SOLUTIONS

1. The water volume reduction is

$$15\ \text{cm}^3 - 9.57\ \text{cm}^3 = 5.43\ \text{cm}^3$$

Since 1 cm^3 of water has a mass of 1 g, the mass loss is 5.43 g. The fractional mass loss (dry basis) is

$$0.60 - 0.25 = 0.35$$

Therefore, from Eq. 35.6, and using a Δw to indicate the change in the water content, the solid mass is

$$m_s = \frac{\Delta m_w}{\Delta w} = \frac{5.43\ \text{g}}{0.35} = 15.5\ \text{g}$$

The water volume at the shrinkage limit is

$$\begin{aligned} V_w &= \frac{m_w}{\rho_w} = \frac{w m_s}{\rho_w} = \frac{(0.25)(15.5\ \text{g})}{1\ \frac{\text{g}}{\text{cm}^3}} \\ &= 3.875\ \text{cm}^3 \end{aligned}$$

Volumes determined from mercury submersion are combined water and solid volumes. At the shrinkage limit, there are no air voids, as the clay is saturated. Therefore, the volume of the solid at the shrinkage limit is

$$9.57\ \text{cm}^3 - 3.875\ \text{cm}^3 = 5.695\ \text{cm}^3$$

The density of the solids is

$$\rho = \frac{m}{V} = \frac{15.5\ \text{g}}{5.695\ \text{cm}^3} = 2.72\ \text{g/cm}^3$$

$$\text{SG} = \frac{\rho_s}{\rho_w} = \frac{2.72\ \frac{\text{g}}{\text{cm}^3}}{1\ \frac{\text{g}}{\text{cm}^3}} = \boxed{2.72\quad (2.7)}$$

The answer is (D).

2. The plasticity index is given by Eq. 35.23.

$$\text{PI} = \text{LL} - \text{PL} = 37 - 18 = 19$$

The group index is given by Eq. 35.3.

$$\begin{aligned} I_g &= (F_{200} - 35)\big(0.2 + 0.005(\text{LL} - 40)\big) \\ &\quad + 0.01(F_{200} - 15)(\text{PI} - 10) \\ &= (57 - 35)\big(0.2 + (0.005)(37 - 40)\big) \\ &\quad + (0.01)(57 - 15)(19 - 10) \\ &= 7.85 \quad [\text{round to } 8] \end{aligned}$$

$$\text{classification} = \boxed{\text{A-6(8)}}$$

The answer is (C).

3. (a) The density of the in situ soil is

$$\begin{aligned} \rho &= \frac{m_t}{V_t} = \frac{56.74\ \text{lbm}}{0.514\ \text{ft}^3} \\ &= \boxed{110.4\ \text{lbm/ft}^3 \quad (\boxed{100}\ \text{lbm/ft}^3)} \end{aligned}$$

110

The answer is (C).

(b) The unit weight of the in situ soil is

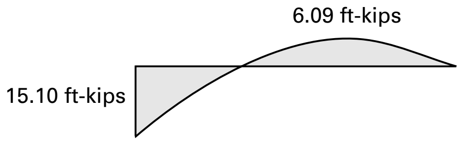
$$\begin{aligned} \gamma &= \frac{\rho g}{g_c} = \frac{\left(110.4\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(32.2\ \frac{\text{ft}}{\text{sec}^2}\right)}{32.2\ \frac{\text{lbm-ft}}{\text{lbf-sec}^2}} \\ &= \boxed{110.4\ \text{lbf/ft}^3 \quad (110\ \text{lbf/ft}^3)} \end{aligned}$$

The answer is (C).

(c) The void ratio is as follows.

$$\begin{aligned} m_w &= m_t - m_s = 56.74\ \text{lbm} - 48.72\ \text{lbm} \\ &= 8.02\ \text{lbm} \\ V_s &= \frac{m_s}{\rho_s} = \frac{48.72\ \text{lbm}}{(2.69)\left(62.4\ \frac{\text{lbm}}{\text{ft}^3}\right)} \\ &= 0.29025\ \text{ft}^3 \\ V_w &= \frac{8.02\ \text{lbm}}{62.4\ \frac{\text{lbm}}{\text{ft}^3}} = 0.12853\ \text{ft}^3 \\ V_g &= 0.514\ \text{ft}^3 - 0.12853\ \text{ft}^3 - 0.29025\ \text{ft}^3 \\ &= 0.09522\ \text{ft}^3 \end{aligned}$$

(b) Once the force in the cable is known, the moment diagram in the beam can be determined. The maximum moment occurs at the fixed end and has a value of $\boxed{15.10 \text{ ft-kips.}}$



3. (a) When the roller support at C is removed, the structure becomes a statically determinate cantilever.

