Solutions for Reinforced Concrete Design 9th Edition by Aghayere

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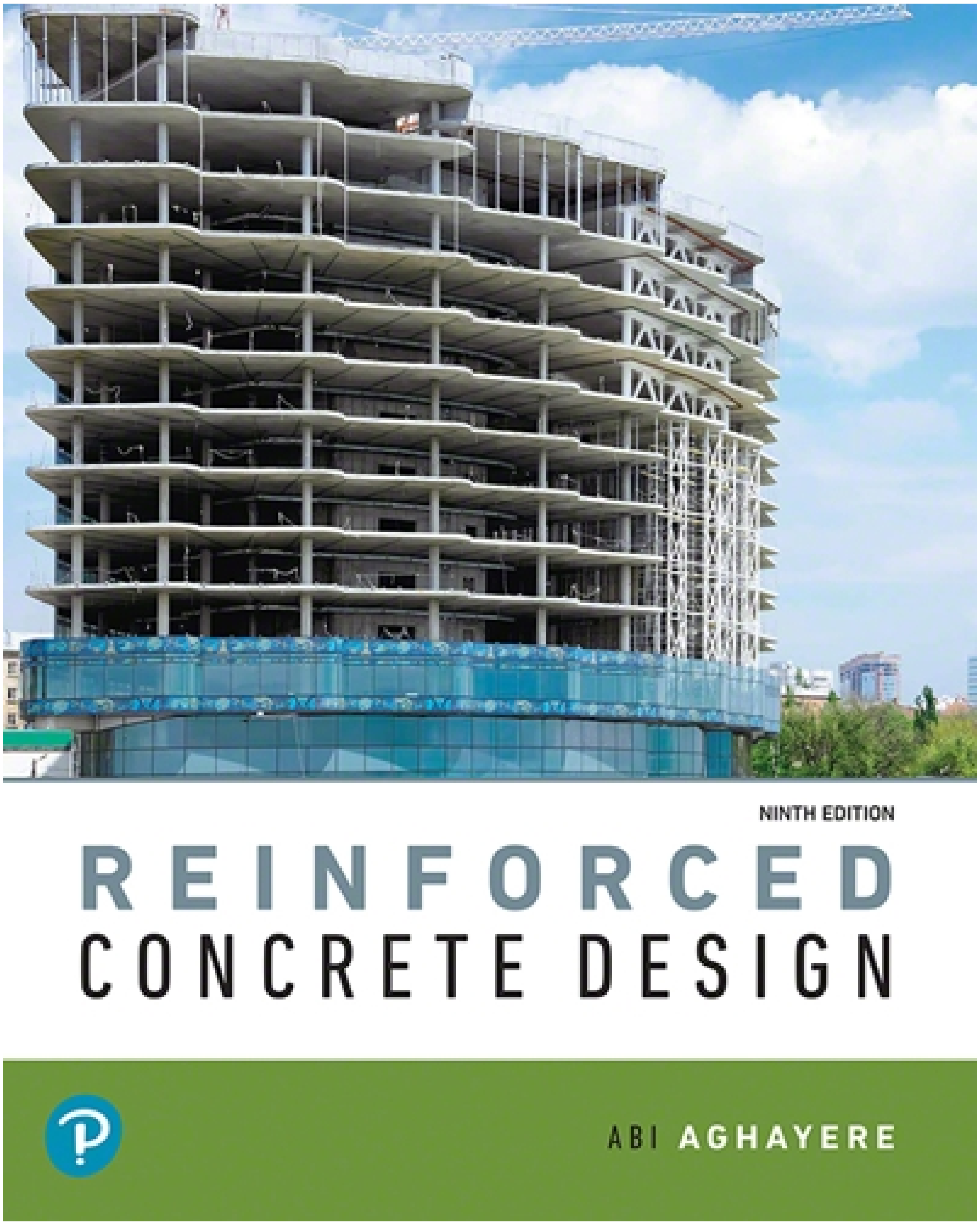

Solutions

Instructor's Solutions Manual
To accompany

Reinforced Concrete Design

Ninth Edition

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NOTES:

This manual is intended solely as an aid for teachers and educators in their individual course preparation.

The solutions presented herein are, in general, somewhat abbreviated. The solutions follow, as closely as possible, the procedures developed in the examples in the text. They are satisfactory solutions within the scope of the text and are based on the limited tables and design aids furnished in the text.

The solutions for the design problems are generally not the only solutions, nor are they necessarily the most economical solutions.

Prob. 1-1

(a) $\dfrac{16(28)}{144}(150) = 467 \text{ lb/ft}$

(b) $\dfrac{12(26-6)}{144}(150) + \dfrac{6(38)}{144}(150) = 488 \text{ lb/ft}$

Prob. 1-2

Spreadsheet problem: $E_c = w_c^{1.5} 33\sqrt{f_c'}$ Check value for w_c = 145 lb/ft^3 and f_c' = 4000 psi:

E_c = 3,644,000 psi

Prob. 1-3 L = 24 in. with 2100 lb load at midspan.

Beam weight $= \dfrac{6(6)}{144}(0.145) = 0.036 \text{ kip/ft}$ $I = \dfrac{1}{12}(6)^4 = 108 \text{ in.}^4$

$$M = \frac{0.036(2)^2}{8} + \frac{2.1(2)}{4} = 1.068 \text{ ft - kips}$$

$$f = \frac{Mc}{I} = f_r = \frac{1.068(12)(3)}{108} = 0.356 \text{ ksi}$$

By ACI formula:

$$f_r = 7.5\sqrt{f_c'} = 7.5\sqrt{3000} = 411 \text{ psi}$$

Prob. 1-4 Simply supported beam of length L.

Beam weight $= \dfrac{10(10)}{144}145 = 100.7 \text{ lb/ft};$ $f_r = 350 \text{ psi};$ $I = \dfrac{10(10)^3}{12} = 833 \text{ in.}^4$

$$M = \frac{100.7L^2}{8} = 12.59L^2$$

$$f = \frac{Mc}{I} = f_r = \frac{12.59(12)(5)L^2}{833} = 350$$

$L = 19.65 \text{ ft}$

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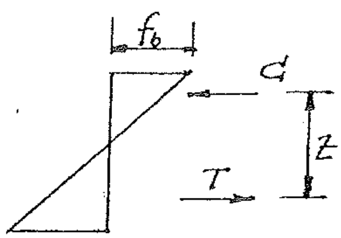
Prob. 1-5



$$M = \frac{0.5(10)^2}{8} + \frac{2(10)}{4} = 11.25\text{ ft - kips}$$

(a) $C = \frac{f_b}{2}(8)(8) = 32 f_b \text{ in.}^2$

$M = CZ$

$$11.25\text{ ft - kips} = 32 f_b\ (\text{in.}^2)\left(\frac{2}{3}\right)(16\text{ in.})$$

$$f_b = \frac{11.25\text{ ft - kips}(12\text{ in./ft})}{32\text{ in.}^2\left(\frac{2}{3}\right)(16\text{ in.})} = 0.396\text{ ksi}$$

(b) $S_x = \frac{bh^2}{6} = \frac{8(16)^2}{6} = 341\text{ in.}^3$; $f_b = \frac{M}{S_x} = \frac{11.25(12)}{341} = 0.396\text{ ksi}$ (O.K.)

Prob. 1-6

$f_r = 7.5\sqrt{3000} = 411\text{ psi} = 0.411\text{ ksi}$

(a) I.C. method: $Z = 16 - 2(2.67) = 10.67\text{ in.}$

$C = T = 0.5(0.411)(8)(10) = 16.44\text{ kips}$

$$M_{cr} = CT = TZ = \frac{16.44(10.67)}{12} = 14.62\text{ ft - kips}$$

(b) Flexure formula check:

$$S_x = \frac{10(16)^2}{6} = 427\text{ in.}^3$$

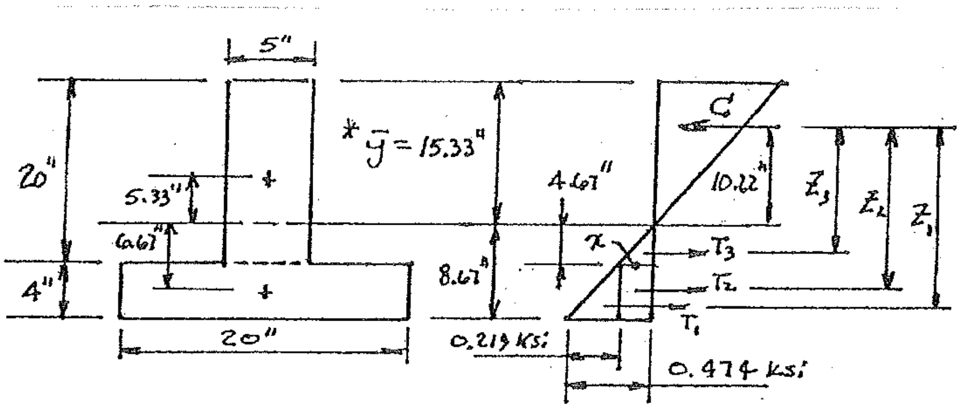
$M_{cr} = f_r S_x = 0.411(427) = 175.5\text{ in - kips} = 14.62\text{ ft - kips}$ (O.K.)

