x\,10}$ = 0.075 k/in^2 = 10.8 k/ft^2.

Problem-78: Determine the maximum shear stress at 25 cm arm of equivalent triangle of a 3 m span of a cantilever beam carrying 1000 kg/m.



Solution:



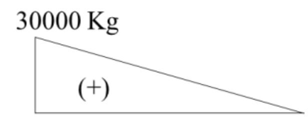
AD = $\sqrt{25^2 - 12.5^2}$ = 21.65 cm; AF = $\frac{2}{3}$ AD = 14.43 cm.

$\frac{EG}{AF} = \frac{BC}{AD}$ => EG = $\frac{25}{21.65}$ * 14.43 = 16.67 cm.

V = 3000 kg; b = 16.67 cm; I = $\frac{25\,x\,21.65^3}{36}$ = 7047.11 cm^4

Now, Q = $A'\bar{Y}$ = Area of AEG * $\frac{1}{3}$ of AE = $\frac{1}{2}$ x 16.67 x 14.43 x $\frac{1}{3}$ x 14.43 = 578 cm^3

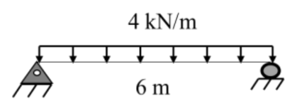
Bending stress, $\sigma_{max} = \frac{MC}{I} = \frac{0.5\,x\,3\,x\,3000\,x\,14.43}{7047.11}$ x 100 = 922 kg/cm^2.



SFD

Shear stress, $\tau_{max} = \frac{VQ}{Ib} = \frac{3000\,x\,578.51}{7047.11\,x\,16.67}$ = 14.77 kg/cm^2.

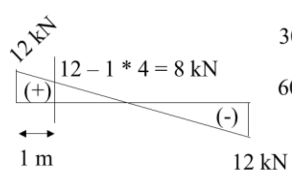
Problem-79: Determine the shear stress at a distance 1 m from left support for 30 mm from the top fiber.

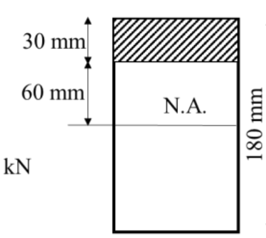


Solution: V = 8 kN; b = 120 mm = 0.12 m; I = $\frac{0.12\,x\,0.18^3}{12}$ = 5.83 x 10^{-5} m^4

Now, Q = $A'\bar{Y}$

= 0.03 x 0.12 x (0.06 + 0.015) = 0.00027 m^3



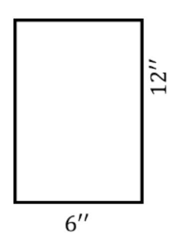


Shear stress, $\tau_{max} = \frac{VQ}{Ib}$

$= \frac{8\,x\,0.00027}{5.83\,x\,10^{-5}\,x\,0.12}$ = 308.75 kN/m^2.

Problem-80: Find the maximum shear stress subjected to vertical shear force 48 kips. [PGCL – 2015]

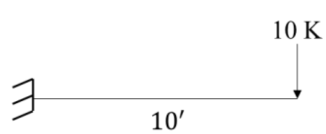
Solution: I = $\frac{6\,x\,12^3}{12}$ = 864 in^4



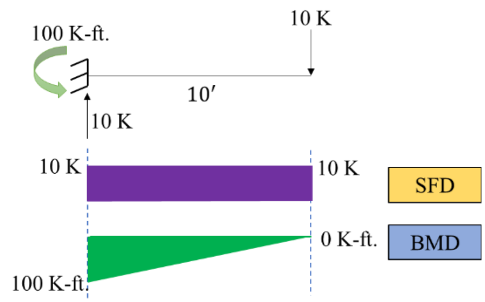
Now, Q = $A'\bar{Y}$ = (6 x $\frac{12}{2}$) x $\frac{12}{4}$ = 108 in^3

Shear stress, $\tau_{max} = \frac{VQ}{Ib} = \frac{48\,x\,108}{864\,x\,6}$ = 1 k/in^2.

Problem-81: Determine the flexure and shear stress of the following cantilever beam, if the section is 1 ft. x 1 ft. [Meghna – 2017]



Solution: M = 100 k-ft.; V = 10 k.

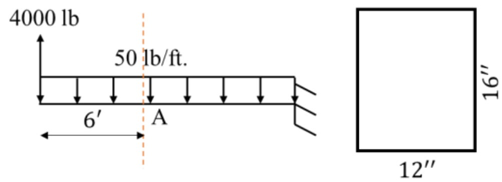


I = $\frac{1\ x\ 1^3}{12}$ = 1/12 ft^4; Q = 1 x 0.5 x 0.25 = 0.125ft^3

Bending stress, σ_{max} = $\frac{MC}{I}$ = $\frac{100\ x\ 0.5}{1/12}$ = 600 k/ft^2

Shear stress, τ_{max} = $\frac{VQ}{Ib}$ = $\frac{10\ x\ 0.125}{(1/12)\ x\ 1}$ = 15 k/ft^2.

Problem-82: A 12″ x 16″ wooden cantilever beam weighing 50 lb/ft. carries an upward counterforce of 4000 lb at the free end. Determine maximum bending stress at a section 6 ft. from the free end.



Solution: I = ($\frac{12\ x\ 16^3}{12}$)/12^4 = 0.1975 ft^4; C = 16/2 = 8 inch

M_A = 4000 x 6 – 50 x 6 x 3 = 23100 lb-ft.

Bending stress, σ_A = $\frac{MC}{I}$ = $\frac{23100\ x\ (8/12)}{0.1975}$ = 77978.58 lb/ft^2 = 542 psi.

Problem-83: A cantilever beam 3 m long subjected to a uniformly distributed load of 30 kN/m. The allowable working stress in either tension/compression is 150 MPa. If the cross section is to be rectangular, determine the dimension. Height is twice of width. [BUET]

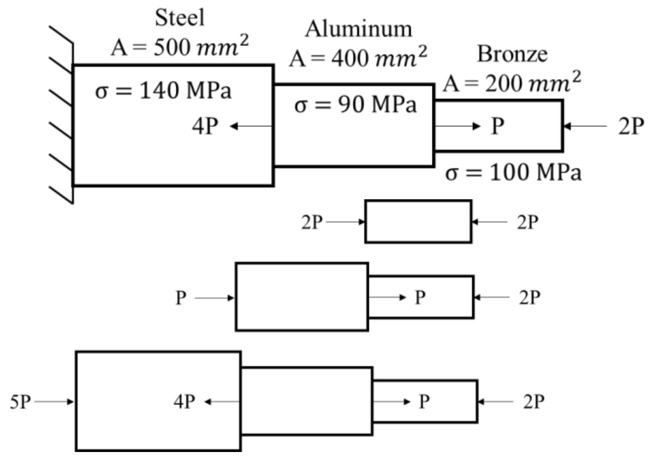
Solution: M = $\frac{wl^2}{2}$ = $\frac{30\ x\ 3^2}{2}$ = 135 kN-m; I = $\frac{b\ x\ (2b)^3}{12}$ = $\frac{2b^4}{3}$; C = 2b/2 = b.

Now, σ_A = $\frac{MC}{I}$ => 150 x 10^6 = $\frac{135\ x\ 10^3\ x\ b}{\frac{2b^4}{3}}$ => b = 0.1105 m ≈ 110.5 mm

∴ H = 2b = 221 mm.

∴ Size of the beam is 110.5 mm x 221 mm.

Problem-84: Find the value of P.



Solution: For bronze:

σ = $\frac{2P}{A}$ => P = $\frac{100\ x\ 200}{2}$ = 10000 N.

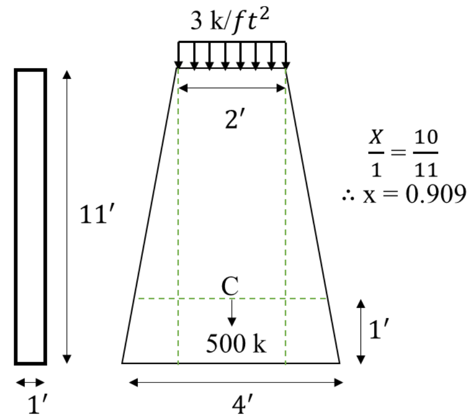
For aluminum:

σ = P/A => P = 90 * 400 = 36000 N.

For steel:

$\sigma = \frac{5P}{A}$ => P = $\frac{140\ x\ 500}{5}$ = 14000 N.

The safest value of P is 10000 N.



Problem-85: Find out the stress at point C (1′ above the base of the pile).

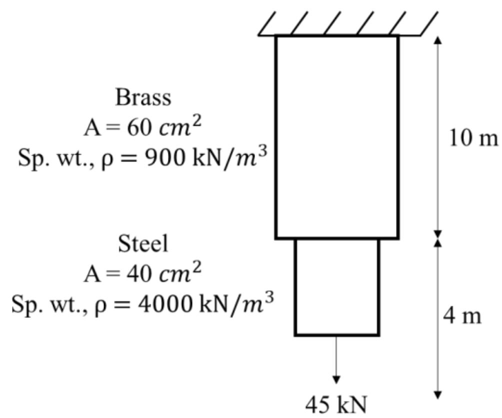
Solution: Length above 1′, L = 2 x 0.909 + 2 = 3.82 ft.

Area above 1′, A = 3.82 x 1 = 3.82 ft^2.

Total load act = 500 + 3 x (2 x 1) = 506 kips.

∴ Stress at 1′ above the base, δ = $\frac{506}{3.82}$ = 132.46 k/ft^2.

Problem-86: Determine maximum shear stress for the following structure.



Solution: Weight of brass, W_B = PAL

= 900 x 60 x 10^{-4} x 10

= 54 kN

Weight of steel, W_S = PAL

= 400 x 40 x 10^{-4} x 4 = 64 kN

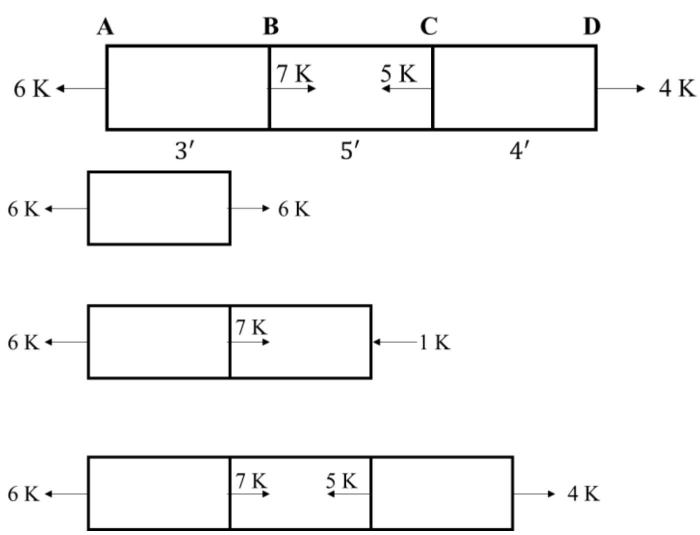
∴ Total force = 45 + 54 + 64 = 163 kN.

∴ Stress on brass = $\frac{45+54}{60}$ = 1.65 kN/cm^2

∴ Stress on steel = $\frac{45+64}{60}$ = 2.73 kN/cm^2

∴ Maximum shear stress = 1.65 + 2.73 = 4.38 kN/cm^2.

Problem-87: A = 0.5 in^2 & E = 10 x 10^6 psi, then δ_{total} = ?



Solution:

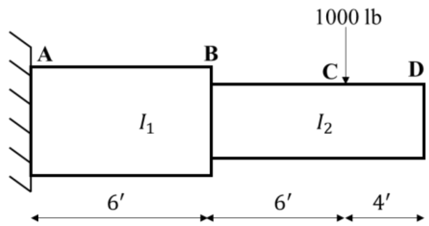
$\delta_{AB} = \frac{PL}{AE} = \frac{6\ x\ 10^3\ x\ 3\ x\ 12}{0.5\ x\ 10\ x\ 10^6}$ = + 0.0432 in.

$\delta_{BC} = \frac{PL}{AE} = \frac{1\ x\ 10^3\ x\ 5\ x\ 12}{0.5\ x\ 10\ x\ 10^6}$ = - 0.012 in.

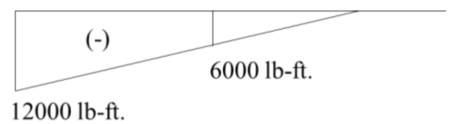
$\delta_{CD} = \frac{PL}{AE} = \frac{4\ x\ 10^3\ x\ 4\ x\ 12}{0.5\ x\ 10\ x\ 10^6}$ = + 0.0384 in.

∴ δ_{total} = 0.0432 – 0.012 + 0.0384 = 0.0696 in.

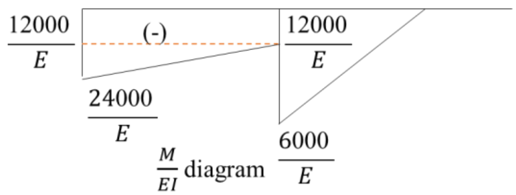
Problem-88: I_1 = 5 in^4; I_2 = 1 in^4 & E = 10^7 psi, then δ_D = ?



Solution:

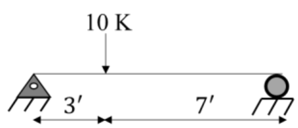


M diagram

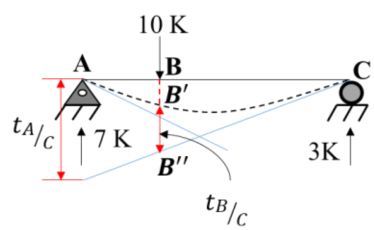


$$\delta_D = \frac{0.5 \ x \ 6000 \ x \ 6 \ x \left(4+\frac{2}{3} x \ 6\right)+1200 \ x \ 6 \ x \ 13+0.5 \ x \ 6 \ x \ 1200 \ x \ (10+\frac{2}{3} x \ 6)}{E} = \text{- 0.0288 in.}$$

Problem-89: Find δ_B & θ_A from the following figure.



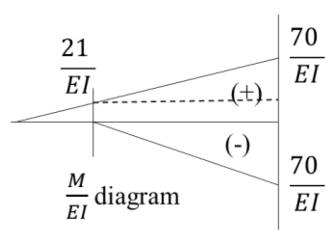
Solution:



$$t_{A/C} = \frac{0.5 \ x \ 10 \ x \ 70 \ x \frac{2}{3} x \ 10 - 0.5 \ x \ 7 \ x \ 70 \ x \ (3+\frac{2}{3} x \ 7)}{EI} = \frac{455}{EI}$$

$$t_{B'/C} = B'B''$$

$$= \frac{0.5 \ x \ 7 \ x \ 49 \ x \frac{2}{3} x \ 7+21 \ x \ 7 \ x \frac{7}{2} - 0.5 \ x \ 7 \ x70 \ x \frac{2}{3} x \ 7}{EI} = \frac{171.5}{EI}$$



From similar triangle,

$$\frac{t_{A/C}}{10} = \frac{BB''}{7} \Rightarrow BB'' = \frac{318.5}{EI}$$

$$\therefore \quad \delta_B = BB'' - B'B'' = \frac{147}{EI}$$

$$\therefore \quad \tan\theta_A = \theta_A = \frac{BB''}{3} = \frac{106.17}{EI}$$

Problem-90: Find the shortest length for a steel column with pinned ends having a cross-sectional area of 60 mm by 100 mm for which the elastic Euler's formula applies. Let, E = 200 GPa, assume the proportional limit to be 250 MPa.

