CORRECTION OF BEAM MOMENT AT FACE OF SUPPORTS

- This makes the design for negative moments considerably economical, as the drop of moments near a support is usually very sudden.
- A typical moment diagram / envelop shown in Fig. 10.57 can be used to carry out this type of correction.

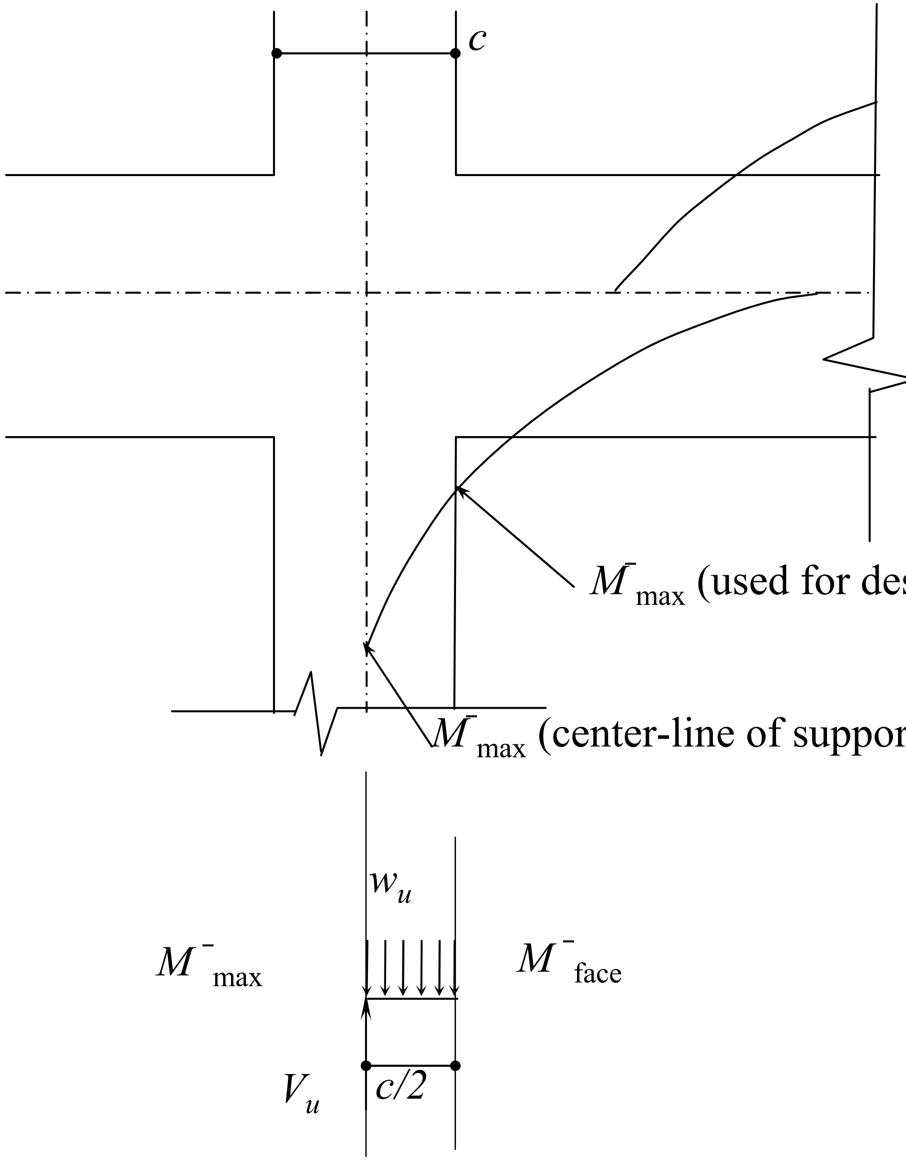


Fig. 10.57. Moment Envelope Near Beam Joint With Column.

Considering V_u approximately equal to $w_u \ell/2$,

$$M^-_{face} = M^-_{\max} - w_u\left(\frac{c\ell}{4}\right) + w_u\left(\frac{c^2}{8}\right)$$

The term $\frac{w_u c^2}{8}$ is relatively small and may be neglected to get the following reduced expression for moment at the face of support:

$$M^-_{face} = M^-_{\text{center-line}} - \frac{V_u c}{2}$$

Some designers prefer to approximately include the effect of third positive term in the expression by reducing the value of the negative term reasonably as under:

$$M^{-}_{face} = M^{-}_{\text{center-line}} - \frac{V_u c}{3}$$

MOMENT ENVELOPE

If bending moment diagrams are plotted for each load combination and load pattern on one diagram, the outline of these diagrams represents the design moment diagram and is called a moment envelope.

For plotting moment envelope the number of individual bending moment diagrams depends on the number of load combinations, number of directions in which horizontal loads may act and the number of pattern loads to be considered.

Similarly a shear envelope may also be plotted.

TWO-CYCLE MOMENT DISTRIBUTION

- At the time of initial proportioning of the members, the member sizes are not available.
- In the absence of member stiffness, the exact analysis for loads becomes impossible.
- In order to speed up the process of determining the trial sizes, the stiffness ratios may be assumed and approximate and quick analysis may be performed.
- For gravity loads, one of the approximate methods is the two-cycle moment distribution.
- The major steps involved in this method are listed below:

- Assume the stiffness of each member meeting at a joint to be equal. The stiffness of members is not known for the preliminary design.
- Calculate distribution factors for the members accordingly.
- The 2-cycle moment distribution is equal to performing ordinary moment distribution for a total of 2 cycles and then terminating the analysis.
- It is used to find moment at a single required joint out of a big frame.

- Apply fixed end moments at the joint under consideration and the joints adjacent to it.
- Unlock the joints adjacent to the joint under consideration.
- Calculate balancing moments and distribute into the members.
- Carry-over these moments to the joint under consideration.
- Re-lock the adjacent joints.
- Sum up the moments at the joint.

- Unlock the joint of interest.
- Apply balancing moment and distribute into the members.
- Sum up the moments again.
- For fixed end moments on the joints, use moments acting from the members on the joints, counter-clockwise positive.

Example 1.1: Calculate the bending moment at point B for the given continuous beam for initial proportioning. The span lengths and the loading are shown in Fig. 1.5.

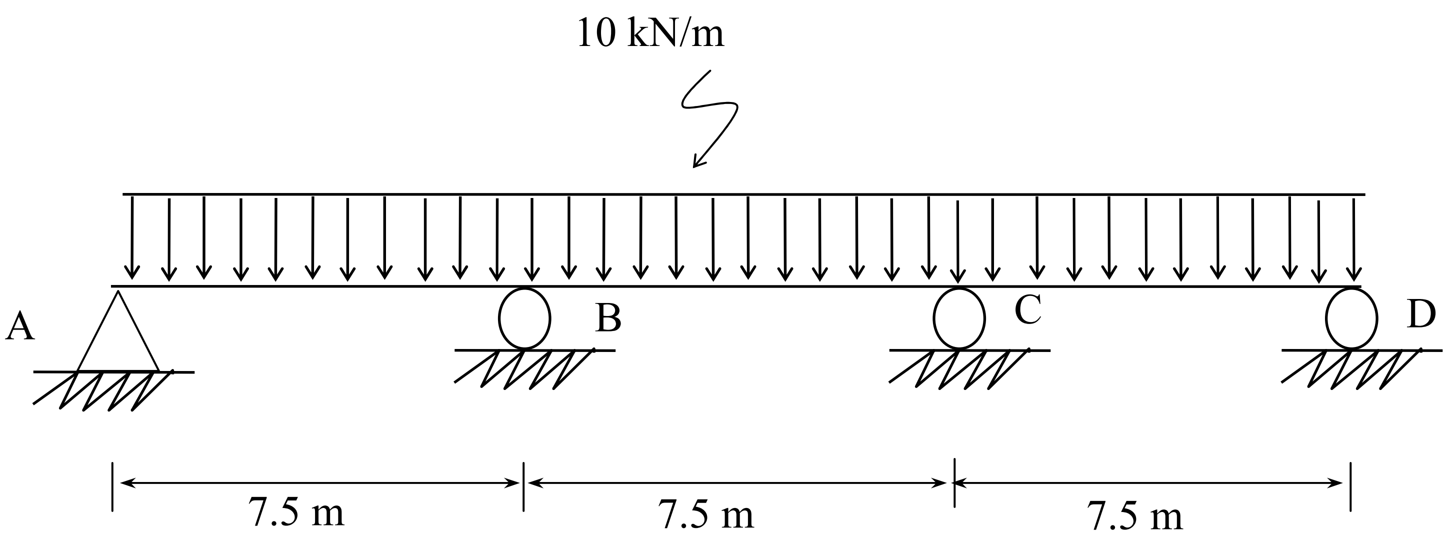


Fig. 1.5. Continuous Beam For Approximate Analysis.