Prob. 1-8

(a) $f_c' = 4000$ psi

$$f_r = \frac{7.5\sqrt{4000}}{1000} = 0.474 \text{ ksi}$$

$$x = 0.474\left(\frac{4.67}{8.67}\right) = 0.255 \text{ ksi}$$



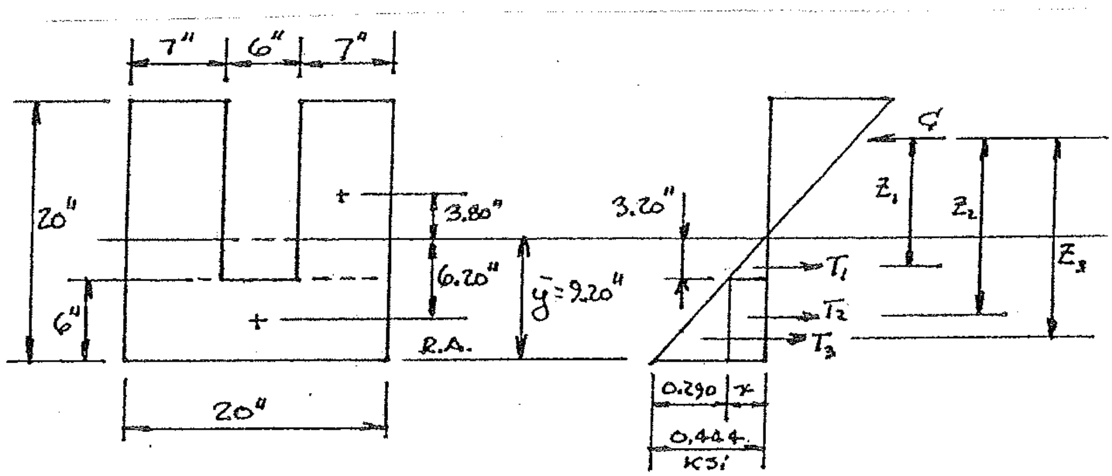
Force	Magnitude (kips)	Moment arm (in.)	I.C. (in.-kips)
T_1	0.5(0.219)(20)(4)=8.76	10.22+(2/3)(4.67) = 17.56	153.8
T_2	0.255(20)(4)=20.4	10.22 +4.67+2=16.89	344.6
T_3	0.5(0.255)(4.67)=2.89	10.22+4.67+(2/3)(4) = 12.33	39.7
		Total :M_{cr} =	538 in-kips

(b) $I = \dfrac{20(4)^3}{12} + 20(4)(6.67)^2 + \dfrac{5(20)^3}{12} + 5(20)(5.33)^2 = 9840 \text{ in.}^2$

$c = 8.67$ in. (to tension side.)

$$M_{cr} = \frac{0.474(9840)}{8.67} = 538 \text{ in - kips} \quad \text{(O.K.)}$$

Prob. 1-9



$f_c' = 3500$ psi; $\quad f_r = 7.5\sqrt{3500} = 444 \text{ psi } = 0.444 \text{ ksi}$

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{20(6)(3) + 2(7)(14)(13)}{20(6) + 2(7)(14)} = 9.20 \text{ in.}; \qquad x = 0.444\left(\frac{3.20}{9.20}\right) = 0.1544 \text{ ksi}$$

(a)

Force	Magnitude (kips)	Moment arm (in.)	I.C. (in.-kips)
T_1	2(0.5)(0.1544)(7)(3.20)=3.46	7.20+(2/3)(3.20)=9.33	32.3
T_2	0.1544(20)(6)=18.53	7.20+3.20+3=13.40	248.3
T_3	0.5(0.290)(20)(6)=17.40	7.20+3.20+(2/3)(6)=14.40	250.6
		Total :M_{cr} =	531 in-kips

(b) $I = 2\left(\dfrac{7(14)^3}{12}\right) + 2(7)(14)(3.80)^2 + \dfrac{20(6)^3}{12} + 6(20)(6.20)^2 = 11{,}004 \text{ in.}^4$

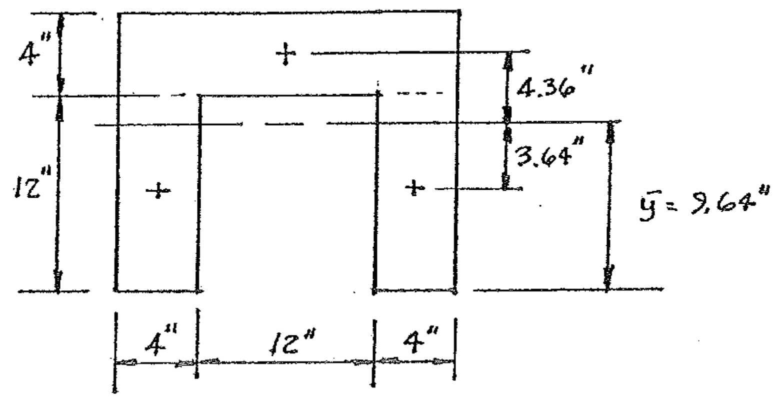
$$M_{cr} = \frac{f_r I}{c} = \frac{0.444(11{,}004)}{9.20} = 531 \text{ in - kips (O.K.)}$$

Prob. 1-10

$f_c' = 3000$ psi

$$f_r = \frac{7.5\sqrt{3000}}{1000} = 0.411 \text{ ksi}$$

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{2(4)(12)(6) + 4(20)(14)}{2(4)(12) + 4(20)} = 9.64 \text{ in.}$$



$$I = 2\left(\frac{4(12)^3}{12}\right) + 2(4)(12)(3.64)^2 + \frac{20(4)^3}{12} + 4(20)(4.36)^2 = 4051 \text{ in.}^4$$

(a) $M_{cr} = \dfrac{f_r I}{c} = \dfrac{0.411(4051)}{9.64} = 172.7 \text{ in. - kips}$

(b) Beam weight $= \dfrac{4(20) + 2(4)(12)}{144}(0.145) = 0.1772 \text{ kip/ft}$

Beam weight moment $= \dfrac{0.1772(12)^2}{8} = 3.19 \text{ ft - kips} = 38.3 \text{ in. - kips}$

$\dfrac{PL}{4} = M_{cr} - 38.3 = 172.7 - 38.3 = 134.4 \text{ in - kips};$ $\quad P = \dfrac{4(134.4 \text{ in - k})}{12 \text{ ft } (12 \text{ in/ft})} = 3.73 \text{ kips}$

Prob 1-11

Part (a): Dead Loads

Slab weight
(8"/12)(150pcf) = 100psf
½" light wt. floor finish = 4psf
susp. ceiling = 2psf
M/E (industrial) = 20psf
Partitions = 20psf

Σ_{DL} = 146psf (with partitions)
Σ_{DL} = 126psf (without partitions)

Part (b): Live Load = 100psf

1.4D = (1.4)(126) = 176.4psf

1.2D + 1.6L = (1.2)(126) + (1.6)(100)= **311psf** ← controls

Part (c): Load on spandrel beam

Trib. width = (18 ft/2) + 1.0 ft = 10 ft

Cladding:
Block: (55psf)(10 ft. – 2'-2") = 431 plf
Brick: (40psf)(10 ft.) = 400 plf

Beam Stem:
(8"/12)(12"/12)(150pcf) = 225 plf

Service Dead Load:

(126psf)(10 ft) + 431plf + 400 + 225 plf = 2316 plf = **2.32 k/ft**

Service Live Load:

(100psf)(10 ft) = 1000 plf = **1.0 k/ft**

Part (d): Factored Load on spandrel beam:

1.2D + 1.6L = (1.2)(2.32) + (1.6)(1.0)= **4.4plf**

Part (e): Load on interior beam

Trib. width = (18 ft/2) + (18 ft/2) + 1.0 ft = 19 ft

Beam Stem:

(8”/12)(12”/12)(150pcf) = 225 plf

Service Dead Load:

(126psf)(19 ft) + 225 plf = 2619 plf = **2.62 k/ft**

Service Live Load:

(100psf)(19 ft) = 1000 plf = **1.9 k/ft**

Part (f): Factored Load on interior beam:

1.2D + 1.6L = (1.2)(2.62) + (1.6)(1.9)= **6.2k/ft**

Part (g):

Spandrel Beam:

$$V_u = \frac{w_u L}{2} = \frac{(4.4)(36)}{2}$$ = **79.2 k**

$$M_u = \frac{w_u L^2}{8} = \frac{(4.4)(36)^2}{8}$$ = **713 k-ft**

Prob 1-12

Roof Loads

Dead Load:

7” slab (7”/12 x 150 pcf)	= 87.5 psf
5 ply + gravel	= 6.5 psf
Insulation	= 3.5 psf
M & E	= 10 psf
Suspended ceiling	= 2 psf
Total roof dead load, D	= 109.5 psf
Roof live load (snow) S	= 35 psf

Typical Floor Loads

Dead Load:

7” slab (7”/12 x 150 pcf)	= 87.5 psf
0.5” light wt floor finish = 4 psf	
Partitions	= 20 psf
M & E	= 10 psf
Suspended ceiling	= 2 psf
Total roof dead load, D	= 123.5 psf
Floor live load (office) L	= 50 psf

A.

Roof: $w_{DL\ slab}$ = 109.5 psf; $w_{LL\ slab}$= 35 psf
Using the load combinations, we find the maximum factored load to be,
$\mathbf{w_{u\ slab}}$ **= 1.2 (109.5psf) + 1.6 (35 psf) = 188 psf**

Floor: $w_{DL\ slab}$ = 123.5 psf; $w_{LL\ slab}$= 50 psf
Using the load combinations, we find the maximum factored load to be,
$\mathbf{w_{u\ slab}}$ **= 1.2 (123.5 psf) + 1.6 (50 psf) = 229 psf**

B.

(i) TYPICAL INTERIOR *FLOOR* BEAM

Tributary width of beam = 16 ft
Beam stem weight = (16”/12) [(26” – 7”)/12] x 150 pcf = 317 Ib/ft = 0.32 kip/ft

w_{DLbeam} = 123.5 psf x 16 ft + 317 Ib/ft = 2293 Ib/ft = 2.3 kip/ft
w_{LLbeam} = 50 psf x 16 ft = 800 Ib/ft = 0.8 kip/ft
$w_{s\ beam}$ = w_{DLbeam} + w_{LLbeam} = **3.1 kip/ft**

$\mathbf{w_{u\ beam}}$ = $w_{u\ slab}$ x beam trib width + 1.2 x beam stem weight
= 229 psf x 16 ft + 1.2 (317 Ib/ft) = 4045 Ib/ft = **4.1 kip/ft**

For a beam subjected to a uniformly distributed load, the beam reactions, assuming simple supports, are:

R_{DL} = w_{DLbeam} x L/2 = 2.3 kip/ft x 32 ft /2 = 37 kip
R_{LL} = w_{LLbeam} x L/2 = 0.8 kip/ft x 32 ft /2 = 12.8 kip

R_u = $w_{u\ beam}$ x L/2 or 1.2 (R_{DL}) + 1.6 (R_{LL})

= 4.1 kip/ft x 32 ft/2 = **66 kip** or 1.2 (37 kip) + 1.6 (12.8 kip) = **66 kip (same!)**

(ii) TYPICAL INTERIOR *ROOF* BEAM

Tributary width of beam = 16 ft

Beam stem weight = (16"/12) [(26" – 7")/12] x 150 pcf = 317 lb/ft = 0.32 kip/ft

w_{DLbeam} = 109.5 psf x 16 ft + 317 lb/ft = 2070 lb/ft = 2.1 kip/ft

w_{LLbeam} = 35 psf x 16 ft = 560 lb/ft = 0.56 kip/ft

$w_{s\ beam}$ = w_{DLbeam} + w_{LLbeam} = **2.7 kip/ft**

$w_{u\ beam}$ = wu $_{slab}$ x beam trib width + 1.2 x beam stem weight
= 188 psf x 16 ft + 1.2 (317 lb/ft) = 3389 lb/ft = **3.4 kip/ft**