Solution: Here, P = σ_{p1}A = 250 x 60 x 100 = 1.5 x 10^6 N; I = $\frac{100 \; x \; 60^3}{12}$ = 1.8 x 10^6 mm^4; n = 1 & L_e = L.

We know, P = $\frac{\pi^2 n^2 EI}{{L_e}^2}$ => 1.5 x 10^6 = $\frac{\pi^2 \; x \; 1^2 \; x \; 200 \; x \; 10^3 \; x \; 1.8 \; x \; 10^6}{L^2}$ => L = 1539 m.

Problem-91: A 50 mm x 100 mm timber is used as a column with fixed ends. Determine the minimum length required at which Euler's formula can be used if E = 10 GPa and proportional limit is 30 MPa. What central working/safe load can be carried with a FS of 2 if the length is 2.5 m.

Solution: Here, P = σ_{p1}A = 30 x 50 x 100 = 150 x 10^3 N; I = $\frac{100 \; x \; 50^3}{12}$ = 1.04 x 10^6 mm^4; n = 1 & L_e = 0.5 L.

We know, P = $\frac{\pi^2 n^2 EI}{{L_e}^2}$ => 105 x 10^3 = $\frac{\pi^2 \; x \; 1^2 \; x \; 10 \; x \; 10^3 \; x \; 1.04 \; x \; 10^6}{(0.5L)^2}$ => L = 1654 m.

∴ Working load, P = $\frac{Load}{FS}$ = $\frac{\pi^2 n^2 EI}{FS * {L_e}^2}$ = $\frac{\pi^2 \; x \; 1^2 \; x \; 10 \; x \; 10^3 \; x \; 1.04 \; x \; 10^6}{2 \; x \; (0.5 \; x \; 2500)^2}$ = 32846 N.

Problem-92: The combined fineness modulus of fine aggregate (Sand, F_f = 2.85) and course aggregate (Stones, F_c = 6.77) was found to be 5.30. If 8.49 cft of combined and well packed aggregate is required. Determine the volume of fine and course aggregate mixed initially. Take shrinkage factor to be 0.75.

Solution: The ratio of the fine aggregate to be mixed with course aggregate (CA) is

FM = $\frac{F_C - F_{com}}{F_{com} - F_f}$ = $\frac{6.77-5.30}{5.30-2.85}$ = 0.6

∴ V_f/V_c = 60/100 = 0.6

Total volume, V = V_f + V_c

= 8.49/0.75 = 11.32 cft [Due to shrinkage volume will decrease and so the volume should be increased by using a factor. Here, factor value is given 0.75]

∴ V_f = $\frac{60}{60+100}$ * 11.32 = 4.25 cft.

∴ V_c = $\frac{100}{60+100}$ * 11.32 = 7.07 cft.

Problem-93: Calculate the number of bricks required for 100 sft BFS.

Solution: Size of the brick = 9.5″ x 4.5″ x 2.75″

After using mortar = 10″ x 5″ x 3″

The bricks area in BFS = $\frac{10 \; x \; 5}{144}$ = 0.347 sft

∴ Nos. of bricks required for 100 sft BFS = $\frac{100}{0.347}$ = 288 Nos.

5% additional bricks are required due to wastage.

∴ Total nos. of bricks = 288 + 0.05 x 288 ≈ 303 nos.

Problem-94: Calculate Nos. of brick required for 100 cft brick works.

Solution: Size of the brick = 9.5″ x 4.5″ x 2.75″

After using mortar = 10″ x 5″ x 3″

Volume of single brick work using mortar = $\frac{10 \, x \, 5 \, x \, 3}{12 \, x \, 12 \, x \, 12}$ = 0.087 cft.

∴ Nos. of bricks required for 100 cft brick work = $\frac{100}{0.087}$ = 1152 Nos.

5% additional bricks are required due to wastage.

∴ Total nos. of bricks = 1152 + 0.05 x 1152 ≈ 1200 nos.

Problem-95: Calculate the amount of mortar required for 100 cft brick work.

Solution: Size of the brick = 9.5″ x 4.5″ x 2.75″

After using mortar = 10″ x 5″ x 3″

Volume of single brick work using mortar = $\frac{10 \, x \, 5 \, x \, 3}{12 \, x \, 12 \, x \, 12}$ = 0.087 cft.

∴ Nos. of bricks required for 100 cft brick work = $\frac{100}{0.087}$ = 1152 Nos.

Mortar volume in 100 cft brick work = 100 - $\frac{9.5 \, x \, 4.5 \, x \, 2.75}{12 \, x \, 12 \, x \, 12}$ x 1152 = 21.625 cft.

10% additional mortar required for frog mark filling.

∴ Volume = 21.625 + 0.1 x 21.625 = 23.79 cft.

50% additional mortar required due to shrinkage.

∴ Wet volume = 23.79 x 1.5 = 35.69 cft.

25% additional mortar required due to use of brick bats.

∴ Required mortar = 35.69 x 1.25 = 44.61cft.

Problem-96: Calculate nos. of brick for 100 cft brick khoa.

Solution: Size of the brick = 9.5″ x 4.5″ x 2.75″

Volume of single brick work = $\frac{9.5 \, x \, 4.5 \, x \, 2.75}{12 \, x \, 12 \, x \, 12}$ = 0.068 cft.

∴ Nos. of bricks required for 100 cft brick work = $\frac{100}{0.068}$ = 1470 Nos.

42% voids are present when bricks are broken.

∴ Bricks required = 1470 – 0.42 x 1470 ≈ 853 Nos.

Problem-97: Calculate the amount of materials required for 100 sft of cement plaster.

Solution: Let, thickness of plaster = $\frac{1}{2}''$

Cement sand ratio = 1:4

Net volume of mortar = 100 x $\frac{1/2}{12}$ 4.16 cft

Dry volume = 1.5 x 4.16 = 6.25 cft

∴ Cement = $\frac{1}{1+4}$ x 6.25 = 1.25 cft = 1 bag.

∴ Sand = $\frac{4}{1+4}$ x 6.25 = 5 cft.

Problem-98: Calculate the ingredients required for cement concrete with mix proportion 1:3:6 also w/c ratio.

Solution: Let, wet volume of cc = 100 cft.

Dry volume of cc = 1.5 x 100 cft = 150 cft.

∴ Cement = $\frac{1}{1+3+6}$ x 150 = 15 cft = 15/1.25 bags = 12 bags.

∴ Sand = $\frac{3}{1+3+6}$ x 150 = 45 cft.

∴ Coarse aggregate/Brick khoa = $\frac{6}{1+3+6}$ x 150 = 90 cft = 90 x 8.5 = 765 Nos. of bricks.

Water = 30% of cement + 5% of (FA + CA) = 0.3 x 15 + 0.05 x (90 + 45) = 11.25 cft.

∴ w/c = 11.25/15 = 0.75

Problem-99: Calculate the amount of materials & reinforcement (1.5%) required for RCC with mix proportion 1:3:6.

Solution: Let, wet volume of RCC = 100 cft.

Dry volume of cc = 1.5 x 100 cft = 150 cft.

∴ Cement = $\frac{1}{1+3+6}$ x 150 = 15 cft = 15/1.25 bags = 12 bags.

∴ Sand = $\frac{3}{1+3+6}$ x 150 = 45 cft.

∴ Coarse aggregate/Brick khoa = $\frac{6}{1+3+6}$ x 150 = 90 cft = 90 x 8.5 = 765 Nos. of bricks.

∴ Steel = 1.5% of 100 = 1.5 cft = 1.5 x 490 lb = 735 lb ≈ 330 kg.

Problem-100: Determine the member of bags of cement required to cast $40'$ long span beam if the beam section is $12''$ x $15''$ and mix ratio 1:2:4.

Solution: Let, wet volume of RCC = 40 x $\frac{12}{12}$ x $\frac{15}{12}$ = 50 cft.

Dry volume of cc = 1.5 x 50 cft = 75 cft.

∴ Cement = $\frac{1}{1+2+4}$ x 75 = 10.714 cft = 10.714/1.25 bags = 8.57 ≈ 9 bags.

Problem-101: For a building construction, total beam length is 1650 m is required 5 – 20 mm dia plain bars. Unit weight of plain bar is 7850 kg/m^3 and cost is Tk 48000 per metric ton. Make the cost estimate for the steel bars.

Solution: Volume occupying by bars = $\frac{\pi}{4}$ x $(\frac{20}{1000})^2$ x 5 x 1650 = 2.592 m^3

Weight of plain bar = 2.592 x 7850 = 20345.74 kg = 20.35 tons.

Total cost = 20.35 x 48000 = 976800 tk.

Problem-102: The estimated batch quantities per cubic meter of concrete for SSD condition of aggregates are: cement = 306 kg, CA = 1152 kg, FA = 870 kg, water = 162 kg. If fine aggregate contains 5% surface moisture and CA absorbs 10% of water. Workout field adjustment.

Solution: Water required for CA = $\frac{10}{100}$ x 1152 = 115.2 kg.

Water required for FA = $\frac{5}{100}$ x 870 = 43.5 kg.

Total water requirement for adjustment = 115.2 + 43.5 + 162 = 320.4 kg.

Problem-103: Design a concrete mix by the minimum void method for the following data: voids of CA is 40%, voids of FA is 30%, size of CA is $\frac{3}{4}''$ to $1''$, size of FA is $\frac{3}{16}''$ to $\frac{1}{4}''$. Allow an excess of 10% for cement & 7% for FA.

Solution: Let, volume of coarse aggregate = 100 cft.

∴ FA = 40% x CA x (1 + 7%) [FA will fill up the empty space between the CA]

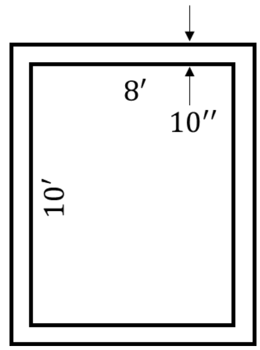
= 0.4 x 100 x 1.07 = 42.8 cft

∴ Cement = 30% x FA x (1 + 10%) [Cement will fill up the empty space between the FA]

= 0.3 x 42.8 x 1.10 = 14.14 cft

∴ Cement: Sand(FA): CA = 14.14: 42.8: 100 = 1:3:7.

Problem-104: Calculate the number of bricks required for making a room of inside dimension of $8'$ width; $10'$ long & $9'$ height with $10''$ wall.



Solution: Brick required for brick flat soling (BFS) = 10 x 8 x 3 = 240 Nos.

Total length = 2 (10 + $\frac{10}{12}$) + 2 (8 + $\frac{10}{12}$) = 39.33 ft.

Width = $\frac{10}{2}$ = 0.833 ft.; height = 9′

∴ Volume of brick work = 39.33 x 0.833 x 9 = 295 cft.

∴ Brick required = 295 x $\frac{1200}{100}$ = 3540 nos.

∴ Total brick required = 3540 + 240 = 3780 Nos.

Problem-105: Estimate the yield produced of concrete per bag of cement for concrete mix proportion 1:3:6.

Solution: Thumb rule:

Volume of one bag cement = 1.25 cft = 0.0354 m^3

∴ Yield of concrete per bag of cement = $\frac{2}{3}$ (0.354 x 1 + 0.354 x 3 + 0.0354 x 6) = 0.236 m^3

Absolute volume method:

Yield of concrete per bag of cement = volume of cement + sand + CA + water

$$= \frac{50}{3.15 \; x \; 1000} + \frac{3 \; x \; 0.354 \; x \; 1600}{2.65 \; x \; 1000} + \frac{6 \; x \; 0.0354 \; x \; 1500}{2.8 \; x \; 1000} + \frac{25}{1 \; x \; 1000} = 0.219 \; m^3$$

[Sp. Gravity of cement, sand, CA & water is 3.15, 2.65, 2.8 & 1 respectively]

Problem-106: Determine the FM of coarse aggregate of % finer.

Sieve size	$3''$	$1\frac{1}{2}''$	$\frac{3}{4}''$	$\frac{3}{8}''$	$\frac{3}{16}''$
Wt. retained (gm)	10	60	140	350	410

Solution:

Sieve size	Weight retained (gm)	Cumulative wt. retained (gm)	Cumulative wt. retained (%)	FM
$3''$	10	10	$\frac{10}{970}$ x 100 = 1.03	$\frac{187.63}{100}$ = 1.88
$1\frac{1}{2}''$	60	70	7.22	
$\frac{3}{4}''$	140	210	21.65	
$\frac{3}{8}''$	350	560	57.73	
$\frac{3}{16}''$	410	970	100	

	$\sum = 970$		$\sum = 187.63$	

Problem-107: Find the FM value of following sand.

Sieve size	#4	#8	#16	#20	#30	#50	#100	#200	Pan
Wt. retained (gm)	10	60	90	110	130	70	25	10	5

Solution:

Sieve size	Weight retained (gm)	Cumulative wt. retained (gm)	Cumulative wt. retained (%)	FM
#4	10	10	1.96	
#8	60	70	13.73	
#16	90	160	31.37	
#20	110	270	x	
#30	130	400	78.43	$\frac{314.71}{100} = 3.15$
#50	70	470	92.16	
#100	25	495	97.06	
#200	10	505	x	
Pan	5	510	x	
	$\sum = 510$		$\sum = 314.71$	

Problem-108: Determine the FM for sand in which 100% sample retains on #30 sieve only.

Solution: Let, total weight of sample = 100 gm.

Sieve size	Weight retained (gm)	Cumulative wt. retained (gm)	Cumulative wt. retained (%)	FM
#4	0	0	0	
#8	0	0	0	
#16	0	0	0	
#20	0	0	0	
#30	100	100	100	$\frac{300}{100} = 3.00$
#50	0	100	100	
#100	0	100	100	
#200	0	100	x	
Pan	0	100	x	
	$\sum = 100$		$\sum = 300$	

Problem-109: Compute the FM value of following data-

Sieve size	$3''$	$1\frac{1''}{2}$	$\frac{3''}{4}$	$\frac{3''}{8}$	#4	#8	#16	#30	#50	#100
Cumulative % retained (gm)	0	0	0	0	0	0	10	30	100	100

Solution: FM = $\frac{10+30+100+100}{100}$ = 2.40

Problem-110: Compute the combined FM value of two samples having total weight of 1250 gm.

