Module 5 : Force Method - Introduction and applications

Lecture 3 : Analysis of Statically Indeterminate Structure

Objectives

In this course you will learn the following

- Energy method for analysis of statically indeterminate structures.
- Illustrative examples for analysis of statically indetrminate structures using every method.

5.4 Analysis of Statically Indeterminate Structures by Energy Method

Let a statically indeterminate structure has degree of indeterminacy as *n* . On the selected basic determinate structure apply the unknown forces R_1, R_2 ..... and R_n . Using the Eq. (4.16) the displacement Δ_j in the direction of R_j is expressed by

$$\Delta_j = \frac{\partial U}{\partial R_j} \quad (j = 1, 2, ...n) \qquad (5.1)$$

The equations (5.1) will provide the *n* linear simultaneous equations with *n* unknowns R_1, R_2 ..... and R_n. Since the Δ_j is known, therefore, the solution of simultaneous equations will provide the desired R_j (*j* =1, 2,...., *n*).

For structures with members subjected to the axial forces only (i.e. pin-jointed structures), the equation (5.1) is re-written as

$$\Delta_j = \frac{\partial}{\partial R_j}\sum\left(\frac{P^2 L}{2AE}\right) = \sum\left(\frac{P\dfrac{\partial P}{\partial R_j}L}{AE}\right) \qquad (5.2)$$

where *P* is the force in the member due to applied loading and unknown R_j (*j* =1, 2,...., *n*); and *L* and *AE* are length and axial rigidity of the member, respectively.

For structures with members subjected to the bending moments (i.e. beams and rigid-jointed frames), the equation (5.1) is re-written as

$$\Delta_j = \frac{\partial}{\partial R_j}\left(\int\frac{M^2 dx}{2EI}\right) = \int\frac{M\dfrac{\partial M}{\partial R_j}dx}{EI} \qquad (5.3)$$

where *M* is the bending moment due to applied loading and unknown R_j (*j* =1, 2,...., *n*) at a small element of length *dx* ; and *EI* is the flexural rigidity.

Example 5.14 A beam is suspended by three springs as shown in Figure 5.17(a). The flexibility of the springs *AD* , *BE* and *CF* are f_1, f_2 and f_3 respectively. The beam carries a load *W* at the middle of *DE*. Determine the force in the spring *BE* assuming (i) the beam to be stiff in comparison to the springs and (ii) flexible with flexural rigidity *EI* .

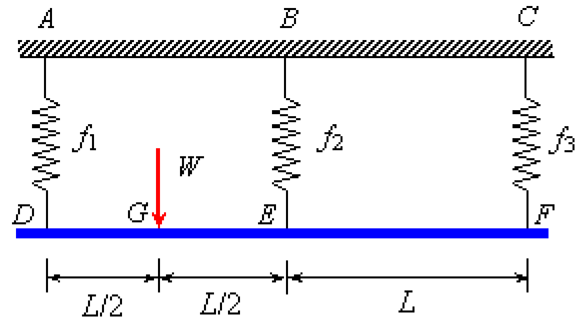


Figure 5.17(a)

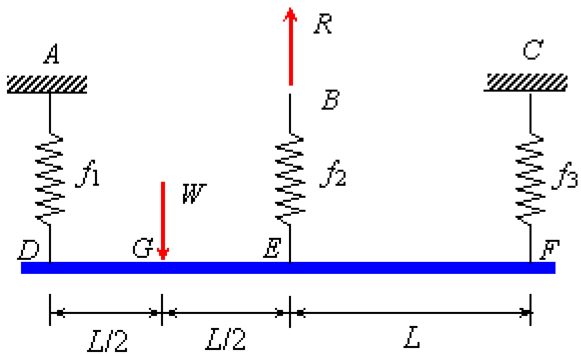


Figure 5.17(b)

Solution: The degree of static indeterminacy = 3–2 = 1. Let the force in the spring *BE* be *R* as shown in Figure 5.17(b). Taking moment about point *F* , we have

$$F_{AD} \times 2L = W \times \frac{3L}{2} - RL$$

$$\therefore \qquad F_{AD} = \frac{3W}{4} - \frac{R}{2}$$

Similarly, taking moment about point *D* , we have

$$F_{CF} \times 2L = W \times \frac{L}{2} - RL$$

$$\therefore \qquad F_{CF} = \frac{W}{4} - \frac{R}{2}$$

(i) When beam is rigid

Total energy stored in the system is due to springs only as the beam is rigid. Thus,

$$U_s = \frac{1}{2} f_1 \left(\frac{3W}{4} - \frac{R}{2} \right)^2 + \frac{1}{2} f_2 R^2 + \frac{1}{2} f_3 \left(\frac{W}{4} - \frac{R}{2} \right)^2$$