For a beam subjected to a uniformly distributed load, the beam reactions, assuming simple supports, are:

R_{DL} = w_{DLbeam} x L/2 = 2.1 kip/ft x 32 ft /2 = 34 kip

R_{LL} = w_{LLbeam} x L/2 = 0.56 kip/ft x 32 ft /2 = 9 kip

R_u = $w_{u\ beam}$ x L/2 or 1.2 (R_{DL}) + 1.6 (R_{LL})

= 3.4 kip/ft x 32 ft/2 = **55 kip** or 1.2 (34 kip) + 1.6 (9 kip) = **55 kip (same!)**

(iii) TYPICAL *FLOOR* SPANDREL BEAM

Tributary width of beam = (16 ft / 2) + [(16"/12)/2] = 8.67 ft

Beam stem weight = (16"/12) [(26" – 7")/12] x 150 pcf = 317 lb/ft = 0.32 kip/ft

Exterior Cladding load = 55 psf block x 7.83' height + 40 psf brick x 10' height = 0.83 kip/ft

w_{DLbeam} = 123.5 psf x 8.67 ft + 317 lb/ft + 830 lb/ft = 2218 lb/ft = 2.2 kip/ft

w_{LLbeam} = 50 psf x 8.67 ft = 434 lb/ft = 0.44 kip/ft

$w_{s\ beam}$ = wDL_{beam} + wLL_{beam} = **2.7 kip/ft**

$w_{u\ beam}$ = $w_{u\ slab}$ x beam trib width + 1.2 x beam stem weight
= 229 psf x 8.67 ft + 1.2 (317 lb/ft + 830 lb/ft) = 3362 lb/ft = **3.4 kip/ft**

For a beam subjected to a uniformly distributed load, the beam reactions, assuming simple supports, are:

R_{DL} = wDL_{beam} x L/2 = 2.2 kip/ft x 32 ft /2 = 36 kip

R_{LL} = wLL_{beam} x L/2 = 0.44 kip/ft x 32 ft /2 = 7 kip

R_u = $w_{u\ beam}$ x L/2 or 1.2 (R_{DL}) + 1.6 (R_{LL})
= 3.4 kip/ft x 32 ft/2 = **55 kip** or 1.2 (36 kip) + 1.6 (7 kip) = **55 kip (same!)**

(iv) TYPICAL *ROOF* SPANDREL BEAM

Tributary width of beam = (16 ft / 2) + [(16”/12)/2] = 8.67 ft
Beam stem weight = (16”/12) [(26” – 7”)/12] x 150 pcf = 317 Ib/ft = 0.32 kip/ft

*On the roof beam and girder, there is usually a one to two feet high parapet. However, if we assume **NO PARAPET** in this example, the exterior cladding load on the roof spandrel beam will be:*
Exterior Cladding load = 55 psf block x 0’ height + 40 psf brick x 0’ height = 0 kip/ft

w_{DLbeam} = 109.5 psf x 8.67 ft + 317 Ib/ft + 0 Ib/ft = 1267 Ib/ft = 1.3 kip/ft
w_{LLbeam} = 35 psf x 8.67 ft = 303 Ib/ft = 0.3 kip/ft
$w_{s\ beam}$ = w_{DLbeam} + wLL_{beam} = **1.6 kip/ft**

$w_{u\ beam}$ = $w_{u\ slab}$ x beam trib width + 1.2 x beam stem weight
= 188 psf x 8.67 ft + 1.2 (317 Ib/ft + 0 Ib/ft) = 2010 Ib/ft = **2.0 kip/ft**

For a beam subjected to a uniformly distributed load, the beam reactions, assuming simple supports, are:

R_{DL} = w_{DLbeam} x L/2 = 1.3 kip/ft x 32 ft /2 = 21 kip
R_{LL} = w_{LLbeam} x L/2 = 0.3 kip/ft x 32 ft /2 = 5 kip

R_u = $w_{u\ beam}$ x L/2 or 1.2 (R_{DL}) + 1.6 (R_{LL})
= 2.0 kip/ft x 32 ft/2 = **32 kip** or 1.2 (21 kip) + 1.6 (5 kip) = **33 kip (same!)**

C.

(i) TYPICAL INTERIOR *FLOOR* GIRDER

Girder stem weight = (18”/12) [(26” – 7”)/12] x 150 pcf = 357 Ib/ft = 0.36 kip/ft

This girder has TWO interior beams framing into it at the MIDSPA, in addition to a uniformly distributed loading (UDL) due to the girder stem weight. Therefore, the total concentrated loads acting on the girder are:

$P_{DL\ girder}$ = 2 beams x $R_{DL\ beam}$ = 2 x 37 kip = 74 kip (acts at midspan)
$P_{LL\ girder}$ = 2 x $R_{LL\ beam}$ = 2 x 12.8 kip = 26 kip (acts at midspan)
$P_{s\ girder}$ = $P_{DL\ girder}$ + $P_{LL\ girder}$ = 74 + 26 = **100 kip** (acts at midspan)
$P_{u\ girder}$ = 1.2 $P_{DL\ girder}$ + 1.6 $P_{LL\ girder}$ = 1.2(74) + 1.6(26) = **131 kip** (acts at midspan)

The uniformly distributed load (UDL) on this girder is due to the girder stem weight. Thus,

$\mathbf{w_{DLgirder}}$ = girder stem weight = 357 lb/ft

$\mathbf{w_{LL\ girder}}$ = 0

The total UDL on the girder are:

$\mathbf{w_{s\ girder}}$ = $\mathbf{w_{DLgirder}}$ + $\mathbf{w_{LLgirder}}$ = 357 lb/ft

$\mathbf{w_{u\ girder}}$ = 1.2 $\mathbf{w_{DLgirder}}$ + 1.6 $\mathbf{w_{LLgirder}}$

= 1.2 (357 lb/ft) + 1.6 (0) = 430 lb/ft = **0.43 kip/ft**

The REACTIONS for a GIRDER subjected to a uniformly distributed load, w, in addition to concentrated loads at MIDSPAN (see plan) from the beam reactions, assuming simple supports, are:

R_{DL} = $w_{DLgirder}$ x L/2 + $P_{DLgirder}$ /2 = (0.36 kip/ft x 32 ft /2) + (74 kip /2) = 43 kip

R_{LL} = $w_{LLgirder}$ x L/2 + $P_{LLgirder}$ /2 = (0 kip/ft x 32 ft /2) + (26 kip /2) = 13 kip

R_u = $w_{u\ girder}$ x L/2 + $P_{u\ girder}$ /2 = (0.43 kip/ft x 32 ft /2) + (131 kip /2) = **73 kip**

(ii) TYPICAL INTERIOR *ROOF* GIRDER

Girder stem weight = (18"/12) [(26" – 7")/12] x 150 pcf = 357 lb/ft = 0.36 kip/ft

This girder has TWO interior beams framing into it at the MIDSPAN, in addition to a uniformly distributed loading (UDL) due to the girder stem weight. Therefore, the total concentrated loads acting on the girder are:

$P_{DL\ girder}$ = 2 beams x $R_{DL\ beam}$ = 2 x 34 kip = 68 kip (acts at midspan)

$P_{LL\ girder}$ = 2 x $R_{LL\ beam}$ = 2 x 9 kip = 18 kip (acts at midspan)

$P_{s\ girder}$ = $P_{DL\ girder}$ + $P_{LL\ girder}$ = 68 + 18 = **86 kip** (acts at midspan)

$P_{u\ girder}$ = 1.2 $P_{DL\ girder}$ + 1.6 $P_{LL\ girder}$ = 1.2(68) + 1.6(18) = **111 kip** (acts at midspan)

The uniformly distributed load (UDL) on this girder is due to the girder stem weight. Thus,

$\mathbf{w_{DLgirder}}$ = girder stem weight = 357 lb/ft; $\mathbf{w_{LL\ girder}}$ = 0

The total UDL on the girder are:

$\mathbf{w_{s\ girder}}$ = $\mathbf{w_{DLgirder}}$ + $\mathbf{w_{LLgirder}}$ = 357 lb/ft

$\mathbf{w_{u\ girder}}$ = 1.2 $\mathbf{w_{DLgirder}}$ + 1.6 $\mathbf{w_{LLgirder}}$

= 1.2 (357 lb/ft) + 1.6 (0) = 430 lb/ft = **0.43 kip/ft**

The REACTIONS for a GIRDER subjected to a uniformly distributed load, w, in addition to concentrated loads at MIDSPAN (see plan) from the beam reactions, assuming simple supports, are:

R_{DL} = $w_{DLgirder}$ x L/2 + $P_{DLgirder}$ /2 = (0.36 kip/ft x 32 ft /2) + (68 kip /2) = 40 kip
R_{LL} = $w_{LLgirder}$ x L/2 + $P_{LLgirder}$ /2 = (0 kip/ft x 32 ft /2) + (18kip /2) = 9 kip

R_u = $w_{u\ girder}$ x L/2 + $P_{ugirder}$ /2 = (0.43 kip/ft x 32 ft /2) + (111 kip /2) = **63 kip**

(iii) TYPICAL *FLOOR* SPANDREL GIRDER

Girder stem weight = (18"/12) [(26" – 7")/12] x 150 pcf = 357 lb/ft = 0.36 kip/ft
Exterior Cladding load = 55 psf block x 7.83' height + 40 psf brick x 10' height = 0.83 kip/ft

This girder has ONE interior beam framing into it at the MIDSPAN, in addition to a uniformly distributed loading (UDL) due to the girder stem weight, the girder edge distance, AND the exterior cladding. Therefore, the total concentrated loads acting on the girder are:

$P_{DL\ girder}$ = 1 beam x $R_{DL\ beam}$ = 1x 37 kip = 37kip (acts at midspan)
$P_{LL\ girder}$ = 1 x $R_{LL\ beam}$ = 1 x 12.8 kip = 13 kip (acts at midspan)
$P_{s\ girder}$ = $P_{DL\ girder}$ + $P_{LL\ girder}$ = 37 + 13 = **50 kip** (acts at midspan)
$P_{u\ girder}$ = 1.2 $P_{DL\ girder}$ + 1.6 $P_{LL\ girder}$ = 1.2(37) + 1.6(13) = **65 kip** (acts at midspan)

Uniform floor load on Girder edge distance:

