See Example

Flexure IV

Rules of Thumb
What if
Example

Hmwrk 2.28, 2.36, 3.8, 4.2, 4.11

Step 1 Decide on ρ to use

Row

Choose @ 1/2 maximum

$\rho_{max} = 0.75\,\rho_{bal} = 0.0214$

$\rho = \frac{1}{2}\rho_{max} = 0.011$

Step 2 Determine required load

$M_u = 1.2\,M_D + 1.6\,M_L$

$M_L = \dfrac{(1.3\ k/ft)(40\ ft)^2}{8} = 260\ ft\text{-}k$

$M_D = \dfrac{(0.8 + 0.4)(40)^2}{8} = 240\ ft\text{-}k$

estimate beam wt

Step 3 Estimate Beam Size

$d \approx \dfrac{\ell_n}{16} = \dfrac{40}{16} \approx 2.5 ft \approx 30''$

$b \approx 0.5d = 15''$

Step 4 Verify Assumed Wt.

cover

$h = 30 + 2.5 = 32.5$

$\Downarrow$

$h = 34''$ round up

$w = \dfrac{\overset{b}{(15'')}\ \overset{h}{(34'')}}{144\ in^2/ft^2}\left(0.15\ k/ft^3\right) = 0.531\ k/ft$

unit wt concrete

$$\text{Revised } M_D = \frac{(0.8 + 0.531)(40)^2}{8} = 266 \text{ ft-k}$$

$$\text{Revised } M_u = 1.2(266) + 1.6(260) = 736.4 \text{ ft-k}$$ wrong #

$$\text{Revised } M_n \text{ required} = \frac{M_u}{\phi} = \frac{736.4}{0.9} = 818 \text{ ft-k}$$

Step 5 - Select steel

$$d = h - 2.5 = 34 - 2.5 = 31.5 \text{ in}$$

$$A_{s,req} = \frac{M_u}{\phi f_y j_d} = \frac{(736.4)(12'')(10{,}000)}{(0.9)(60{,}000)(0.87)(31.5)} = 5.97 \text{ in}^2$$

Check A_{smin}

$$= \frac{3\sqrt{f'_c}}{f_y} b_w d = \frac{3\sqrt{4000 \text{ psi}}}{60{,}000 \text{ psi}} (15'')(31.5'')$$

$$= 1.49 \text{ in}^2 << A_{sreq} \checkmark \text{ ok}$$

Now Select Bar 5.97 in^2

select	$A_s (in^2)$	Notes
2 - #18	8.00	High, very large bars
3 - #14	6.75	large bars
6 - #9	6.00	won't fit in 1 layer [tbl 3.9...
3 - #11 & 2#9	6.68	O.K.
4 - #11	6.24	OK

Select 4 - #11

Step 6 Check strength & provide design sketch

assume #5 stirrups

$d = h - \text{cover} - \text{stirrup} - \frac{1}{2}\text{bar}\,\phi$
$= 34 - 1\,1/2 - 5/8 - 1/2\left(\frac{11}{8}\right)$
$= 31.1875\,in \approx 31.2$

$C = 0.85 f'_c\, b a = 0.85(4000\,psi)(15\,in)\,a = 51{,}000\,a$

$T = A_s f_y = 6.24(60{,}000) = 374{,}400$

$T = C \Rightarrow a = \frac{374.4^k}{51^k} = 7.34\,in$

$M_n = A_s f_y(d - a/2) = 6.24(60{,}000)\left(31.2 - \frac{7.34}{2}\right)$
$= 10{,}307{,}232\ in\cdot\#$

$M_n = 859\ ft\cdot k$

Check $\phi M_n \overset{?}{\geq} M_u$

$(0.9)(859) \geq 736.4$

$773 \geq 736.4$ ✓ O.K.

Now Check $\underset{\text{Strain}}{\epsilon} \geq 0.005$

Rules of Thumb

COVER [7.7.1]

cover $\geq 1.5^{in}$ for internal beams

- cover protects the steel from corrosion

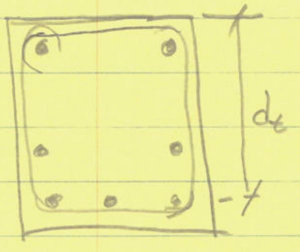
Spacing [7.6.1]

$$S_h = \max \begin{cases} d_{bar} \\ 1in \\ 4/3 \text{ max aggregate size [3.3.2]} \end{cases}$$

What IF ?

What if $A_{s,min} > A_{s,req}$? Use $A_{s,min}$

What if A_s can not be plased in 1 row
- use 2 rows
- calculate S_v



$d \leq d_t$

↑ to center of bars

- make beam wider
  - don't exceed $w/d \approx 0.6$

  recalcute W_D!
- wider beams are less efficient

Rules of Thumb cont.

<u>What if $\epsilon_t < 0.005$?</u>

if $\epsilon_t \geq 0.004$ [10.3.5]

re calulate ϕ and check $\phi M_n \geq M_u$

if $\epsilon_t < 0.004$, not valid design, redesign.

What if $\phi M_n \ngeq M_u$?
Design Not Good

<u>Investigate</u>:

- deeper beam
- More steel
- use compression steel @ top of beam

Example

$f_y = 60{,}000$

$f'_c = 4{,}000$ psi

$L = 30$ ft

$DL = 2^k/ft$

$LL = 1^k/ft$

$$\rho_{balance} = \frac{0.18 f'_c}{f_y} = \frac{(.18)(4000)}{60{,}000} = 0.012$$

Design a rectangle section

Assume Beam dead weight $500^{\#}/ft$

$$W_u = 1.2(DL + W_t) + 1.6(LL)$$

$$= 1.2\,(2^k/ft + .5^k/ft) + 1.6\,(1^k/ft) = 4.6^k/ft$$

$$M_u = \frac{W_u L^2}{8} = \frac{(4.6^k/ft)(30)^2}{8} = 517.5 \text{ ft}\cdot k$$

Go to table A-13 in book

read for $\rho = 0.012$

$$\frac{M_u}{\phi b d^2} = 643.5$$

convert to in

$$bd^2 = \frac{M_u}{\phi\, 643.5} = \frac{12\,(517{,}500 \text{ ft}\cdot\#)}{(0.9)(643.5)}$$

$bd^2 = 10{,}723$

b	d
14	27.68
→ 16	25.89 ← Use this
18	24.41

Next ↴

check beam wt:

include concrete below bar

$$wt = \frac{bh}{144}(\gamma_c) = \frac{(16")(29")}{144}(150 \text{ \#/ft}^3)$$

$$= 483 \text{ \#/ft} < 500 \text{ \#/ft (assumed)}$$

$$A_s = \rho bd = (0.0612)(16)(26.50)$$

$$= 5.09 \text{ in}^2$$

Use 4 #10 bars (5.06 in^2)

since bar size is different

$$\rho = \frac{A_s}{bd} = \frac{5.06}{(16")(26.5")} = 0.0119$$

$> \rho_{min} = 0.0033$ table A.7

$< \rho_{max} = 0.0181$

$\therefore$ Setion is ductile