# Drilled Shaft to Resist Overturning

This application performs an analysis 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

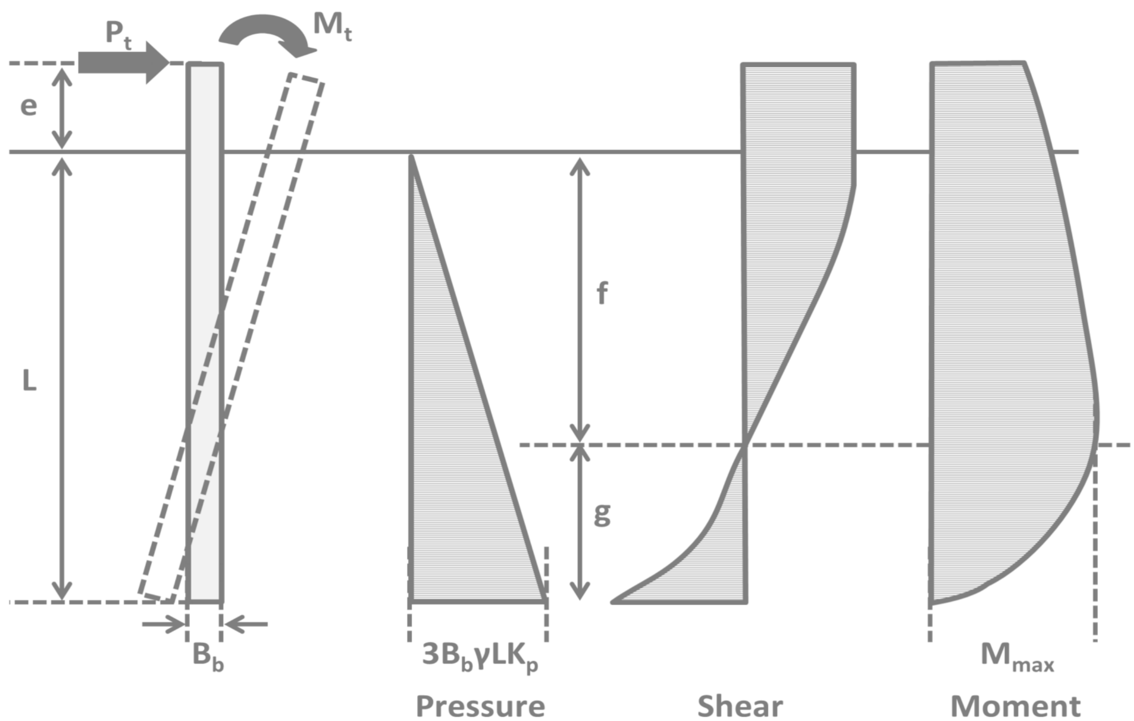


**Figure 1 : Broms Pressure, Shear, Moment Diagram for Cohesionless soils**

## Design Parameters

### Soil properties

Soil friction angle $\phi_s := 32\ \mathbf{deg}$

Soil shear strength $c_s := 15\ \mathbf{psi}$

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

## Geometrical parameters

| | |
|---|---|
| Diameter of shaft | $B_b := 4.0\ \mathbf{ft}$ |
| Ground line to top of foundation | $Offset := 0.0\ \mathbf{ft}$ |

## Applied loads

| | |
|---|---|
| Force of X-direction | $V_x := 40\ \mathbf{kip}$ |
| Force of Z-direction | $V_z := 25.0\ \mathbf{kip}$ |
| Moment of X-direction | $M_x := 250\ \mathbf{kip \cdot ft}$ |
| Moment of Z-direction | $M_z := 1075\ \mathbf{kip \cdot ft}$ |
| Torsional load | $T_{load} := 150\ \mathbf{kip \cdot ft}$ |
| Overturning factor | $\phi_{ot} := 0.6$ |
| Torsional load factor | $\phi_{tor} := 0.9$ |

