Reinforced Concrete Design | (8th Edition)

Problem

For the following problem, unless otherwise noted, concrete is normal weight and steel is uncoated grade 60 (f_y= 60,000 psi).

A simply supported, uniformly loaded beam carries a total factored load of 4.8 kips/ft (this includes the beam weight) on a clear span of 34 ft. The cross section has been designed and is shown. The required tension steel area for the design was 5.48 in.2 The supports are 12-in. wide. Use f'_c = 3ksi psi.

a. Determine the cutoff location for the two center bars (indicated in the sketch).

b. Design the shear reinforcement and check whether code requirements are met for bars terminated in a tension zone. Redesign the stirrups if necessary.

PROBLEM 5-13

Step-by-step solution

Step 1 of 18

(a)

Establish a bar cutoff for first two bars and followed by cutting of other two bars.

Eliminate the two center bars of #9.

The area of steel bars provided to the corners is 1.40in.^2.

Thus, the width of beam (b) is 17 in.

The effective depth of the beam (d) is 33.6 in.

Refer Table A-5, "Design concepts" in the textbook.

Find the minimum area of reinforcement $\left(A_{s,\min}\right)$ using the relation.

$$A_{s,\min} = 0.0033bd$$

Substitute 17 in. for *b* and 33.6 in. for *d*.

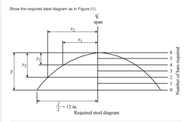
$$\begin{aligned} A_{s,\min} &= 0.0033 \times 17 \times 33.6 \\ &= 1.89 \text{in.}^2 \end{aligned}$$

Thus, the requirement of minimum reinforcement area is met and the reinforcement is O.K.

Comment

Step 2 of 18

Show the required steel diagram as in Figure (1).



Comment

Step 3 of 18

Find the distance from the centerline of the span $\left(x_1\right)$ using the interpolation.

$$\frac{0.6\ell}{\left(\frac{\ell}{2}\right)} = \frac{y_1}{y_2}$$

Here, *l* is length of span.

Substitute 35 ft for *l*, 2 bars for y_1, and 6 bars for *Y*.

Comment

Step 4 of 18

Check the development length for two terminated bars:

Refer Table 5-1, "Coefficient K_{tr} for ACI code equation (12-1)" in the textbook.

(1) The value of coefficient K_{tr} is 82.2.

(2) Establish the values for the factors as follows:

(a) ψ_t = 1.0 (The bars are not top bars)

(b) The bars are uncoated, ψ_e = 1.0.

(c) The bars are No.7, ψ_s = 1.0.

(d) The normal weight of concrete is used; thus, the modulus of rupture $\left(\lambda\right)$ is 1.0.

(3) Check the product of $\psi_t \psi_e \psi_s$ = 1.0 × 1.7 ∴O.K.

(4) Find the half-space $\left(c_b\right)$ based on cover.

$$\begin{aligned} c_b &= 1.5 + 0.38 + \frac{1.13}{2} \\ &= 2.45 \text{in.} \end{aligned}$$

Comment

Step 5 of 18

Find the half space based on bar spacing as follows.

$$\begin{aligned} c_s &= \frac{17 - 2(1.5) - 2(0.38) - 2\left(\frac{1.13}{2}\right)}{3(1)} \\ &= 1.21 \text{in.} \end{aligned}$$

Thus, use the half spacing of 1.21 in.

(5) The value of K_{tr} is 0.

Comment

Step 6 of 18

(6) Check the value of $\frac{c_b + K_{tr}}{d_b}$:

$$\begin{aligned} \frac{c_b + K_{tr}}{d_b} &= \frac{1.21 + 0}{1.13} \\ &= 1.07 > 2.5 \text{(N.G.)} \end{aligned}$$

(7) Find the excess reinforcement $\left(K_{ex}\right)$ using the relation.

$$K_{ex} = \frac{A \text{ required}}{A \text{ provided}}$$

Substitute 5.48in.^2 for A_s required and 6.00in.^2 for A_s provided.

$$\begin{aligned} K_{ex} &= \frac{5.48}{6} \\ &= 0.913 \end{aligned}$$

Comment

Step 7 of 18

(8) Find the development length $\left(\ell_d\right)$ using the relation.

$$\ell_d = \frac{f_y}{\lambda}\left[\frac{\psi_t \psi_e \psi_s}{\left(\frac{c_b + K_{tr}}{d_b}\right)}\right] K_{ex} d_b$$

Substitute 82.2 for K_{tr}, 1 for λ, 1 for ψ_t, 1 for ψ_e, 1 for ψ_s, 1.07 for $\frac{c_b + K_{tr}}{d_b}$, 0.913 for K_{ex}, and 1.13 in. for d_b.

$$\begin{aligned} \ell_d &= \frac{82.2}{1}\left[\frac{1 \times 1 \times 1}{1.07}\right] \times 0.913 \times 1.13 \\ &= 79.3 \text{in.} > 12 \text{in.} \text{(O.K.)} \end{aligned}$$

The second two bars must be extending at least development past this point.