Sieve size	$3''$	$1\frac{1}{2}''$	$\frac{3}{4}''$	$\frac{3}{8}''$	#4	#8	#16	#30	#50	#100
Cumulative % retained (gm) (Sample -I)	0	0	0	0	50	200	300	650	1120	1150
Cumulative % retained (gm) (Sample –II)	0	0	0	0	0	50	250	400	625	1250

Solution:

$F_1 = \frac{50+200+300+650+1120+1150}{100} = 2.78$

$F_2 = \frac{50+250+400+625+1250}{100} = 2.06$

$F_{com} = \frac{m_1 F_1 + m_2 F_2}{m_1 + m_2} = \frac{1250\ x\ 2.78 + 1250\ x\ 2.06}{1250+1250} = 2.42$

Problem-111: Two samples of sand having fineness modulus of 2.81 and 2.24 were mixed together to get a combined FM of 2.54. Determine the ratio in which they were mixed.

Solution: Desired ratio, R = $\frac{F_C - F_{com}}{F_{com} - F_f} = \frac{2.84-2.54}{2.54-2.24}$ = 1:1

Problem-112: Combined FM of two types of soil is 2.75 and whose total weight 100 gm. First fineness modulus of soil is 2.65 with a mass of 60 gm. Find FM and mass of 2nd soil mass.

Solution: Here, $m_1 + m_2$ = 100 gm; m_2 = 100 – 60 = 40 gm.

$F_{com} = \frac{m_1 F_1 + m_2 F_2}{m_1 + m_2}$ => 2.75 = $\frac{2.65\ x\ 60 + F_2\ x\ 40}{100}$ => F_2 = 2.90.

Problem-113: The combined FM of FA (F_f = 2.85) + CA (F_c = 6.77) was found to be 5.3. If 8.49 cft of combined and well packed aggregate is required. Determine the volume of CA + FA mixed initially. Take shrinkage factor to 0.75.

Solution: Desired ratio, R = $\frac{F_C - F_{com}}{F_{com} - F_f} = \frac{6.77-5.3}{5.3-2.85}$ = 0.6

Here, Compact volume, V = 8.49 cft.
Loose volume = 8.49/0.75 = 11.32 cft.
$\frac{V_f}{V_c}$ = 0.6 = 60/100

∴ Volume of FA, $V_f = \frac{60}{100+60}$ x 11.32 = 4.25 cft

∴ Volume of CA, $V_C = \frac{100}{100+60}$ x 11.32 = 7.07 cft

Problem-114: Design a concrete mix for $f_c{}'$ = 3000 psi in 28 days. Slump = $2''$; CA = $\frac{3}{4}''$; FA = $\frac{1}{16}''$ to $\frac{3}{16}''$; F_c = 6.27; F_f = 2.85. Shrinkage factor 0.75. Moisture content in CA & FA is 5% & 29.5%.

Solution: Let, F_{com} = 5.3.

Compacted volume = 3.75 cft; Loose volume = 3.75/0.75 = 5 cft.

Desired ratio, R = $\frac{F_C - F_{com}}{F_{com} - F_f}$ = 0.4; $\frac{V_f}{V_c}$ = 40/100

∴ Volume of FA, $V_f = \frac{40}{100+40}$ x 5 = 1.43 cft

∴ Volume of CA, $V_C = \frac{100}{100+40}$ x 5 = 3.57 cft

∴ Mix ratio = 1:1.43:3.57

∴ Volume of FA in field, $V_{f(field)}$ = 1.43 x 1.295 = 1.85 cft.

∴ Volume of CA in field, $V_{C(field)}$ = 3.57 x 1.05 = 3.75 cft.

∴ Mix ratio = 1:1.85:3.75.

Problem-115: Determine the FM of fine aggregate portion only. Also determine the % of CA, silt & clay.

Sieve size (mm)	19	12.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	Pan
Wt. retained (gm)	175	125	100	50	20	10	10	4	4	2

Solution: For fine aggregate only:

Sieve size	Weight retained (gm)	Cumulative wt. retained (gm)	Cumulative wt. retained (%)	FM
19.00 mm	175	x	x	$\frac{492}{100}$ = 4.92
12.50 mm	125	x	x	
4.75 mm	100	100	50	
2.36 mm	50	150	75	
1.18 mm	20	170	85	
0.60 mm	10	180	90	
0.30 mm	10	190	95	
0.15 mm	4	194	97	
0.075 mm	4	198	x	
Pan	2	200	x	
	∑ = 500		∑ = 492	

∴ % of CA = $\frac{175+125+100}{500}$ x 100 = 80%

∴ % of FA = $\frac{50+20+10+10+4+4}{500}$ x 100 = 19.6%

∴ % of silt & clay = (100 – 80 – 19.6) % = 0.4%

Problem-116: For a coarse aggregate sample air dry wt. of sample is 1790 gm; wt. when it is measured in water is 1180 gm and SSD wt. is 1850 gm. Calculate the bulk specific gravity. Apparent specific gravity and percentage of absorption.

Solution: A = 1790 gm; B = 1850 gm; C = 1180 gm.

Bulk specific gravity (SSD) = $\frac{B}{B-C}$ = 2.76

Bulk specific gravity (Dry) = $\frac{A}{B-C}$ = 2.67

Apparent specific gravity = $\frac{A}{A-C}$ = 2.93

Absorption = $\frac{B-A}{A}$ x 100% = 3.35%

Problem-117: Dry weight of a sample is 1206 gm & SSD weight is 1226.4 gm. The volume of water occupying the same volume excluding the pores is 440.6 cm^3. Find bulk specific gravity, apparent specific gravity & % absorption.

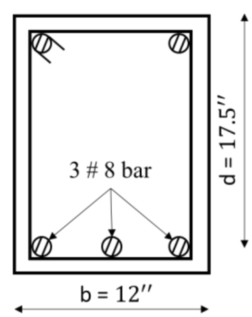
Solution: Weight of water = 1226.4 – 1206 = 20.4 gm.

Volume of water = $\frac{20.4}{1}$ = 20.4 cm^3

Bulk specific gravity = $\frac{1206}{440.6+20.4}$ = 2.62

Apparent specific gravity = $\frac{1206}{440.6}$ = 2.74

Absorption = $\frac{20.4}{1206}$ x 100 = 1.7%



Problem-118: A rectangular beam has a width of 12″ and an effective depth to the centroid of the reinforcing steel is 17.5″. It is reinforced with three no. of #8 bars in one row. f_y = 60 ksi; $f_c{'}$ = 4 ksi. Find the maximum flexural moment capacity of the beam. Also find out the load capacity. Length of the beam is 25 ft. [WSD Method – Singly Analysis Problem]

Solution:

ρ = $\frac{A_s}{bd} = \frac{3 \; x \; 0.79}{12 \; x \; 17.5}$ = 0.011

n = $\frac{E_s}{E_c} = \frac{29 \; x \; 10^6}{57000\sqrt{4000}} \approx 8$

ρn = 0.088

k = $\sqrt{(\rho n)^2 + 2\rho n} - \rho n$ = 0.34

j = 1 - $\frac{k}{3}$ = 0.89

$M_c = \frac{f_c}{2}$ bjkd^2 = [$\frac{0.45 \; x \; 4000}{2}$ x 12 x 0.89 x 0.34 x 17.5^2]/ 12000 = 83.40 k-ft.

$M_s = A_s f_s$jd = [3 x 0.79 x 0.4 x 60000 x 0.89 x 17.5]/12000 = 73.83 k-ft.

∴ Maximum flexural moment capacity = 73.83 k-ft.

M = $\frac{wl^2}{8}$ => 73.83 = $\frac{w \; x \; 25^2}{8}$ => w = 0.95 k/ft.

Problem-119: A rectangular beam has width of 12″ and an effective depth to the centroid of the reinforcing steel is 17.5″. It is reinforced with four no. of #9 bars in one row. f_y = 60 ksi; $f_c{'}$ = 4 ksi. Find the ultimate moment capacity of the beam [USD Method – Singly Analysis Problem]

Solution:

$\rho = \frac{A_s}{bd} = \frac{4 \ x \ 1}{12 \ x \ 17.5} = 0.019$

$\rho_b = 0.85\beta_1 \frac{f_c{'}}{f_y} \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$

$= 0.85 \text{ x } 0.85 \text{ x } \frac{4}{60} \text{ x } \frac{0.003}{0.003 + 0.002}$

$= 0.0289$

$\rho \leq \rho_b$

Under reinforced beam & steel yields at failure.

$a = \frac{A_s f_y}{0.85 f_c{'} b} = \frac{4 \ x \ 60}{0.85 \ x \ 4 \ x \ 12} = 5.88$

$\epsilon_t = \epsilon_u \text{ x } \frac{d-c}{c} \leq 0.005$

$= 0.003 \text{ x } \frac{17.5 - \frac{5.88}{0.85}}{5.88/0.85} \leq 0.005 = 0.0045$

$\varphi = 0.483 + 83.3 \ \epsilon_t$

$= 0.483 + 83.3 \text{ x } 0.0045 = 0.86$

$M_n = A_s f_y (\text{d} - \frac{a}{2}) = 4 \text{ x } 60 \text{ x } (17.5 - \frac{5.88}{2})$

$= 3494.4$ k-in $= 291.2$ k-ft.

$M_u = \varphi M_n = 0.86 \text{ x } 291.2 = 250.4$ k-ft.

Problem-120: Design a beam and find amount of steel as a simply supported beam having span of 20′ with a uniformly distributed laod of 650 lb/ft. (including self-weight). f_y = 60 ksi; $f_c{'}$ = 3 ksi. [WSD Method – Singly Design Problem] [BUET]

Solution: Let, b = 12 inch.

$n = \frac{E_s}{E_c} = \frac{29 \ x \ 10^6}{57000\sqrt{3000}} \approx 9$

$r = \frac{f_s}{f_c} = \frac{0.4 \ f_y}{0.45 \ f_c{'}} = \frac{0.4 \ x \ 60}{0.45 \ x \ 3} = 17.78$

$k = \frac{n}{n+r} = \frac{9}{9+17.78} = 0.378$

$j = 1 - \frac{k}{3} = 0.874$

$M = \frac{wl^2}{8} = \frac{650 \ x \ 20^2}{8 \ x \ 1000} = 32.5$ k-ft.

$R = \frac{f_c}{2} \text{jk}$

$= \frac{0.45 \ x \ 3000}{2} \text{ x } 0.874 \text{ x } 0.378 = 223$

$d_{req} = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{32.5 \ x \ 12000}{223 \ x \ 12}}$

$= 12.1'' \approx 12.5''$

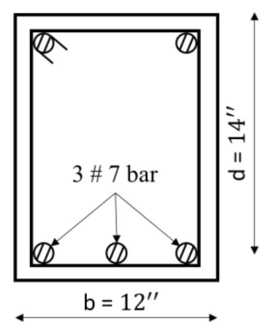
$\therefore$ Depth $= 12.5 + 1.5 = 14''$

$A_s = \frac{M}{f_s j d}$

$= \frac{32.5 \ x \ 12000}{0.4 \ x \ 60000 \ x \ 0.874 \ x \ 12.5}$

$= 1.49 \ in^2$

Use 3 # 7 bar providing 1.8 in^2.



Problem-121: Design the steel when acting moment of a simply supported structure are 1600 k-in. Effective depth 16.5″; width = 10″; f_y = 60 ksi; $f_c{'}$ = 4 ksi. [WSD Method – Singly Design Problem]

Solution:

$n = \frac{E_s}{E_c} = \frac{29 \ x \ 10^6}{57000\sqrt{4000}} \approx 8$

$r = \frac{f_s}{f_c} = \frac{0.4 \ f_y}{0.45 \ f_c{'}}$

$= \frac{0.4 \ x \ 60}{0.45 \ x \ 4} = 13.33$

$k = \frac{n}{n+r} = \frac{8}{8+13.33} = 0.376$

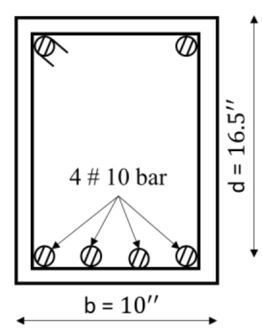
$j = 1 - \frac{k}{3} = 0.874$

$A_s = \frac{M}{f_s j d}$

$= \frac{1600 \ x \ 1000}{0.4 \ x \ 60000 \ x \ 0.874 \ x \ 16.5}$

$= 4.62 \ in^2$

Use 4 # 10 bar providing 5.08 in^2.



Problem-122: Find the cross-section and area of steel required for a simply supported rectangular beam with a 20 ft. span subjected to a calculated dead load of 1.5 k/ft. and live load of 2 k/ft. f_y = 60 ksi; $f_c{}'$ = 5 ksi. [USD Method – Singly Design Problem]

Solution: Let, b = 12 inch.

W_u = 1.2 DL + 1.6 LL
= 1.2 x 1.5 + 1.6 x 2 = 5 k/ft.

$M_u = \frac{w_u L^2}{8} = \frac{5 \ x \ 20^2}{8}$ = 250 k-ft.

β_1 = 0.80 for $f_c{}'$ = 5 ksi

$\rho = 0.85\beta_1 \frac{f_c{}'}{f_y} \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$

$= 0.85 \times 0.8 \times \frac{5}{60} \times \frac{0.003}{0.003+0.005}$

= 0.0213

$M_u = \varphi \rho f_y b d_{req}{}^2 \left(1 - \frac{\beta}{\propto} \frac{\rho f_y}{f_c{}'}\right)$

=> 250 x 12 = 0.9 x 0.0213 x 60 x 12 x $d_{req}{}^2 \left(1 - \frac{0.8}{0.68} \times \frac{0.0213 \ x \ 60}{5}\right)$

=> $d_{req} = 17.63'' \approx 18''$

∴ Depth = 18 + 2 = 20″

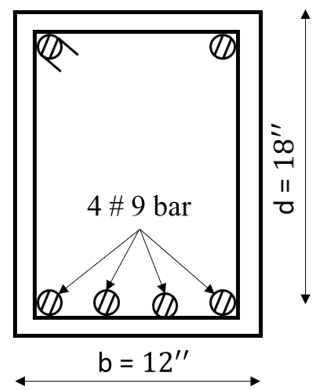
Let, a = 4.09″

$A_s = \frac{M_u}{\varphi f_y (d - \frac{a}{2})} = \frac{250 \ x \ 12}{0.9 \ x \ 60 \ (18 - \frac{4.09}{2})}$

$= 3.48 \ in^2$

$a = \frac{A_s f_y}{0.85 f_c{}' b} = \frac{3.48 \ x \ 60}{0.85 \ x \ 5 \ x \ 12} = 4.09''$

Use 4 # 9 bar providing 4.00 in^2.



