

Reinforced Concrete | (6th Edition)

Chapter 6, Problem 8P

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Problem

The beam shown in Fig. P6-8 supports the unfactored loads shown. The dead load includes the weight of the beam.

- Draw shearing-force diagrams for
 - factored dead and live load on the entire beam;
 - factored dead load on the entire beam plus factored live load on the left half-span; and
 - factored dead load on the entire beam plus factored live load on the right half-span.
- Superimpose the diagrams to get a shear-force envelope. Compare the shear at mid span to that from Eq. (6-26).
- Design stirrups. Use $f'_c = 4500$ psi and No. 3 double-leg stirrups with $f_y = 40,000$ psi.

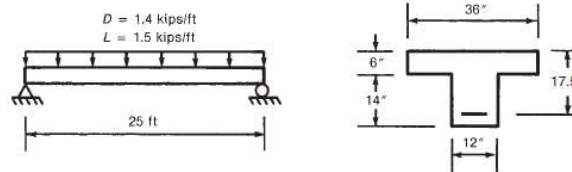


Fig. P6-8

Reference: Eq. (6-26):

$$V_u = w_{Lu} \ell_n / 8$$

Step-by-step solution

Step 1 of 16

a)

Case (1):

Calculate the factored uniform dead load using the formula,

$$w_{Du} = 1.2 \times D$$

Here, the uniform dead load is D .Substitute 1.4 kips/ft for D .

$$\begin{aligned} w_{Du} &= 1.2 \times 1.4 \\ &= 1.68 \text{ kips/ft} \end{aligned}$$

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Step 2 of 16

Calculate the factored live load.

$$w_{Lu} = 1.6 \times L$$

Here, the uniform live load is L .Substitute 1.5 kips/ft for L .

$$\begin{aligned} w_{Lu} &= 1.6 \times 1.5 \\ &= 2.4 \text{ kips/ft} \end{aligned}$$

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Calculate the total factored uniform load.

$$w_u = w_{Du} + w_{Lu}$$

Substitute 1.68 kips/ft for w_{Du} and 2.4 kips/ft for w_{Lu} .

$$\begin{aligned} w_u &= 1.68 + 2.4 \\ &= 4.08 \text{ kips/ft} \end{aligned}$$

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Step 4 of 16

Calculate shear force at the ends using the following formula:

$$\text{Shear force at the ends} = \pm \frac{w_u \times l_n}{2}$$

Here, the length of the span is l_n .

Substitute 4.08 kips/ft for w_u and 25 ft for l_n .

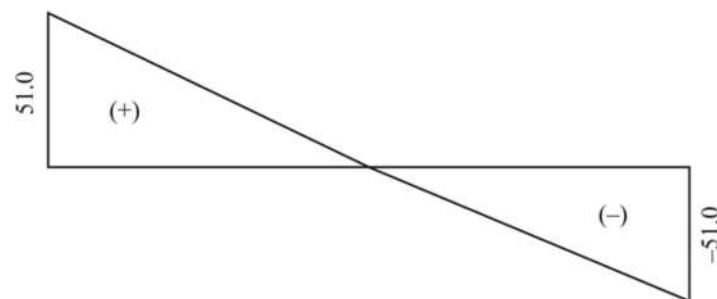
$$\begin{aligned} \text{Shear force at the ends} &= \pm \frac{4.08 \times 25}{2} \\ &= \pm 51 \text{ kips} \end{aligned}$$

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Step 5 of 16

Show the shear force diagram for factored dead load and live load on the entire beam.

V_u , kips

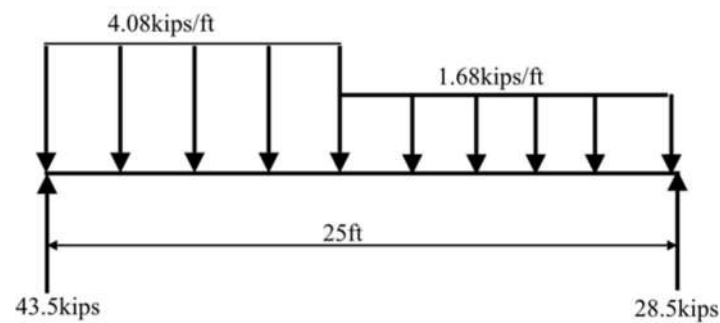


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Step 6 of 16

Case (2):

Draw the loading diagram to second case:



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Consider the right support.

Calculate shear force at the right support.

$$V_u = \frac{1.68 \times \frac{25^2}{2} + 2.4 \times \frac{12.5^2}{2}}{25}$$

$$= 28.5 \text{ kips}$$

Consider left support.