# Load Moment and Force

| | |
|---|---|
| Design load moment | $M_t := \sqrt{M_x^2 + M_z^2} = 1.104 \times 10^3\ \mathbf{kip \cdot foot}$ |
| Design load force | $P_t := \sqrt{V_x^2 + V_z^2} = 47.170\ \mathbf{kip}$ |
| Design torsional force (Torque) | $T_t := T_{load} = 150\ \mathbf{kip \cdot foot}$ |

# 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 | $e_s := Offset = 0.$ |

Objective function to obtain the minimum length of the shaft

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

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

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

$$M_{max\_s} := M_t + P_t \cdot (e_s + f_s) - \frac{1}{2} \cdot B_b \cdot \gamma_s \cdot f_s^3 \cdot K_p \cdot \phi_{ot} = 1.361 \times 10^3 \ \mathbf{kip \cdot foot}$$

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

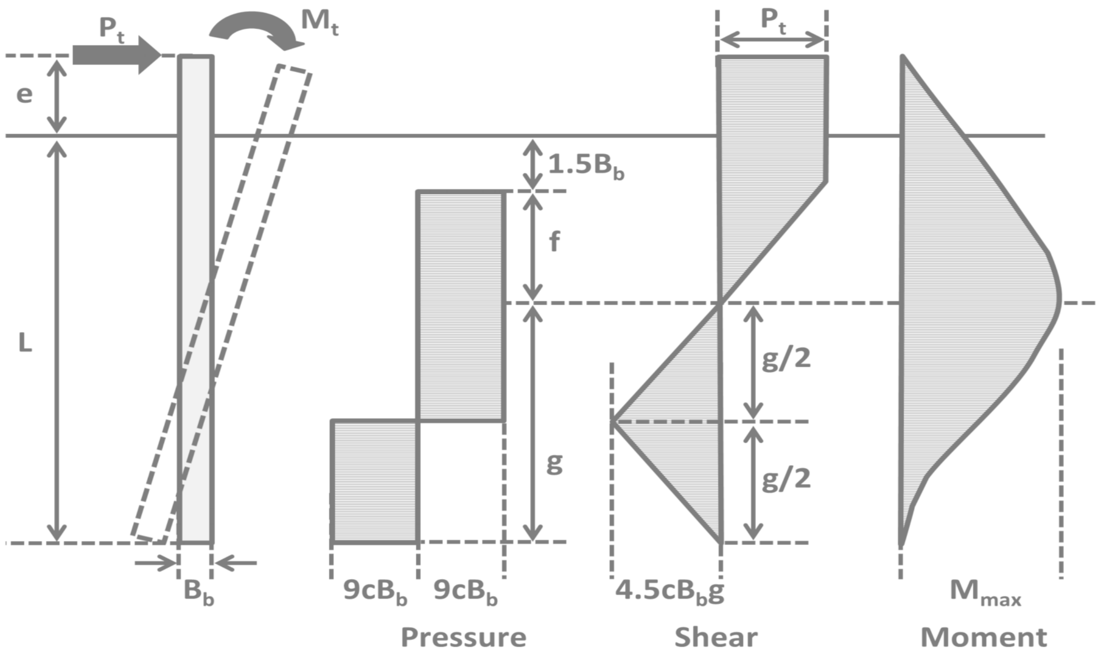


**Figure 2 : Broms Pressure, Shear, Moment diagram for Cohesive soils**

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

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

Maximum moment

$$M_{max\_c} := P_t \cdot \left( \frac{M_t}{P_t} + Offset \right) + \frac{3}{2} \cdot P_t \cdot B_b + \frac{1}{2} \cdot P_t \cdot f = 1.411 \times 10^3\,kip \cdot foot$$

Depth, Point of Zero Shear and Point of Maximum moment

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

Minimum length

$$L_c := 1.5 \cdot B_b + f + g = 18.008\,ft$$