The fixed end moment for each beam segment is calculated as follows:

$$M_F = \frac{w\ell^2}{12} = \frac{10 \times 7.5^2}{12} = 46.88 \text{ kN-m}$$

For the moments acting on the joints, counter-clockwise direction may be considered positive. This corresponds to clockwise moments acting on the members from the joints being positive (Fig. 1.6).

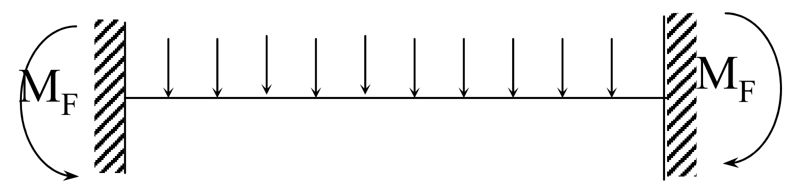


Fig. 1.6. Fixed End Moment For a Beam Segment Having UDL.

	1	½	½	½	½
F.E.M.	−46.88	+46.88	−46.88	+46.88	−46.88
Balancing & Distribution	+46.88			0	0
C.O.		+23.44	0		
Sum		+70.32	−46.88		
Balancing & Distribution		−11.72	−11.72		
Sum		+58.60	−58.60		

Fig. 1.7. Two-Cycle Moment Distribution.

- From the two-cycle moment distribution, as shown in Fig. 1.7, it is clear that the approximate moment at joint B will be 58.60 kN-m.
- Considering actual stiffness after actual beam design, where the central panel may be less stiff, the difference between the actual and approximate results is not more than 5 to 10 percent.

PORTAL FRAME METHOD FOR LATERAL LOADS

The approximate method that may be used for the approximate analysis of frames for the lateral loads is called portal frame method.

The salient features of this method are explained below:

- This method gives good results for moderate-rise buildings.

- Assume inflection points at column mid-heights and at beam mid-spans.
- Assume horizontal shear of each column equal to the total horizontal story-shear distributed proportional to its tributary area.
- For example, if adjacent spans are equal, interior columns carry twice the shear than the exterior columns.
- Consider this shear to be acting at the mid-height or inflection points level.
- Due to column shear at the level of the inflection points, find the moments in the columns at the beam level.

- Start calculating the beam moments from one end to maintain joint equilibrium.

Example 1.2: Find moments and shear for the frame, shown in Fig. 1.8, using the Portal Frame Method. The frames are on 6m centers.

Wind pressure	= 700 Pa
Half height	= 2 m
C/C distance of frames	= 6 m

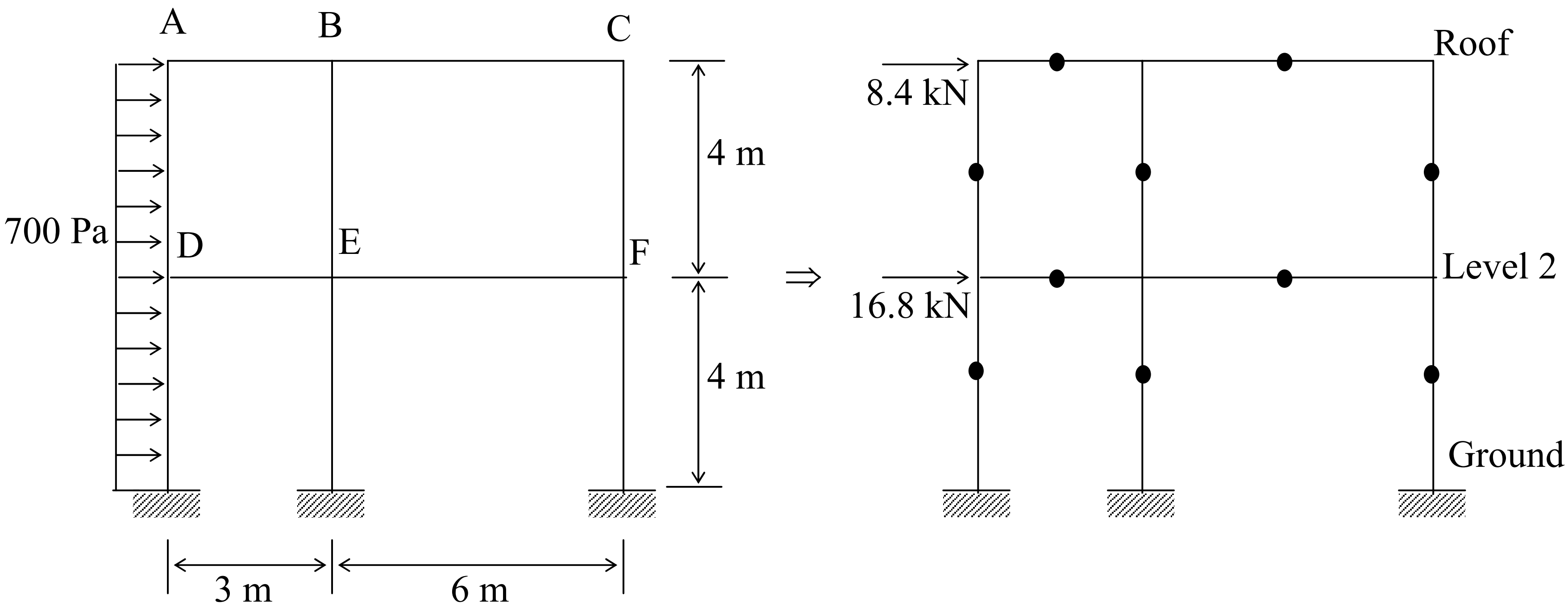
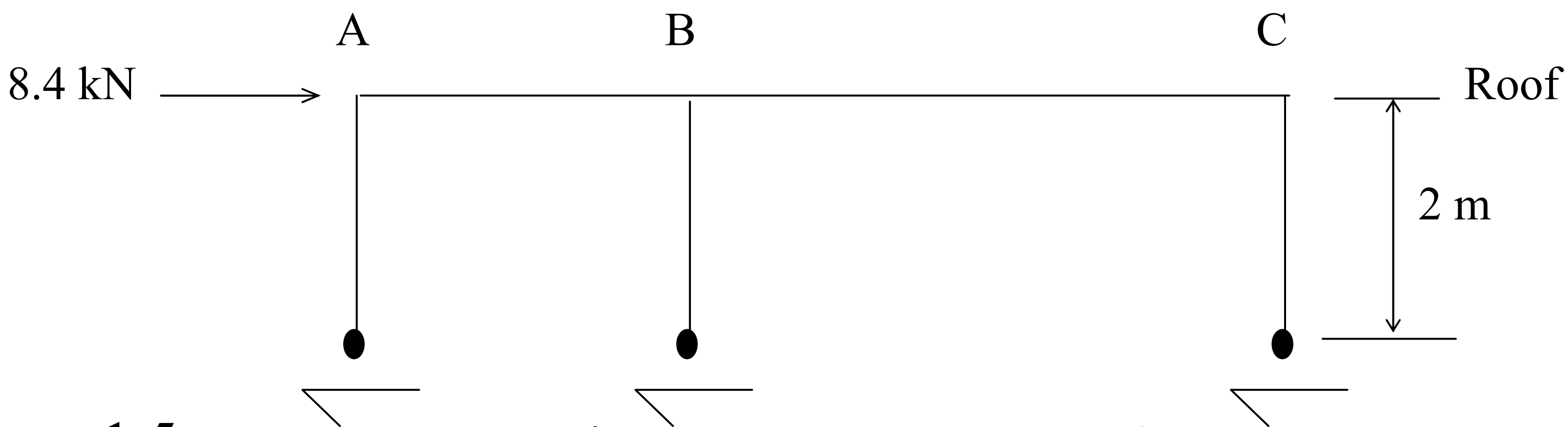


Fig. 1.8. Data And Position Of Inflection Points For Example 1.2.