$w_{DL\ edge\ distance}$ = (9"/12) x 123.5 psf = 93 lb/ft
$w_{LL\ edge\ distance}$ = 0 (Because the WHOLE girder edge distance is occupied by the block wall cladding and thus there can be no live load in that edge distance)

The uniformly distributed load (UDL) on this girder is due to the girder stem weight, the load on the girder edge distance, AND the exterior cladding. Thus,
$\mathbf{w_{DLgirder}}$ = girder stem weight + girder edge distance + exterior cladding
= 357 lb/ft + 93 + 830 lb/ft = 1280 lb/ft ; $\mathbf{w_{LL\ girder}}$ = 0

The total uniformly distributed load (UDL) on the girder is:
$\mathbf{w_{s\ girder}}$ = $\mathbf{w_{DLgirder}}$ + $\mathbf{w_{LLgirder}}$ = 1280 lb/ft

$\mathbf{w_{u\ girder}}$ = 1.2 $\mathbf{w_{DLgirder}}$ + 1.6 $\mathbf{w_{LLgirder}}$
= 1.2 (1280 lb/ft) + 1.6 (0) = 1536 lb/ft = **1.54 kip/ft**

The REACTIONS for a GIRDER subjected to a uniformly distributed load, w, in addition to concentrated loads at MIDSPAN (see plan) from the beam reactions, assuming simple supports, are:

R_{DL} = $w_{DLgirder}$ x L/2 + $P_{DLgirder}$ /2 = (1.28 kip/ft x 32 ft /2) + (37 kip /2) = 39 kip
R_{LL} = $w_{LLgirder}$ x L/2 + $P_{LLgirder}$ /2 = (0 kip/ft x 32 ft /2) + (13 kip /2) = 6.5 kip

R_u = $w_{u\ girder}$ x L/2 + $P_{ugirder}$ /2 = (1.54 kip/ft x 32 ft /2) + (65 kip /2) = **57 kip**

(iv) **TYPICAL *ROOF* SPANDREL GIRDER**

Girder stem weight = (18"/12) [(26" – 7")/12] x 150 pcf = 357 lb/ft = 0.36 kip/ft *(no parapet)*

This girder has ONE interior beam framing into it at the MIDSPAN, in addition to a <u>uniformly distributed loading</u> (UDL) due to the girder stem weight, the load on the girder edge distance, AND the exterior cladding. Therefore, the total concentrated loads acting on the girder are:

$P_{DL\ girder}$ = 1 beam x $R_{DL\ beam}$ = 1x 34 kip = 34kip (acts at midspan)
$P_{LL\ girder}$ = 1 x $R_{LL\ beam}$ = 1 x 9 kip = 9 kip (acts at midspan)
$P_{s\ girder}$ = $P_{DL\ girder}$ + $P_{LL\ girder}$ = 34 + 9 = **43 kip** (acts at midspan)
$P_{u\ girder}$ = 1.2 $P_{DL\ girder}$ + 1.6 $P_{LL\ girder}$ = 1.2(34) + 1.6(9) = **55 kip** (acts at midspan)

Uniform roof load on Girder edge distance:

$w_{DL\ edge\ distance}$ = (9"/12) x 109.5 psf = 82 lb/ft
$w_{LL\ edge\ distance}$ = (9"/12) x 35 psf = 26 lb/ft

The uniformly distributed load (UDL) on this girder is due to the girder stem weight, the load on the girder edge distance, AND the exterior cladding. Thus,

$\mathbf{w_{DLgirder}}$ = girder stem weight + girder edge distance + exterior cladding/parapet
= 357 lb/ft + 82 lb/ft + 0 lb/ft = 439 lb/ft (assuming no parapet)

$\mathbf{w_{LL\ girder}}$ = 26 lb/ft

The total UDL on the girder are:

$\mathbf{w_{s\ girder}}$ = $\mathbf{w_{DLgirder}}$ + $\mathbf{w_{LLgirder}}$ = 465 lb/ft

$\mathbf{w_{u\ girder}}$ = 1.2 $\mathbf{w_{DLgirder}}$ + 1.6 $\mathbf{w_{LLgirder}}$
= 1.2 (439 lb/ft) + 1.6 (26 lb/ft) = 568 lb/ft = **0.57 kip/ft**

The REACTIONS for a GIRDER subjected to a uniformly distributed load, w, in addition to concentrated loads at MIDSPAN (see plan) from the beam reactions, assuming simple supports, are:

R_{DL} = $w_{DLgirder}$ x L/2 + $P_{DLgirder}$ /2 = (0.44 kip/ft x 32 ft /2) + (34 kip /2) = 24 kip
R_{LL} = wLL_{girder} x L/2 + $P_{LLgirder}$ /2 = (0.026 kip/ft x 32 ft /2) + (9 kip /2) = 4.9 kip

R_u = wu_{girder} x L/2 + $P_{ugirder}$ /2 = (0.57 kip/ft x 32 ft /2) + (55 kip /2) = **36.6 kip**

General notes at beginning of Chapter 2 problem-set apply

Prob. 2-1

(a) 4#9, $A_s = 4.00$ in.^{2}

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4.00(60)}{0.85(3)(16)} = 5.88 \text{ in.}$$

$$M_n = A_s f_y \left(d - \frac{a}{2}\right) = \frac{4.00(60)\left(24 - \frac{5.88}{2}\right)}{12} = 421 \text{ ft - kips}$$

(b) 4#10, $A_s = 5.08$ in.^{2}

$$a = \frac{5.08(60)}{0.85(3)(16)} = 7.47 \text{ in.} \qquad M_n = \frac{5.08(60)\left(24 - \frac{7.47}{2}\right)}{12} = 515 \text{ ft - kips}$$

% Increase: A_s: +27%; M_n: +22%

(c) 4#9, $A_s = 4.00$ in.^{2}, $a = 5.88$ in. (from part (a))

$$M_n = \frac{4.00(60)\left(28 - \frac{5.88}{2}\right)}{12} = 501 \text{ ft - kips}$$

% Increase: d: +16.7 %; M_n: +19%

(d) $f_c' = 4000$ psi

$$a = \frac{4(60)}{0.85(4)(16)} = 4.41 \text{ in.} \qquad M_n = \frac{4.00(60)\left(24 - \frac{4.41}{2}\right)}{12} = 436 \text{ ft - kips}$$

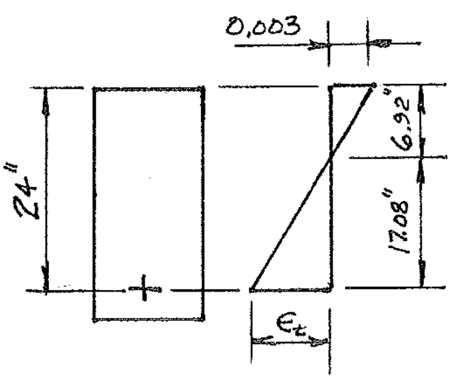
% Increase: f_c' : 33.3%; M_n: 3.6%

Prob. 2-2 Check ε_t for Prob. 2-1(a)

$$c = \frac{a}{\beta_1} = \frac{5.88}{0.85} = 6.92 \text{ in.}$$ then, from a strain diagram :

$$\frac{\varepsilon_t}{(24 - 6.92)} = \frac{0.003}{6.92}$$

$$\varepsilon_t = 0.0074 > \varepsilon_y = 0.00207 \quad \therefore \quad f_s = f_y$$



Prob. 2-3

(a) [4/40], 4#8, $A_s = 3.16 \text{ in.}^2$, $b = 13$ in., $d = 24$ in. $\rho = \dfrac{3.16}{13(24)} = 0.0101$

$A_{s,\min} = 0.005(13)(24) = 1.56 \text{ in.}^2 < 3.16 \text{ in.}^2$ (O.K.)

(Table A-9) $\bar{k} = 0.3800$ ksi and $\varepsilon_t > 0.005$, $\therefore\ \phi = 0.90$

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.90(13)(24)^2(0.3800)}{12} = 213 \text{ ft - kips}$$

(b) [4/60], 4#8, $A_s = 3.16 \text{ in.}^2$, $b = 13$ in., $d = 24$ in. $\rho = \dfrac{3.16}{13(24)} = 0.0101$

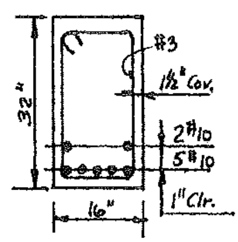
$A_{s,\min} = 0.0033(13)(24) = 1.03 \text{ in.}^2 < 3.16 \text{ in.}^2$ (O.K.)

(Table A-10) $\bar{k} = 0.5520$ ksi and $\varepsilon_t > 0.005$, $\therefore\ \phi = 0.90$

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.90(13)(24)^2(0.5520)}{12} = 310 \text{ ft - kips}$$

% Increase: f_y: +50%; ϕM_n: +45.5%

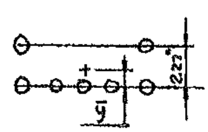
Prob. 2-4 [4/60]



$$\bar{y} = \frac{2A(2.27)}{7A} = 0.649 \text{ in.}$$

$d = 32 - 1.5 - 0.375 - 1.27/2 - 0.649 = 28.8$ in.

$$\rho = \frac{8.89}{16(28.8)} = 0.0193, \quad \bar{k} = 0.9609 \text{ ksi}, \quad \varepsilon_t = 0.00449$$



$$\therefore\ \phi = 0.65 + (0.00449 - 0.002)\left(\frac{250}{3}\right) = 0.858$$

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.858(16)(28.8)^2(0.9609)}{12} = 912 \text{ ft - kips}$$

Prob. 2-5 [3/40], $b = 20$ in., $d = 42$ in., $h = 45$ in., $L = 28$ ft
Beam is adequate if $\phi M_n \geq M_u$

$$\text{Beam weight} = \frac{20(45)}{144}(0.150) = 0.938 \text{ kip/ft}$$

$w_u = 1.2(0.938 + 2.20) + 1.6(3.60) = 9.53$ kips/ft; $\quad M_u = \dfrac{9.53(28)^2}{8} = 939$ ft - kips

(a) 6#10, $A_s = 7.62$ in.^{2}, $\rho = \dfrac{7.62}{20(42)} = 0.00907$

$A_{s,\min} = 0.005(20)(42) = 4.20\text{in.}^2 < 7.62 \text{ in.}^2$ (O.K.)

