7.3.4 Example 7-1 Single Tieback Sheet Pile Wall

Check the adequacy of a single tieback sheet pile wall with a single soil layer shown below with a tieback spacing = 10 feet. The sheet pile section is a PZ22, steel grade 42 ksi.

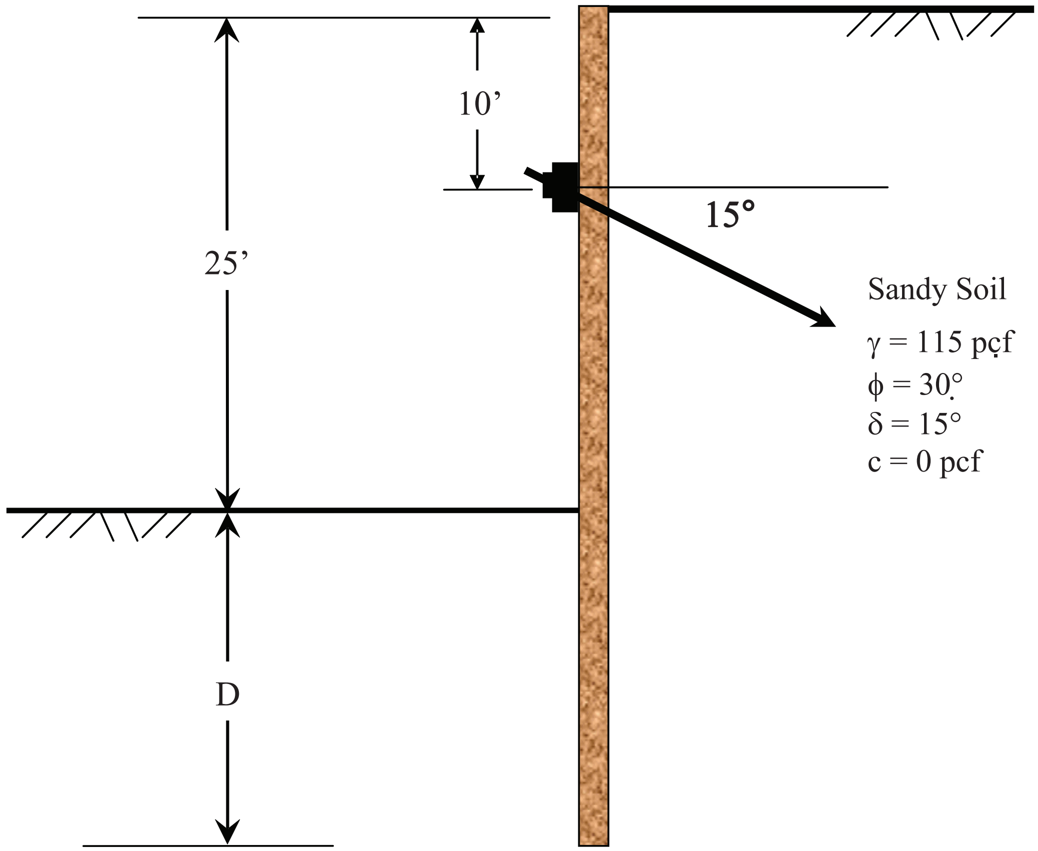

Figure 7-9. Example 7-1

Determine:

1. Active & Passive Earth Pressures.
2. Pile Embedment D with FS = 1.3.
3. Tieback Load with FS = 1.0.
4. Maximum Shear, Maximum Moment.

Structural properties of sheet pile section PZ22 are:

- Section Modulus per foot of wall width: $S = 18.10\ \text{in}^3$.
- Moment of Inertia per foot of wall width: $I = 84.70\ \text{in}^4$.
- Radius of Gyration per foot of wall width: $r = 3.62$ in.
- Area per foot of wall width: $A = \dfrac{I}{r^2} = \dfrac{84.7\ \text{in}^4}{(3.62\ \text{in})^2} = 6.46\ \text{in}^2$

Develop the pressure diagram:

From Rankine's Theory: $K_a = 1/3$. Using the Log Spiral Theory, from Figure 4-37: $K_p = 4.7$. Also, since the wall friction angle (δ) is 0:

$$K_{ph} = K_p = 4.7.$$

The lateral earth pressure distribution for the analysis of anchored walls constructed in cohesionless soils may be determined using Figure 7-10.