Solution:

$$\text{Wind load on roof} = \frac{(700)(2)(6)}{1000} = 8.4\ \text{kN}$$

$$\text{Wind load on level-2} = 2 \times 8.4 = 16.8\ \text{kN}$$



$$\frac{1.5}{9}(8.4) = 1.4 \qquad \frac{4.5}{9}(8.4) = 4.2\ \text{kN} \qquad \frac{3}{9}(8.4) = 2.8\ \text{kN}$$

Fig. 1.9. Columns Shears For Upper Floor.

The column moments may be calculated from the column shears, given in Fig. 1.9, as follows:

$$\text{Column moment at A} = 2(1.4) = 8.8\ \text{kN-m}$$
$$\text{Column moment at B} = 2(4.2) = 8.4\ \text{kN-m}$$
$$\text{Column moment at C} = 2(2.8) = 5.6\ \text{kN-m}$$

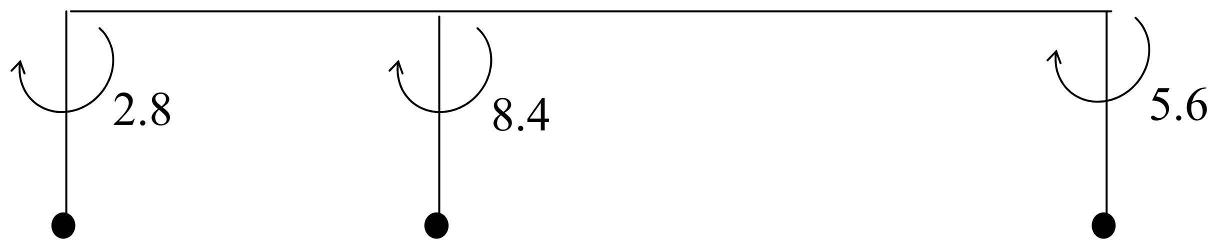


Fig. 1.9. Columns Moments For Upper Floor.

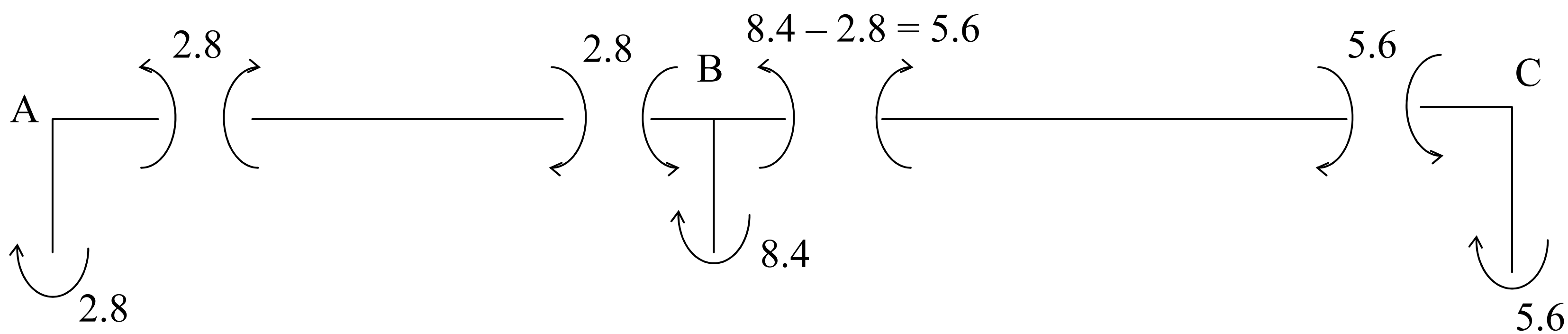
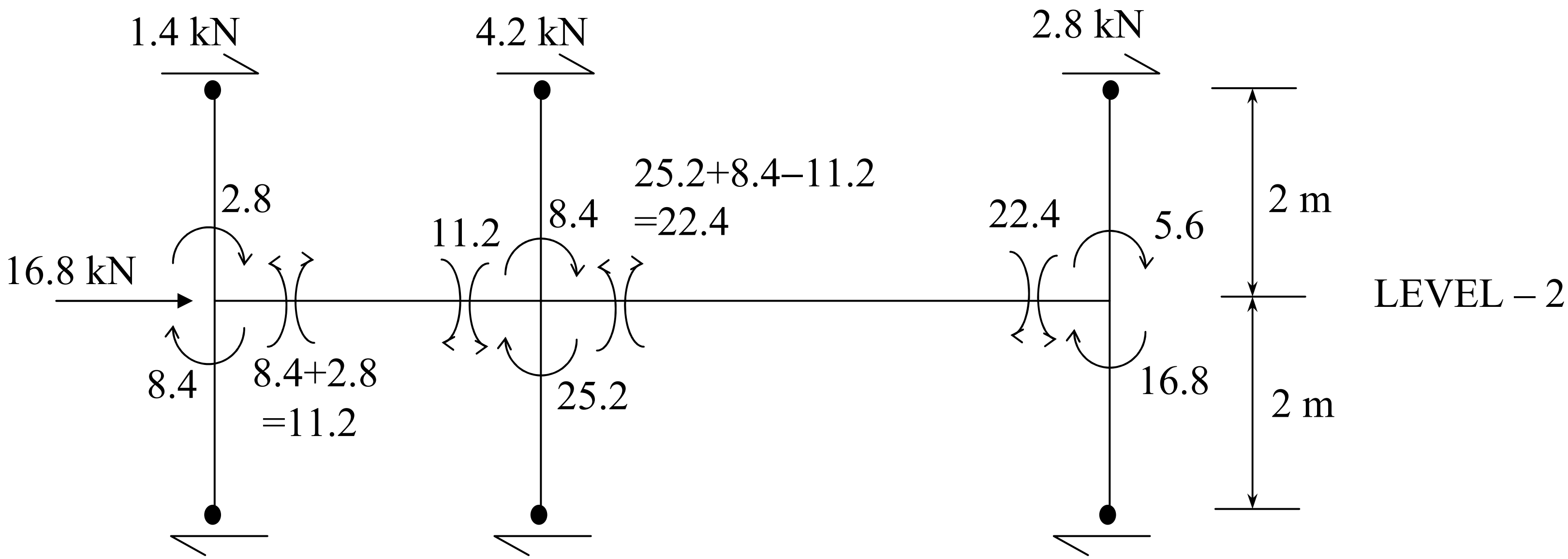


Fig. 1.10. Calculation of Beam Moments For Upper Floor.

- Same clockwise-counterclockwise direction is transferred from A-end of member AB to its B-end in Fig. 1.10, as there is no other load acting in-between.
- The sagging-hogging sense of moment changes from A-end to B-end due to presence of shears at the ends in order to get inflection point at mid-span.
- In this figure, moments near the joints are the moments applied by the members on the joints and the joint reactions are shown away from the joints.

Total shear for the lower floor = 16.8 + 8.4 = 25.2 kN



$$\frac{1.5}{9}(25.2) = 4.2 \qquad \frac{4.5}{9}(25.2) = 12.6 \text{ kN} \qquad \frac{3}{9}(25.2) = 8.4 \text{ kN}$$

Fig. 1.11. Calculation of Shears And Moments For Lower Floor.