(Table A-7) $\bar{k} = 0.3380$ ksi and $\varepsilon_t > 0.005$, $\therefore \phi = 0.90$

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.90(20)(42)^2(0.3380)}{12} = 894 \text{ ft - kips} < 939 \text{ ft - kips} \quad \text{(N.G.)}$$

(b) 6#11, $A_s = 9.36$ in.^{2}, $\rho = \dfrac{9.36}{20(42)} = 0.0111$

$A_{s,\min} = 4.20 \text{ in.}^2 < 9.36 \text{ in.}^2$ (O.K.)

(Table A-7) $\bar{k} = 0.4053$ ksi and $\varepsilon_t > 0.005$, $\therefore \phi = 0.90$

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.90(20)(42)^2(0.4053)}{12} = 1072 \text{ ft - kips} > 939 \text{ ft - kips} \quad \text{(O.K.)}$$

Prob. 2-7 [4/60] $b = 12$ in., $h = 20$ in., 3#8 ($A_s = 2.37$ in.^{2})

$$\text{Beam weight} = \frac{12(20)}{144}(0.150) = 0.250 \text{ k/ft}$$

$d = 20 - 1.5 - 0.38 - 0.50 = 17.62$ in.; $\quad A_{s,\min} = 0.0033(12)(17.62) = 0.700$ in.^{2} (O.K.)

$\rho = \dfrac{2.37}{12(17.62)} = 0.0112$; $\bar{k} = 0.6056$ ksi, $\varepsilon_t > 0.005$, $\phi = 0.90$

$$\phi M_n = \frac{0.90(12)(17.62)^2(0.6056)}{12} = 169 \text{ ft - kips}$$

$$M_u = \frac{[1.2(0.7 + 0.250) + 1.6(2.5)](16)^2}{8} = 164.5 \text{ ft - kips} < 169 \text{ ft - kips} \quad \text{(O.K.)}$$

Prob. 2-8

[3/60] $b = 16$ in., $h = 38$ in., $L = 26.5$ ft simple span. Check moment adequacy.

$$\text{Beam weight} = \frac{16(38)}{144}(0.150) = 0.633 \text{ k/ft}$$

$$M_u = \frac{[1.2(1.80 + 0.633) + 1.6(3.20)]}{8}(26.5)^2 = 706 \text{ ft - kips}$$

(a) 5#9, $A_s = 5.00$ in.^{2}, $d = 35$ in., $\rho = \dfrac{5.00}{16(35)} = 0.0089$

$$A_{s,\min} = 0.0033(16)(35) = 1.85 \text{ in.}^2 < 5.00 \text{ in.}^2 \quad \text{(O.K.)}$$

$$\bar{k} = 0.4781 \text{ ksi}, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(16)(35)^2(0.4781)}{12} = 703 \text{ ft - kips} < 706 \text{ ft - kips} \quad \text{(N.G.)}$$

(a) 6#9, $A_s = 6.00$ in.^{2}, $d = 34.4$ in., $\rho = \dfrac{6.00}{16(34.4)} = 0.0109$

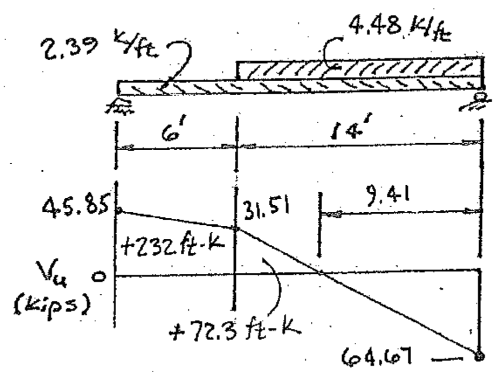
$$A_{s,\min} = 0.0033(16)(34.4) = 1.82 \text{ in.}^2 < 6.00 \text{ in.}^2 \quad \text{(O.K.)}$$

$$\bar{k} = 0.5702 \text{ ksi}, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(16)(34.4)^2(0.5702)}{12} = 808 \text{ ft - kips} > 706 \text{ ft - kips} \quad \text{(O.K.)}$$

Prob. 2-9 [3/60] 3#10, $A_s = 3.81$ in.^{2}, $b = 14.5$ in., $h = 26$ in. check moment adequacy.

$d = 26 - 1.5 - 0.38 - 1.27/2 = 23.5$ in.
Calculated beam weight = 0.393 k/ft
Max. M_u from diag. = 304 ft-kips



$$\rho = \frac{3.81}{14.5(23.5)} = 0.0112$$

$$A_{s,\min} = 0.0033(14.5)(23.5) = 1.12 \text{ in.}^2$$

$$\bar{k} = 0.5835, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(14.5)(23.5)^2 0.5835}{12} = 350 \text{ ft - kips} > 304 \text{ ft - kips} \quad \text{(O.K.)}$$

Prob. 2-10 [4/60] 4#9, $b = 14$ in., $h = 24$ in., find max simple span L

$d = 24 - 1.5 - 0.38 - 1.13/2 = 21.6$ in.

Beam wt. $= \dfrac{14(24)}{144}(0.150) = 0.350$ k/ft; $\rho = \dfrac{4.00}{14(21.6} = 0.0132$

$A_{s,\min} = 0.0033(14)(21.6) = 1.00 \text{ in.}^2$

$\bar{k} = 0.6998 \text{ ksi}, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$

$$\phi M_n = \frac{0.90(14)(21.6)^2 0.6998}{12} = 343 \text{ ft - kips}$$

$$M_u = \frac{[1.2(0.60 + 0.35) + 1.6(1.4)]L^2}{8} = 343 \text{ ft - kips, from which } L = 28.5 \text{ ft}$$

Prob. 2-11 [3/60] One-way slab analysis. #7@6 in., A_s=1.20 in.^{2}/ft, $h = 10$ in., $L = 16$ ft

Slab weight$= \dfrac{10(12)}{144}(0.150) = 0.125$ k/ft;

$$M_u = \frac{[1.2(0.125) + 1.6(0.600)]16^2}{8} = 35.5 \text{ ft - kips}$$

$d = 10 - 0.75 - 0.875/2 = 8.81$ in.; $\rho = \dfrac{1.20}{12(8.81)} = 0.0113$

$A_{s,\min} = 0.0018(12)(8.81) = 0.19 \text{ in.}^2/\text{ft}$ (O.K.); $\bar{k} = 0.5879$ ksi, $\varepsilon_t > 0.005$, $\phi = 0.90$

$$\phi M_n = \frac{0.90(12)(8.81)^2(0.5879)}{12} = 41.4 \text{ ft - kips} > 35.5 \text{ ft - kips} \quad \text{(O.K.)}$$

Prob. 2-12 [3/40] One-way slab analysis, $h = 8$ in., #8@6 in., $A_s = 1.58$ in.^{2}/ft, $L = 12$ ft

Slab weight$= \dfrac{8(12)}{144}(0.150) = 0.100$ k/ft;

$d = 8 - 0.75 - 1.00/2 = 6.75$ in.; $A_{s,\min} = 0.0020(12)(6.75) = 0.16 \text{ in.}^2/\text{ft}$ (O.K.)

$\rho = \dfrac{1.20}{12(6.75)} = 0.0195$, $\bar{k} = 0.6608$ ksi, $\varepsilon_t > 0.005$, $\phi = 0.90$

$$\phi M_n = \frac{0.90(12)(6.75)^2(0.6608)}{12} = 27.1 \text{ ft - kips}$$

$$M_{u(\text{D.L.})} = \frac{1.2(0.100)(12)^2}{8} = 2.16 \text{ ft - kips}, \quad M_{u(\text{L.L.})} = \frac{1.6 w_{\text{LL}} L^2}{8} = 27.1 - 2.16 = 24.9 \text{ ft - kips}$$

From which, $w_{LL} = 0.865$ k/ft $= 865$ psf

Prob. 2-13 [4/60] One-way slab w/ construction errors.

As designed: #7@11, $A_s = 0.65$ in.^{2}/ft, $d = 8.5 - 1 - 0.875/2 = 7.06$ in.
$A_{s,min} = 0.0018(12)(8.50) = 0.18$ in.^{2}/ft (O.K.)

$$\rho = \frac{0.65}{12(7.06)} = 0.0077; \quad \bar{k} = 0.4306\,\text{ksi}, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(12)(7.06)^2(0.4306)}{12} = 19.3\,\text{ft-kips}$$

As built: $d = 8.5 - 3.5 - 0.875/2 = 4.56$ in.

$$\rho = \frac{0.65}{12(4.56)} = 0.0119; \quad \bar{k} = 0.6391\,\text{ksi}, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(12)(4.56)^2(0.6391)}{12} = 11.96\,\text{ft-kips} \qquad (\%\,\text{Change} = -38\%)$$

Prob. 2-14 Design. [3/60] $M_u = 133$ ft-kips, $b = 11\frac{1}{2}$ in., $h = 23$ in.
Est. $d = 20$ in., Assume $\phi = 0.90$.

$$\text{Required } \bar{k} = \frac{133(12)}{0.90(11.5)(20)^2} = 0.3855\,\text{ksi}$$

Required $\rho = 0.0070$ ($\varepsilon_t > 0.005$, $\phi = 0.90$)

Required $A_s = 0.007(11.5)(20) = 1.61\,\text{in.}^2$, $A_{s,min} = 0.0033(11.5)(20) = 0.76\,\text{in.}^2$ (O.K.)

Select 3#7, one layer ($A_s = 1.80\,\text{in.}^2$, $b_{min} = 8.5$ in.)

$$\text{Calculated } d = 23 - 1.5 - 0.38 - \frac{0.875}{2} = 20.7\,\text{in.} > 20\,\text{in.} \quad (\text{O.K.})$$

Prob. 2-15 Design. [4/60] $M_u = 400$ ft-kips, $b = 16$ in., $h = 28$ in.

Est. $d = 25$ in., Assume $\phi = 0.90$.

$$\text{Required } \bar{k} = \frac{400(12)}{0.90(16)(25)^2} = 0.5333\,\text{ksi}$$

Required $\rho = 0.0098$ ($\varepsilon_t > 0.005$, $\phi = 0.90$)

Required $A_s = 0.0098(16)(25) = 3.92\,\text{in.}^2$, $A_{s,min} = 0.0033(16)(25) = 1.32\,\text{in.}^2$ (O.K.)