Problem-123: Find out the amount of steel required when ultimate moment capacity 1600 k-in. Effective depth = 17″; width = 10″; f_y = 60 ksi; $f_c{}'$ = 4 ksi. [USD Method – Singly Design Problem]

Solution:

Let, a = 3.40″

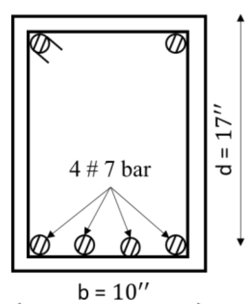
$A_s = \frac{M_u}{\varphi f_y (d - \frac{a}{2})} = \frac{1600}{0.9 \ x \ 60 \ (17 - \frac{3.40}{2})}$

$= 1.94 \ in^2$

$a = \frac{A_s f_y}{0.85 f_c{}' b}$

$= \frac{1.94 \ x \ 60}{0.85 \ x \ 4 \ x \ 10} = 3.42''$ [Almost same as previous calculated value]

Use 4 # 7 bar providing 2.40 in^2.



Problem-124: Find out the flexural moment capacity & load capacity of a rectangular beam which contains 5 #6 bars at tension face and 2 #5 bars at compression face. The span length of the simply supported beam is 18′. Effective depth = 17.5″; b = 10″; f_y = 60 ksi; $f_c{}'$ = 3 ksi. [WSD Method – Doubly Analysis Problem]

Solution:

$n = \frac{E_s}{E_c} = \frac{29 \; x \; 10^6}{57000\sqrt{3000}} \approx 9$

$r = \frac{f_s}{f_c} = \frac{0.4 \; f_y}{0.45 \; f_c{'}} = \frac{0.4 \; x \; 60}{0.45 \; x \; 3} = 17.78$

$k = \frac{n}{n+r} = \frac{9}{9+17.78} = 0.336$

$j = 1 - \frac{k}{3} = 0.888$

$M_1 = \frac{f_c}{2} \text{bjk}d^2$

$= \frac{0.45 \; x \; 3}{2}$ x 10 x 0.888 x 0.336 x 17.5^2

= 617 k-in.

$A_{s1} = \frac{M_1}{f_s jd} = \frac{617}{0.4 \; x \; 60 \; x \; 0.888 \; x \; 17.5} = 1.65 \; in^2$

$A_{s2} = A_s - A_{s1}$ = 5 x 0.44 – 1.65 = 0.55 in^2

$f_s{'} = 2 \; f_s \frac{k - d'/d}{1 - k} \leq f_s$

$= 2$ x 0.4 x 60 x $\frac{0.336 - \frac{2}{17.5}}{1 - 0.336} \leq 24$ ksi

= 16.02 ksi.

$M_2 = A_{s2} f_s (\text{d} - d')$

= 0.55 x 24 x (17.5 – 2) = 204.6 k-in

Again,

$M_2 = A_s{'} f_s{'} (\text{d} - d')$

= 2 x 0.31 x 16.02 x (17.5 – 2)

= 153.95 k-in

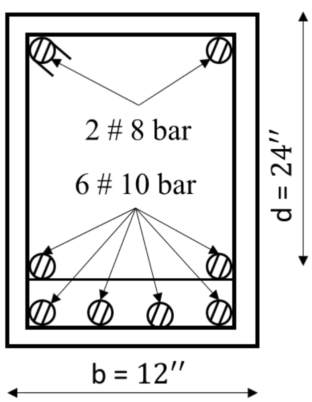
M = $M_1 + M_2$ = 617 + 153.95 = 770.95 k-in

$M = \frac{wl^2}{8} \Rightarrow \frac{770.95}{12} = \frac{w \; x \; 18^2}{8}$

∴ w = 1.586 k/ft.

Problem-125: A rectangular beam has a width of 12″ and an effective depth to the centroid of the tension reinforcement of 24″. The tension reinforcement consists of 6 #10 bars in two rows. Compression reinforcement consisting of 2 # 8 bars is placed 2.5 in from the compression face of the beam. f_y = 60 ksi; $f_c{'}$ = 5 ksi. [USD Method – Doubly Analysis Problem]

Solution:



$A_s{'}$ = 2 x 0.79 = 1.58 in^2

A_s = 6 x 1.27 = 7.62 in^2

$\rho' = \frac{A_s{'}}{bd} = \frac{1.58}{12 \; x \; 24} = 0.0055;$

$\rho = \frac{A_s}{bd} = \frac{7.62}{12 \; x \; 24} = 0.0265;$

$\rho_{max} = 0.85\beta_1 \frac{f_c{'}}{f_y} \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$

$= 0.85$ x 0.80 x $\frac{5}{60}$ x $\frac{0.003}{0.003+0.004}$

= 0.0243

$\rho_{max} < \rho$ *[It should be doubly reinforced beam analysis]*

$\overline{\rho_{cy}} = 0.85\beta_1 \frac{f_c{'}}{f_y} \frac{\epsilon_u}{\epsilon_u + \epsilon_y} \frac{d'}{d} + \rho'$

= 0.85 x 0.80 x $\frac{5}{60}$ x $\frac{0.003}{0.003+0.004}$ x $\frac{2.5}{24}$

+ 0.0055 = 0.00803

$\overline{\rho_{cy}} \leq \rho$

Compression bar will yield when beam fails.

$M_{n1} = A_s{'} f_y (\text{d} - \text{d}')$

= 1.58 x x60 x (24 – 2.5) = 2038.2 k-in

$a = \frac{(A_s - A_s{'})f_y}{0.85 f_c{'} b} = \frac{(7.62 - 1.58) x \; 60}{0.85 \; x \; 5 \; x \; 12} = 7.11''$

$M_{n2} = (A_s - A_s{'}) f_y (\text{d} - \frac{a}{2})$

= (7.62 – 1.58) x 60 (24 – $\frac{7.11}{2}$)

= 7409.3 k-in

$M_n = M_{n1} + M_{n2}$ = 9447.5 k-in

$\epsilon_t = \epsilon_u$ x $\frac{d - c}{c} \leq 0.005$

= 0.003 x $\frac{24 - \frac{7.11}{0.8}}{7.11/0.80} \leq 0.005 = 0.005$

$\varphi = 0.483 + 83.3 \; \epsilon_t$

= 0.483 + 83.3 x 0.005 = 0.90

∴ $M_u = \varphi M_n$ = 0.9 x 9447.5 = 8503 k-in.

Problem-126: A rectangular beam of 15′ simple span carries a UDL of 2600 lb/ft. (excluding self-weight). Calculate the amount of steel if, f_y = 60 ksi; $f_c{}'$ = 4 ksi. [WSD Method – Doubly Design Problem]

Solution:

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{4000}} \approx 8$$

$$r = \frac{f_s}{f_c} = \frac{0.4\, f_y}{0.45\, f_c{}'} = \frac{0.4 \times 60}{0.45 \times 4} = 13.33$$

$$k = \frac{n}{n+r} = \frac{8}{8+13.33} = 0.375$$

$$j = 1 - \frac{k}{3} = 0.875$$

$$R = \frac{f_c}{2} jk = \frac{0.45 \times 4000}{2} \times 0.875 \times 0.375 = 295.31 \text{psi}$$

Let, size of the beam = 10″ x 18″

Self-weight = $\frac{10 \times 18}{144}$ x 150 = 187.5 lb/ft.

Total UDL, w = 187 + 2600 = 2787.5 lb/ft.

Developed moment, $M = \frac{wl^2}{8} = \frac{2787.5 \times 15^2}{8 \times 1000}$ k – ft. = 78.4 k – ft.

$$d_{req} = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{78398.4 \times 12}{295.31 \times 10}} = 17.84'' > d \text{ (Doubly)}$$

$$M_1 = \frac{f_c}{2} bjk{d_{eff}}^2 = \frac{1800}{2} \times 10 \times 0.875 \times 0.375 \times 15.5^2$$

= 709488 lb – in = 59.12 k – ft.

$$A_{s1} = \frac{M_1}{f_s jd} = \frac{59.12 \times 12000}{24000 \times 0.875 \times 15.5} = 2.18\ in^2$$

M_2 = M - M_1 = 78.4 – 59.12 = 19.28 k – ft.

$$A_{s2} = \frac{M_2}{f_s(d-d')} = \frac{19.28 \times 12000}{24000\ (15.5 - 2.50)} = 0.74\ in^2$$

$$f_s{}' = 2\, f_s \frac{k - d'/d}{1-k} \le f_s$$

$$= 2 \times 0.4 \times 60 \times \frac{0.375 - \frac{2.5}{15.5}}{1 - 0.375} \le 24 \text{ ksi}$$

= 16.41 ksi.

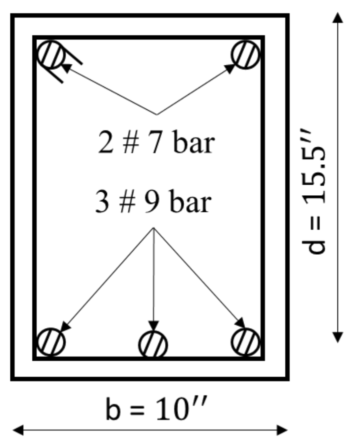
$$A_s{}' = \frac{M_2}{f_s{}'(d-d')} = \frac{19.28 \times 12}{16.41 \times (15.5 - 2.5)} = 1.08\ in^2$$

Tension side reinforcement, $A_s = A_{s1} + A_{s2}$
= 2.92 1.08 in^2

∴ Provide 3 # 9 bar.

Compression reinforcement, $A_s{}'$ = 1.08 in^2

∴ Provide 2 # 7 bar.



Problem-127: A rectangular beam carries a service load of 2 k/ft. & dead load of 1.35 k/ft. The beam is simply supported with a section of 10″ x 22″ and span length of 32′. Design the beam when f_y = 60 ksi; $f_c{}'$ = 4 ksi. [USD Method – Doubly Design Problem]

Solution:

$$\rho = 0.85\beta_1 \frac{f_c'}{f_y} \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$$

$$= 0.85 \text{ x } 0.85 \text{ x } \frac{4}{60} \text{ x } \frac{0.003}{0.003+0.005} = 0.01806$$

$$DL = 1.35 + \frac{10 \text{ x } 22}{144} \text{ x } 0.15 = 1.58 \text{ k/ft.}$$

LL = 2 k/ft.

Factored load, w_u = 1.2 DL + 1.6 LL

= 1.2 x 1.58 + 1.6 x 2

= 5.1 k/ft.

$$\text{Developed moment, } M_u = \frac{w_u l^2}{8}$$

$$= \frac{5.1 \text{ x } 32^2}{8} \text{ k – ft.}$$

= 652.8 k – ft.

$$M_u = \varphi\rho f_y b d_{req}^2 \left(1 - \frac{\beta}{\propto}\frac{\rho f_y}{f_c'}\right)$$

$$=> 652.8 \text{ x } 12 = 0.9 \text{ x } 0.01806 \text{ x } 60 \text{ x } 12 \text{ x } d_{req}^2 \text{ x } \left(1 - 0.59 \text{ x } \frac{0.01806 \text{ x } 60}{4}\right)$$

d_{req} = 30.92″> d (Doubly)

A_{s1} = ρbd_{eff}

= 0.01806 x 10 x 18 = 3.25 in^2

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{3.25 \text{ x } 60}{0.85 \text{ x } 4 \text{ x } 10} = 5.74''$$

$$M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

$$= [3.25 \text{ x } 60 \text{ x } (18 - \frac{5.74}{2})]/12$$

= 245.86 k – ft.

$$M_1 = \frac{M_u}{\varphi} - M_n$$

$$= \frac{652.8}{0.9} - 245.86 = 479.5 \text{ k – ft.}$$

$$\epsilon_t = \epsilon_u \text{ x } \frac{d-c}{c} \leq 0.005$$

$$= 0.003 \text{ x } \frac{18 - \frac{5.74}{0.85}}{5.74/0.85} \leq 0.005 = 0.005$$

$$f_s' = E_s \epsilon_u \text{ x } \frac{c-d'}{c} \leq f_y$$

$$= 29 \text{ x } 10^6 \text{ x } 0.003 \text{ x } \frac{\frac{5.74}{0.85} - 4}{\frac{5.74}{0.85}} \leq f_y$$

= 35.5 ksi

$$A_s' = \frac{M_1}{f_s'(d-d')} = \frac{479.5 \text{ x } 12}{35.5 \text{ x } (18-4)} = 11.58 \ in^2$$

Tension side reinforcement,

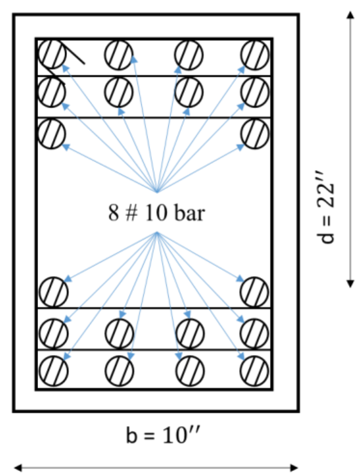
$$A_s = A_{s1} + A_{s2} \ [A_{s2} = A_s' \text{ x } \frac{f_s'}{f_y}]$$

$$= 3.25 + 11.58 \text{ x } \frac{35.5}{60} = 10.10 \ in^2$$

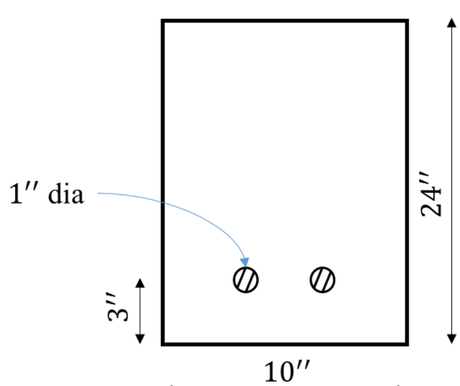
∴ Provide 8 # 10 bar.

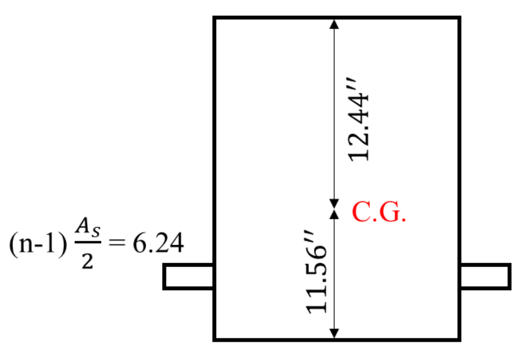
Compression reinforcement, A_s' = 11.58 in^2

∴ Provide 10 # 10 bar.



Problem-128: A rectangular beam 10″ x 24″ carries a moment of 45 k – ft. Find out the stress at extreme fiber of concrete beam and steel. Take, n = 9.