Since the displacement of point *E* is zero in the vertical direction implying that

$$\frac{\partial U_s}{\partial R} = f_1 \left(\frac{3W}{4} - \frac{R}{2} \right) \left(-\frac{1}{2} \right) + f_2 R + f_3 \left(\frac{W}{4} - \frac{R}{2} \right) \left(-\frac{1}{2} \right)$$

or $$0 = -\frac{W}{8}(3f_1 + f_3) + \frac{R}{4}(f_1 + 4f_2 + f_3)$$

$$\therefore \qquad R = \frac{W}{2}\left(\frac{3f_1 + f_3}{f_1 + 4f_2 + f_3}\right)$$

(ii) When beam is flexible

The total energy stored in the beam

$$U_b = U_{DG} + U_{GE} + U_{EF}$$

Span *DG* **:** (*x* measured from *D*)

$$M_x = \left(\frac{3W}{4} - \frac{R}{2}\right)x$$

$$\frac{\partial M_x}{\partial R} = -\frac{x}{2}$$

$$\frac{\partial U_{DG}}{\partial R} = \frac{1}{EI}\int_0^{L/2}\left[\frac{3W}{4} - \frac{R}{2}\right]\left(-\frac{x^2}{2}\right)dx = \frac{1}{EI}\left[\frac{3W}{4} - \frac{R}{2}\right]\left[\frac{-L^3}{48}\right]$$

Span *GE* **:** (*x* measured from *D*)

$$M_x = \left(\frac{3W}{4} - \frac{R}{2}\right)x - W\left(x - \frac{L}{2}\right)$$

$$\frac{\partial M_x}{\partial R} = -\frac{x}{2}$$

$$\frac{\partial U_{GE}}{\partial R} = \frac{1}{EI}\int_{L/2}^{L}\left[\left(\frac{3W}{4} - \frac{R}{2}\right)\left(-\frac{x^2}{2}\right) + W\left(x - \frac{L}{2}\right)\left(\frac{x}{2}\right)\right]dx$$

$$\frac{\partial U_{GE}}{\partial R} = \frac{1}{EI}\left[\left(\frac{3W}{4} - \frac{R}{2}\right)\left(\frac{-L^3}{6} + \frac{L^3}{48}\right) + W\left(\frac{L^3}{6} - \frac{L^3}{8} - \frac{L^3}{48} + \frac{L^3}{32}\right)\right] = \frac{1}{EI}\left[\left(\frac{3W}{4} - \frac{R}{2}\right)\left(\frac{-7L^3}{48}\right) + W\left(\frac{5L^3}{96}\right)\right]$$

Span *EF* **:** (*x* measured from *F*)

$$M_x = \left(\frac{W}{4} - \frac{R}{2}\right)x$$

$$\frac{\partial M_x}{\partial R} = -\frac{x}{2}$$

$$\frac{\partial U_{BC}}{\partial R} = \frac{1}{EI}\int_0^{L}\left[\frac{W}{4} - \frac{R}{2}\right]\left(-\frac{x^2}{2}\right)dx = \frac{1}{EI}\left[\frac{W}{4} - \frac{R}{2}\right]\left[\frac{-L^3}{6}\right]$$

Thus, $$\frac{\partial U_b}{\partial R} = \frac{\partial U_{DG}}{\partial R} + \frac{\partial U_{GE}}{\partial R} + \frac{\partial U_{EF}}{\partial R}$$

$$= \frac{1}{EI}\left[\frac{3W}{4} - \frac{R}{2}\right]\left[\frac{-L^3}{48}\right] + \frac{1}{EI}\left[\left(\frac{3W}{4} - \frac{R}{2}\right)\left(\frac{-7L^3}{48}\right) + W\left(\frac{5L^3}{96}\right)\right] + \frac{1}{EI}\left[\frac{W}{4} - \frac{R}{2}\right]\left[\frac{-L^3}{6}\right]$$

$$= \frac{1}{EI}\left[-\frac{11WL^3}{96} + \frac{RL^3}{6} \right]$$

Total strain energy in the system

$$U = U_s + U_b$$

Hence, $$\frac{\partial U}{\partial R} = \frac{\partial U_s}{\partial R} + \frac{\partial U_b}{\partial R}$$

$$= -\frac{W}{8}\left(3f_1 + f_3\right) + \frac{R}{4}\left(f_1 + 4f_2 + f_3\right) + \frac{1}{EI}\left[-\frac{11WL^3}{96} + \frac{RL^3}{6} \right]$$

