

Appendix D

Soil Nail Capacity Calculation
Equivalent Bond Stress Calculation For SNAIL
Crack Depth Calculation

Soil Nail Capacity Calculation

Strength Reduction Factors:

Bond Stress - .5

Punching Shear - .67

Tendon Yield - .55

Figure 9: Soil Nailed Wall in Silty Sand

Ultimate Bond Stress = 15 psi

Drill Hole Diameter = 4"

Ultimate Punching Shear Capacity = 35 kips

Nail Length = 45'

Nail Diameter = 1.25"

Nail Area = 1.2272 in²

Nail Yield Strength = 60 ksi

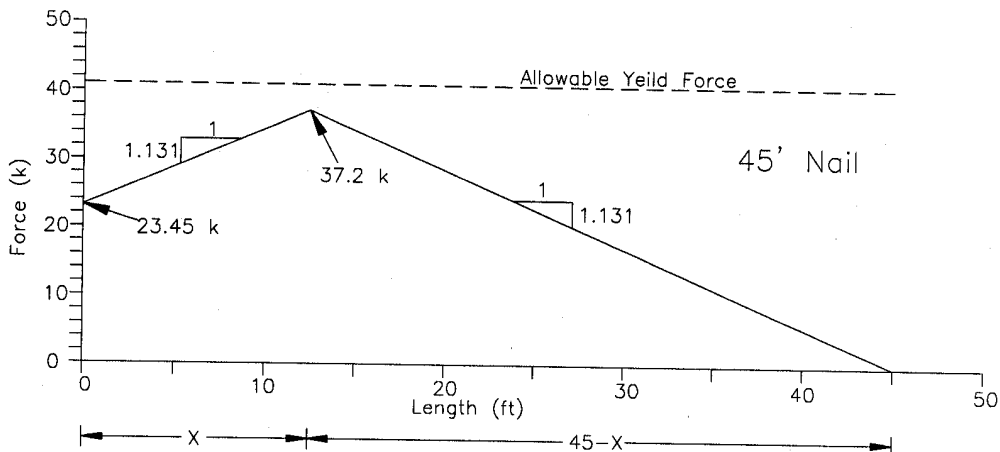
$$\begin{aligned} \text{Ultimate Pullout Resistance} &= \text{Bond Stress} \times \text{Circumference} \times 1 \text{ ft} \\ &= 15 \text{ psi} \times (4''\pi) \times 12''/\text{ft} \\ &= 2,262 \text{ #/ft} \\ &= 2.262 \text{ k/ft} \end{aligned}$$

$$\text{**Allowable Pullout Resistance} = 2.262 \text{ kips} (.5) = 1.131 \text{ k/ft}$$

$$\begin{aligned} \text{Ultimate Nail Yield Force} &= \text{Nail Yield Strength} \times \text{Nail Area} \\ &= 60 \text{ ksi} \times 1.2272 \text{ in}^2 \\ &= 73.63 \text{ kips} \end{aligned}$$

$$\text{**Allowable Yield Force} = 73.63 \text{ kips} (.55) = 40.5 \text{ kips}$$

$$\text{**Allowable Punching Shear} = 35 \text{ kips} (.67) = 23.45 \text{ kips}$$



$$23.45k + X(1.131k/\text{ft}) - (45\text{ft}-X)(1.131k/\text{ft}) = 0$$

$$2X(1.31k/\text{ft}) = (45)(1.131k/\text{ft}) - 23.45k$$

$$2X = 45 \text{ ft} - \frac{23.45k}{1.131 \text{ k/ft}}$$

$$2X = 24.267 \text{ ft}$$

$$X = 12.133\text{ft}$$

$$\text{Peak} = 23.45k + 12.133\text{ft}(1.131k/\text{ft}) = 37.2 \text{ kips}$$

Less Than Allowable Yield Force

Soil Nail Capacity Calculation

Figure 8: Soil Nailed Wall in Layered Soil
 Ultimate Bond Stress = 10 psi (for clay soil)
 Drill Hole Diameter = 6" (for clay soil)
 Ultimate Punching Shear Capacity = 40 kips
 Nail Length = 60'
 Nail Diameter = 1.25"
 Nail Area = 1.2272 in²
 Nail Yield Strength = 60 ksi

Strength Reduction Factors:
 Bond Stress - .5
 Punching Shear - .67
 Tendon Yield - .55