Thus, the final cutoff measured from the center of span is:

$$\begin{aligned} \text{Final cutoff point received} &= 17.5 + 33.6 \\ &= 194.6 \text{in.} \\ &= 16 \text{ft} \end{aligned}$$

Provide the development length of bar 79.3 in. for remaining four bars. The half-clear span length is 17 ft.

Find the available development length as follows:

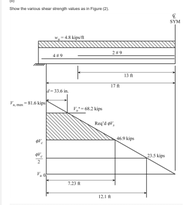
$$\begin{aligned} \text{Available} \ell_d &= 17(12) + 12 - 1.5 - 123 \\ &= 95.5 \text{in.} > 79.3 \text{in.} \text{(O.K.)} \end{aligned}$$

Comment

Step 8 of 18

(b)

Show the various shear strength values as in Figure (2).



Comment

Step 9 of 18

Find the maximum shear strength $\left(V_{u,\max}\right)$ using the formula.

$$\text{Max.} V_u = w_u l$$

Here, w_u is total factored load.

Substitute 4.8 kips/ft for w_u and 17 ft for *l*.

$$\begin{aligned} V_{u,\max} &= 4.8 \times 17 \\ &= 81.6 \text{kips} \end{aligned}$$

Comment

Step 10 of 18

Find the shear force at critical section $\left(V_u'\right)$ using the relation.

$$V_u' = V_{u,\max} - w_u d_b$$

Substitute 81.6 kips for $V_{u,\max}$, 33.6 in. for *d*, and 4.8 kips/ft for w_u.

$$\begin{aligned} V_u' &= 81.6 - \frac{33.6 \times 4.8}{12} \\ &= 68.2 \text{kips} \end{aligned}$$

Find the concrete shear strength $\left(\phi V_c'\right)$ using the relation.

$$\phi V_c' = 2\phi\lambda\sqrt{f'_c}\, b_w d$$

Here, ϕ is strength reduction factor, λ is modulus of rupture of fresh concrete, f'_c is compressive strength of concrete, and b_w is web width.

Substitute 0.75 for ϕ, 1 for λ, 3,000 psi for f'_c, 17 ft for b_w, and 33.6 ft for *d*.

$$\begin{aligned} \phi V_c' &= 2 \times 0.75 \times 1 \times \sqrt{3,000} \times 17 \times 33.6 \\ &= 46.9 \text{kips} \end{aligned}$$

Check the requirements of stirrups.

$$\begin{aligned} \frac{\phi V_c'}{2} &= \frac{46.9}{2} \\ &= 23.5 \text{kips} \\ &< 68.2 \text{kips} \end{aligned}$$

Thus, the stirrup is required.

The stirrups are required to 12.1 ft from the POS.

The allowable shear strength $\left(V_s'\right)$ is about to 7.23 ft from the POS.

Comment

Step 11 of 18

Find the required shear strength of steel $\left(\phi V_s'\right)$ using the relation.

$$\phi V_s' = V_u' - \phi V_c' - 4.8x \text{ For } 2.80 \text{ ft} \le x \le 7.23 \text{ ft}$$

Substitute 81.6 kips for V_u' and 46.9 kips for $\phi V_c'$.

$$\begin{aligned} \phi V_s' &= 81.6 - 46.9 - 4.8x \\ &= 34.7 - 4.8x \end{aligned}$$

Assume #3 single-loop stirrups with the area of stirrups $\left(A_v\right)$ is 0.22in.^2.

Comment

Step 12 of 18

Find the required spacing $\left(s^*\right)$ using the relation.

$$s^* = \frac{\phi A_v f_y d}{V_s' - \phi V_c'}$$

Here, f_y is stirrup yield strength,

Substitute 0.75 for ϕ, 0.22in.^2 for A_v, 60,000 psi for f_y, 33.6 for *d*, 68.2 kips for V_u', and 46.9 kips for required $\phi V_c'$.

$$\begin{aligned} s^* &= \frac{0.75 \times 0.22 \times 60 \times 33.6}{68.2 - 46.9} \\ &= 13.6 \text{in.} \end{aligned}$$

Find the shear strength of steel $\left(V_s'\right)$ using the relation.

$$V_s' = \frac{A_v f_y d}{15 s}$$

Substitute 0.22in.^2 for A_v, 60,000psi for f_y, and 33.6 for *d*.