Since $$\frac{\partial U}{\partial R} = 0 \Rightarrow -\frac{W}{8}\left(3f_1 + f_3\right) + \frac{R}{4}\left(f_1 + 4f_2 + f_3\right) + \frac{1}{EI}\left[-\frac{11WL^3}{96} + \frac{RL^3}{6} \right] = 0$$

$$R\left(\frac{L^3}{6EI} + \frac{f_1}{4} + f_2 + \frac{f_3}{4} \right) = W\left(\frac{11}{96}\frac{L^3}{EI} + \frac{3}{8}f_1 + \frac{f_3}{8} \right)$$

$$\therefore \; R = \frac{W\left(\frac{11}{96}\frac{L^3}{EI} + \frac{3}{8}f_1 + \frac{f_3}{8} \right)}{\left(\frac{L^3}{6EI} + \frac{f_1}{4} + f_2 + \frac{f_3}{4} \right)}$$

Example 5.15 The free ends of two cantilever beams each of length *L* and flexural rigidity *EI* are joined together with a spring as shown in Figure 5.18(a). The stiffness of the spring is EI / L^3. Determine the force in the spring due to a concentrated load *W* acting at center of the lower cantilever.

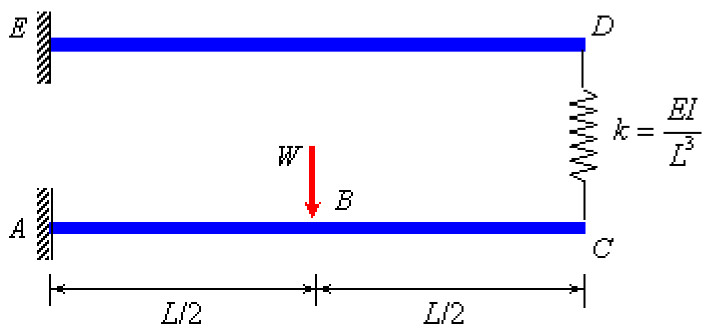


Figure 5.18(a)

Solution: Let the force in the spring be *R* as shown in Figure 5.18(b). According to the Castigliano's theorem

$$\frac{\partial U}{\partial R} = 0$$

where *U* is the total strain energy stored in the system.

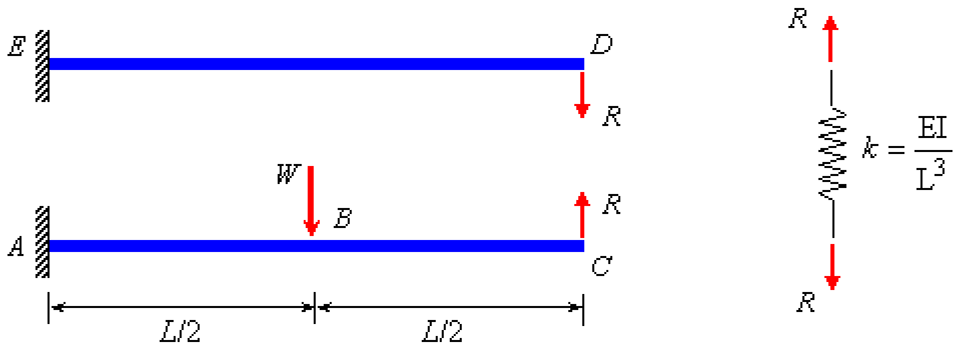


Figure 5.18(b)

Consider beam *DE* : (*x* measured from *D*),

$$M_x = -Rx \text{ and } \frac{\partial M_x}{\partial R} = -x$$

$$\frac{\partial U_{DE}}{\partial R} = \frac{1}{EI}\int_0^L M_x \frac{\partial M}{\partial R} dx = \frac{RL^3}{3EI}$$

Consider the spring,

$$\frac{\partial U_s}{\partial R} = \frac{\partial}{\partial R}\left(\frac{R^2}{2k}\right) = \frac{RL^3}{EI}$$

Consider the beam *AC* ,

$$M_x = \begin{cases} Rx & 0 < x < L/2 \text{ for part } CB \\ R(x + L/2) - Wx & 0 < x < L/2 \text{ for part } AB \end{cases}$$

$$\frac{\partial U_{BC}}{\partial R} = \frac{1}{EI}\int_0^{L/2} (Rx)\, x\, dx = \frac{RL^3}{24EI}$$

$$\frac{\partial U_{AB}}{\partial R} = \frac{1}{EI}\int_0^{L/2} \left[R\left(x + L/2\right) - Wx\right]\left(x + L/2\right) dx = \frac{7RL^3}{24EI} - \frac{5WL^3}{48EI}$$

Since $\frac{\partial U}{\partial R} = 0$ $\quad \Rightarrow \quad \frac{RL^3}{3EI} + \frac{RL^3}{EI} + \frac{RL^3}{24EI} + \frac{7RL^3}{24EI} - \frac{5WL^3}{48EI} = 0$

$$\therefore \quad R = \frac{W}{16}$$

Example 5.16 Find the expression for the prop reaction in the propped cantilever beam shown in the Figure 5.19(a).

