Drilled shaft to resist Overturning

This application perform to calculate the required depth of Drilled shaft to prevent overtuning based on AASHTO LRFD (Load and Resistance Factor Design).

References:
- AASHTO LRFD Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals
- AASHTO LRFD Bridge Design Specification
- FDOT Structures Manual

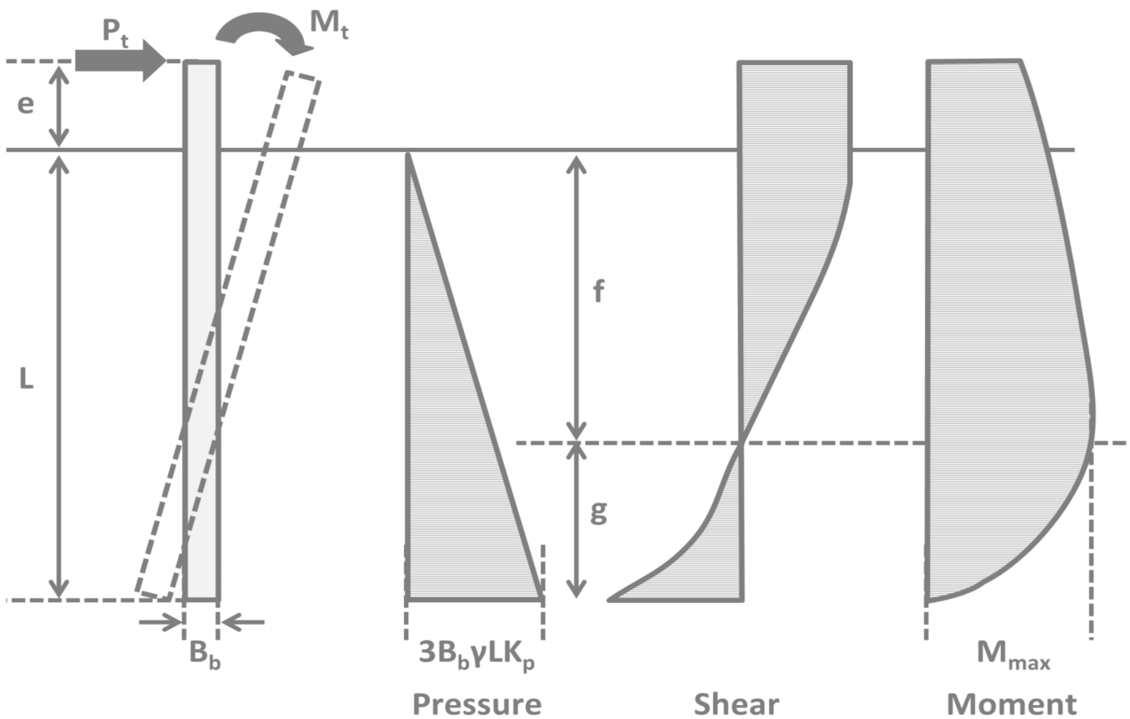

Figure 1 : Broms Pressure, Shear, Moment diagram for Cohesionless soils

Design parameters

Soil properties

Soil friction angle $\phi_s := 32\ deg$

Soil shear strength $c_s := 15\ psi$

Effective siol weight $\gamma_s := 60\ \frac{lbf}{ft^3}$

Geometrical parameters

Diameter of shaft $B_b := 4.0\ ft$

Groupline to top of fundation $Offset := 0.0\ ft$

Applied loads

Force of X-direction $V_x := 40\ kip$

Force of Z-direction $V_z := 25.0\ kip$

Moment of X-direction $M_x := 250\ kip \cdot ft$

Moment of Z-direction $M_z := 1075\ kip \cdot ft$

Torsional load $T_{load} := 150\ kip \cdot ft$

Overturning factor $\phi_{ot} := 0.6$

Torsional load factor $\phi_{tor} := 0.9$

Load moment and force

Design load moment $M_t := \sqrt{M_x^{\ 2} + M_z^{\ 2}} = 1103.687\ kip\ foot$

Design load force $P_t := \sqrt{V_x^{\ 2} + V_z^{\ 2}} = 47.170\ kip$

Design torsional force (Torque) $T_t := T_{load} = 150\ kip \cdot foot$

Cohesionless soil (Sand)