$$\begin{aligned} V_s' &= \frac{0.22 \times 60 \times 33.6}{15} \\ &= 29.568 \text{kips} \end{aligned}$$

Comment

Step 13 of 18

Find the maximum shear strength $\left(V_{s,\max}\right)$ using the formula.

$$V_{s,\max} = 8\sqrt{f'_c}\, b_w d$$

Substitute 3,000 psi for f'_c, 17 in. for b_w and 33.6 for *d*.

$$\begin{aligned} V_{s,\max} &= 8\sqrt{3,000} \times 17 \times 33.6 \\ &= 125.2 \text{kips} \end{aligned}$$

Comment

Step 14 of 18

Find the critical shear strength of stirrups $\left(V_s''\right)$ using the relation.

$$V_s'' = \frac{V_u' - \phi V_c'}{\phi}$$

Substitute 68.2 kips for V_u', 46.9 kips for required $\phi V_c'$, 0.75 for ϕ.

$$\begin{aligned} V_s'' &= \frac{68.2 - 46.9}{0.75} \\ &= 28.4 \text{kips} < 125.2 \text{kips} \end{aligned}$$

Comment

Step 15 of 18

Find the maximum spacing $\left(s_{\max}\right)$ using the relation.

$$s_{\max} = \frac{d}{2} \text{ or } 24 \text{in.} \left(\text{Lesser value}\right)$$

Substitute 33.6 in. for *d*.

$$\begin{aligned} s_{\max} &= \frac{33.6}{2} \text{ or } 24 \text{in.} \left(\text{Lesser value}\right) \\ &= 16.8 \text{in.} \end{aligned}$$

Check the maximum spacing using the relation.

$$s_{\max} = \frac{A_v f_y}{50 b_w}$$

Substitute 0.22in.^2 for A_v, 60,000psi for f_y, and 17 in. for b_w.

$$\begin{aligned} s_{\max} &= \frac{0.22 \times 60}{50 \times 17} \\ &= 15.5 \text{in.} < 16.8 \text{in.} \end{aligned}$$

Hence, use the maximum spacing of 15 in. throughout the beam.

Comment

Step 16 of 18

Check the shear at cutoff of 2#9 bars at the midspan of distance 4 ft from the FOS.

$V_u = V_{u,\max} - 4.8x$

Substitute 81.6 kips for $V_{u,\max}$ and 4 ft for *x*.

$$\begin{aligned} V_u &= 81.6 - 4.8(4) \\ &= 62.4 \text{kips} \end{aligned}$$

Find the value of $\frac{2}{3}\phi\left(V_c' + V_s'\right)$.

Substitute 62.6 kips for V_u, 0.75 for ϕ, and 29.568 kips for V_s.

$$\begin{aligned} \frac{2}{3}\phi\left(V_c' + V_s'\right) &= \frac{2}{3} \times 0.75 \times (62.6 + 29.568) \\ &= 46.5 \text{kips} < 62.4 \text{kips} \end{aligned}$$

Thus, the stirrups are not satisfactory.

Comment

Step 17 of 18

Provide the additional stirrups over the last 0.75*d* of the cut bars.

Find the number of stirrups required $\left(N_s\right)$ using the relation.

$$N_s = \frac{450 \, d}{A_v f_y} + 1$$

Substitute 17 in. for b_w, 33.6 in. for *d*, 0.22in.^2 for A_v and 60,000 psi for f_y.

$$\begin{aligned} N_s &= \frac{45 \times 17 \times 33.6}{0.22 \times 60,000} + 1 \\ &= 2.95 \text{stirrups} \\ &\approx 3 \text{stirrups} \end{aligned}$$

Find the new required spacing at the 0.75*d* at the end of the cut bars.

$$\begin{aligned} \text{Stirrups required} &= \frac{25.2}{15} \\ &= 1.68 \text{stirrups} \end{aligned}$$

Thus, the total number of stirrups required is:

$$\begin{aligned} \text{Total stirrups} &= 3 + 1.68 \\ &= 4.68 \text{stirrups} \end{aligned}$$

Find the new spacing using the relation.

$$\begin{aligned} \text{New } s &= \frac{25.2}{4.68} \\ &= 5.38 \text{in.} \\ &\approx 5 \text{in.} \end{aligned}$$

Thus, privide the spacing for the stirrups as 5 in.

Comment

Step 18 of 18

Show the stirrup details as in Figure (3).

Comment

Was this solution helpful?

Recommended solutions for you in Chapter 5

Chapter 5, Problem 6P

For the following problem, unless otherwise noted, concrete is normal weight and steel is uncoated grade 60 (fy= 60,000 psi).The tension bars in the beam shown are to be terminated. Assuming wall are No. 9 at 7 in. o.c. and are to be lap...

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