Solution:

$A_s = 2 \text{ x } \frac{\pi}{4} \text{ x } 1^2 = 1.56\ in^2$ $f_c = \frac{MC}{I}$ $= \frac{45 \ x\ 12000\ x\ (24-11.56)}{12481.96} = 538.18$ psi $f_s = \frac{MC}{I}$ $= \frac{45\ x\ 12000\ x\ (11.56-3)}{12481.96} = 370.33$ psi	$\bar{y} = \frac{24\ x\ 10\ x\ 12+(6.24\ x\ 1\ x\ 3)x\ 2}{24\ x\ 10+6.24\ x\ 1\ x\ 2} = 11.56''$ $I = \frac{10\ x\ 24^3}{12} + [24 \text{ x } 10 \text{ x } (12 - 11.56)^2] +$ $\frac{6.24\ x\ 1^3}{12} + [6.24 \text{ x } 1 \text{ x } (11.56 - 3)^2] \text{ x } 2$ $= 12481.96\ in^4$

Problem-129: A floor slab 4″ thick is supported by reinforced concrete beams 9 ft. c/c which together with the slab act as T – beams. The beams are simply supported and their span is 19 ft. The cross section of each beam below the slab is 10″ x 20″; the reinforcement consists of 6 # 8 bars in two rows, 2 in c/c vertically, the centre of the lower row being 2.5″ above the lower arm face of the beam. If a 2500 psi concrete and an allowable steel stress of 20000 psi are used, what is the maximum allowable working moment of the beam? [WSD Method – Analysis Problem]

Solution:

$b = \frac{L}{4} = \frac{19\ x\ 12}{4} = 57$ in

$= 16h_f + b_w = 16 \text{ x } 4 + 10 = 74$ in

= c/c spacing between two slab = 108 in

∴ b= 57 in

$A_s = 6 \text{ x } 0.79 = 4.74\ in^2$

d = 20 + 4 – 3.5 = 20.5 inch.

$\rho = \frac{A_s}{bd} = \frac{4.74}{57\ x\ 20.5} = 0.00406$

$n = \frac{E_s}{E_c} = \frac{29\ x\ 10^6}{57000\sqrt{2500}} \approx 10$

ρn = 10 x 0.00406 = 0.0406

$k = \frac{\rho n+\frac{1}{2}(\frac{t}{d})^2}{\rho n+\frac{t}{d}} = \frac{0.0406+\frac{1}{2}(\frac{4}{20.5})^2}{0.0406+\frac{4}{20.5}} = 0.253$

kd = 0.253 x 20.5 = 5.19 > t (T-beam satisfied)

$z = \frac{3kd-2t}{2kd-t} \text{ x } \frac{t}{3} = 1.582$

jd = d – z = 20.5 – 1.582 = 18.918

$M = A_s f_s jd$

= 4.74 x 20 x 18.918 = 1793.4 k – in.

$f_s = \frac{M}{\left(1-\frac{t}{2kd}\right)btjd} \leq f_c$

$= \frac{1793.4\ x\ 1000}{\left(1-\frac{4}{2\ x\ 5.19}\right)x\ 57\ x\ 4\ x\ 18.918} \lesssim 1125$ psi

= 675 psi ≤ 1125 psi (ok)

Problem-130: Design a T-beam by W.S.D. method of 20 ft. span and 55 in centers, having width 12 in and depth is 20 in. What is the tensile steel required at mid-span if the working moment is 80 k-ft. f_s= 20000psi and $f_c{}'$ = 3000 psi and the slab thickness is 5 in. [WSD Method – Design Problem]

Solution:

$b = \frac{L}{4} = \frac{20 \, x \, 12}{4} = 60$ in

$= 16h_f + b_w = 16 \text{ x } 5 + 12 = 92$ in

= c/c spacing between two slab = 55 in

∴ b= 55 in

$A_s = \frac{M}{f_s(d - {t}/{2})} = \frac{80 \, x \, 12000}{20000 \, x \, (20 - {5}/{2})} = 2.74 in^2$

$\rho = \frac{A_s}{bd} = \frac{2.74}{55 \, x \, 20} = 0.0025$

$n = \frac{E_s}{E_c} = \frac{29 \, x \, 10^6}{57000\sqrt{f_c{'}}} = 9$

ρn = 9 x 0.0025 = 0.0224

$k = \frac{\rho n + \frac{1}{2}(\frac{t}{d})^2}{\rho n + \frac{t}{d}} = \frac{0.0224 + \frac{1}{2}(\frac{5}{20})^2}{0.0224 + \frac{5}{20}} = 0.2$

kd = 0.2 x 20 = 4 < t (T-beam does not satisfy)

The beam should be designed as rectangular beam.

$r = \frac{f_s}{f_c} = \frac{f_s}{0.45 \, f_c{'}} = 14.81$

$k = \frac{n}{n+r} = 0.38$; $j = 1 - \frac{k}{3} = 0.87$; $d_{eff} = 20''$

$R = \frac{f_c}{2} kj$

$= \frac{0.45 \, x \, 3000}{2} \text{ x } 0.38 \text{ x } 0.87 = 223.16$ psi

$M = \frac{f_c}{2} bjkd^2 = 89.3$ k-ft. > 80 k-ft. (Singly)

$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{80 \, x \, 12000}{223.16 \, x \, 12}} = 18.93'' < d_{eff}$ (OK)

$A_s = \frac{M}{f_s jd} = \frac{80 \, x \, 12000}{20000 \, x \, 0.87 \, x \, 20} = 2.75 \, in^2$

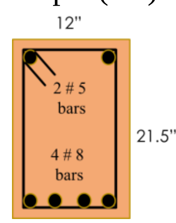
Provide 4 # 8 bar.

Check:

$f_c = \frac{M}{(1 - \frac{t}{2kd}) \, btjd}$

$= \frac{80 \text{ x } 12000}{(1 - \frac{5}{2\text{x } 0.2 \text{ x } 20}) \text{ x } 55 \text{ x } 5 \text{ x } 17.4}$

= 535 psi <1350 psi (Ok).



Problem-131: Design a T-beam by W.S.D. method of 24 ft. span and 47 in centers, having width 11 in and depth is 20 in. What is the tensile steel required at mid-span if the working moment is 208 k-ft. f_s= 20000psi and $f_c{'}$ = 3000 psi and the slab thickness is 3 in. [WSD Method – Design Problem]

Solution:

$b = \frac{L}{4} = \frac{24 \, x \, 12}{4} = 72$ in

$= 16h_f + b_w = 16 \text{ x } 3 + 11 = 59$ in

= c/c spacing between two slab = 47 in

∴ b= 47 in

∴ $A_s = \frac{M}{f_s(d - {t}/{2})}$

$= \frac{208 \, x \, 12000}{20000 \, x \, (20 - {3}/{2})} = 6.75 in^2$

$\rho = \frac{A_s}{bd} = \frac{6.75}{47 \, x \, 20} = 0.0072$

$n = \frac{E_s}{E_c} = \frac{29 \, x \, 10^6}{57000\sqrt{f_c{'}}} = 9$

ρn = 9 x 0.0072 = 0.0648

$k = \frac{\rho n + \frac{1}{2}(\frac{t}{d})^2}{\rho n + \frac{t}{d}} = \frac{0.0068 + \frac{1}{2}(\frac{3}{20})^2}{0.0648 + \frac{3}{20}} = 0.35$

$A_s = \frac{M}{f_s jd} = \frac{208 \text{ x } 12000}{20000 \text{ x } 18.63} = 6.7 \text{ in}^2$

Provide 2 #18 bar

Check:

$f_c = \frac{M}{(1 - \frac{t}{2kd}) \, btjd}$

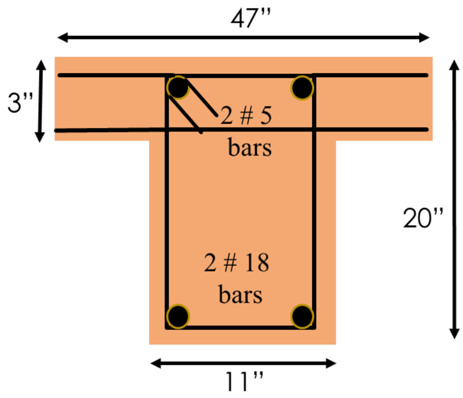
$= \frac{208 \text{ x } 12000}{(1 - \frac{3}{2\text{x } 0.35 \text{ x } 20}) \text{ x } 47 \text{ x } 3 \text{ x } 18.63}$

= 1209psi <1350 psi (Ok)

kd = 0.35 x 20 = 7 > t (T-beam satisfied)

$z = \frac{3kd - 2t}{2kd - t} \times \frac{t}{3} = 1.3636$

jd = d – z = 20 – 1.3636 = 18.6363



Problem-132: A floor system consists of a 4″ concrete slab, b_w = 10″, d = 20.5″, c/c spacing of beam = 40″. What is the nominal moment capacity if the steel area used is 6.88 in^2 and the span length is 24′. f_y = 50 ksi; $f_c{}'$ = 2.4 ksi. [USD Method – Analysis Problem]

Solution:

$b = \frac{L}{4} = \frac{24 \times 12}{4} = 72$ in

$= 16h_f + b_w = 16 \times 4 + 10 = 74$ in

= c/c spacing between two slab = 40 in

∴ b = 40 in

$a = \frac{A_s f_y}{0.85 f_c{}' b} = \frac{6.88 \times 50}{0.85 \times 2.4 \times 40} = 4.22'' > h_f$

∴ T – beam confirmed.

$A_{sf} = \frac{0.85 f_c{}'(b - b_w)h_f}{f_y}$

$= \frac{0.85 \times 2.4 \times (40-10) \times 4}{50} = 4.90\ in^2$

$A_s - A_{sf} = 6.88 - 4.90 = 1.98\ in^2$

$a = \frac{(A_s - A_{sf})f_y}{0.85 f_c{}' b_w} = \frac{1.98 \times 50}{0.85 \times 2.4 \times 10} = 4.86''$

c = a/β_1 = 4.86/0.85 = 5.72

c/d = 5.72/20.5

= 0.279 < 0.375 [Tension controlled]

$M_n = A_{sf} f_y (d - \frac{h_f}{2}) + f_y (A_s - A_{sf})(d - \frac{a}{2})$

$= 4.9 \times 50\ (20.5 - \frac{4}{2}) + 50 \times 1.98 \times (20.5 - \frac{4.86}{2})$

= 4530 + 1790 = 6320 k – in.

Problem-133: A floor system consists of a 3″ concrete slab supported by continuous T – beams of 24 ft. span, 47″ on centers. Web dimensions, as determined by negative moment requirements at the supports are b_w = 11″, d = 20″. What tensile steel area is required at mid-span to resist a moment of 6400 kip – in. f_y = 60 ksi; $f_c{}'$ = 3 ksi. [USD Method – Design Problem]

Solution:

$b = \frac{L}{4} = \frac{24 \times 12}{4} = 72$ in

$= 16h_f + b_w = 16 \times 3 + 13 = 59$ in

= c/c spacing between two slab = 47 in

∴ b = 47 in

$A_s = \frac{M_u}{\varphi f_y (d - \frac{a}{2})} = \frac{6400}{0.9 \times 60 \times (20 - \frac{3}{2})} = 6.40\ in^2$

$a = \frac{A_s f_y}{0.85 f_c{}' b} = \frac{6.40 \times 60}{0.85 \times 3 \times 47} = 3.2'' > h_f$

∴ T – beam confirmed.

$A_s - A_{sf} = \frac{\varphi M_{n2}}{\varphi f_y (d - \frac{a}{2})}$

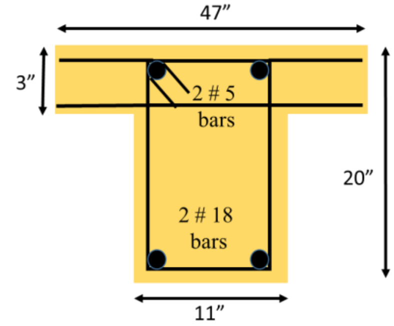
$= \frac{1830}{0.9 \times 60 \times (20 - \frac{4.02}{1})} = 1.88\ in^2$

$a = \frac{(A_s - A_{sf})f_y}{0.85 f_c{}' b_w} = \frac{1.88 \times 60}{0.85 \times 3 \times 11} = 4.02''$ (ok)

$A_s = A_{sf} + (A_s - A_{sf}) = 4.58 + 1.88 = 6.46\ in^2$

c = a/β_1 = 4.02/0.85 = 4.73

c/d = 4.73/20

<table>
<tr>
<td>$A_{sf} = \frac{0.85 f_c{}' (b - b_w) h_f}{f_y}$
$= \frac{0.85 \ x \ 3 \ x \ (47-11) \ x \ 3}{60} = 4.58 \ in^2$
$\varphi M_{n1} = \varphi A_{sf} f_y (\text{d} - \frac{h_f}{2})$
= 0.9 x 4.58 x 60 x (20 – 3/2)
= 4570 kip – in.
$\varphi M_{n2} = M_u - \varphi M_{n1}$
= 6400 – 4570 = 1830 kip – in.
Let, a = 4.02″</td>
<td>= 0.237 < 0.375 [Tension controlled]
∴ Provide 2 # 18 bars.

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Problem-134: Design a beam only for shear to carry ultimate shear force of 27 kips. Consider that no reinforcement will be provided. $f_c{}'$ = 4 ksi. [USD Method]

Solution: Here, V_u = 27 kip

Shear capacity, $V_c = 2\sqrt{f_c{}'} b_w \text{d} = 2 \text{ x } \sqrt{4000} \text{ x } b_w \text{d}$

But, shear capacity if no reinforcement is used, $V_c = \frac{1}{2} (2\sqrt{f_c{}'} b_w \text{d}) = \sqrt{4000} \text{ x } b_w \text{d} = 63.25 b_w \text{d}$

Now, $V_u = \varphi V_n = \varphi(V_c + V_s) = \varphi V_c$ [$V_s = 0$, as no stirrup will be used]

=> 27000 = 0.75 x 63.25b_wd

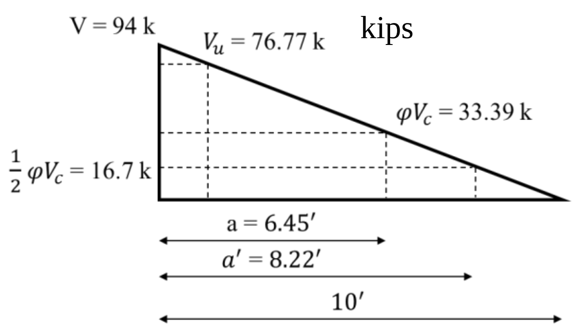
=> b_wd = 569.21 in^2

Let, b_w = 16″

∴ d = 569.21/16 = 35.58 ≈ 36″.