Rankine coefficient of passive earth pressure

$$K_p := \tan\left(45 \cdot \mathbf{deg} + \frac{\phi_s}{2}\right)^2 = 3.255$$

Top of shaft to the ground

$$e_s := \text{Offset} = 0.$$

Objective function to obtain the minimum length of the shaft

$$Obj_s := P_t \cdot \left(e_s + L_{min\_s}\right) + M_t = \phi_{ot} \cdot \left(3 \cdot \gamma_s \cdot B_b \cdot L_{min\_s} \cdot K_p\right) \cdot \left(\frac{1}{2} \cdot L_{min\_s}\right) \cdot \left(\frac{1}{3} \cdot L_{min\_s}\right)$$

$$L_s := \text{fsolve}\left(Obj_s\right) = 20.707\ \mathbf{ft}$$

Depth, Point of zero shear and Point of Maximum moment

$$f_s := \sqrt{\frac{P_t}{1.5 \cdot B_b \cdot \gamma_s \cdot K_p \cdot \phi_{ot}}} = 8.191\ \mathbf{ft}$$

Maximum moment

$$M_{max\_s} := M_t + P_t \cdot \left(e_s + f_s\right) - \frac{1}{2} \cdot B_b \cdot \gamma_s \cdot f_s^{\ 3} \cdot K_p \cdot \phi_{ot} = 1361.278\ \mathbf{kip\ foot}$$

Cohesive soil (Clay, $L > 3 \cdot B_b$)

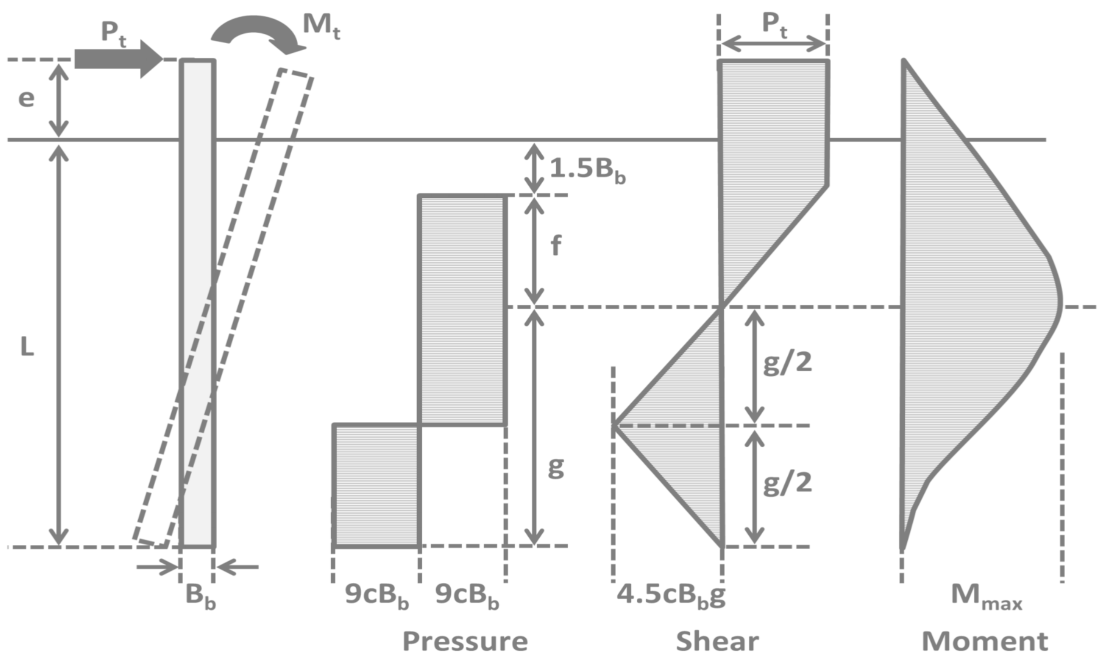

Figure 2 : Broms Pressure, Shear, Moment diagram for Cohesive soils

Soil shear strength
to avoid division-by-zero

$$c_s := \begin{cases} 0 \, \frac{lbf}{ft^2} & c_s = 0.0 \, \frac{lbf}{ft^2} \\ c_s & \text{otherwise} \end{cases}$$

Depth, Point of zero shear and Point of Maximum moment

$$f := \frac{P_t}{\phi_{ot} \cdot 9 \cdot c_s \cdot B_b} = 12.132 \text{ in}$$

Maximum moment

$$M_{max\_c} := P_t \cdot \left(\frac{M_t}{P_t} + Offset \right) + \frac{3}{2} \cdot P_t \cdot B_b + \frac{1}{2} \cdot P_t \cdot f = 1410.551 \text{ kip foot}$$

Depth, Point of zero shear and Point of Maximum moment

$$g := \sqrt{\frac{2 \cdot M_{max\_c}}{4.5 \cdot \phi_{ot} \cdot c_s \cdot B_b}} = 10.997 \text{ ft}$$

Minimum length

$$L_c := 1.5 \cdot B_b + f + g = 18.008 \text{ ft}$$