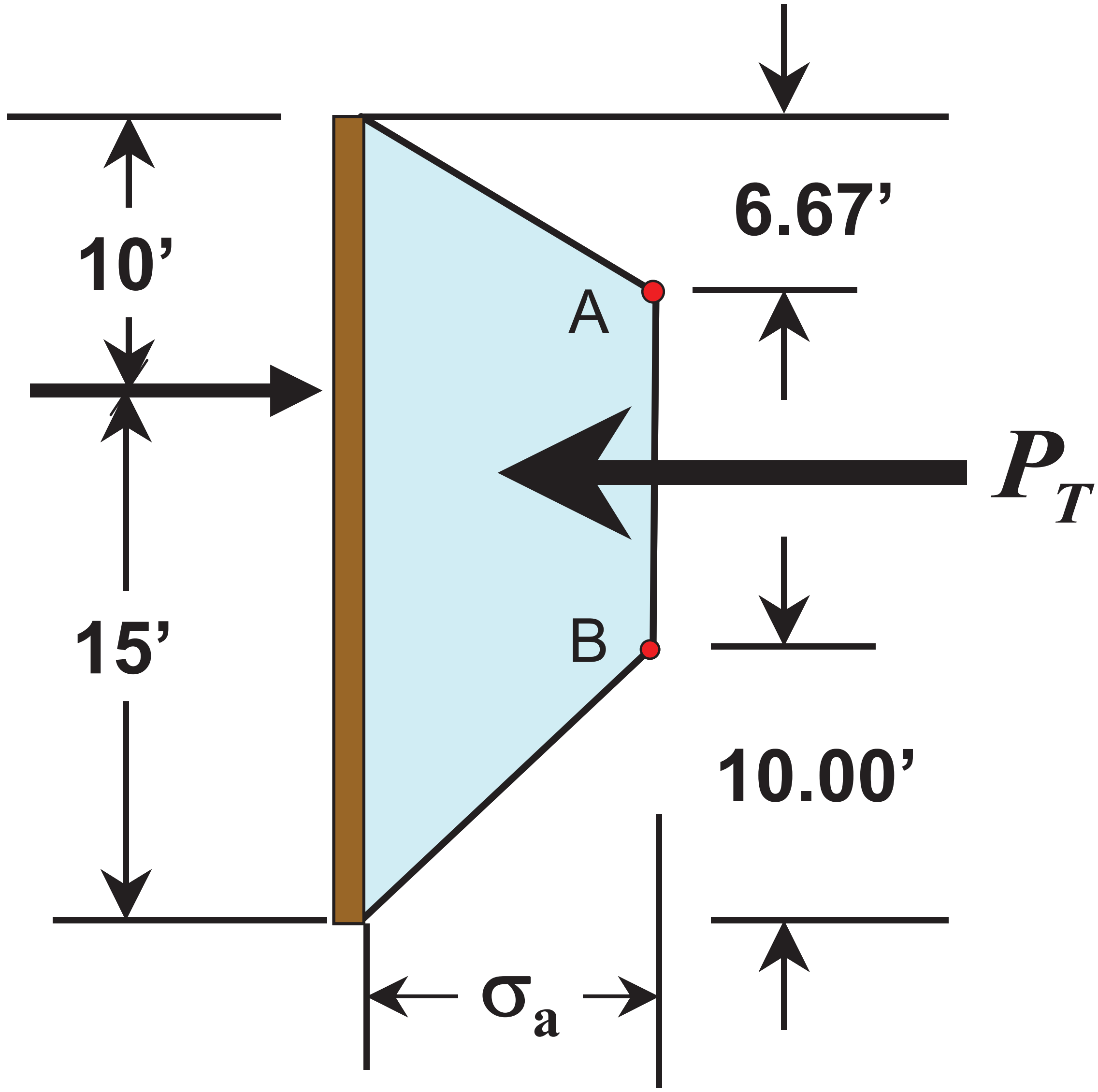

Figure 7-10. Pressure Diagram for Single Tieback Wall

The maximum ordinate (σ_a) of the pressure diagram is determined as follows:

$$\sigma_a = \frac{1.3P}{\left(\frac{2}{3}\right)h} = \frac{P_T}{\left(\frac{2}{3}\right)h}$$

Where the total active earth pressure for a triangular pressure distribution is calculated as follows:

$$P = \frac{1}{2}\gamma h^2 K_a$$

Using Eq. 7-2: $P_T = 1.3 * P$

$$P = \left(\frac{1}{2}\right)(115)(25^2)\left(\frac{1}{3}\right) = 11{,}980\ \text{lb}$$

$$P_T = 1.3P = 1.3 * 11{,}980 = 15{,}574\ \text{lb}$$

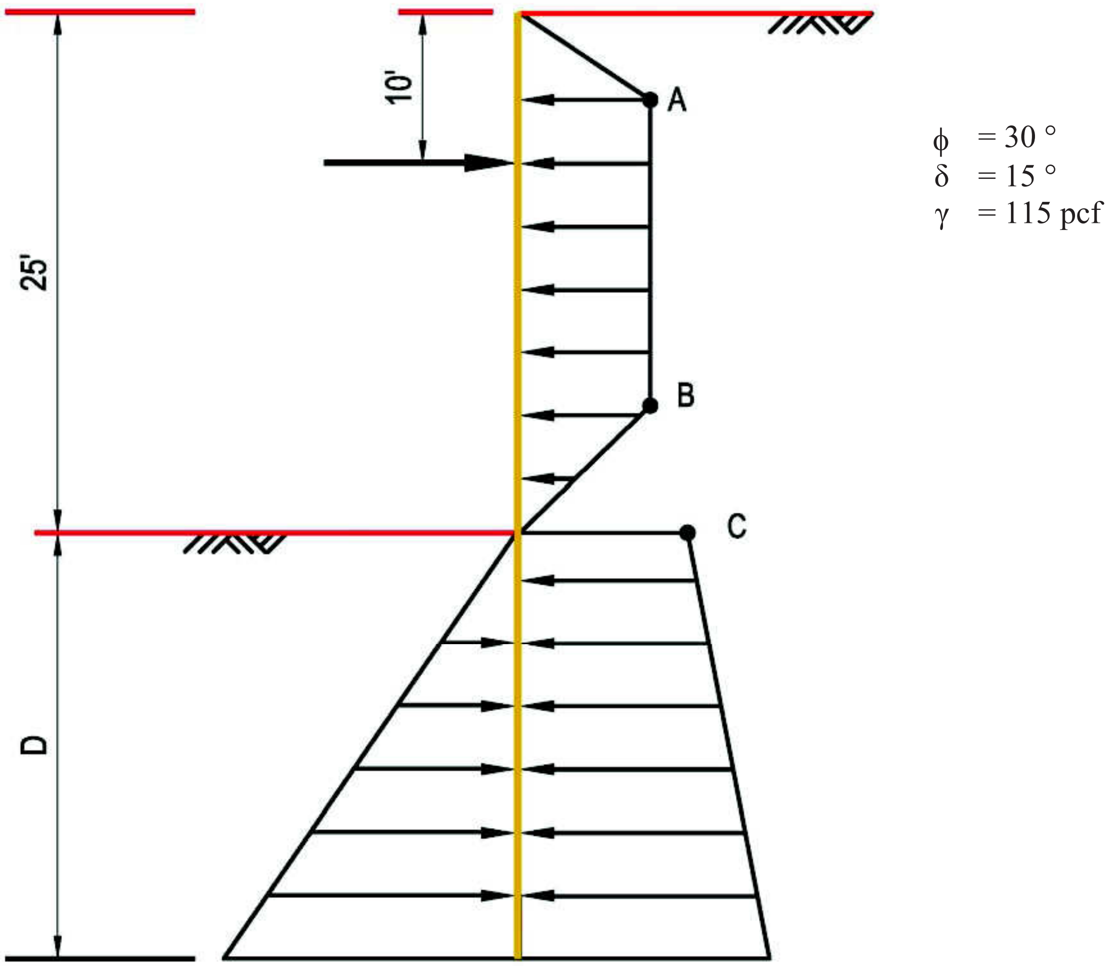

Figure 7-11. Pressure Diagram

Active stress at the point A and B as shown in Figure 7-11:

$$\sigma_a = \frac{15{,}574}{\left(2/3\right)25'} = 934.4\ \text{psf}$$

Active stress at the dredge line point C:

$$\sigma_c = (115)(25')\left(\frac{1}{3}\right) = 958.3\ \text{psf}$$

$$FS = \frac{M_R}{M_D}$$

Let FS=1.3.

$$M_R = 1.3 M_D$$

Take moment about the tieback