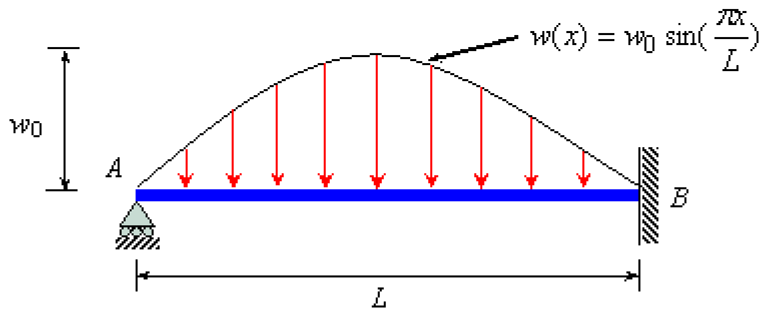


Figure 5.19(a)

Solution: Let reaction at support *A* be *R* . According to the Castigliano's theorem

$$\frac{\partial U}{\partial R} = 0$$

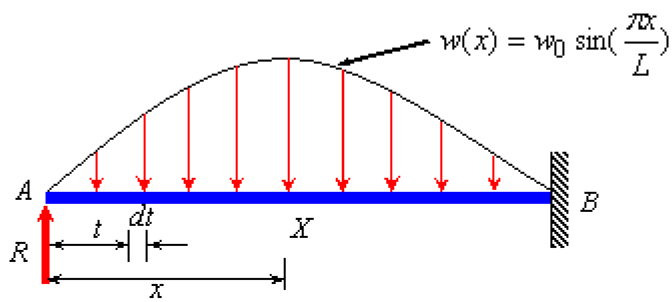


Figure 5.19(b)

The bending moment at any point *X* at a distance *x* from *A* is given by

$$M_x = Rx - \int_0^x w(t)\,dt\,(x-t)$$

$$= Rx - \int_0^x w_0 \sin(\frac{\pi t}{L})\,(x-t)\,dt$$

$$= Rx + \frac{w_0}{\pi^2}\sin(\pi x) - \frac{w_0}{\pi}x$$

$$\frac{\partial M_x}{\partial R} = x$$

$$\frac{\partial U}{\partial R} = \frac{1}{EI}\int_0^L \left(Rx + \frac{w_0}{\pi^2}\sin(\pi x) - \frac{w_0}{\pi}x \right) x\,dx$$

$$= \frac{RL^3}{3EI} - \frac{w_0 L^4}{3\pi EI} - \frac{w_0 L^4}{\pi^3 EI}$$

Since $\frac{\partial U}{\partial R} = 0$ $\Rightarrow$ $\frac{RL^3}{3EI} - \frac{w_0 L^4}{3\pi EI} - \frac{w_0 L^4}{\pi^3 EI} = 0$

$$\therefore \quad R = \frac{(\pi^2 - 3)}{\pi^3} w_0 L$$

Example 5.17 Determine the force in various members of the pin-jointed frame shown in Figure 5.20(a). *Length and AE* is constant for all members.

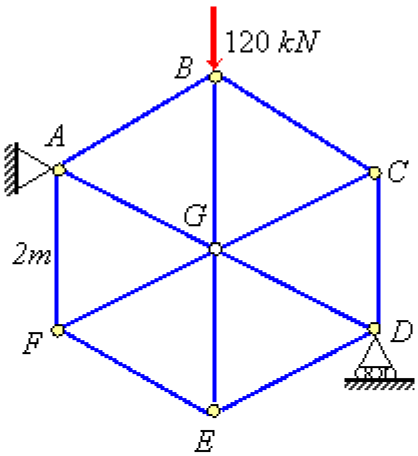


Figure 5.20(a)

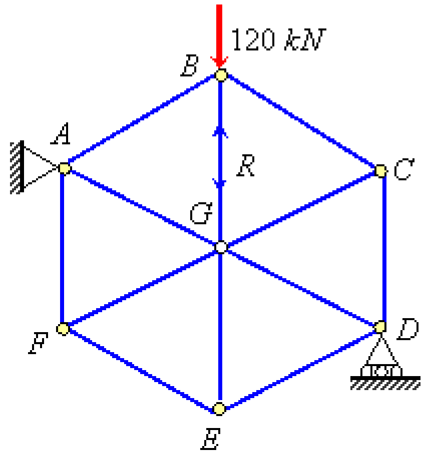


Figure 5.20(b)

Solution: The static indeterminacy of the pin-jointed frame is =12+3–7×2 = 1. Let the force in the member *BG* be *R* as shown in Figure 5.20(b). According to the Castigliano's theorem

$$\frac{\partial U}{\partial R} = 0$$

The computation of $\partial U / \partial R$ is made in Table 5.6.