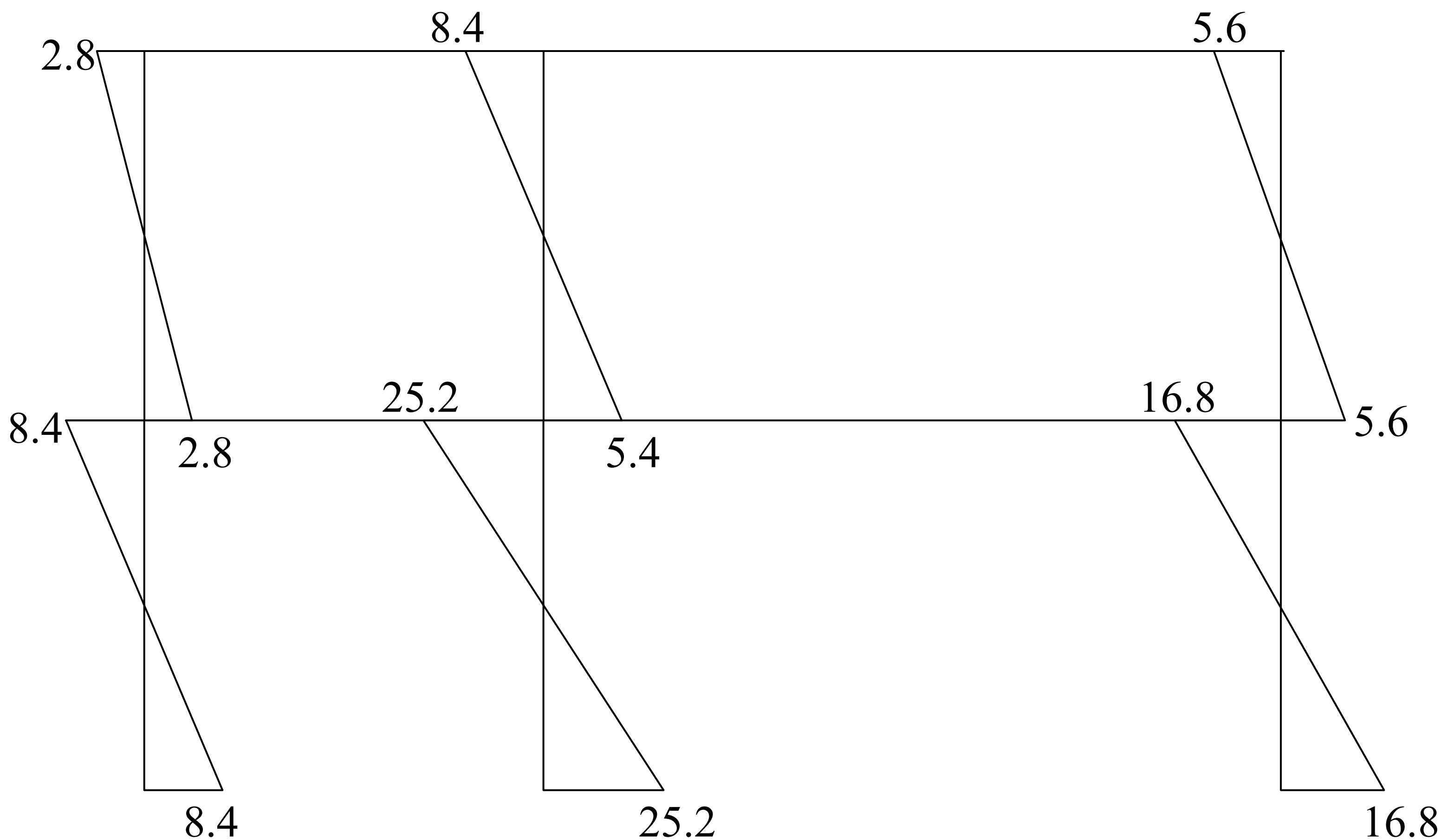


Fig. 1.12. Bending Moment Diagram For Columns.

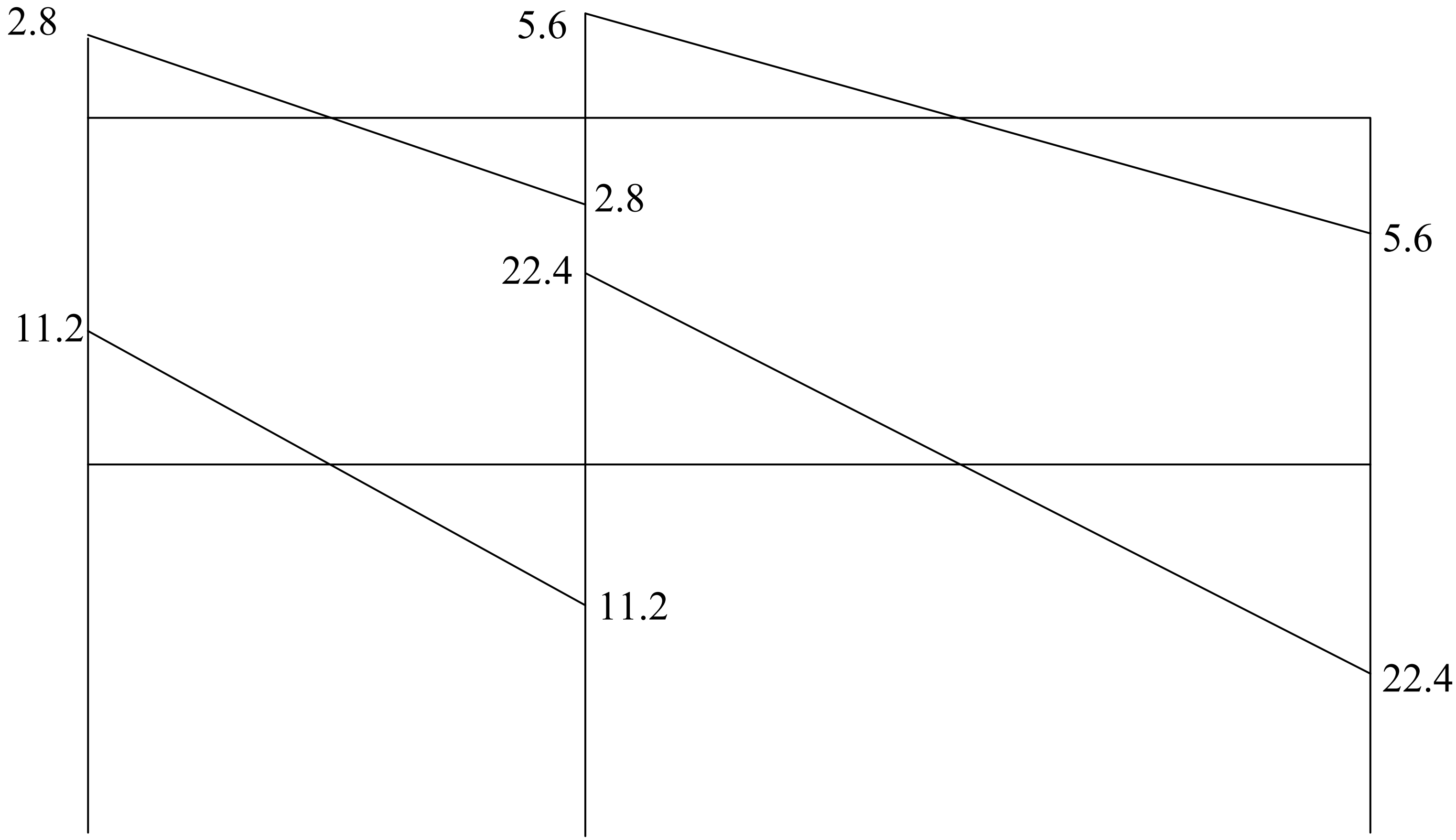
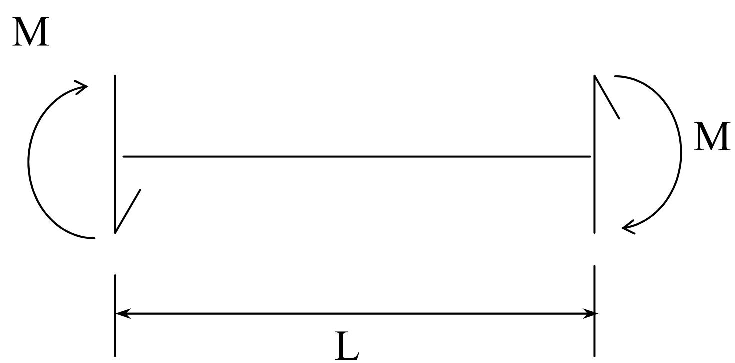


Fig. 1.13. Bending Moment Diagram For Beams.

The shear force for the beams may be calculated from the two end moments using the procedure given below for a typical segment:



$$V = \frac{2M}{L}$$

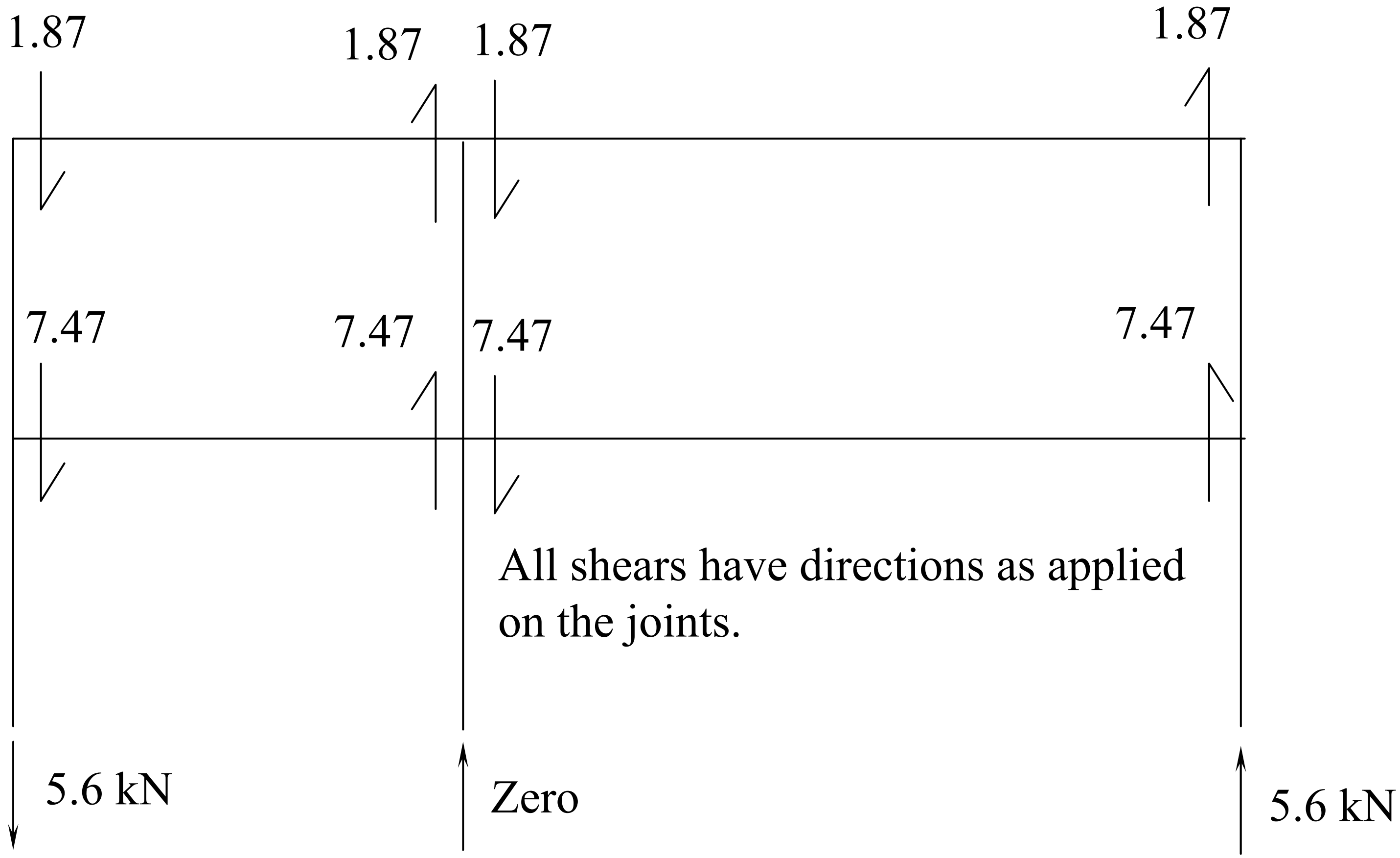


Fig. 1.14. Shear Force Diagram For Columns.

- The elastic curve for the lateral loads is shown in Fig. 1.15.
- This tells us the information about sagging and hogging in the beams.
- The windward side is subjected to sagging or positive moment and the leeward side of each member is subjected to hogging or negative bending moment.

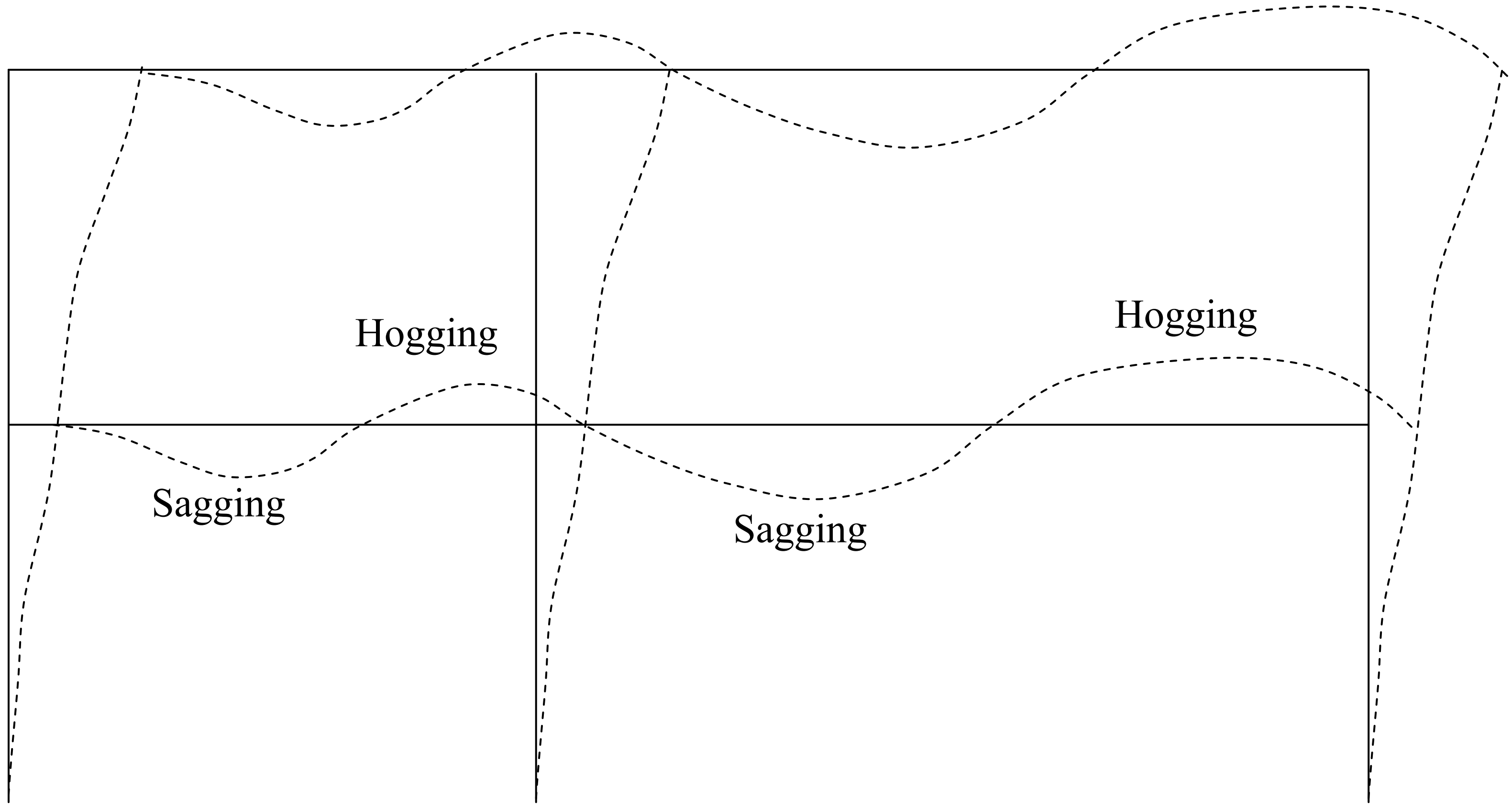
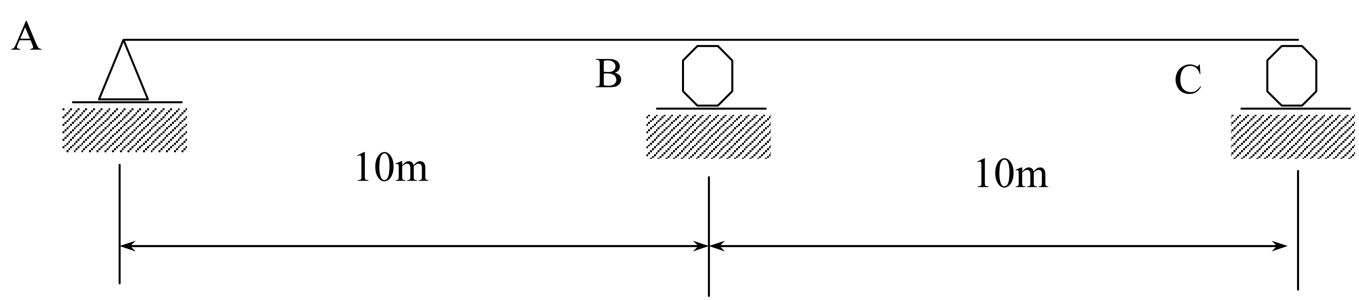


Fig. 1.15. Approximate Elastic Curve Diagram For The Frame Due to Wind Load Showing Sense of Bending.

Example 10.16: Plot shear and moment envelopes for the two span continuous beam shown in Fig. 10.58. The beam is subjected only to dead and live loads having magnitudes given in the figure. Assume $EI_{AB} = EI_{BC}$.