$$M_D = \begin{bmatrix} (934.4)\left(\frac{6.67'}{2}\right)\left(3.33' + \frac{6.67'}{3}\right) - (934.4)(8.33')(0.835') \\ -(934.4)\left(\frac{10'}{2}\right)(8.33') - (958.3)\left(15' + \frac{D}{2}\right)D \\ -(0.5)(115)\left(\frac{1}{3}\right)\left(15' + \frac{2}{3}D\right)D^2 \end{bmatrix}$$

As determined above: K_{ph} is 4.7.

$$M_R = \frac{1}{2}(115)(4.7)\left(15' + \frac{2}{3}D\right)D^2$$

Solve for D.

$$D^3 + 18.7D^2 - 114.53D - 223.98 = 0$$

$$D \approx 6.09 \text{ ft}$$

Solve for tieback force T by setting the resisting moment equal to driving moment as shown below:

$$M_R = M_D$$

Find D':

$$D'^3 + 19.64D'^2 - 85.88D' - 167.95 = 0$$

$$D' \approx 4.89 \text{ ft}$$

$$\sum F_X = 0$$

$$\begin{bmatrix} -\left(\frac{25 + 8.33}{2}\right)(934.4) - \frac{1}{2}(115)(4.89^2)\frac{1}{3} - (958.3)(4.89) + \\ \frac{1}{2}(115)(4.89^2)(4.7) \end{bmatrix}(10) + T_H = 0$$

$$T_H = 142.54 \text{ kips} \quad \text{and} \quad T = \frac{142.54}{cos(15°)} = 147.57 \text{ kips}$$