Table 5.6

Member	Length, *L* (*m*)	*P*	$\frac{\partial P}{\partial R}$	$P \frac{\partial P}{\partial R} L$	Final force (kN)
AB	2	-120 +*R*	1	2 *R*- 240	-40
AG	2	120 -*R*	-1	2 *R*- 240	40
AF	2	-60 +*R*	1	2 *R*- 120	20
BC	2	-120 +*R*	1	2 *R*- 240	-40
BG	2	-*R*	-1	2 *R*	-80
CD	2	-120 +*R*	1	2 *R*- 240	-40
CG	2	120 -*R*	-1	2 *R*- 240	40
DE	2	-60 +*R*	-1	2 *R*- 120	20
DG	2	60 -*R*	-1	2 *R*- 120	-20
EF	2	-60 +*R*	1	2 *R*- 120	20
EG	2	60 -*R*	-1	2 *R*- 120	-20
FG	2	60 -*R*	-1	2 *R*- 120	-20

$$\sum \quad 24R - 1920$$

$$\frac{\partial U}{\partial R} = \frac{1}{AE}\left(P \frac{\partial P}{\partial R} L\right) = 0$$

or

$$\frac{1}{AE}(24R - 1920) = 0$$

$\therefore$ *R* = 80 kN

The final force in various members of the frame is shown in Table 5.6.

Example 5.18 Determine the force in various members of the pin-jointed frame as shown in Figure 5.21(a), if the member *BC* is short by an amount of Δ. All members of the frame have same axial rigidity as *AE.*

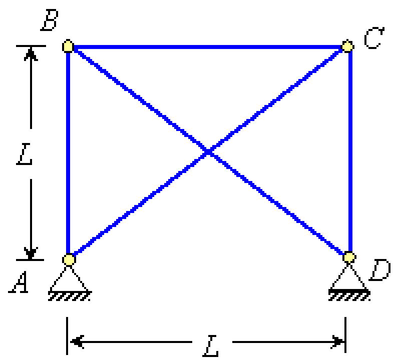


Figure 5.21(a)

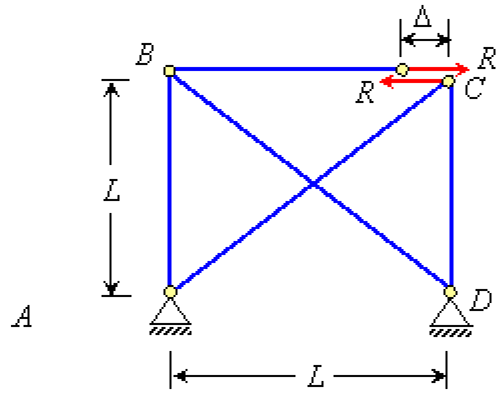


Figure 5.21(b)

Solution: The static indeterminacy of the pin-jointed frame is =5 + 4 - 2×4=1. Since the member *BC* is short by an amount of Δ, therefore, apply a force *R* in the member *BC* such that displacement in the direction of *R* is Δ. Thus, according to the Castigliano's theorem.

$$\frac{\partial U}{\partial R} = \Delta$$

The computation of $\partial U / \partial R$ is made in Table 5.7.

Table 5.7

Member	Length, *L* (*m*)	*F*	$\frac{\partial F}{\partial R}$	$F \frac{\partial F}{\partial R} L$	Final force $\left(\frac{AE\Delta}{(3+4\sqrt{2})L}\right)$
AB	*L*	*R*	1	*RL*	1
AC	$\sqrt{2}L$	$-\sqrt{2}R$	$-\sqrt{2}$	$2\sqrt{2}RL$	$-\sqrt{2}$
BC	*L*	*R*	1	*RL*	1
BD	*L*	$-\sqrt{2}R$	$-\sqrt{2}$	$2\sqrt{2}RL$	$-\sqrt{2}$
CD	$\sqrt{2}L$	*R*	1	*RL*	1
		$\sum$		$(3+4\sqrt{2})RL$	

$$\frac{\partial U}{\partial R} = \frac{1}{AE}\left(F \frac{\partial F}{\partial R} L\right) = \Delta$$

or

$$\frac{1}{AE}\left(3+4\sqrt{2}\right)RL = \Delta$$

$$\therefore \qquad R = \frac{AE\Delta}{(3+4\sqrt{2})L}$$

The final force in various members of the frame is shown in Table 5.7.

Example 5.19 Determine the horizontal reaction of the portal frame shown in Figure 5.22(a) by energy method. Also, calculate the horizontal reaction when the member *BC* is subjected to distributed load, *w* over entire length.