Calculate shear force at the left support.

$$V_u = 1.68 \times 25 + 2.4 \times 12.5 - 28.5$$

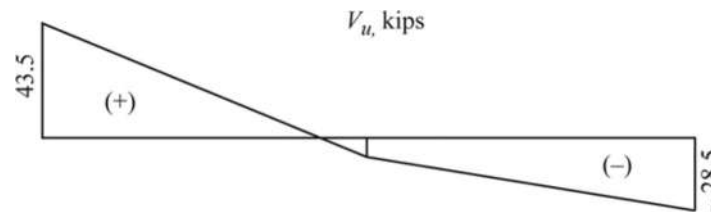
$$= 43.5 \text{ kips}$$

Calculate shear force at mid span using the formula:

$$V_u = 43.5 - (1.68 + 2.4) \times 12.5$$

$$= -7.5 \text{ kips}$$

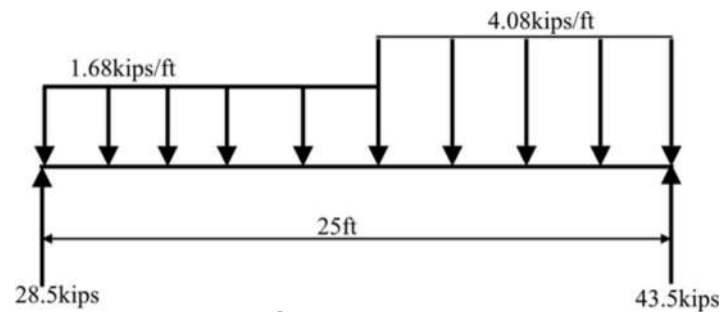
Show the shear force diagram for factored dead load on entire span and live load on left half of span.



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Step 8 of 16

Draw the loading diagram to third case.

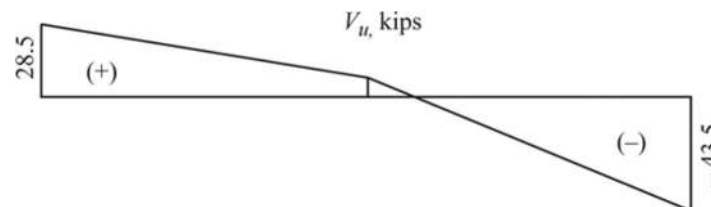


Case (3):

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Step 9 of 16

Draw the shear force diagram for case (3).



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Step 10 of 16

$$V_{u, \text{midspan}} = \pm \frac{w_{L_u} \times l_u}{8}$$

Substitute 2.4 kips/ft for w_u and 25 ft for l_u .

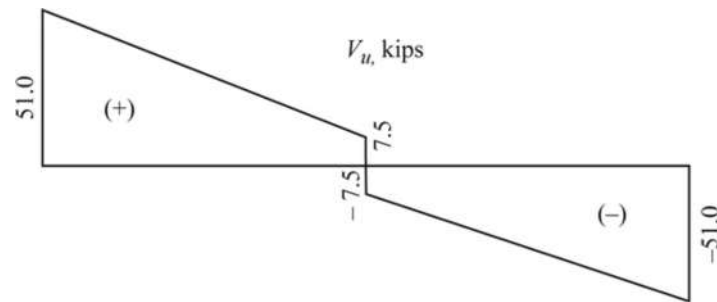
$$\begin{aligned} \text{Shear force at the midspan} &= \pm \frac{2.4 \times 25}{8} \\ &= \pm 7.5 \text{ kips} \end{aligned}$$

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Step 11 of 16

Super impose the three shear force diagrams.

Draw the shear force envelope.



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Step 12 of 16

Calculate mid span shear force with strength reduction factor using the formula.

$$\text{shear force envelope} = \frac{V_u}{\phi}$$

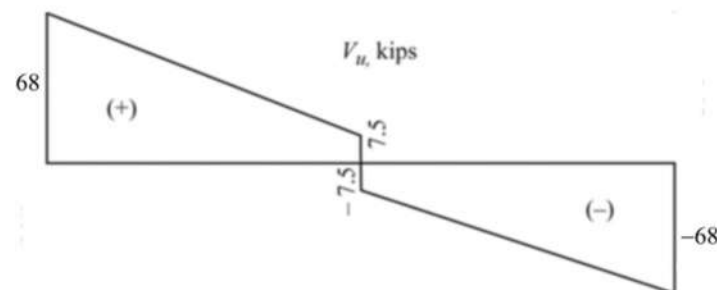
Here, V_u is factored shear force and ϕ is strength reduction factor.

Substitute ± 7.5 kips for V_u , 0.75 for ϕ .

$$\begin{aligned} \text{Mid span shear force envelope} &= \pm \frac{7.5}{0.75} \\ &= \pm 10 \text{ kips} \end{aligned}$$

Similarly use this procedure to calculate end span shear force with strength reduction factor and the value is 68 kips.

Draw the shear-force with strength reduction factor.



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Step 13 of 16

c)

Calculate nominal shear force carried by concrete V_c using the formula.

effective depth is b_w .

Substitute 4,500 ksi for f'_c , 12 in. for b_w , and 17.5 in. for d .

$$V_c = 2\sqrt{4,500} \times 12 \times 17.5 \\ = 28.17 \text{ kip}$$

As the value of V_c is less than the value of $\frac{V_u}{\phi}$, the stirrups are required.