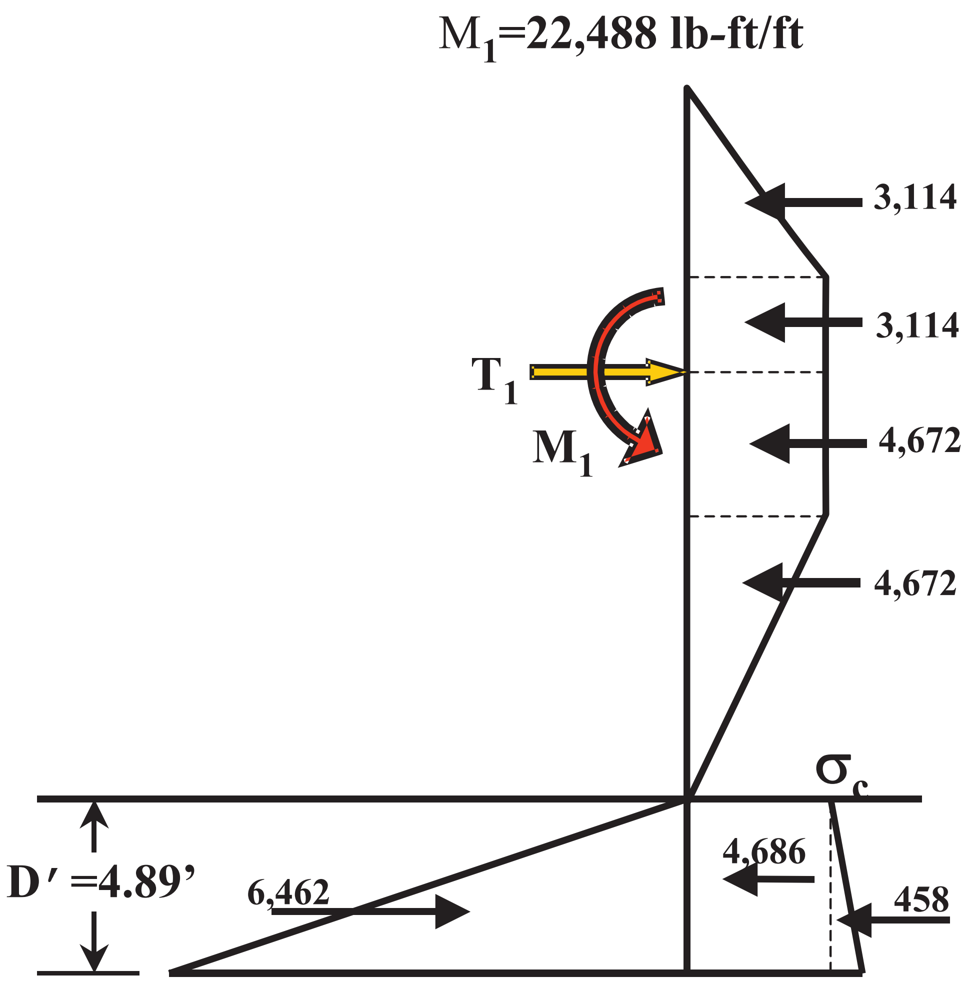

Figure 7-12. Pressure Diagram For Single-Tieback Above Dredge Line

Based on $M_R = M_D$.

The maximum shear in the beam is located at the Tieback.

$$T_{1U} = \frac{1}{2}(934.4)(6.667') + (934.4)(3.333') = 3{,}114 + 3{,}114 = 6{,}228 \text{ lbs}$$

$$T_{1L} = \frac{1}{2}(934.4)(10') + (934.4)(5') + (958.3)(4.89') + \frac{1}{2}(115)(\frac{1}{3} - 4.7)(4.89')^2 =$$
$$= 4{,}672 + 4{,}672 + 4{,}686 - 6{,}004 = 8{,}026 \text{ lbs}$$

Maximum shear is T_{1L} = 8,026 lbs.

$$f_v = \frac{8{,}026 \text{ lbs}}{6.46 \text{ in}^2} = 1{,}242 \text{ psi} < 16{,}800 \text{ psi}$$

$F_v = 42{,}000 \text{ psi} * 0.4 \approx 17{,}000 \text{ psi} \therefore$ PZ22 is satisfactory in shear.

Determine moment M_1 at top tieback due to cantilever loads:

$M_1 = F_1$ * Mom arm of triangular load + F_2 * Mom arm of rectangular load

$$M_1 = \frac{1}{2}(934.4)(6.667)\left(3.333 + \frac{6.667}{3}\right) + (934.4)(3.333)\left(\frac{3.333}{2}\right)$$
$$= (3{,}114)(5.555) + (3{,}114)(1.667) = 17{,}299 + 5{,}189 = 22{,}488 \text{ lb - ft}$$

Determine moment at zero shear below tieback. Please refer to Figure 7-15 for shear diagram of single tieback. The point of zero shear is either located below the bottom of excavation or it is located between the tieback and the bottom of excavation. For this particular example problem, when the summation of forces in the horizontal direction includes the area below the bottom of excavation, a quadratic equation results with two possible roots. As shown below, one root lies at depth D but is not the root we are looking for. The other root is negative and therefore, cannot be used:

$$\sum F_H = 8026 - 4672 - 4672 - 958.3y' - \frac{1}{2}(115)(\frac{1}{3} - 4.7)(y')^2$$
$$= -1318 - 958.3y' + 251.09y'^2 = 0$$