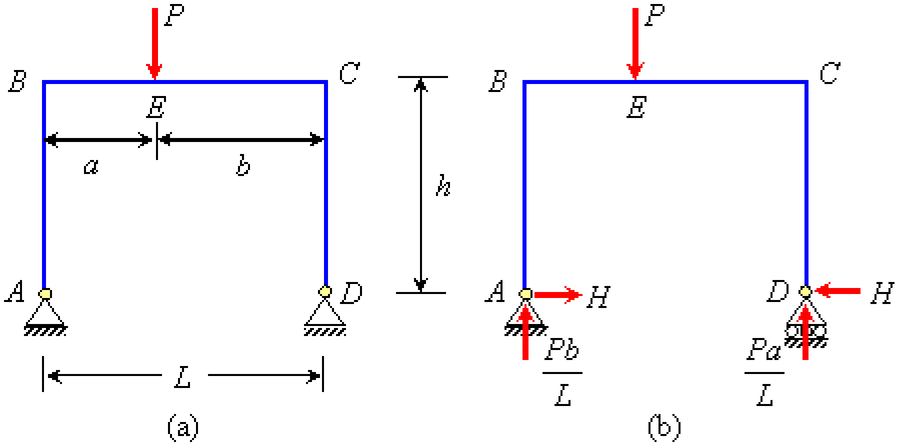


Figure 5.22(a)-(b)

Solution: Static indeterminacy of the frame = 1.

Let the horizontal reaction, *H* at *D* be the redundant. The reaction at *A* and *D* are

$$H_A = H; \qquad H_D = H \qquad R_A = Pb/L \quad \text{and} \quad R_D = Pa/L$$

For the span *AB* (*x* measured from *A*), $M_x = Hx$ and $\frac{\partial M_x}{\partial H} = x$

$$\frac{\partial U_{AB}}{\partial H} = \frac{Hh^3}{3EI}$$

For the span *BE* (*x* measured from *B*), $M_x = Hh - \frac{Pb}{L}x$ and $\frac{\partial M_x}{\partial H} = h$

$$\frac{\partial U_{BE}}{\partial H} = \frac{1}{EI}\int_0^a \left[Hh - \frac{Pb}{L}x\right] h\,dx = \frac{Hh^2 a}{EI} - \frac{Pa^2 bh}{2EIL}$$

For the span *CD* (*x* measured from *D*), $M_x = Hx$ and $\frac{\partial M_x}{\partial H} = x$

$$\frac{\partial U_{CD}}{\partial H} = \frac{Hh^3}{3EI}$$

For the span *CE* (*x* measured from *C*), $M_x = Hh - \frac{Pa}{L}x$ and $\frac{\partial M_x}{\partial H} = h$

$$\frac{\partial U_{CE}}{\partial H} = \frac{Hh^2 b}{EI} - \frac{Pab^2 h}{2EIL}$$

Since $\frac{\partial U}{\partial H} = 0$ $\Rightarrow \frac{Hh^3}{3EI} + \frac{Hh^2 a}{EI} - \frac{Pa^2 bh}{2EIL} + \frac{Hh^2 b}{EI} - \frac{Pab^2 h}{2EIL} + \frac{Hh^3}{3EI}$

$$\frac{2Hh^2}{3} + HhL - \frac{Pab}{2} = 0$$

$$H = \frac{3Pab}{2h(2h + 3L)}$$

Horizontal reaction due to udl, w over BC :

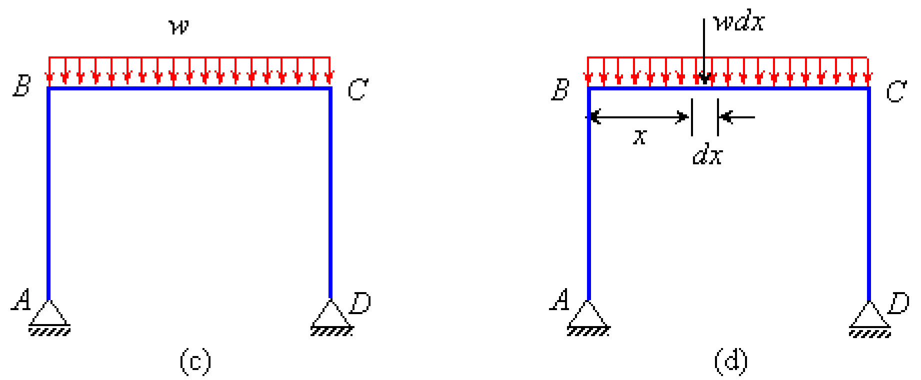


Figure 5.22(c)-(d)

The horizontal reaction due to small incremental load *wdx* is given by

$$dH = \frac{3wdx.x(L-x)}{2h(2h+3L)}$$

(using the expression derived earlier for concentrated force and putting $P = wdx$, $a = x$ and $b = L - x$).