Problem-135: A simple supported beam on a 20 ft. span is carrying a factored load of 9.4 k/ft. Width of the beam is 16″ and effective depth is 22″. The beam is reinforced with 4 # 9 bars. If, f_y = 60 ksi; $f_c{}'$ = 4 ksi, determine upto what part of the length of beam web reinforcement should be provided and spacing of vertical stirrup. [USD Method]

Solution: w_u = 9.4 k/ft.; $V_{max} = \frac{w_u L}{2} = \frac{9.4 \ x \ 20}{2}$ = 94 kips



∴ $V_u = 94 - 9.4 \text{ x } \frac{22}{12}$ = 76.77 kips

∴ $\varphi V_c = \varphi 2\sqrt{f_c{}'} b_w \text{d}$

= [0.75 x 2 x $\sqrt{4000}$ x 16 x 22]/1000

= 33.39 kips < V_u.

∴ Stirrup is required.

From similar triangle, $\frac{94}{10} = \frac{94-33.39}{a}$ => a = 6.45′

Similarly, $\frac{94}{10} = \frac{94-16.7}{a'}$ => a' = 8.22′

Let us assume the # 3 bar will be used for U – stirrup.

∴ A_v = 2 x 0.11 in^2 = 0.22 in^2.

Spacing, S = $\frac{\varphi A_v f_y d}{V_u - \varphi V_c} = \frac{0.75 \; x \; 0.22 \; x \; 60 \; x \; 22}{76.77 - 33.39} = 5.02'' \approx 5''$

$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c{}'}b_w} \leq \frac{A_v f_y}{50 b_w} = \frac{0.22 \; x \; 60000}{0.75\sqrt{4000} \; x \; 16} \leq \frac{0.22 \; x \; 60000}{50 \; x \; 16} = 17.39'' \leq 16.5'' \approx 16.5''$

$S_{max} = \frac{d}{2} = \frac{22}{2} = 11''$

$S_{max} = 24''$

∴ Upto a = 6.45′, use # 3 bar @ 5″ c/c. From a = 6.45′ to a' = 8.22′, use # 3 bar @ 11″ c/c. For the rest portion no stirrup is required.

Problem-136: A rectangular beam is to carry a service dead load of 1.6 k/ft. including its own weight and service live load of 3.2 k/ft. on a simple span of 20 ft. Select the width and effective depth of the beam in which web reinforcement provides shear strength V_s = 2 V_c. Use of $f_c{}'$ = 4000 psi. Find the spacing of vertical stirrup from support if f_y = 40000 psi. [USD Method]

Solution: Here, DL = 1.6 k/ft. and LL = 3.2 k/ft.

∴ w_u = 1.2 x 1.6 + 1.6 x 3.2 = 7.04 k/ft.

Now, V_{max} at support = $\frac{w_u l}{2} = \frac{7.04 \; x \; 20}{2}$ = 70.4 k

∴ V_u = 70.4 – 7.04 x $\frac{d}{12}$

Now, $V_u = \varphi V_n = \varphi(V_c + V_s) = \varphi(V_c + 2V_c) = 3\varphi V_c$ = 3 x 0.75 x $\sqrt{4000}$ x b_w x d

=> 70.4 – 7.04 x $\frac{d}{12}$ = 142.30b_w x d

Let, b_w = 12″

∴ d = 17.5″

∴ V_u = 70.4 – 7.04 x $\frac{17.5}{12}$ = 60.13 k

∴ $\varphi V_c = \varphi 2\sqrt{f_c{}'}b_w$d = [0.75 x 2 x $\sqrt{4000}$ x 12 x 17.5]/1000 = 19.92 k

Spacing, S = $\frac{\varphi A_v f_y d}{V_u - \varphi V_c} = \frac{0.75 \; x \; 0.22 \; x \; 40 \; x \; 17.5}{60.13 - 19.92} = 2.85'' \approx 2.75''$

$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c{}'}b_w} \leq \frac{A_v f_y}{50 b_w} = \frac{0.22 \; x \; 40000}{0.75\sqrt{4000} \; x \; 12} \leq \frac{0.22 \; x \; 40000}{50 \; x \; 12} = 15.46'' \leq 14.67'' \approx 14.5''$

$S_{max} = \frac{d}{2} = \frac{17.5}{2} = 8.75''$

$S_{max} = 24''$

∴ Use # 3 bar @ 2.75″ c/c.

Problem-137: A rectangular beam of span length 10′ carries a distributed load of 6.25 k/ft. and maximum shear at support is 31.25 k. The width of the beam is 12″ & effective depth of the beam is 18.5″. Use of $f_c{}'$ = 4000 psi. Find the spacing of vertical stirrup from support if f_y = 60000 psi. [WSD Method]

Solution: Here, $V_{max} =$ 31.25 kip.

Shear at a distance d from the support, V_d = 31.25 – 6.25 x $\frac{18.5}{12}$ = 21.61 kip.

Allowable concrete shear, $V_c = 1.1\sqrt{f_c{}'}$bd = [1.1 x $\sqrt{4000}$ x 12 x 18.5]/1000 kip = 15.44 kip < V_d

∴ Stirrup is required.

Use # 3 bar U – stirrup,

Spacing, S = $\frac{A_v f_v d}{V - V_c} = \frac{(2\ x\ 0.11)\ x\ 24000\ x\ 18.5}{(21.61-15.44)\ x\ 1000} = 15.83'' \approx 15.75''$

$S_{max} = \frac{A_v}{0.0015b} = \frac{2\ x\ 0.11}{0.0015\ x\ 12} = 12.22'' \approx 12.00''$

$S_{max} = \frac{d}{2} = \frac{18.5}{2} = 9.25''$

$S_{max} = 24''$

∴ Use # 3 bar @ 9.25″ c/c.

Problem-138: Determine the development length required for the # 8 uncoated bottom bars shown in figure for (a) k_{tr} = 0 & (b) k_{tr} = Use computed value, if f_y = 60 ksi; $f_c{}'$ = 3 ksi.

Solution: Development length, $l_d = (\frac{3}{40} \frac{f_y}{\lambda\sqrt{f_c{}'}} \frac{\psi_t \psi_c \psi_s}{\frac{C + k_{tr}}{d_b}})\ d_b$

Where, ψ_t = Loading factor = 1

ψ_c = Coating factor = 1

ψ_s = Size factor = 1

λ = 1 for normal weight concrete

Value of C: Side cover = 2.5″; One – half of c/c spacing of bars = $\frac{3''}{2}$ = 1.5″

$\therefore$ C = 1.5″.

k_{tr} = Transverse reinforcement index = $\frac{40\,A_{tr}}{Sn} \leq 2.5 = \frac{40\,x\,(2\,x\,0.11)}{8\,x\,3}$ = 0.367 inch

(a) $\frac{C+\,k_{tr}}{d_b} \leq 2.50 = \frac{1.5+0}{1}$ = 1.50 < 2.5 (ok)

Development length, $l_d = (\frac{3}{40}\,\frac{f_y}{\lambda\sqrt{f_c{}'}}\,\frac{\psi_t\psi_c\psi_s}{\frac{C+\,k_{tr}}{d_b}})\,d_b$

$= \frac{3}{40} \text{ x } \frac{60000}{1\sqrt{3000}} \text{ x } \frac{1\,x\,1\,x\,1}{1.50} \text{ x } \frac{8}{8}$ = 55 inch

(b) $\frac{C+\,k_{tr}}{d_b} \leq 2.50 = \frac{1.5+0.367}{1}$ = 1.867 < 2.5 (ok)

Development length, $l_d = (\frac{3}{40}\,\frac{f_y}{\lambda\sqrt{f_c{}'}}\,\frac{\psi_t\psi_c\psi_s}{\frac{C+\,k_{tr}}{d_b}})\,d_b$

$= \frac{3}{40} \text{ x } \frac{60000}{1\sqrt{3000}} \text{ x } \frac{1\,x\,1\,x\,1}{1.867} \text{ x } \frac{8}{8}$ = 44 inch

Problem-139: Determine the spacing for the temperature & shrinkage reinforcement in a one way slab of thickness t = 6″. Consider # 3 deformed bar with f_y = 60 ksi; $f_c{}'$ = 3 ksi. Follow the ACI code specification.

Solution: A_s = 0.0018bt
= 0.0018 x 12 x 6 = 0.13 in^2/ft.

Spacing, S = $\frac{0.11\,x\,12}{0.13}$ = 10.15″ ≈ 10″ c/c.

Problem-140: An Engineer designed a slab using 60 grade steel to provide #4 bar @ 4.5″c/c. If you want to provide 500W 10 mm bar, then what would be the spacing?

Solution: Spacing = $\frac{0.2x\,12}{A_{s1}}$ = 4.5
or, A_{s1} = 0.53 in^2
500W means $\frac{500 \text{ x } 145}{1000}$ = 72.5 grade steel

$A_{s1}f_1 = A_{s2}f_2 \Rightarrow A_{s2} = \frac{0.53\,x\,60}{72.5} = 0.44\,in^2$

Spacing = $\frac{\frac{\pi}{4}\,x\,10^2 x 1000}{0.44\,x\,25.4^2}$
= 276.67 ≈ 250 mm c/c

Problem-141: Calculate the slab thickness for a panel dimension of 20′ x 18′ with ACI code standard.

Solution: Slab thickness, t = $\frac{2\,(L+B)}{180}$ x 12 = $\frac{2\,(20+18)}{180}$ x 12 = 5.07″ ≈ 5.25″

According to ACI code minimum slab thickness is 3.5″.

$\therefore$ Slab thickness = 5.25″.

Problem-142: Calculate the slab thickness for a panel dimension of 12′ x 12′ with ACI code standard.

Solution: Slab thickness, t = $\frac{2\,(L+B)}{180}$ x 12 = $\frac{2\,(12+12)}{180}$ x 12 = 3.2″ ≈ 3.25″

According to ACI code minimum slab thickness is 3.5″.

∴ Slab thickness = 3.50″.

Problem-143: Check the bond stress in W.S.D. method for shear 9 k. Main reinforcement #6 bars @ 4.75" c/c. j = 0.87, k = 0.33, d = 7 in, $f_c{}'$ = 4 ksi.

Solution: $U_d = \frac{V_{max}}{\sum_0 jd} = \frac{V_{max}}{\pi\varphi\, x\, \frac{12}{spacing}\, x\, jd}$

$= \frac{9\, x\, 1000}{\pi\, x\, \frac{6}{8}\, x\, \frac{12}{4.75}\, x\, 0.87\, x\, 7}$ = 248.3 psi.

$U_{all} = \frac{3.4\sqrt{f_c{}'}}{\varphi} = \frac{3.4\sqrt{4000}}{\frac{6}{8}}$ = 286.7 psi.

$U_{all} > U_d$ (OK)

Problem-144: Check dowel embedment length into footing for compression by U.S.D. method for main reinforcement 4 # 6 bars, $f_c{}'$ = 3 ksi, f_y = 60 ksi.

Solution: Dowel embedment length,

$l_{dc} = \frac{0.02\, f_y d_b}{\sqrt{f_c{}'}} = \frac{0.02\, x\, 60000\, x\, \frac{6}{8}}{\sqrt{3000}}$

= 16.43 in

Minimum, $l_{dc} = 0.0003 f_y d_b$

= 0.0003 x 60000 x $\frac{6}{8}$

= 13.5 in

Minimum, l_{dc} = 8 in

∴ Dowel embedment length, l_d = 16.5 in.

Problem-145: Find length of lapped splices of dowels with column bar by U.S.D. method for main reinforcement 4#6 bars, $f_c{}'$ = 3 ksi, f_y = 50 ksi.

Solution: Splices length, $l_s = 0.0005 f_y d_b$

= 0.0005 x 50000 x $\frac{6}{8}$

= 18.75 in

Minimum, l_s = 12 in

∴ Splices length, l_s = 18.75 in.

Problem-146: Calculate development length for beam by W.S.D. method for main reinforcement 4 # 6 bars, shear 21 k, j = 0.87, k = 0.33, d = 20 in, $f_c{}'$ = 3 ksi, f_y = 60 ksi.

Solution: $U_d = \frac{V_{max}}{\sum_0 jd} = \frac{V_{max}}{n\pi\varphi\, x\, jd}$

$= \frac{21\, x\, 1000}{4\, x\, \pi\, x\, \frac{6}{8}\, x\, 0.87\, x\, 20}$ = 128.1 psi.

Development length,

$l_d = \frac{f_s d}{4U_d} = \frac{0.4\, x\, 60000\, x\, \frac{6}{8}}{4\, x\, 128.1}$

= 35 in.

Problem-147: If live load is 400 k and dead load is 500 k as well as $f_c{}'$ = 4 ksi, f_y = 60 ksi. What is the gross area of tied column? [USD Method]

Solution: P_u = Øk [0.85(A_g- A_s)$f_c{}'$+ $A_s f_y$]

For tied column, φ = 0.65 & k = 0.8

$A_s = \rho_g A_g$

Let, ρ_g = 0.03

$A_s = 0.03A_g$

P_u = 0.65 x 0.8 [0.85(A_g- A_s)$f_c{}'$+ $A_s f_y$]

=> 1.2 x 500 + 1.6 x 400 = 0.6 x 0.8 x [0.85 x (A_g- .03A_g) x 4 + 60 x 0.03 x A_g]

=> A_g = 467.75 in^2.

Column size = 22″ x 22″ = 484 in^2.

Problem-148: A column with cross-section 15″ x 15″ is reinforced with 8 # 8 bars subjected to a concentric load. If f_c'= 4 ksi, f_y = 60 ksi, calculate the ultimate load carrying capacity of the column. [USD Method]

Solution: A_s = 8 x 0.79 = 6.32 in^2
A_g = 15 x 15 = 225 in^2
P_u = Øk [0.85(A_g- A_s)f_c'+ $A_s f_y$] = 0.65 x 0.8 [0.85(A_g- A_s)f_c'+ $A_s f_y$]
= 0.65 x 0.8 [0.85 x (225 – 6.32) x 4 + 6.32 x 60] = 583.81 kips.

Problem-149: Compute the steel/concrete ratio if steel uses in the column is 1% of total size of column area & steel ratio, r = 10. [RRI – 14]

Solution: r = 10

=> $\frac{f_s}{f_c}$ = 10; => $\frac{\rho_s / A_s}{\rho_c / A_c}$ = 10

=> $\frac{\rho_s}{A_s}$ x $\frac{A_c}{\rho_c}$ = 10

=> $\frac{\rho_s}{\rho_c}$ x $\frac{A_g - A_s}{A_s}$ = 10

=> $\frac{\rho_s}{\rho_c}$ x $\frac{A_g - 0.01A_g}{0.01A_g}$ = 10

=> $\frac{\rho_s}{\rho_c}$ = 0.1010 = 10.1%

Problem-150: Find the design ultimate axial stress of the column with zero eccentricity [k = 1]. Steel area 2%, column size 12″ x 12″, f_c'= 3.5 ksi, f_y = 60 ksi. [USD Method]

Solution: A_g = 12 x 12 = 144 in^2
A_s = 0.02 x 144 = 2.88 in^2
P_u = Øk [0.85(A_g- A_s)f_c'+ $A_s f_y$]
= 0.65 x 1 [0.85(A_g- A_s)f_c'+ $A_s f_y$]
= 0.65 x 1 [0.85 x (144 – 2.88) x 3.5 + 2.88 x 60]
= 385.21 kips.