$w_{DL} = 10$ kN/m $\qquad w_{LL} = 20$ kN/m

Fig. 10.58. Two-Span Continuous Beam of Example 10.16.

Solution:

LOAD CASE - I (Total load on both spans)

The loads for this case are shown in Fig. 10.59.

Our first purpose of analysis is to calculate moment at support-B to make the beam determinate.

The calculations are carried out as under and the free body diagrams of the two spans are shown in Fig. 10.60:

$$
\begin{aligned}
w_u &= 1.2\, w_{DL} + 1.6\, w_{LL} \\
&= 1.2\times 10 + 1.6\times 20 \\
&= 44 \text{ kN/m}
\end{aligned}
$$

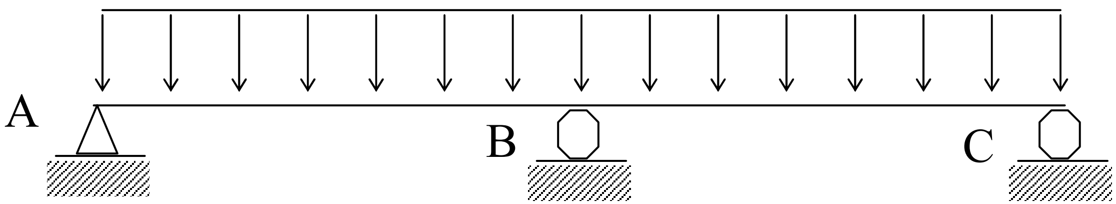


Fig. 10.59. Loading of Case-1 for Beam of Example 10.16.

$$
\text{F.E.M.} = \frac{(44)(10)^2}{12} = 366.67 \text{ kN-m}
$$

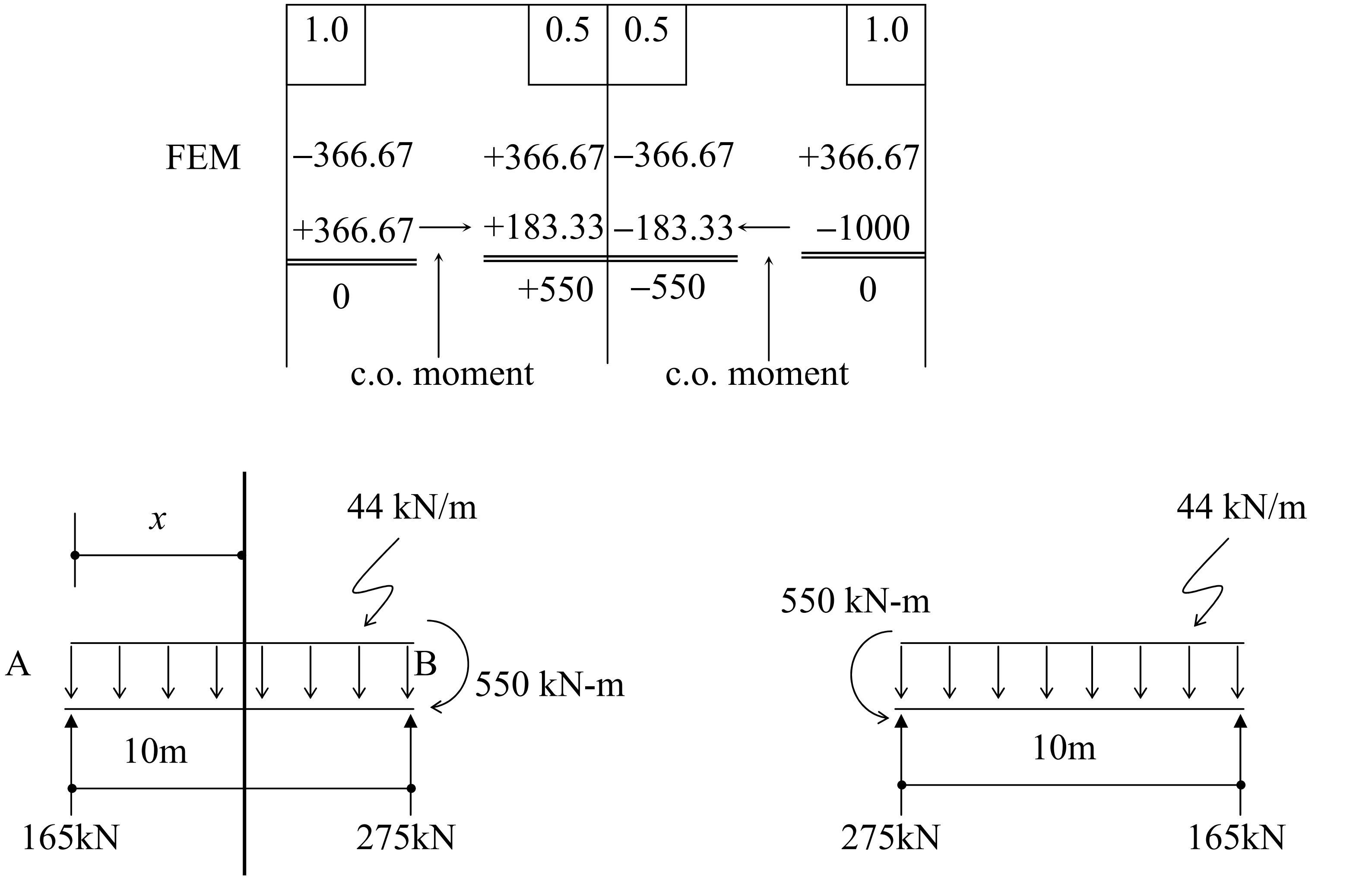
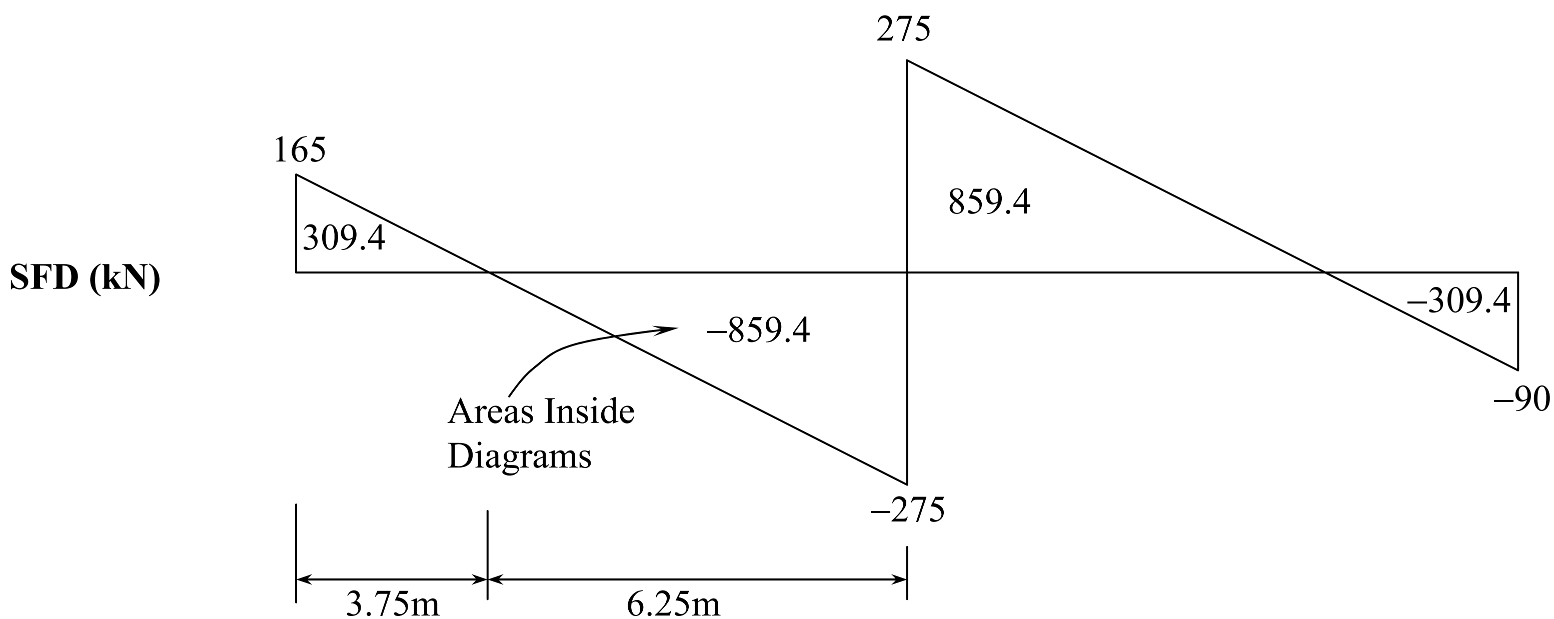


Fig. 10.60. Free Body Diagrams For Beam of Example 10.16.