Select 4#9, one layer ($A_s = 4.00\,\text{in.}^2$, $b_{min} = 12$ in.)

$$\text{Calculated } d = 28 - 1.5 - 0.38 - \frac{1.13}{2} = 25.6\,\text{in.} > 25\,\text{in.} \quad (\text{O.K.})$$

Prob. 2-16 (Prob. 2-15 with incorrectly placed steel making $d = 24$ in.)
[4/60] $M_u = 400$ ft-kips, $b = 16$ in.,

$d = 24$ in., Assume $\phi = 0.90$.

$$\rho = \frac{4.00}{16(24)} = 0.0104$$

$$A_{s,\min} = 0.0033(16)(24) = 1.27 \text{ in.}^2$$

$$\bar{k} = 0.5667, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

$$\phi M_n = \frac{0.90(16)(24)^2 0.5667}{12} = 392 \text{ ft-kips} < 400 \text{ ft-kips} \quad \text{(N.G.)}$$

Prob. 2-17 [4/60] $L = 32$ ft, $b = 11\tfrac{1}{2}$ in., $h = 26$ in.

Beam weight $= \dfrac{11.5(26)}{144}(0.150) = 0.312$ kip/ft Assume $\phi = 0.90$

$$M_u = \frac{[1.2(0.85 + 0.312) + 1.6(1.0)](32)^2}{8} = 383 \text{ ft-kips}$$

Estimated $d = 23$ in.

$$\text{Required } \bar{k} = \frac{383(12)}{0.90(11.5)(23)^2} = 0.8394 \text{ ksi} \qquad (\varepsilon_t > 0.005, \ \phi = 0.90)$$

Required $\rho = 0.0164$

Required $A_s = 0.0164(11.5)(23) = 4.34$ in.^{2} $A_{s,\min} = 0.0033(11.5)(23) = 0.87$ in.^{2}

Select 3#11 in one layer ($A_s = 4.68$ in.^{2}, $b_{\min} = 11$ in.)
Calculated $d = 26 - 1.5 - 0.38 - 1.41/2 = 23.4$ in. > 23 in. (O.K.)
Check ϕM_n:

$$\rho = \frac{4.68}{11.5(23.4)} = 0.0174, \quad \bar{k} = 0.8838 \text{ ksi}, \quad (\varepsilon_t > 0.005, \ \phi = 0.90)$$

$$\phi M_n = \frac{0.90(11.5)(23.4)^2(0.8838)}{12} = 417 \text{ ft-kips} \quad > 383 \text{ ft-kips} \quad \text{(O.K.)}$$

Prob. 2-18 [5/60] $L = 30$ ft, $b = 12$ in., $h = 27$ in.

Beam weight $= \dfrac{12(27)}{144} = 0.338$ k/ft

Estimated $d = 24$ in., assume $\phi = 0.90$

$$M_u = \frac{[1.2(0.338) + 1.6(1.35)30^2}{8} = 289 \text{ ft-kips}$$

Required $\bar{k} = \dfrac{289(12)}{0.90(12)(24)^2} = 0.5575$ ksi, required $\rho = 0.0100$, $(\varepsilon_t > 0.005, \phi = 0.90)$

Required $A_s = 0.0100(12)(24) = 2.88 \text{ in.}^2$, $A_{s,\min} = 0.0035(12)(24) = 1.01 \text{ in.}^2$ (O.K.)
Select 3#9 ($A_s = 3.00 \text{ in.}^2$, $b_{\min} = 9.5$ in.)
Calculated $d = 27 - 1.5 - 0.38 - 1.13/2 = 24.6$ in. > 24 in. (O.K.)
Check ϕM_n:

$$\rho = \frac{3.00}{12(24.6)} = 0.0102, \quad \bar{k} = 0.5679 \text{ ksi}, \quad (\varepsilon_t > 0.005, \quad \phi = 0.90)$$

$$\phi M_n = \frac{0.90(12)(24.6)^2(0.5679)}{12} = 309 \text{ ft-kips} \quad > 289 \text{ ft-kips} \quad \text{(O.K.)}$$

Prob. 2-19 (Redo Prob. 2-18 using superimposed loads: L.L. = 1.75 k/ft, D.L. = 1.0 k/ft)

$$M_u = \frac{[1.2(1.0 + 0.338) + 1.6(1.75)]30^2}{8} = 496 \text{ ft-kips}$$

Est. $d = 24$ in., assume $\phi = 0.90$

Required $\bar{k} = \dfrac{496(12)}{0.90(12)(24)^2} = 0.9568$ ksi, required $\rho = 0.0184$, $(\varepsilon_t > 0.005, \phi = 0.90)$

Required $A_s = 0.0184(12)(24) = 5.30 \text{ in.}^2$, $A_{s,\min} = 0.0035(12)(24) = 1.01 \text{ in.}^2$ (O.K.)
Select 6#9, two layers, 1 in. clear ($A_s = 6.00 \text{ in.}^2$, $b_{\min} = 9.5$ in.)
Calculated $d = 27 - 1.5 - 0.38 - 1.13 - 0.5 = 23.5$ in. < 24 in. (Check ϕM_n)

$$\rho = \frac{6.00}{12(23.5)} = 0.0213, \quad \bar{k} = 1.0859 \text{ ksi}, \quad (\varepsilon_t > 0.005, \quad \phi = 0.90)$$

$$\phi M_n = \frac{0.90(12)(23.5)^2(1.0859)}{12} = 540 \text{ ft-kips} \quad > 496 \text{ ft-kips} \quad \text{(O.K.)}$$

Prob. 2-20 [3/60] $L = 22$ ft, $b = 15$ in., h: full inches.

$$M_u = \frac{[1.2(1.6) + 1.6(1.4)](22)^2}{8} = 252 \text{ ft-kips (Estimated beam weight included.)}$$

Try $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi $(\varepsilon_t > 0.005, \phi = 0.90)$

$$\text{Req'd } d = \sqrt{\frac{252(12)}{0.90(15)(0.4828)}} = 21.5 \text{ in.} \quad \left(\frac{d}{b} = \frac{21.5}{15} = 1.4 \text{ (Say O.K.)}\right)$$

Required $A_s = 0.009(15)(21.5) = 2.90 \text{ in.}^2$, $A_{s,\min} = 0.0033(15)(21.5) = 1.06 \text{ in.}^2$ (O.K.)
Select 3#9 ($A_s = 3.00 \text{ in.}^2$, $b_{\min} = 9.5$ in.)
Req'd $h = 21.5 + 1.13/2 + 0.38 + 1.5 = 23.9$ in. Use 24 in.

Check ϕM_n: $d = 21.6$ in., $\rho = \dfrac{3.00}{15(21.6)} = 0.0093$, $\bar{k} = 0.4970$ ksi, $(\varepsilon_t > 0.005, \phi = 0.90)$

$$\phi M_n = \frac{0.90(15)(21.6)^2(0.4970)}{12} = 261 \text{ ft-kips} \quad > 252 \text{ ft-kips} \quad \text{(O.K.)}$$

Prob. 2-21 Design, [3/60], $L = 30$ ft, $b \le 16$ in., beam wt. not incl. in given loads.

Neglecting beam weight: $M_u = \dfrac{[1.2(1.0)+1.6(2.0)30^2}{8} = 495$ ft - kips

Try $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi $(\varepsilon_t > 0.005, \phi = 0.90)$

For $b = 16$ in.: Req'd $d = \sqrt{\dfrac{495(12)}{0.90(16)(0.4828)}} = 29.2$ in. $\left(\dfrac{d}{b} = \dfrac{29.2}{16} = 1.8 \text{ (O.K.)}\right)$

Estimate h assuming #8 bars: $h = 29.2 + 0.5 + 0.38 + 1.5 = 31.6$ in. Use $h = 32$ in.

Beam wt. $= \dfrac{16(32)}{144}(0.150) = 0.533$ kips/ft, new $M_u = 495 + \dfrac{1.2(0.533)(30)^2}{8} = 567$ ft - kips

With $b = 16$ in., $d = 29$ in., solve for A_s

Required $\bar{k} = \dfrac{567(12)}{0.90(16)(29)^2} = 0.5618$ ksi, required $\rho = 0.0108$, $(\varepsilon_t > 0.005, \phi = 0.90)$

Required $A_s = 0.0108(16)(29) = 5.01\text{ in.}^2$, $A_{s,\min} = 0.0033(16)(29) = 1.53\text{ in.}^2$ (O.K.)

Select 5#9 ($A_s = 5.00$ in.^{2}, $b_{\min} = 14$ in.)

Calculated $d = 32 - 1.5 - 0.38 - 1.13/2 = 29.6$ in. > 29 in. (O.K.)

Use $b = 16$ in., $h = 32$ in., 5#9 bars.

Prob. 2-22 Redo Prob. 2-21 with $h \le 30$ in. and no limitation on b.

Try estimated beam wt. of 0.533 k/ft and $M_u = 567$ ft-kips from Prob. 2-21.

Assume $h = 30$ in., $d = 27$ in.; try $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi and $\phi = 0.90$

Required $b = \dfrac{567(12)}{0.90(27)^2(0.4828)} = 21.5$ in. Use $b = 21$ in.

$\dfrac{d}{b} = \dfrac{27}{21} = 1.29$ Low due to restricted h. (Use)

Beam weight $= \dfrac{30(21)}{144}(0.150) = 0.656$ kips/ft

New $M_u = 567 + \dfrac{1.2(0.656 - 0.533)(30)^2}{8} = 584$ ft - kips

Required $\bar{k} = \dfrac{584(12)}{0.90(21)(27)^2} = 0.5086$ ksi, req'd $\rho = 0.0096$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0096(21)(27) = 5.44$ in.^{2}

Select 7#8 ($A_s = 5.53$ in.^{2}, $b_{\min} = 17$ in.) $A_{s,\min} = 0.0033(21)(27) = 1.87$ in.^{2} (O.K.)

Calculated $d = 30 - 1.5 - 0.38 - 0.5 = 27.6$ in. > 27 in. (O.K.)

Use $b = 21$ in., $h = 30$ in., 7#8 bars

Prob. 2-23 Design, [3/60], L = 32 ft, $b \le 18$ in.

Neglect beam weight: $M_u = \dfrac{[1.2(1.5)+1.6(2.0)](32)^2}{8} = 640$ ft - kips

Try b = 18 in., $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi ($\varepsilon_t > 0.005$, $\phi = 0.90$)

Req'd $d = \sqrt{\dfrac{640(12)}{0.90(18)(0.4828)}} = 31.3$ in. $\left(\dfrac{d}{b} = \dfrac{31.3}{18} = 1.74 \text{ (O.K.)}\right)$

Estimated h = 31.3 + 0.5 + 0.38 + 1.5 = 33.7 Use h = 35 in.

Beam weight $= \dfrac{18(35)}{144}(0.150) = 0.656$ kip/ft

New $M_u = 640 + \dfrac{1.2(0.656)(32)^2}{8} = 741$ ft - kips

Estimated d = 32 in.