Solving:

$y'^2 - 3.816y' - 5.25 = 0$ yields: $y' = 4.89$ ft and $y' = -1.07$ ft

Since the second root is invalid, the point of zero shear must be located above the bottom of excavation. Further, it can be surmised that the point of zero shear is located within the sloping portion of the load diagram below the tieback since:

$T_{1L} - (934.4)(5') = 8{,}026 \text{ lbs} - 4{,}672\ lbs = 3354 \text{ lbs} > 0$

The slope of the load line just above the dredge line is $934.4 / 10' = 93.44$. Solving for y':

$$(8{,}026 - 4{,}672) = \frac{1}{2}(934.4 + 934.4 - 93.44y')y' =$$
$$(2)(3{,}354) = 1{,}868.8y' - 93.44y'^2$$
$$\therefore 93.44y'^2 - 1{,}868.8y' + 6{,}708 = 0$$
$$y' = 4.69'$$

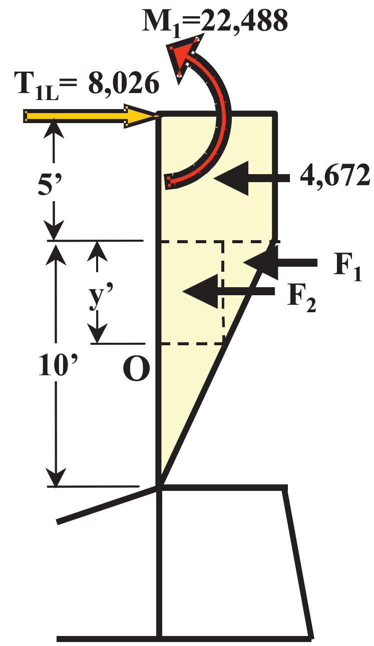

Figure 7-13. Zero shear

The point of zero shear is located $5'+4.69' = 9.69'$ below T_1. Taking moments about the point of zero shear (O) in Figure 7-13:

$$F_1 = \frac{1}{2}(93.44)(4.69')(4.69') = 1{,}027.6 \text{ lbs/ft}$$
$$F_2 = (93.44)(10'-4.69')(4.69') = 2{,}326.7 \text{ lbs/ft}$$

$$M_{1-tip} = \left[\begin{array}{l}(8{,}026)(9.69') - (4{,}672)\left(\frac{5'}{2} + 4.69'\right) - \frac{2}{3}(1{,}027)(4.69') - \frac{1}{2}(2{,}326)(4.69') \\ -22{,}488\end{array}\right]$$

$$M_{1-tip} = 77{,}772 - 33{,}592 - 3{,}211 - 5{,}455 - 22{,}488 = 13{,}026 \text{ ft - lbs/ft}$$

Therefore the maximum moment is at T_1: $M_1 = 22{,}488$ ft - lbs/ft.

Check the bending stress in the sheet pile section:

$$f_b = \frac{22{,}488 \text{ ft - lb} * 12 \text{ in/ft}}{18.10 \text{ in}^3} = 14{,}909 \text{ psi}$$

$F_b = 42{,}000 \text{ psi} * 0.6 \approx 25{,}000 \text{ psi} \therefore$ Therefore, PZ22 is satisfactory in bending.

The process to check deflection can be found in Example 6-2 and EXAMPLE 8-1 and will not be calculated for this example. Figure 7-17 represents the deflected shape of the PZ22 sheet pile based on the Moment Area method; therefore, use these values with caution. The deflection due to the cantilever is 0.20 inches. The maximum deflection is 0.23 inches and is located about 9.6 ft below T_1. The respective diagrams are shown in Figure 7-14 through Figure 7-17 and are for information only.