∴ Stress = $\frac{Axial\ load}{Area}$
= $\frac{385.21}{144}$ = 2.68 psi

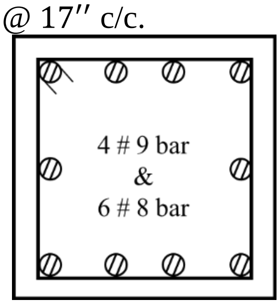
Problem-151: Design a square tied column to carry an axial service loads of 320 k dead load and 190 k live load. Use f_c'= 4 ksi, f_y = 60 ksi. [USD Method]

Solution: P_u = Øk [0.85(A_g- A_s)f_c'+ $A_s f_y$]
For tied column, φ = 0.65 & k = 0.8
$A_s = \rho_g A_g$
Let, ρ_g = 0.03
$A_s = 0.03A_g$
P_u = 0.65 x 0.8 [0.85(A_g- A_s)f_c'+ $A_s f_y$]
=> 1.2 x 320 + 1.6 x 190 = 0.6 x 0.8 x [0.85 x (A_g – .03A_gx 4 + 60 x 0.03 x A_g]
=> A_g = 259.53 in^2.
Column size = 17″ x 17″ = 289 in^2.
A_s = 0.03 x 289 = 8.67 in^2
Use 4 # 9 bars & 6 # 8 bars.

Tie Design:
Use # 3 bar as the bar size used # 9 as main reinforcement.

Spacing, S = 16 d_b = 16 x $\frac{9}{8}$ = 18″
= 48 d_b = 48 x $\frac{3}{8}$ = 18″
= 17″ [Column least dimension]

Use # 3 bar @ 17″ c/c.



Problem-152: Determine the ultimate axial load on a 15" square column reinforced with 4 #9 bars. Ties are number placed at 12" c/c. $f_c{}'$ = 4 ksi and f_y = 60 ksi. Also check whether the column satisfy the ACI code requirements.

Solution: According to ACI minimum area = 96 in^2

Used area = 15 x 15 = 225 in^2(ok)

Minimum size of main reinforcement #5 bar

Used main bar #9 (ok)

Amount of reinforcement = 4 x 1 = 4 in^2

$\rho_g = \frac{4}{225}$ = 0.017

0.01 ≤ ρ_g ≤ 0.08 (ok).

Tie bar #3 bar should be use for main reinforcement up to #9 bar is used.

Used tie bar #3 bar (ok).

Spacing = 16 d_b = 16 x $\frac{9}{8}$ = 18"c/c

= 48 d_b = 48 x $\frac{3}{8}$ = 18"c/c

= 15"c/c [Column least dimension]

Spacing should be 15"c/c.

Used spacing 12"c/c (ok).

Ultimate load, P_u = Øk [0.85$A_c f_c{}'$ + $A_s f_y$]

= 0.65 x 0.8 [0.85 x 225 x 4 + 4 x 60]

= 522.6 kips

Problem-153: Design of a spiral column to carry ultimate axial load of 400 kips. $f_c{}'$ = 4 ksi and f_y = 60 ksi. [USD Method]

Solution: Ultimate load,

P_u = Øk [0.85(A_g- A_s)$f_c{}'$+ $A_s f_y$]

= Øk A_g[0.85(1-ρ_g)$f_c{}'$+$\rho_g f_y$]

Let, ρ_g = 0.04

=> 400 = 0.7 x 0.85 A_g[0.85 x (1-0.04)x 4 + 0.04 X 60]

=> A_g = 118.69 in^2

=> $\frac{\pi}{4} D^2$ = 118.69 in^2

=> D = 12.29 ≈ 12.5 inch

∴ $A_s = \rho_g$ x A_g

= 0.04 x $\frac{\pi}{4}$ 12.5^2 = 4.91 in^2

∴ Use 12 #6 bar.

<u>*Design of spiral:*</u>

Using #3 bar

ρ_{sp} = 0.45 x $\frac{f_c{}'}{f_y}$ [$(\frac{D}{D_c})^2$ - 1]

= 0.45 x $\frac{4}{60}$ [$(\frac{12.5}{9.5})^2$-1] = 0.022

$\rho_{sp} = \frac{4\,a_s}{gD_c}$

⇒ g = $\frac{4\,a_s}{\rho_{sp}D_c} = \frac{4 \times 0.11}{0.022 \times 9.5}$

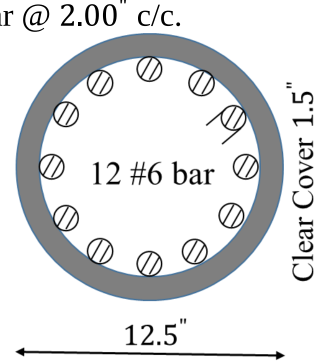
= 2.10 ≈ 2.00 inch

⇒ $S_{max} = \frac{D_c}{6} = \frac{9.5}{6}$ = 1.58 ≈ 1.50 inch

= 3"

S_{min} = 1"

Use #3 bar @ 2.00" c/c.



Problem-154: Design of a spiral column to carry axial load of 280 kips. $f_c{}'$ = 4 ksi and f_y = 60 ksi. [WSD Method]

Solution: Axial load, P = A_g[0.25$f_c{}'$+$\rho_g f_s$]

Let, ρ_g = 0.04

=> 280 = A_g[0.25 x 4 + 0.04 X 0.4 x 60]

=> A_g = 143 in^2

=> $\frac{\pi}{4} D^2$ = 143 in^2

$\rho_{sp} = \frac{4\,a_s}{gD_c}$

=> g = $\frac{4\,a_s}{\rho_{sp}D_c} = \frac{4 \times 0.11}{0.02 \times 10.5}$ = 2.10 ≈ 2.00 inch

=> $S_{max} = \frac{D_c}{6} = \frac{10.5}{6}$ = 1.75 inch

= 3"

=> D = 13.49 ≈ 13.5 inch

∴ $A_s = \rho_g$ x A_g

$= 0.04 \text{ x } \frac{\pi}{4} 13.5^2 = 5.73\ in^2$

∴ Use 6 #9 bar.

Design of spiral:

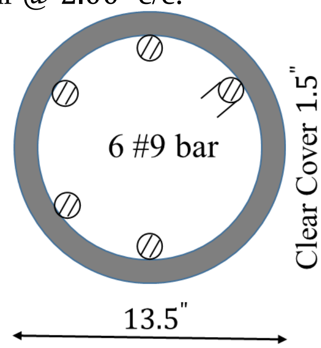
Using #3 bar

$\rho_{sp} = 0.45 \text{ x } \frac{f_c'}{f_y} [(\frac{D}{D_c})^2 - 1]$

$= 0.45 \text{ x } \frac{4}{60} [(\frac{13.5}{10.5})^2 - 1] = 0.02$

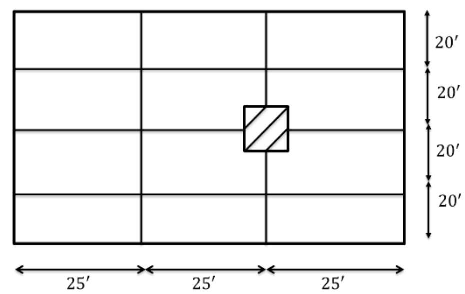
$S_{min} = 1''$

Use #3 bar @ 2.00" c/c.



Problem-155: Design of a tied column for six story building from the following data:

- Floor thickness 6".
- Live load on floor 125 psf.
- Size of the beam on both direction 12" x 24"
- $f_c' = 4$ ksi and $f_y = 60$ ksi.
- Story height 10′.



Solution:

Load Calculation:

Live load = $Loaded\ area * intensity\ of\ load * no\ of\ story$

= 20 x 25 x 125 x 6 = 375 kips

Dead load = $Loaded\ area * thickness * unit\ weight * no\ of\ story$

$= 20 \text{ x } 25 \text{ x } \frac{6}{12} \text{ x } 150 \text{ x } 6$

= 225 kips

Beam load = $\frac{12 \ x\ (24-6)}{144}$ x 150 x (20+25) x 6

= 60.75 kips

Assume column size = 21 in square

Weight of column = $\frac{21\ x\ 21}{144}$ x 10 x 150 x 6

= 27.56 kips

Total dead load, DL = 313.3 kip

Total live load, LL = 375 kip

Ultimate load, P_u = 1.2 DL + 1.6 LL

= 1.2 x 313.3 + 1.6 x 375

= 976 kip

$P_u = \emptyset k\, [0.85(A_g - A_s) f_c' + A_s f_y]$

$= \emptyset k\, A_g [0.85(1-\rho_g) f_c' + \rho_g f_y]$

=> 976 = 0.65 x 0.8 x A_g[0.85(1 – 0.04) x 4 + 0.04 x 60]

=> $A_g = 334.4\ in^2$

Providing 19 in x 19 in section, $A_g = 361\ in^2$

$A_s = A_g \rho_g = 361 \text{ x } 0.04 = 14.45\ in^2$

Use 12 #10 bar

Web reinforcement calculation:

Using #3 bar,

Spacing = 16 d_b = 16 x $\frac{10}{8}$ = 20"c/c

= 48 d_b = 48 x $\frac{3}{8}$ = 18"c/c

= 19"c/c

Use # 3 bar @18" c/c.

Problem-156: A column consists of 12 no # 9 bars. Calculate the size spacing and draw them.

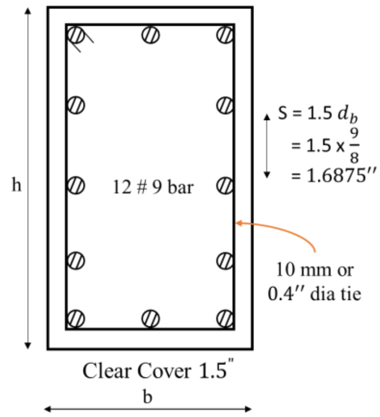
Solution: Consider a tied column,

h = 2 x 1.5 + 2 x 0.4 + 5 x 1.125 + 4 x 1.6875
 = 16.18″
 ≈ 16.5″

b = 2 x 1.5 + 2 x 0.4 + 3 x 1.125 + 2 x 1.6875
 = 10.55″
 ≈ 11″

Spacing, S = 1.6875″

Size = 16.5″ x 11″



Problem-157: A-20 inch square tied column reinforced with eight ft. 9 bars carries a concentric load of 380 kips. Design a square footing by working stress method using values given-allowable soil pressure 7000 lb/ft^2, $f_c{}'$ = 3000 psi and f_s = 20000 psi.

Solution: Assume the unit weight of soil = 110 pcf

∴ Average unit weight of concrete & soil = $\frac{110+150}{2}$ = 130 pcf

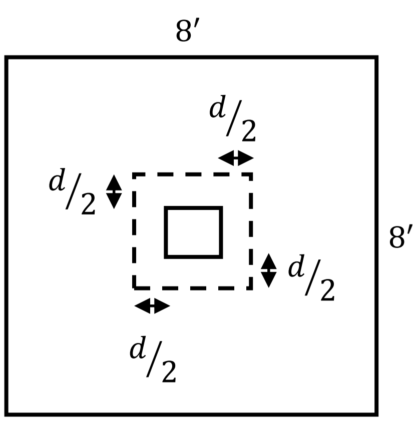
Assume the depth of the foundation 5 ft. below the ground surface.

∴ Soil pressure at 5 ft. below the ground surface = 5 x 130 = 650 psf.

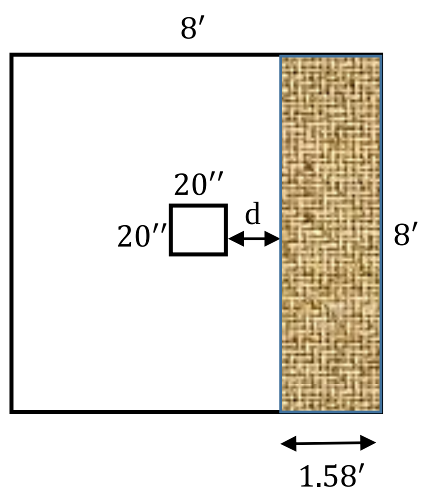
∴ Effective soil pressure to carry the column load, q_e = 7000 – 650 = 6350 psf.

∴ Required footing area, $A_{req} = \frac{380\ x\ 1000}{6350}$ = 59.84 ft^2.

Assume footing size = 8′ x 8′ = 64 ft^2> 59.84 ft^2 (ok).



Punching shear



Beam shear

Punching shear check:

$$q = \frac{380 \ x \ 1000}{64} = 5937.5 \text{ psf} = 5.9 \text{ ksf}$$

Critical perimeter for punching shear, b_0 = 4 (a + d) = 4 (20 + d) = 80 + 4d

Shear force acting on this perimeter, V_c = q x $[L^2 - (a + d)^2]$ = 5.9 $[8^2 - (\frac{20+d}{12})^2]$ kips

Nominal shear strength, $V_{all} = 2\sqrt{f_c'}\, b_0 d$ = [2 x $\sqrt{3000}$ x (80 + 4d) x d]/1000 kips

Now, $V_c = V_{all}$

or, [2 x $\sqrt{3000}$ x (80 + 4d) x d]/1000 = 5.9 $[8^2 - (\frac{20+d}{12})^2]$

or, d = 18.67 inch ≈ 19 inch [Using calculator]

Height of the footing, h = 19 + 3 = 22 inch.

[Clear cover is min 3 in. but 4 inch is better to provide]

Beam shear check:

Shear force, V_v = qL $[\frac{B}{2} - \frac{a}{2} - d]$ = 5.9 x 8 x $[\frac{8}{2} - \frac{20}{2 \ x \ 12} - \frac{19}{12}]$ = 74.73 kips.

Nominal shear strength, $V_{all} = 1.1\sqrt{f_c'}$ bd = [1.1 x $\sqrt{3000}$ x 8 x 12 x 19]/1000

= 109.9 kips > 74.73 kips (ok).

Steel calculation:

c = $\frac{L-a}{2} = \frac{8-20/12}{2}$ = 3.167 ft.