Required $\bar{k} = \dfrac{741(12)}{0.90(18)(32)^2} = 0.5361$ ksi, required $\rho = 0.0102$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required A_s = 0.0102(18)(32)=5.87 in.^{2}, $A_{s,min}$ = 0.0033(18)(32) = 1.90 in.^{2} (O.K.)
Select 6#9 (A_s= 6.00 in.^{2}, b_{min} = 16.5 in.)
Calculated d = 35 – 1.5 – 0.38 – 1.13/2 = 32.6 in > 32 in. (O.K.)
Use b = 18 in. h = 35 in., 6#9 bars

Prob. 2-24 Redo Prob. 2-23 with $h \le 32$ in. and no limitation on b.
Neglect beam weight. M_u = 640 ft-kips from Prob. 2-23.
Assume h = 32 in., d = 29 in.; try $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi and $\phi = 0.90$

Required $b = \dfrac{640(12)}{0.90(29)^2(0.4828)} = 21$ in. Use $b = 21$ in.

$\dfrac{d}{b} = \dfrac{29}{21} = 1.38$ Low due to restricted h. (Use)

Beam weight $= \dfrac{32(21)}{144}(0.150) = 0.700$ kips/ft

New $M_u = 640 + \dfrac{1.2(0.700(32)^2}{8} = 748$ ft - kips

Required $\bar{k} = \dfrac{748(12)}{0.90(21)(29)^2} = 0.5647$ ksi, req'd $\rho = 0.0108$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required A_s = 0.0108(21)(29) = 6.58 in.^{2}
Select 7#9 (A_s = 7.00 in.^{2}, b_{min} = 18.5 in.) $A_{s,min}$ = 0.0033(21)(29) = 2.01 in.^{2} (O.K.)
Calculated d = 32 – 1.5 – 0.38 – 1.13/2 = 29.6 in. > 29 in. (O.K.)
Use b = 21 in., h = 32 in., 7#9 bars

Prob. 2-25 [4/60] Design, $L = 40$ ft

Neglect beam weight: $M_u = \dfrac{[1.2(0.8)+1.6(1.4)](40)^2}{8} = 640$ ft - kips

Try $\rho = 0.0120$, $\bar{k} = 0.6438$ ksi ($\varepsilon_t > 0.005$, $\phi = 0.90$,) and $d/b \approx 2$.

Required $d = \sqrt[3]{\dfrac{2(640)(12)}{0.90(0.6438)}} = 29.8$ in. (make $b = 16$ in. and $h = 34$ in.)

Beam weight $= \dfrac{16(34)}{144}(0.150) = 0.567$ kip/ft

New $M_u = 640 + \dfrac{1.2(0.567)(40)^2}{8} = 776$ ft - kips

Estimated $d = 31$ in.

Required $\bar{k} = \dfrac{776(12)}{0.90(16)(31)^2} = 0.6729$ ksi, req'd. $\rho = 0.0127$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0127(16)(31) = 6.30$ in.^{2}

Select 5#10 ($A_s = 6.35$ in.^{2}, $b_{min} = 15.5$ in.) $A_{s,min} = 0.0033(16)(31) = 1.64$ in.^{2} (O.K.)

Calculated $d = 34 - 1.5 - 0.38 - 1.27/2 = 31.5$ in. > 31 in. (O.K.)

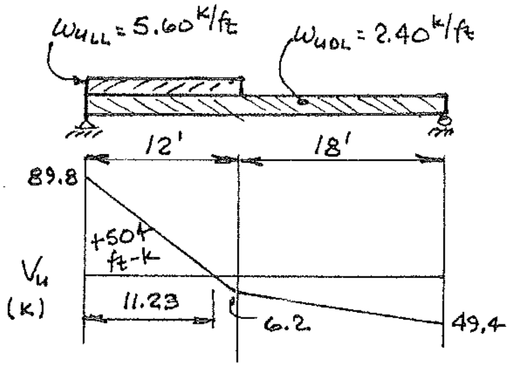
Use $b = 16$ in., $h = 34$ in., 5#10 bars

Prob. 2-26 [5/60] Design. Unsymmetrical load.

From V_u diag. (neg. bm. wt.): $M_{u(max)} = 504$ ft-kips

Try $\rho = 0.0150$, $\bar{k} = 0.8047$ ksi and $d/b \approx 2$.

($\varepsilon_t > 0.005$, $\phi = 0.90$,)



Required $d = \sqrt[3]{\dfrac{2(504)(12)}{0.90(0.8047)}} = 25.6$ in.

Make $b = 13$ in. and $h = 28$ in.

Beam weight $= \dfrac{13(28)}{144}(0.150) = 0.379$ kip/ft

New $w_{uDL} = 2.40 + 1.2(.379) = 2.86$ k/ft :

new diagram yields $M_{u(max)} = 553$ ft-kips.

Estimated $d = 25$ in.

Required $\bar{k} = \dfrac{553(12)}{0.90(13)(25)^2} = 0.9075$ ksi, req'd. $\rho = 0.0173$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0173(13)(25) = 5.62$ in.^{2}

Select 6#9 (two layers, 3 each, 1 in. clear) ($A_s = 6.00$ in.^{2}, $b_{min} = 9.5$ in.)

$A_{s,min} = 0.0035(13)(25) = 1.14$ in.^{2} (O.K.)

Calculated $d = 28 - 1.5 - 0.38 - 1.13 - 0.50 = 24.5$ in. <25 in. (N.G., check ϕM_n)

$\rho = \dfrac{6.00}{13(24.5)} = 0.0188$, $\bar{k} = 0.9783$ ksi, ($\varepsilon_t > 0.005$, $\phi = 0.90$)

Prob. 2-26 (cont.)

$$\phi M_n = \frac{0.90(13)(24.5)^2(0.9783)}{12} = 572\text{ ft-kips} \quad > 553\text{ ft-kips} \quad \text{(O.K.)}$$

Use b = 13 in., h = 28 in., 6#9 bars in two layers

Prob. 2-27 [5/60] Design, L = 28 ft

Neglect beam weight: $M_u = \frac{1.6(0.8)(28)^2}{8} + \frac{[1.2(10)+1.6(14)](28)}{4} = 366\text{ ft-kips}$

Try $\rho = 0.0150$, $\bar{k} = 0.8047\text{ ksi}$ $(\varepsilon_t > 0.005,\ \phi = 0.90,)$ and $d/b \approx 2$.

Required $d = \sqrt[3]{\frac{2(366)(12)}{0.90(0.8047)}} = 23\text{ in.}$ (try b = 12 in. and h = 27 in., est d = 24 in.)

Beam weight $= \frac{12(27)}{144}(0.150) = 0.338\text{ kip/ft}$

New $M_u = 366 + \frac{1.2(0.338)(28)^2}{8} = 406\text{ ft-kips}$

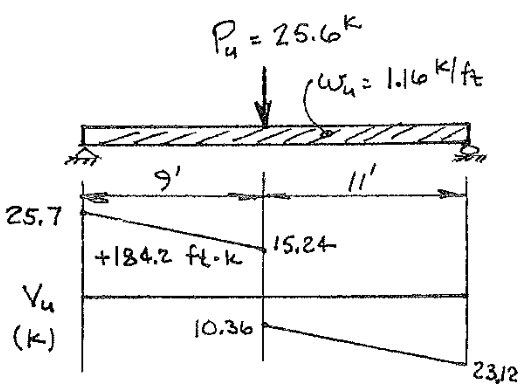
Required $\bar{k} = \frac{406(12)}{0.90(12)(24)^2} = 0.7832\text{ ksi}$, req'd. $\rho = 0.0146$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0146(12)(24) = 4.20\text{ in.}^2$
Select 3#11 (A_s = 4.68 in.^{2}, b_{min} = 11 in.) $A_{s,min} = 0.0035(12)(24) = 1.01\text{ in.}^2$ (O.K.)
Calculated d = 27 – 1.5 – 0.38 – 1.41/2 = 24.4 in. > 24 in. (O.K.)
Use b = 12 in., h = 27 in., 3#11 bars

Prob. 2-28 [3/60]

P_u = 1.2(8) + 1.6(10) = 25.6 kips
w_u = 1.2(0.3) + 1.6(0.5) = 1.16 kips/ft
V_u diag. (neg. bm. wt.): $M_{u(max)}$ = 184.2 ft-kips

Try $\rho = 0.0090$, $\bar{k} = 0.4828\text{ ksi}$ and $d/b \approx 2$.
$(\varepsilon_t > 0.005,\ \phi = 0.90,)$



Required $d = \sqrt[3]{\frac{2(184.2)(12)}{0.90(0.4828)}} = 21.7\text{ in.}$

Make b = 11 in. and h = 25 in.

Beam weight $= \frac{11(25)}{144}(0.150) = 0.287\text{ kip/ft}$

New w_{uDL} = 1.16 +1.2(0.287) = 1.504 k/ft :
new diagram yields $M_{u(max)}$ = 201 ft-kips.
Estimated d = 22 in.

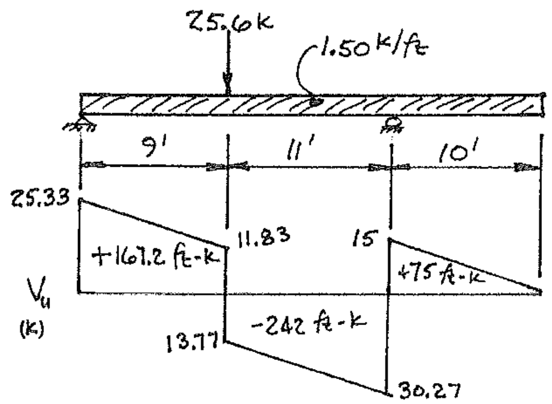
Required $\bar{k} = \frac{201(12)}{0.90(11)(22)^2} = 0.5034\text{ ksi}$, req'd. $\rho = 0.0095$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0095(11)(22) = 2.30\text{ in.}^2$
Select 2#10 (A_s = 2.54 in.^{2}, b_{min} = 8.0 in.)

Prob. 2-28 (cont.)
$A_{s,\min} = 0.0033(11)(22) = 0.80 \text{ in.}^2$ (O.K.)
Calculated $d = 25 - 1.5 - 0.38 - 1.27/2 = 22.5 \text{ in.} > 22 \text{ in.}$ (O.K.)
Use $b = 11$ in., $h = 25$ in., 2#10 bars

Prob. 2-29 [3/60] Rework Prob. 2-28 w/ addition of an overhanging span.