The horizontal reaction due to entire distributed load

$$H = \int dH$$

$$= \int_0^L \frac{3wdx.x(L-x)}{2h(2h+3L)}$$

$$= \frac{3w}{2h(2h+3L)} \int_0^L x(L-x)dx$$

$$= \frac{wL^3}{4h(2h+3L)}$$

Example 5.20 Analyze the portal frame shown in Figure 5.23 by strain energy method.

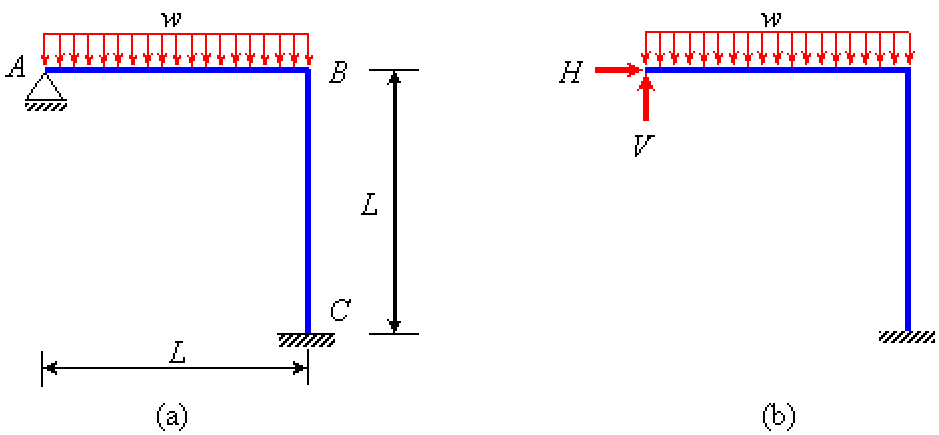


Figure 5.23

Solution: Static indeterminacy of the frame = 2. Horizontal and vertical reactions at *A* are taken as redundant.

For the span *AB* (*x* measured from *A*), $M_x = Vx - wx^2/2$

$$\frac{\partial M_x}{\partial H} = 0 \qquad \text{and} \quad \frac{\partial M_x}{\partial V} = x$$

$$\frac{\partial U_{AB}}{\partial H} = 0$$

$$\frac{\partial U_{AB}}{\partial V} = \frac{1}{EI}\int_0^L \left[Vx - wx^2/2\right]\left[x\right]dx = \frac{VL^3}{3EI} - \frac{wL^4}{8EI}$$

$$M_x = Hx + VL - wL^2/2$$

$$\frac{\partial M_x}{\partial H} = x \qquad \text{and} \quad \frac{\partial M_x}{\partial V} = L$$

$$\frac{\partial U_{BC}}{\partial H} = \frac{1}{EI}\int_0^L \left[Hx + VL - wL^2/2\right]\left[x\right]dx = \frac{VL^3}{2EI} + \frac{HL^3}{3EI} - \frac{wL^4}{4EI}$$

$$\frac{\partial U_{BC}}{\partial V} = \frac{1}{EI}\int_0^L \left[Hx + VL - wL^2/2\right]\left[L\right]dx = \frac{VL^3}{EI} + \frac{HL^3}{2EI} - \frac{wL^4}{2EI}$$

Since $\frac{\partial U}{\partial H} = 0 \quad \Rightarrow \frac{VL^3}{2EI} + \frac{HL^3}{3EI} - \frac{wL^4}{4EI} = 0$

or $6V + 4H = 3wL$ (i)

and $\frac{\partial U}{\partial V} = 0 \quad \Rightarrow \frac{VL^3}{3EI} - \frac{wL^4}{8EI} + \frac{VL^3}{EI} + \frac{HL^3}{2EI} - \frac{wL^4}{2EI} = 0$

or $32V + 12H = 15wL$ (ii)

Solving Eqs (i) and (ii) for *H* and *V* ,

$$H = \frac{3wL}{28} \quad \text{and } V = \frac{3wL}{7}$$

Example 5.21 Determine the support reactions of the continuous beam as shown in Figure 5.24(a) if the beam is assumed to be subjected to a linear temperature gradient such that the top surface of the beam is at temperature T_t and lower at T_b. The beam is uniform having flexural rigidity as *EI* and depth *d* . The coefficient of thermal expansion for beam material is α.