Check stirrup anchorage.

Use No.3 Grade 40 stirrups ACI code Sec.12.13.2.1. allows these to be anchored by a hook around a top bar.

Check the maximum spacing .

$$\frac{V_u}{\phi} < 6\sqrt{f'_c} \times b_w \times d$$

Substitute 33 for $\frac{V_u}{\phi}$, 4,500 psi for f'_c , 12 in. for b_w , and 17.5 in. for d .

$$33 < 6\sqrt{4,500} \times 12 \times 17.5 \\ 33 < 84.52 \text{ kips}$$

Hence, the maximum spacing of $\frac{d}{4}$ would not be sufficient.

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Step 14 of 16

Calculate maximum spacing.

$$s_{\max} = \frac{d}{2}$$

Substitute 17.5 in. for d .

$$s_{\max} = \frac{21.5}{2} \\ = 10.75 \text{ in.}$$

[Comments \(1\)](#)

Step 15 of 16

Calculate spacing to resist the shear force using the formula,

$$s = \frac{A_v \times f_{yt}}{0.75\sqrt{f'_c} \times b_w}$$

Here, the area of shear reinforcement within a distance s is A_v and the specified yield tensile strength of non pre-stressed reinforcement is f_{yt} .

Obtain the value of A_v from U.S rebar size chart No. 3 stirrups.

Substitute 0.22 in.² for A_v , 40,000 psi for f_{yt} , 4,500 psi for f'_c , and 12 in. for b_w .

$$s = \frac{0.22 \times 40,000}{0.75\sqrt{4,500} \times 12} \\ = 14.6 \text{ in.} < s_{\max}$$

Hence, use spacing of 4 in. to resist shear force effectively.

Use No.3 double-leg stirrups at a spacing of 4in. near the support with the first stirrup placed at 2 in. from the face of the support.

Consider stirrup spacing of 6in. for placing of stirrups.

Calculate nominal shear strength provided by shear reinforcement V_s using the formula.

$$V_s = \frac{A_v \times f_{yt} \times d}{s}$$

Here, the specified yield tensile strength of nonpre-stressed reinforcement is f_{yt} and the spacing of shear reinforcement measured along the longitudinal axis of the structured member is s .

Substitute 0.22 in.² for A_v because of double legged stirrups, 40 kips for f_{yt} , 17.5 in. for d ,

$$= 25.6 \text{ kips}$$

Calculate nominal shear strength using the following formula:

$$\frac{V_n}{\phi} = V_c + V_s$$

Substitute 28.17 in. for V_c and 25.6 in. for V_s .

$$\begin{aligned} \frac{V_n}{\phi} &= 28.17 + 25.6 \\ &= 53.77 \text{ kips} \end{aligned}$$

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Step 16 of 16

Calculate the distance where nominal shear strength occurs.

$$\begin{aligned} x &= \frac{68 - 53.77}{68 - 10} \times (12.5 \text{ ft} \times 12 \text{ in. / ft}) \\ &= 53.08 \text{ in.} \end{aligned}$$

Therefore, the nominal shear stress of 53.77 kips occurs at a distance of 36.80 in. at a stirrup spacing of 6 in.

Similarly, use this procedure to calculate stirrup spacing and distance at which nominal shear strength occurs; for 8 in. space, the nominal shear stress is 47.47 kips and this would occur at a distance of 53.09 in..

Terminate stirrups when $\frac{V_n}{\phi} = \frac{V_c}{2} = 14.085 \text{ kips}$ and this strength would occur at a distance of 139 in., and this can be found out by substituting 14.085 kips for V_s in the above-mentioned procedure.

Calculate the number of stirrup required.

From the center of the support, use One No.3 Grade 40 stirrups at the spacing of 2 in..

Calculate required number of stirrups at the spacing of 4 in..

$$\begin{aligned} \text{No. of stirrups at the spacing of 4 in.} &= \frac{36.80 - 2}{4} \\ &= 8.7 \end{aligned}$$

Therefore, use 9 No.3 Grade 40 stirrups at the spacing of 4 in.

Calculate required number of stirrups at the spacing of 6 in..

$$\begin{aligned} \text{No. of stirrups at the spacing of 4 in.} &= \frac{53.09 - (2 + 9 \times 4)}{6} \\ &= 2.515 \end{aligned}$$

Here, the previous stirrup number is subtracted because the space is considered from the center of the support.

Therefore, use Three No.3 Grade 40 stirrups at the spacing of 6 in.

Similarly, use this procedure to calculate for 8 in. space and use Ten No.3 Grade 40 stirrups at the spacing of 8 in.

Hence, Use No.3 Grade 40U and Stirrups starting from the center of the support, use

One No.3 at 2 in., Nine No.3 at 4 in., Three No.3 at 6 in., and Ten No.3 at 8 in..

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