From Fig. 10.60, $V_x = 165 - 44\,x$ and $M_x = 165\,x - 22\,x^2$

The shear force and bending moment diagrams are given in Fig. 10.61.



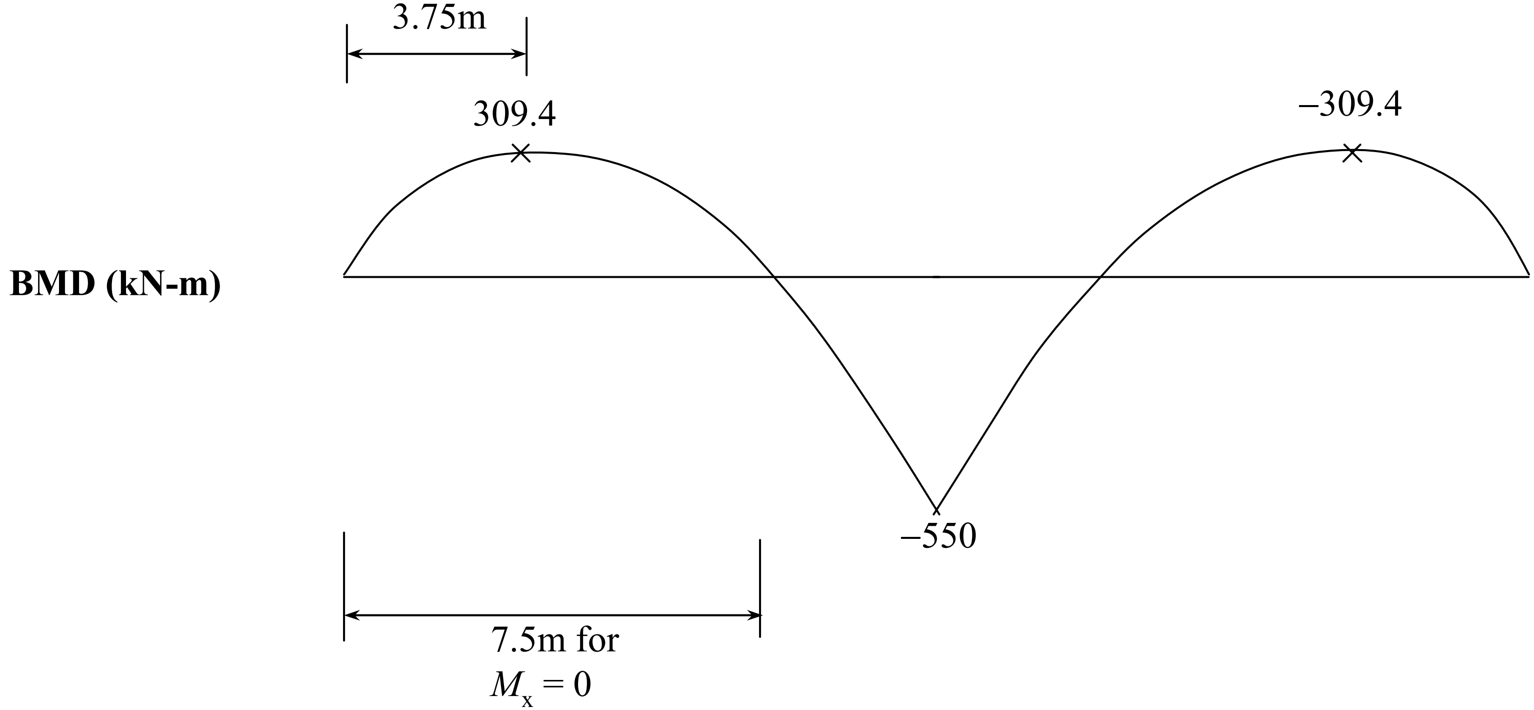


Fig. 10.61. SF and BM Diagrams for Case-I of Example 10.16.

LOAD CASE - II (Total load on left span and dead load on right span)

The loading, calculations and free body diagrams of the two spans are given in Fig. 10.62.

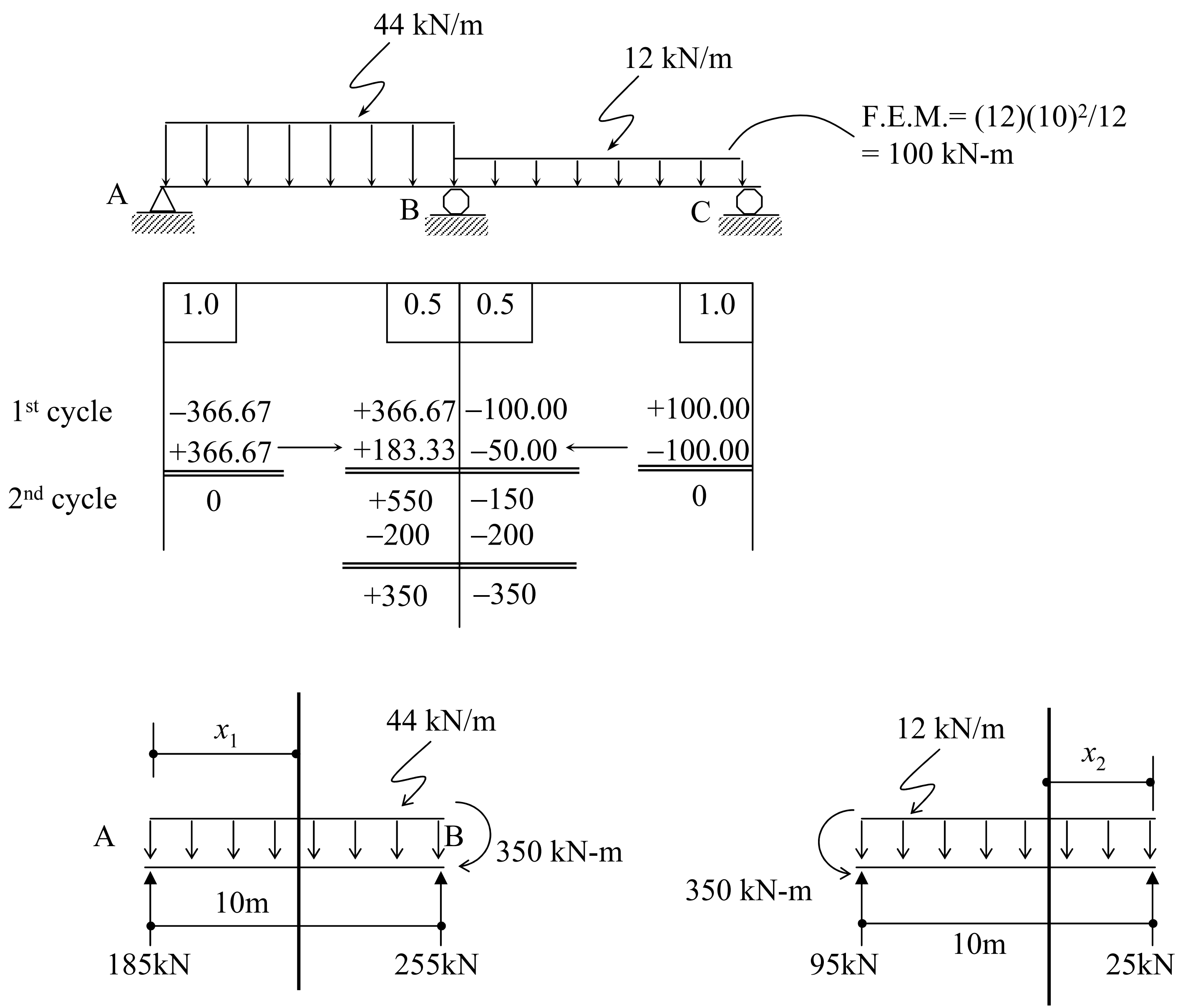


Fig. 10.62. Solution of Example 10.16 For Case-II.