The degree of indeterminacy is $\boxed{1.}$

The answer is (B).

(b) The 50 kip load introduces a moment of 100 ft-kips at point B. From App. 47.A, case 20, the fixed-end moments due to this applied external moment at each end are

(3(b/L)-1)

$$a = b = \frac{L}{2}$$

$$\begin{aligned} \text{FEM}_{\text{AB}} = \text{FEM}_{\text{BA}} &= M\left(\frac{a}{L}\right)\boxed{3\left(\frac{b}{L} - 1\right)} \\ &= (100 \text{ ft-kips})\left(\frac{1}{2}\right)\boxed{(3)\left(\frac{1}{2} - 1\right)} \\ &= 25 \text{ ft-kips} \end{aligned}$$

(3(1/2)-1)

Distribute moments as follows: The unbalance at C is 25 ft-kips, so change the sign and multiply by a distribution factor of 1 (since there is a pin at C); carry half (−12.5 ft-kips) of the distributed moment to A; the final moment at A is

$$25 \text{ ft-kips} - 12.5 \text{ ft-kips} = \boxed{12.5 \text{ ft-kips} \quad (13 \text{ ft-kips})} \quad \text{[clockwise]}$$

This moment induces compression on the side of the dotted line.

The answer is (B).

(c) Using the fact that the moment at A is 12.5 ft-kips, sum the moments about C.

$$\begin{aligned} V_{\text{A}} &= \frac{12.5 \text{ ft-kips} + 100 \text{ ft-kips}}{20 \text{ ft}} \\ &= \boxed{5.63 \text{ kips} \quad (5.6 \text{ kips})} \end{aligned}$$

The answer is (B).

(d) Since the vertical reaction at C is zero, the axial force in CB is $\boxed{\text{zero.}}$

The answer is (A).

(e) The shear in bar CB is the same as in bar AB: $\boxed{5.63 \text{ kips } (5.6 \text{ kips}).}$

The answer is (B).

(f) A free-body diagram shows that the moment (in ft-kips) in bar AB is given by $12.5 - 5.625y$, where y is the distance measured from point A. Solving, the point of inflection is located at $y = \boxed{2.22 \text{ ft.}}$

The answer is (B).

(g) The maximum moment occurs at point B on bar BC. This moment equals the product of the reaction at C times the distance to B, or (5.63 kips)(10 ft) = $\boxed{56.3 \text{ ft-kips}}$ $\boxed{(56 \text{ ft-kips}).}$

The answer is (C).

(h) Use the dummy load method to compute this deflection. Treating the reaction at C as an applied load, the unit load case consists of a horizontal force acting (to the right) at B on a cantilever fixed at A. For this condition, the moments are

$$m_Q = -10 + y \quad \text{[bar AB]}$$
$$m_Q = 0 \quad \text{[bar BC and bar BD]}$$

Only the moment m_P in bar AB (since the others are multiplied by zero) is needed. From part (f), $m_P = 12.5 - 5.625y$. Therefore, the vertical deflection is given by Eq. 47.9.

$$\begin{aligned} \Delta_{\text{B}} &= \int \frac{m_Q m_P}{EI} dy \\ &= \int_0^{10} \frac{(12.5 - 5.625y)(-10 + y)}{EI} dy \end{aligned}$$

This is integrated to give the deflection.

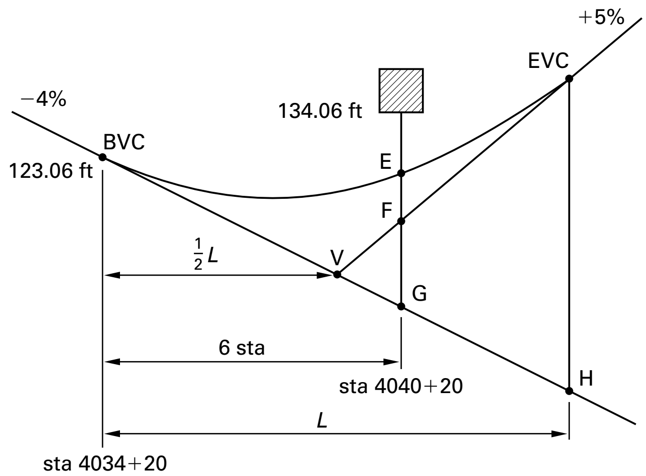
$$\Delta_{\text{B}} = \frac{-125y + 34.375y^2 - 1.875y^3}{EI}$$

At $y = 10$,

$$\begin{aligned} \Delta_{\text{B}} &= \frac{(-125)(10) + (34.375)(10)^2 - (1.875)(10)^3}{EI} \\ &= \frac{312.5 \text{ ft}^3\text{-kips}}{10^4 \text{ ft}^2\text{-kips}} \\ &= \boxed{0.0325 \text{ ft} \quad (0.03 \text{ ft})} \end{aligned}$$

The answer is (C).