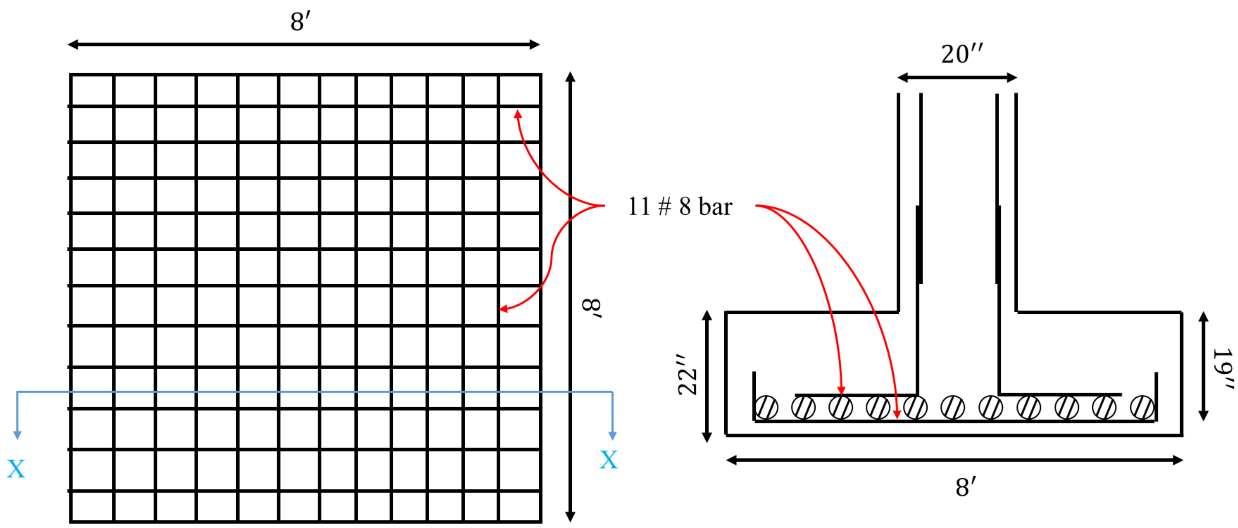
Moment at the face of the column, M = $\frac{qLc^2}{2} = \frac{5.9 \ x \ 8 \ x \ 3.167^2}{2}$ = 236.71 k-ft.

∴ $A_s = \frac{M}{f_s jd} = \frac{236.71 \ x \ 12000}{20000 \ x \ 0.88 \ x \ 19} = 8.49 \ in^2$

∴ $A_{s(\min)}$ = 0.002bt = 0.002 x 8 x 12 x 22 = 4.22 in^2 [Shrinkage reinforcement check]

∴ $A_{s(\min)} = \frac{200}{f_y}$ bd = $\frac{200}{60000}$ x 8 x 12 x 19 = 6.08 in^2

∴ Provide 11 # 8 bar in each direction.



Plan View

Cross sectional view X-X

Problem-158: A-18 inch square tied column with $f_c{}'$ = 4000 psi reinforced with 8 - # 8 bars of f_y = 60000 psi, supports a dead load of 225 kips and live load of 175 kips. The soil has a unit weight of 100 pcf. The allowable soil pressure 5000 lb/ft^2. Design the square footing with base 5 ft. below grade in USD Method.

Solution: Given that, the unit weight of soil = 100 pcf

∴ Average unit weight of concrete & soil = $\frac{100+150}{2}$ = 125 pcf

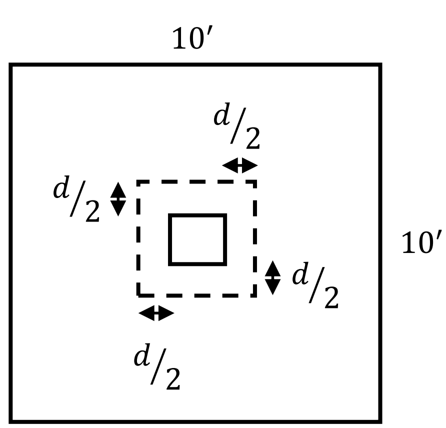
The depth of the foundation 5 ft. below the ground surface.

∴ Soil pressure at 5 ft. below the ground surface = 5 x 125 = 625 psf.

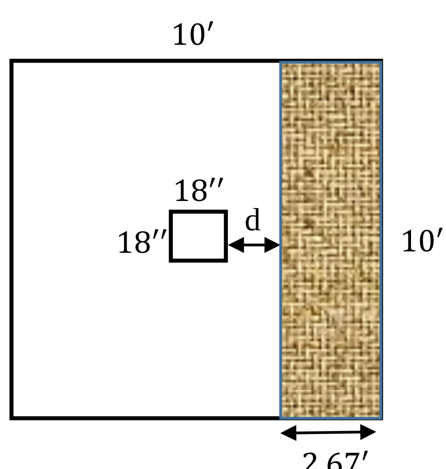
∴ Effective soil pressure to carry the column load, q_e = 5000 – 625 = 4375 psf.

∴ Required footing area, $A_{req} = \frac{(225+175)\ x\ 1000}{4375}$ = 91.5 ft^2.

Assume footing size = 10′ x 10′ = 100 ft^2> 91.5 ft^2 (ok).



Punching shear



Beam shear

Punching shear check:

$$q_u = \frac{(1.2 \, x \, 225 + 1.6 \, x \, 175) x \, 1000}{100} = 5500 \text{ psf} = 5.5 \text{ ksf}$$

Critical perimeter for punching shear, b_0 = 4 (a + d) = 4 (18 + d) = 72 + 4d

Shear force acting on this perimeter, $V_u = q_u$ x $[L^2 - (a+d)^2]$ = 5.5 [10^2 - $(\frac{18+d}{12})^2$] kips

Nominal shear strength, $V_{all} = 4\varphi \sqrt{f_c{}'}\, b_0 d$ = [4 x 0.75 x $\sqrt{4000}$ x (72 + 4d) x d]/1000 kips

Now, $V_u = V_{all}$

or, [4 x 0.75 x $\sqrt{4000}$ x (72 + 4d) x d]/1000 = 5.5 [10^2 - $(\frac{18+d}{12})^2$]

or, d = 18.19 inch ≈ 19 inch [Using calculator]

∴ Height of the footing, h = 19 + 3 = 22 inch.

Beam shear check:

Shear force, $V_u = q_u L [\frac{B}{2} - \frac{a}{2} - d]$ = 5.5 x 10 x [$\frac{10}{2} - \frac{18}{2 \, x \, 12} - \frac{19}{12}$] = 146.67 kips.

Nominal shear strength, $V_{all} = 2\varphi \sqrt{f_c{}'}$ bd = [2 x 0.75 x $\sqrt{4000}$ x 10 x 12 x 24]/1000

= 273.22 kips > 146.67 kips (ok).

Steel calculation:

c = $\frac{L-a}{2} = \frac{10-18/12}{2}$ = 4.25 ft.

Moment at the face of the column, M = $\frac{q_u L c^2}{2} = \frac{5.5 \, x \, 10 \, x \, 4.25^2}{2}$ = 496.72 k-ft.

∴ $A_s = \frac{M}{\varphi f_y (d - \frac{a}{2})}$ or, $A_s = \frac{496.72 \, x \, 12000}{0.9 \, x \, 60000 \, x \, (19 - \frac{0.1471 \, A_s}{2})}$

a = $\frac{A_s f_y}{0.85 \, f_c{}' b} = \frac{60}{0.85 \, x \, 4 \, x \, 10 \, x \, 12}$

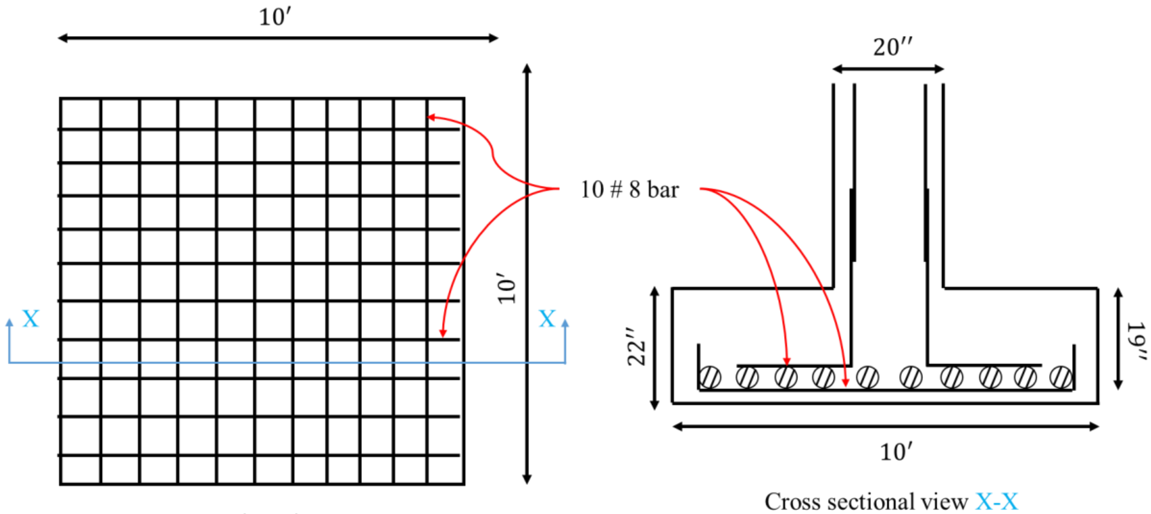
∴ a = $0.1471 A_s$

Solving the equation, $A_s = 5.94 \, in^2$

∴ $A_{s(\min)}$ = 0.0018 bt = 0.0018 x 10 x 12 x 22 = 4.75 in^2 [Shrinkage reinforcement check]

∴ $A_{s(\min)} = \frac{200}{f_y}$ bd = $\frac{200}{60000}$ x 10 x 12 x 19 = 7.60 in^2

∴ Provide 10 # 8 bar in each direction.



Problem-159: A 18″ x 18″ RCC column made a footing size 8′ x 9′ will supports a total dead load of 23000 lb/ft. The ultimate load bearing capacity of soil is 2 tsf. Determine footing depth. f_c' = 3000 psi; f_y = 60000 psi. [Use USD Method]

Solution: Bearing pressure of soil, q_u = 2 tsf = 2 x 2200 = 4400 psf = 4.4 ksf.

Critical perimeter for punching shear, b_0 = 4 (a + d) = 4 (18 + d) = 72 + 4d

Shear force acting on this perimeter, V_u = q_u x [L x B - $(a + d)^2$] = 4.4 [9 x 8- $(\frac{18+d}{12})^2$] kips

Nominal shear strength, V_{all} = 4φ $\sqrt{f_c'}$ b_0d = [4 x 0.75 x $\sqrt{3000}$ x (72 + 4d) x d]/1000 kips

Now, V_u = V_{all}

or, [4 x 0.75 x $\sqrt{3000}$ x (72 + 4d) x d]/1000 = 4.4 [9 x 8 - $(\frac{18+d}{12})^2$]

or, d = 13.72 inch ≈ 14 inch [Using calculator]

∴ Height of the footing, h = 14 + 4 = 18 inch.

Problem-160: A 18″ x 18″ RCC column made a footing size 8′ x 9′ will supports a total dead load of 23000 lb/ft. The bearing pressure of soil is 2 tsf. Determine footing depth. f_c' = 3000 psi; f_y = 60000 psi. [Use WSD Method]

Solution: Bearing pressure of soil, q= 2 tsf = 2 x 2200 = 4400 psf = 4.4 ksf.

Critical perimeter for punching shear, b_0 = 4 (a + d) = 4 (18 + d) = 72 + 4d

Shear force acting on this perimeter, V_c = q x [L x B - $(a + d)^2$] = 4.4 [9 x 8 - $(\frac{18+d}{12})^2$] kips

Nominal shear strength, V_{all} = 2 $\sqrt{f_c{}'}$ b_0d = [2 x $\sqrt{3000}$ x (72 + 4d) x d]/1000 kips

Now, V_c = V_{all}

or, [2 x $\sqrt{3000}$ x (72 + 4d) x d]/1000 = 4.4 [9 x 8 - $(\frac{18+d}{12})^2$]

or, d = 17.73 inch ≈ 18 inch [Using calculator]

∴ Height of the footing, h = 18 + 3 = 21 inch.

Problem-161: A RCC footing size is 10′ x 10′. Determine the punching stress when depth 16.5″ and column size 10″ x 10″. $f_c{}'$ = 4000 psi; f_y = 60000 psi. [Use WSD Method]

Solution: Punching area, A_0 = 4 (a + d) x d = 4 (10 + 16.5) x 16.5 = 1749 in^2.

Shear force acting on this perimeter, V_c = q x [L^2 - $(a + d)^2$]

$$= q \text{ x } [10^2 – (\frac{10 + 16.5}{24})^2] = 95.12 \text{ q.}$$

Punching stress = $\frac{95.12\ q}{1749}$ psi

Nominal shear strength, V_{all} = 2 $\sqrt{f_c{}'}$ = 2 x $\sqrt{4000}$ psi

Now, V_c = V_{all}

or, $\frac{95.12\ q}{1749}$ = 2 x $\sqrt{4000}$

or, q = 2 x $\sqrt{4000}$ x $\frac{1749}{95.12}$ = 2325 psi

∴ Punching stress = $\frac{95.12\ q}{1749}$ psi = $\frac{95.12}{1749}$ x 2325 = 126.45 psi.

Problem-162: A 12″ thick concrete wall carries a dead load of 10 k/ft. and live load of 12.5 k/ft. The bearing pressure of soil is 5 ksf at the level of the base of the footing which is 5 ft. below the final ground surface. $f_c{}'$ = 4000 psi; f_y = 80000 psi and density of the soil is 120 pcf. [Use USD Method]

Solution: Considering 1 ft. strip of footing,

Thickness of footing, t = 1~1.5 times of wall thickness = 12″; d = 12 – 3 – 0.5 = 8.5″

Effective soil pressure, q_e = 5 – (1 x 0.15 + 4 x 0.12) = 4.37 ksf

Required footing area, A_{req} = $\frac{10+12.5}{4.37}$ = 5.2 ft^2 of length.

Check for beam shear:

$$q_u = \frac{1.2 \ x \ 10+1.6 \ x \ 12.5}{5.2} = 6.15 \text{ ksf}$$

Shear force, $V_u = q_u\ [\frac{A_{req}}{2} - \frac{wall\ thickness}{2} - \text{d}] = 6.15\ [\frac{5.2}{2} - \frac{12}{2\ x\ 12} - \frac{8.5}{12}] = 8.56$ kips/ft.

Nominal shear strength, $V_{all} = 2\varphi\sqrt{f_c{}'}$ bd = [2 x 0.75 x $\sqrt{4000}$ x 12 x 8.5]/1000

= 9.6 kips/ft. > 8.56 kips/ft. (ok).

- ∴ Depth of the footing = $8.5''$.
- ∴ Height of the footing = $12''$.