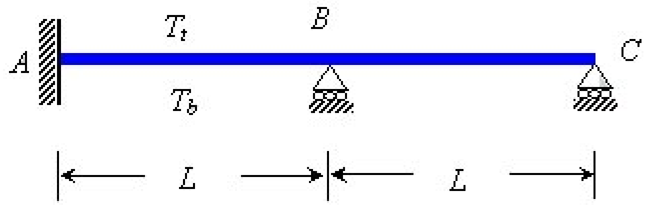


Figure 5.24(a)

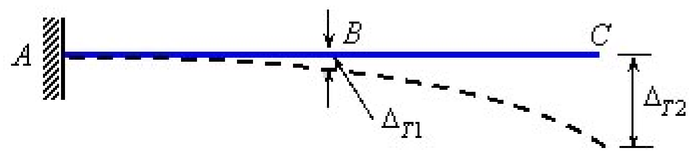


Figure 5.24(b)

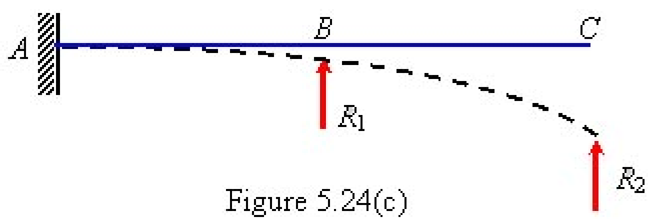


Figure 5.24(c)

Solution: The degree of static indeterminacy =2. Remove the supports at *B* and *C* and allow the beam to deflect freely under the temperature variation. The deflection of the points *B* and *C* of the beam due to temperature variation

$$\Delta_{T1} = \frac{\alpha(T_t - T_b)L^2}{2d} \qquad \text{(i)}$$

$$\Delta_{T2} = \frac{2\alpha(T_t - T_b)L^2}{d} \qquad \text{(ii)}$$

Apply the forces R_1 and R_2 at point *B* and *C* , respectively. According to Castigliano's theorem

$$\frac{\partial U}{\partial R_1} = \Delta_{T1} = \frac{\alpha(T_t - T_b)L^2}{2d} \qquad \text{(iii)}$$

$$\frac{\partial U}{\partial R_2} = \Delta_{T2} = \frac{2\alpha(T_t - T_b)L^2}{d} \qquad \text{(iv)}$$

Consider *BC* : (*x* measured from *C*)

$$M_x = R_2 x, \quad \frac{\partial M_x}{\partial R_1} = 0, \quad \frac{\partial M_x}{\partial R_2} = x$$

$$\frac{\partial U_{BC}}{\partial R_1} = 0$$

$$\frac{\partial U_{BC}}{\partial R_2} = \frac{1}{EI}\int_0^L R_2 x.x.dx = \frac{R_2 L^3}{3EI}$$

Consider *AB* : (*x* measured from *B*)

$$M_x = R_1 x + R_2(L+x) \quad ; \quad \frac{\partial M_x}{\partial R_1} = x, \quad \frac{\partial M_x}{\partial R_2} = (L+x)$$

$$\frac{\partial U_{AB}}{\partial R_1} = \frac{1}{EI}\int_0^L \{R_1 x + R_2(L+x)\} x dx = \frac{R_1 L^3}{3EI} + \frac{5R_2 L^3}{6EI}$$

$$\frac{\partial U_{AB}}{\partial R_2} = \frac{1}{EI}\int_0^L \{R_1 x + R_2(L+x)\}(L+x) dx = \frac{5R_1 L^3}{6EI} + \frac{7R_2 L^3}{3EI}$$

Thus,

$$\frac{\partial U}{\partial R_1} = \frac{R_1 L^3}{3EI} + \frac{5R_2 L^3}{6EI} = \frac{\alpha(T_t - T_b)L^2}{2d}$$

or $$2R_1 + 5R_2 = \frac{3EI\alpha(T_t - T_b)}{dL} \qquad \text{(v)}$$

Similarly,

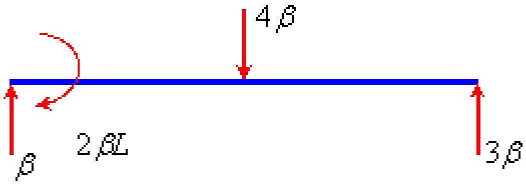
$$\frac{\partial U}{\partial R_2} = \frac{5R_1 L^3}{6EI} + \frac{7R_2 L^3}{3EI} + \frac{R_2 L^3}{3EI} = \frac{2\alpha(T_t - T_b)L^2}{d}$$

or $$5R_1 + 16R_2 = \frac{12EI\alpha(T_t - T_b)}{dL} \qquad \text{(vi)}$$

Solving eqs. (v) and (vi)

$$R_1 = -\frac{12EI\alpha(T_t - T_b)}{7dL} \quad \text{and} \quad R_2 = \frac{9EI\alpha(T_t - T_b)}{7dL}$$

The reactions of the beam are shown in Figure 5.24(d).



$$\beta = \frac{3EI\alpha(T_t - T_b)}{7dL}$$

Figure 5.24(d) Reactions of the beam

Recap

In this course you have learnt the following

- Energy method for analysis of statically indeterminate structures.

- Illustrative examples for analysis of statically indetrminate structures using every method.