2.



step 1: The elevation at point E is

$$134.06\text{ ft} - 15\text{ ft} = 119.06\text{ ft}$$

step 2: The elevation at point G is

$$\begin{aligned}123.06\text{ ft} - \left(4\ \frac{\text{ft}}{\text{sta}}\right)&(4040.2\text{ sta} - 4034.2\text{ sta})\\ &= 99.06\text{ ft}\\ \text{distance EG} = 119.06\text{ ft} &- 99.06\text{ ft} = 20\text{ ft}\end{aligned}$$

step 3: $\angle$FVG is a $5\% - (-4\%) = 9\%$ divergence. Therefore,

$$\begin{aligned}\text{distance EVC-H} &= (9)\left(\tfrac{1}{2}L\right)\\ &= 4.5L\end{aligned}$$

step 4: Measuring all x distances from BVC, and since parabolic offsets from a line (BVC-H in this case) are proportional to x^2,

$$\begin{aligned}\frac{\text{EG}}{(6\text{ sta})^2} &= \frac{\text{EVC-H}}{L^2}\\ \frac{20\text{ ft}}{(6\text{ sta})^2} &= \frac{4.5L}{L^2}\\ L &= \boxed{8.1\text{ sta}}\end{aligned}$$

3. Define the curve mathematically.

$$\begin{aligned}L &= 94\text{ sta} - 82\text{ sta} = 12\text{ sta}\\ \text{elev}_{\text{BVC}} &= 729\text{ ft} + (88\text{ sta} - 82\text{ sta})\left(4\ \frac{\text{ft}}{\text{sta}}\right)\\ &= 753\text{ ft}\end{aligned}$$

The rate of grade per station is

$$\begin{aligned}R &= \frac{G_2 - G_1}{L} = \frac{3\% - (-4\%)}{12\text{ sta}}\\ &= \frac{7}{12}\ \%/\text{sta}\\ y &= \frac{Rx^2}{2} + G_1x + \text{elev}_{\text{BVC}} = \frac{7}{24}x^2 - 4x + 753\text{ ft}\end{aligned}$$

The maximum elevation that provides clearance is $770\text{ ft} - 25\text{ ft} = 745\text{ ft}$. Solve for x.

$$\begin{aligned}745\text{ ft} &= \frac{7}{24}x^2 - 4x + 753\text{ ft}\\ x &= 11.29\text{ sta},\ 2.43\text{ sta}\end{aligned}$$

(a) The minimum station is

$$82{+}2.43 = \boxed{\text{sta } 8{+}43}$$

sta 84 + 43

(b) The maximum station is

$$82{+}11.29 = \boxed{\text{sta } 93{+}29}$$

(c) The turning point is at

$$\begin{aligned}x &= \frac{-(-4\%)}{\frac{7}{12}\ \frac{\%}{\text{sta}}} = 6.86\text{ ft}\\ \text{location} &= (\text{sta } 82{+}00) + (\text{sta } 6{+}86)\\ &= \boxed{\text{sta } 88{+}86}\end{aligned}$$

(d) The elevation of the turning point is

$$\begin{aligned}y &= \left(\frac{7}{24}\ \frac{\%}{\text{sta}}\right)(6.86\text{ sta})^2 - (4\%)(6.86\text{ sta}) + 753\text{ ft}\\ &= \boxed{739.29\text{ ft}}\end{aligned}$$

4. (a) Underpass—20 ft clearance:

Refer to Fig. 79.11.

step 1: The elevation at E is

$$\text{elev}_{\text{E}} = 510\text{ ft} - 20\text{ ft} = 490\text{ ft}$$

step 2: The elevation at G is

$$\begin{aligned}\text{elev}_{\text{G}} &= \text{elev}_{\text{V}} - (\text{slope})x\\ &= 482\text{ ft} - (3\%)(3\text{ sta})\\ &= 473\text{ ft}\\ \text{EG} &= \text{elev}_{\text{E}} - \text{elev}_{\text{G}} = 490\text{ ft} - 473\text{ ft}\\ &= 17\text{ ft}\end{aligned}$$

Transportation