The shear force and bending moment at various sections can be obtained from the following expressions:

$$V_{x1} = 185 - 44\,x_1 \qquad \text{and} \qquad M_{x1} = 185\,x_1 - 22\,x_1^{\,2}$$

$$V_{x2} = 25 - 12\,x_2 \qquad \text{and} \qquad M_{x2} = 25\,x - 6\,x_2^{\,2}$$

The resulting shear force and bending moment diagrams are sketched in Fig. 10.63.

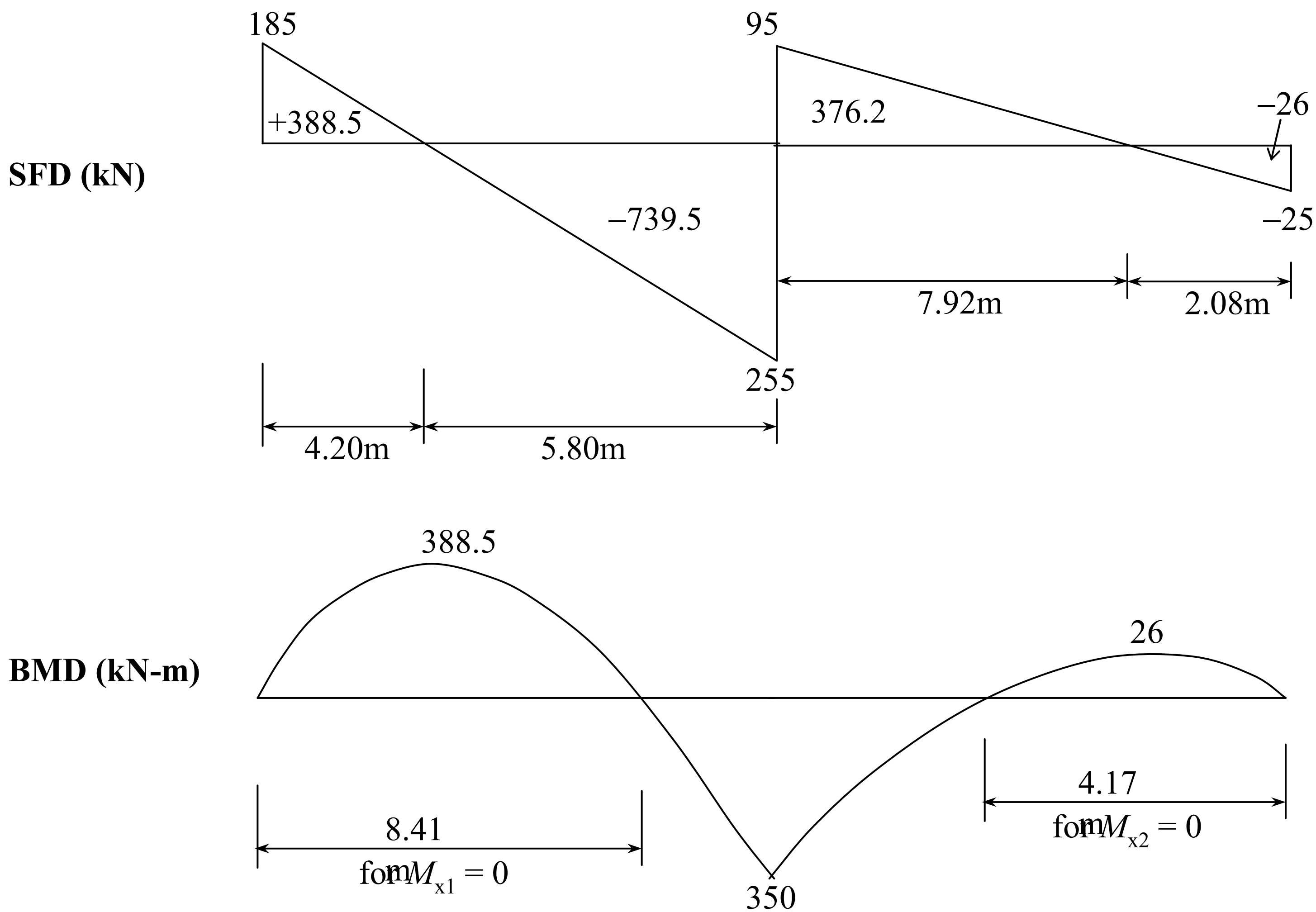


Fig. 10.63. SF and BM Diagrams for Case-II of Example 10.16.

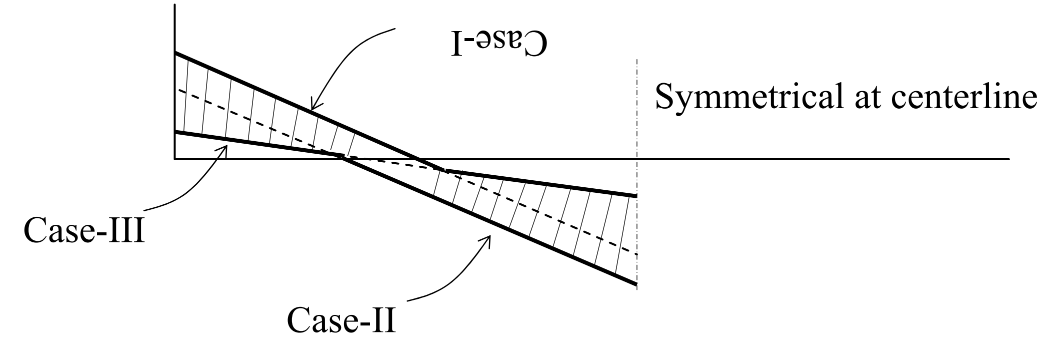
LOAD CASE - III (Total load on right span and dead load on left span)

This case is identical to Case II due to symmetry of loading and the structure and hence there is no need to perform the detailed analysis once again.

SHEAR AND MOMENT ENVELOPES

The shear and moment envelopes are plotted in Fig.10.64 by superimposing the shear force diagrams and bending moment diagrams of the three cases.

Shear Envelope (kN)



Moment Envelope (kN-m)

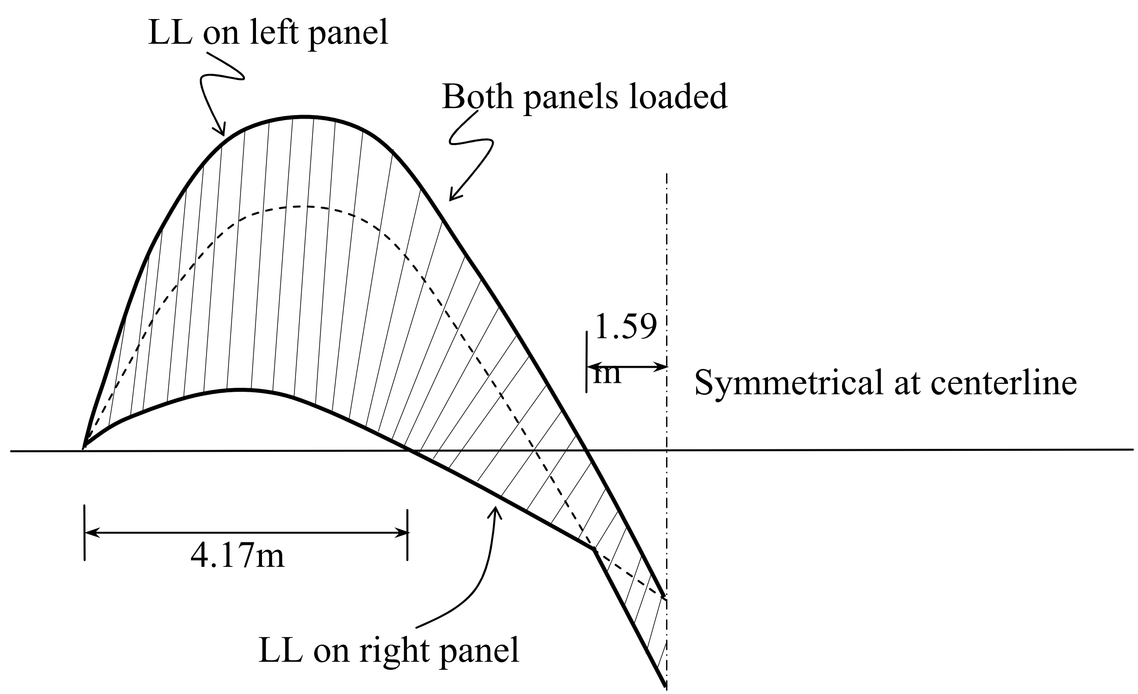


Fig. 10.64. Shear and Moment Envelopes for Beam of Example 10.16.