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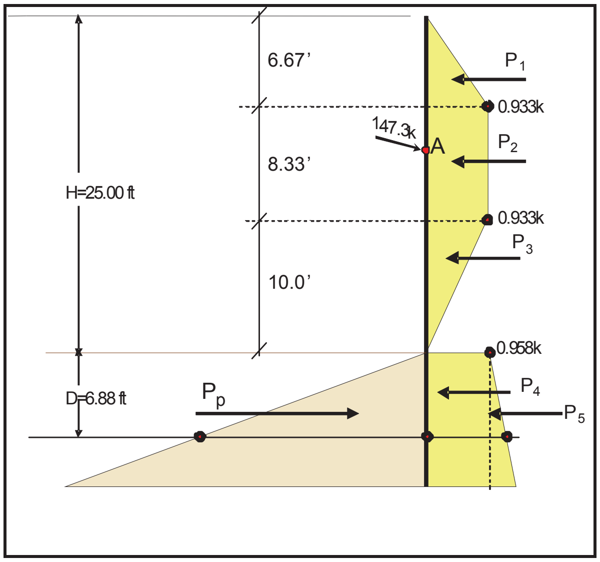

Figure 7-14. Pressure Diagram

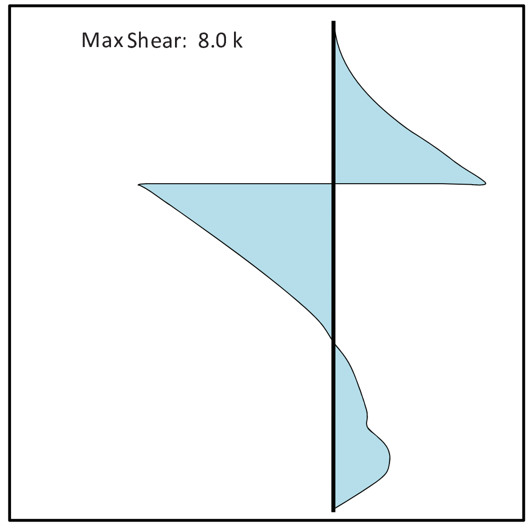

Figure 7-15. Shear Diagram

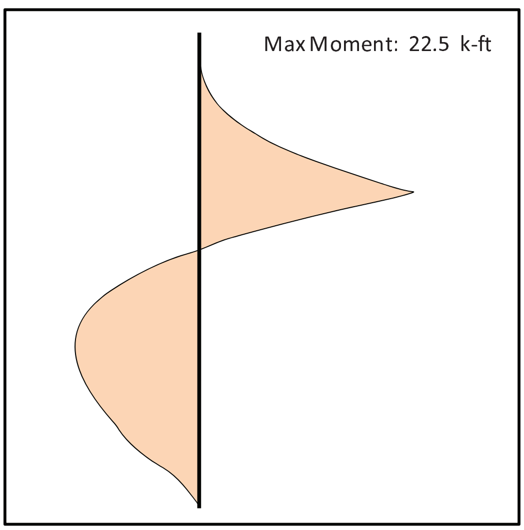

Figure 7-16. Moment Diagram

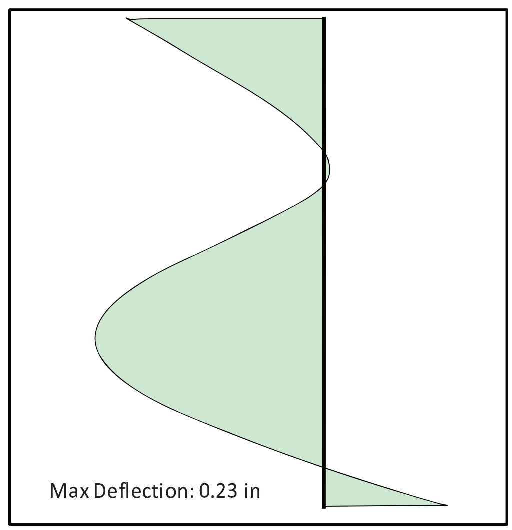

Figure 7-17. Deflection Diagram