Assume bm. wt. = 0.287 k/ft from Prob. 2-28.
V_u diag.: $+M_{u(\max)} = 167.2$ ft-kips
$-M_{u(\max)} = 75$ ft-kips



Design for positive moment:
Try $\rho = 0.0090$, $\bar{k} = 0.4828$ ksi and $d/b \approx 2$.
($\varepsilon_t > 0.005$, $\phi = 0.90$)

$$\text{Required } d = \sqrt[3]{\frac{2(167.2)(12)}{0.90(0.4828)}} = 21 \text{ in. (Use)}$$

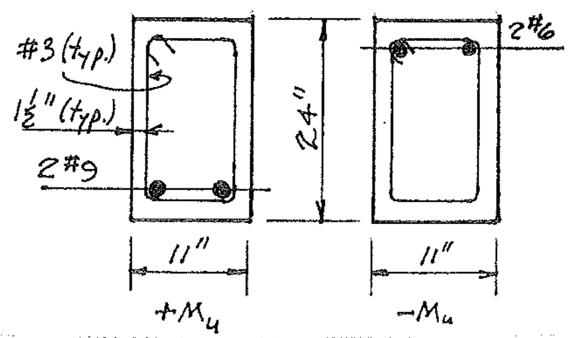
Make $b = 11$ in. and $h = 24$ in.

$$\text{Beam weight} = \frac{11(24)}{144}(0.150) = 0.275 \text{ kip/ft}$$

0.275 k/ft < 0.287 k/ft (O.K.)

$$\text{Required } \bar{k} = \frac{167.2(12)}{0.90(11)(21)^2} = 0.4596 \text{ ksi}$$

req'd. $\rho = 0.0086$, $\varepsilon_t > 0.005$, $\phi = 0.90$
Required $A_s = 0.0086(11)(21) = 1.99 \text{ in.}^2$



Select 2#9 ($A_s = 2.00 \text{ in.}^2$, $b_{\min} = 7.5$ in.)
$A_{s,\min} = 0.0033(11)(21) = 0.76 \text{ in.}^2$ (O.K.)

Calculated $d = 24 - 1.5 - 0.38 - 1.13/2 = 21.6 \text{ in.} > 21 \text{ in.}$ (O.K.)

Design for negative moment: Use $b = 11$ in., $h = 24$ in., est. $d = 21$ in.

$$\text{Required } \bar{k} = \frac{75(12)}{0.90(11)(21)^2} = 0.2061 \text{ ksi}$$

req'd. $\rho = 0.0036$, $\varepsilon_t > 0.005$, $\phi = 0.90$

Required $A_s = 0.0036(11)(21) = 0.83 \text{ in.}^2$
Select 2#6 ($A_s = 0.88 \text{ in.}^2$, $b_{\min} = 6.5$ in.) $A_{s,\min} = 0.0033(11)(21) = 0.76 \text{ in.}^2$ (O.K.)
Calculated $d = 24 - 1.5 - 0.38 - 0.75/2 = 21.7 \text{ in.} > 21 \text{ in.}$ (O.K.)

See design sketches.

<u>Prob. 2-30</u> [3/60] One-way slab design for h_{min}. $L = 8$ ft
ACI $h_{min} = L/20 = [8(12)]/20 = 4.8$ in. Use 5 in.

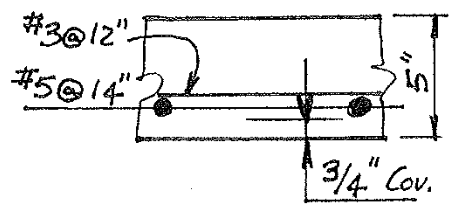
$$\text{Slab weight} = \frac{5(12)}{144}(0.150) = 62.5 \text{ psf}, \quad w_u = \frac{1.2(62.5) + 1.6(300)}{1000} = 0.555 \text{ kip/ft}$$

$$M_u = \frac{0.555(8)^2}{8} = 4.44 \text{ ft - kip}$$

Estimated $d = 5 - 0.75 - 0.75/2 = 3.88$ in. (Assume #6 bars)

$$\text{Required } \bar{k} = \frac{4.44(12)}{0.90(12)(3.88)^2} = 0.3277 \text{ ksi}, \quad \rho = 0.0059, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

Required $A_s = 0.0059(3.88)(12) = 0.27$ in.^{2}/ft
$A_{s,min} = 0.0018(5)(12) = 0.11$ in.^{2}/ft (O.K.)
Main steel: select #5@14 in. o/c
($A_s = 0.27$ in.^{2}/ft, $s_{max} = 3h = 15$ in. ≤ 18 in. (O.K.))
Calc. $d = 5 - 0.75 - 0.625/2 = 3.94$ in. > 3.88 in. (O.K.)
($A_{s,min}$ = required S&T steel)
S&T steel: select #3@12 in. o/c
($A_s = 0.11$ in.^{2}/ft, $s_{max} = 5h = 25$ in. ≤ 18 in. (O.K.))



<u>Prob. 2-31</u> [3/60] One-way slab design. $L = 10$ ft

<u>(a) Design for h_{min}.</u>
ACI $h_{min} = L/20 = [10(12)]/20 = 6$ in. Use 6 in.

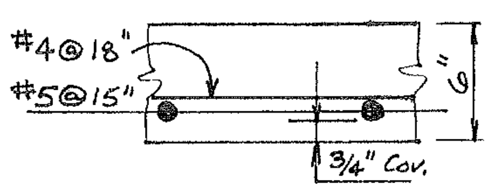
$$\text{Slab weight} = \frac{6(12)}{144}(0.150) = 75 \text{ psf}, \quad w_u = \frac{1.2(25 + 75) + 1.6(175)}{1000} = 0.400 \text{ kip/ft}$$

$$M_u = \frac{0.400(10)^2}{8} = 5.00 \text{ ft - kips}$$

Estimated $d = 6 - 0.75 - 0.75/2 = 4.88$ in. (Assume #6 bars)

$$\text{Required } \bar{k} = \frac{5.00(12)}{0.90(12)(4.88)^2} = 0.2333 \text{ ksi}, \quad \rho = 0.0041, \quad \varepsilon_t > 0.005, \quad \phi = 0.90$$

Required $A_s = 0.0041(4.88)(12) = 0.24$ in.^{2}/ft
$A_{s,min} = 0.0018(6)(12) = 0.13$ in.^{2}/ft (O.K.)
Main steel: select #5@15 in. o/c
($A_s = 0.25$ in.^{2}/ft, $s_{max} = 3h = 18$ in. ≤ 18 in. (O.K.))
Calc. $d = 6 - 0.75 - 0.625/2 = 4.94$ in. > 4.88 in. (O.K.)
($A_{s,min}$ = required S&T steel)
S&T steel: select #4@18 in. o/c
($A_s = 0.13$ in.^{2}/ft, $s_{max} = 5h = 30$ in. ≤ 18 in. (O.K.))



<u>(b) Design thinnest slab based on moment strength</u> (max. ρ with $\varepsilon_t \geq 0.005$)
Estimated slab weight: assume $h = 5$ in. and slab weight = 62.5 psf

$$w_u = \frac{1.2(62.5 + 25) + 1.6(175)}{1000} = 0.385 \text{ k/ft}$$

Prob. 2-31(b) (cont.)

$$M_u = \frac{0.385(10)^2}{8} = 4.81 \text{ ft - kips}$$

Use $\rho = 0.01355$ ($\bar{k} = 0.6835$ ksi, $\varepsilon_t = 0.005$, $\phi = 0.90$)

$$\text{Required } d = \sqrt{\frac{4.81(12)}{0.90(12)(0.6835)}} = 2.79 \text{ in.}$$

Est. $h = 2.79 + 0.75/2 + 0.75 = 3.92$ in. (Use 4 in., neglect decrease in D.L.)

Est. $d = 4.00 - 0.75/2 - 0.75 = 2.88$ in.

$$\text{Required } \bar{k} = \frac{4.81(12)}{0.90(12)(2.88)^2} = 0.6443 \text{ ksi}, \quad \rho = 0.0127, \ \varepsilon_t > 0.005, \ \phi = 0.90$$

Required $A_s = 0.0127(2.88)(12) = 0.44$ in.^{2}/ft

$A_{s,min} = 0.0018(4)(12) = 0.09$ in.^{2}/ft (O.K.)

Main steel: select #6@12 in. o/c

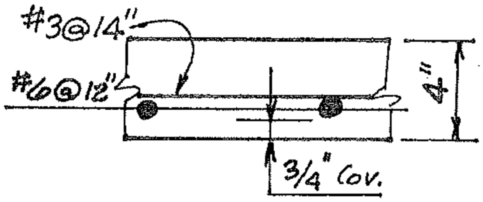
($A_s = 0.44$ in.^{2}/ft, $s_{max} = 3h = 12$ in. ≤ 18 in. (O.K.))

Calc. $d = 4 - 0.75 - 0.75/2 = 2.88$ in. (O.K.)

($A_{s,min} =$ required S&T steel)

S&T steel: select #3@14 in. o/c

($A_s = 0.09$ in.^{2}/ft, $s_{max} = 5h = 20$ in. ≤ 18 in. (O.K.))



Prob. 2-32 [3/60] One-way slab design. $L = 13$ ft

ACI $h_{min} = L/20 = [13(12)]/20 = 7.8$ in. Use 8 in.

$$\text{Slab weight} = \frac{8(12)}{144}(0.150) = 100 \text{ psf}, \quad w_u = \frac{1.2(100) + 1.6(200)}{1000} = 0.440 \text{ kip/ft}$$

$$M_u = \frac{0.440(13)^2}{8} = 9.30 \text{ ft - kip}$$

Estimated $d = 8 - 0.75 - 0.75/2 = 6.88$ in. (Assume #6 bars)

$$\text{Required } \bar{k} = \frac{9.30(12)}{0.90(12)(6.88)^2} = 0.2183 \text{ ksi}, \quad \rho = 0.0039, \ \varepsilon_t > 0.005, \ \phi = 0.90$$

Required $A_s = 0.0039(6.88)(12) = 0.32$ in.^{2}/ft

$A_{s,min} = 0.0018(8)(12) = 0.17$ in.^{2}/ft (O.K.)

Main steel: select #6@16 in. o/c

($A_s = 0.33$ in.^{2}/ft, $s_{max} = 3h = 24$ in. ≤ 18 in. (O.K.))

Calc. $d = 8 - 0.75 - 0.75/2 = 6.88$ in. (O.K.)

($A_{s,min} =$ required S&T steel)

S&T steel: select #4@14 in. o/c

($A_s = 0.17$ in.^{2}/ft, $s_{max} = 5h = 40$ in. ≤ 18 in. (O.K.))