5.18. EXAMPLE. Concrete Dimensions and steel area to resist a given moment.

Select an economical rectangular beam size and select bars using the ACI strength method. The beam is a simply supported span of 40 ft and it is to carry a live load of 1.4 kips/ft and a dead load of 1.4 kip/ft (including beam weight). Without actually checking deflection, use a reinforcement ratio ϱ such that excessive deflection is unlikely. Use f'_c = 4000 psi, and f_y = 60,000 psi.

Solution:

(a) Decide on a c/d ratio to use. To have reasonable expectation that deflection will not be excessive, choose $c/d = 0.3$. Use

(b) Determine the desired R (corresponding to the desired ϱ using Equation (5.43):

$$\rho = 0.85\beta_1 \frac{c}{d} \times \frac{f_c'}{f_y} = 0.85(0.85)(0.3) \times \frac{4}{60} = 0.01445$$

$$R = \rho f_y \left(1 - 0.59 \frac{\rho\ f_y}{f_c'}\right)$$

$$R = (0.01445)(60\text{ ksi})\left(1 - 0.59(0.01445)\frac{60}{4}\right) = 0.756 \qquad \text{ksi}$$

(c) Determine factored moments.

$$M_u = 1.2M_D + 1.6M_L$$

$$M_L = \frac{1}{8}(1.4)(40)^2 = 280 \quad ft.kips$$

$$M_D = \frac{(1.4)(40)^2}{8} = 280 \quad ft.kips$$

$$M_u = 1.2(280) + 1.6(280) = 784 \quad ft.kips$$

required

$$M_n = \frac{m_u}{\phi} = \frac{784}{0.90} = 871 \quad ft.kips$$

(d) Determine required bd^2 from desired R.

$$bd^2 = \frac{M_n}{R} = \frac{871 \times 12}{0.756} = 13,825\ in^3$$

(e) Establish beam size. Select width *b* and determine the corresponding required value for effective depth *d*. Make a table of possibilities

b (in)	**Required d** (in)
12	34.0
15	30.4
18	27.7
20	26.3

Selecting the 18-in. width will give a beam whose overall depth is between 1 1/2 and 2 times its width (suggested guideline).

$$A_s = \rho bd = 0.01445 \times 18 \times 27.7 = 7.20 \quad in^2$$

Use 12-#7 with a total A_s = 7.20 in^2. Put them in two layers. We can compute the overall depth of the member, *h*, as

$$h = d + 1\frac{1}{2} \text{ in cover } + \frac{4}{8} \text{ diameter stirrup } + \text{ bar diameter } + \frac{\text{spacing}}{2}$$

$$h = 27.7 + 1.5 + 4/8 + 0.875 + \frac{1.0}{2} = 31.09$$

As a guideline explained earlier, the overall depth would be in whole inches; so try *h* = 32 in. Since ρ = 0.01445 is not a rigorous requirement, the overall depth selected could be somewhat less or somewhat more than the computed requirement in order to obtain a desired dimension. The stirrup is reinforcement to provide shear strength for the beam and should always be allowed for at this stage of the design.

Check whether 6-#12 will fit into an 18-in width in one layer. We determine the approximate clear spacing between bars by subtracting from the overall width the combined values of the minimum clear cover on both sides (3.0 inches), one stirrup diameter on both sides (0.75), and 6-#7 bar diameters (6x0.875). The result is divided by the number of spaces between bars, and this is the approximate clearance that must exceed the diameter of the larger bar (ACI 7.6.1)

$$clear\ spacing = \frac{18-2(1.5)-2(4/8)-6(0.875)}{5} = 1.75\ in > d_b = 0.875 \quad or \quad 1\ in \quad ok$$

Note that the above clearance computation is approximate because it assumes the #4 stirrup may be bent tightly around the corner longitudinal bar. ACI-7.2.2 requires the inside diameter of bends for stirrups to be not less than four stirrup bar diameters for #5 Stirrups and smaller; thus for #4 stirrups the actual curve of the stirrup at the corner has a radius of 3/4 in., which is larger than the longitudinal bar radius for #7 bars and smaller (see Table 5 thru 8 of your notes).

(g) Check strength and provide design sketch. Using computed *d*

$$d = 32–1.5–4/8–(0.875)–0.5 = 28.63 \quad \text{in}$$

$$a = \frac{A_s f_y}{0.85 f_c{}' \ b} = \frac{(7.2)(60)}{0.85(4)(18)} = 7.06 \quad \rightarrow \quad c = \frac{a}{\beta_1} = \frac{7.06}{0.86} = 8.30$$

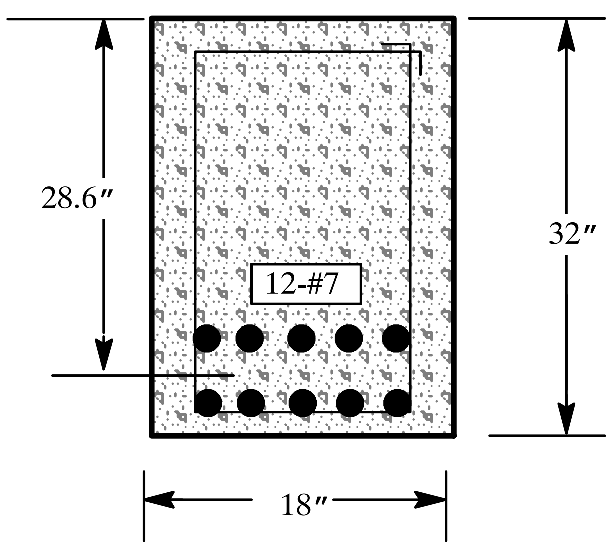
$$\frac{c}{d} = \frac{8.3}{28.63} = 0.29 \qquad < 0.375 \qquad \text{Tension controlled}$$

$$M_n = \rho f_y b d^2 \left(1 - 0.59 \frac{\rho \ f_y}{f_c{}'}\right)$$

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

$$M_n = (7.2\ in^2)(60\ ksi)\left(28.63 – \frac{7.06}{2}\right) = 10,841 \ \ in–kips$$

$$M_u = \phi M_n = 0.9 \times 10,841 = 9757\ in.kips = 813 \ \ ft–kips$$



Spread sheet - design-singly reinforced.xls in ce4135 file in PC

5.19. EXAMPLE. Determination of steel area

Find the steel area required for beam which has b = 10 in. and d = 17.5 in. to carry a factored load moment of 1,600 in-kips. Material strengths are f'_c = 4000 psi, and f_y = 60,000 psi.

Solution:

The necessary flexural resistance factor is

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

$$R = \frac{M_u}{\phi b d^2} = \frac{(1,600 in - kips)(1000 lb/kip))}{(0.9)(10)(17.5)^2} = 580 \qquad \text{psi}$$

$$\rho = \frac{1 - \sqrt{1 - \frac{2.36R}{f'_c}}}{1.18 f_y / f'_c}$$

$$\rho = \frac{1 - \sqrt{1 - \frac{2.36(0.580 \ ksi)}{4 \ ksi}}}{1.18(60)/4} = 0.0107$$

$$A_s = \rho b d = 0.0107 \times 10 \times 17.5 = 1.87 \quad in^2$$

Use 2 - #9 bars with a total A_s = 2.0 in^2. In addition, you need to check for make sure that the minimum and the maximum allowable steel areas according to ACI code are satisfied and check the strength of the final design. Also need to check bar spacings, etc.