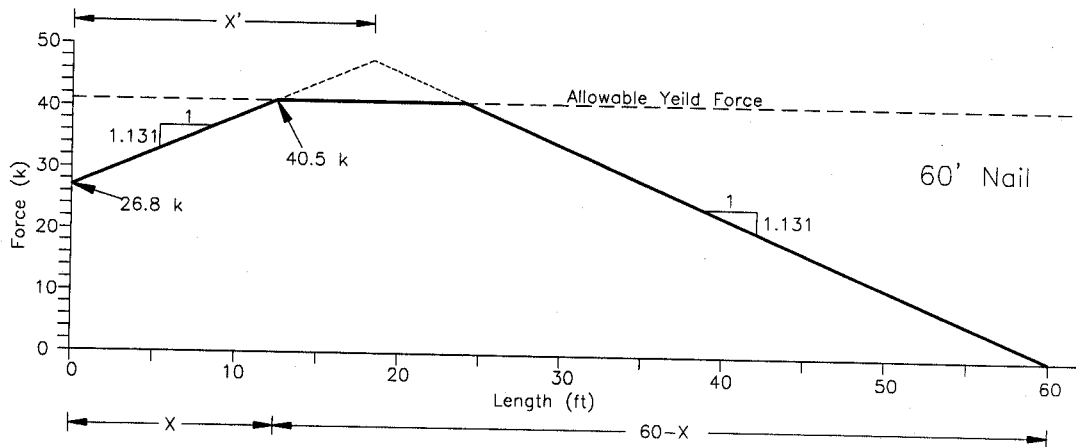
$$\begin{aligned} \text{Ultimate Pullout Resistance} &= \text{Bond Stress} \times \text{Circumference} \times 1 \text{ ft} \\ &= 15 \text{ psi} \times (4''\pi) \times 12''/\text{ft} \\ &= 2,261 \text{ #/ft} \\ &= 2.261 \text{ k/ft} \end{aligned}$$

****Allowable Pullout Resistance = 2.261 kips (.5) = 1.131 k/ft**

$$\begin{aligned} \text{Ultimate Nail Yield Force} &= \text{Nail Yield Strength} \times \text{Nail Area} \\ &= 60 \text{ ksi} \times 1.2272 \text{ in}^2 \\ &= 73.63 \text{ kips} \end{aligned}$$

****Allowable Yield Force = 73.63 kips (.55) = 40.5 kips**

****Allowable Punching Shear = 40kips (.67) = 26.8 kips**



$$26.8k + X'(1.131k/\text{ft}) - (60\text{ft}-X')(1.131k/\text{ft}) = 0$$

$$2X'(1.131k/\text{ft}) = (60)(1.131k/\text{ft}) - 26.8k$$

$$2X' = 60\text{ft} - \frac{26.8k}{1.131 \text{ k/ft}}$$

$$2X' = 36.3 \text{ ft}$$

$$X' = 18.15\text{ft}$$

$$\text{Peak} = 26.8k + 18.15\text{ft}(1.131k/\text{ft}) = 47.33\text{kips}$$

Peak is higher than tendon yield strength,
 so allowable yield force governs.

Intersection with Yield Force

$$40.5k - 26.8k - X(1.131k/\text{ft}) = 0$$

$$X = \frac{(40.5k - 26.8k)}{1.131 \text{ k/ft}}$$

$$X = 1.336\text{ft}$$

Equivalent Bond Stress Calculation for SNAIL

SNAIL requires bond stress and grout hole diameter for input. Calculations must be performed to change pullout resistance for tiebacks and geogrid reinforcement into equivalent soil nail parameters. These are two example calculations on slopes included in this study. A grout hole diameter is assumed, and the bond stress is calculated for data input.

Tiedback Walls

Tendon pullout resistances are typically specified in units of kips per foot of bonded length.

Slope No. 4: Tiedback Wall in Layered Soil

4 k/ft Allowable Pullout

Assume grout hole diameter = 8"

Bond Stress (psi) = $\frac{\text{Allowable Pullout (k/ft)} \times (1000 \text{ \#/ft})}{\text{Circumference} \times (12 \text{ \"/ft})}$

$$B.S. = \frac{4 \text{ k/ft} \left(\frac{1000 \text{ \#/k}}{1} \right)}{(\pi \times 8) \left(\frac{12 \text{ in/ft}}{1} \right)} = 13.3 \text{ psi}$$

Mechanically Stabilized Earth Walls

Geogrid reinforcement pullout resistance increases with increasing overburden pressure, and is usually specified in terms of allowable yield strength and an interface friction angle.

Slope No. 10: 15 ft Mechanically Stabilized Earth Wall

Allowable Yield Strength = 1185 lbs/Lft

Layer No. 5, Depth = 11.5 ft

Assume grout hole diameter = 4"

Development Rate (k/ft) = $\frac{\text{Allowable Yield Strength (lb/Lft)}}{\text{Development Length (ft)}}$

Refer to Appendix D – “Geogrid Reinforcement Capacity Calculation” for illustration development length calculation.

Bond Stress (psi) = $\frac{\text{Development Rate (k/ft)} \times (1000 \text{ \#/ft})}{\text{Circumference} \times (12 \text{ \"/ft})}$

$$B.S. = \frac{1.656 \text{ k/ft} \left(\frac{1000 \text{ \#/k}}{1} \right)}{(\pi \times 4) \left(\frac{12 \text{ in/ft}}{1} \right)} = 10.98 \text{ psi}$$

SNAIL only allows one value of bond stress per soil. Since the bond stress changes for each layer of reinforcement, a Bond Stress Factor must be assigned to each layer. SNAIL multiplies the bond stress by this factor during calculation, thus permitting a unique bond stress to each layer. The Bond Stress Factor is calculated as follows.

Bond Stress Factor = $\frac{\text{Bond Stress Defined for Soil}}{\text{Bond Stress for Reinforcement Layer}}$

$$B.S.F. = \frac{2.39 \text{ psi}}{10.98 \text{ psi}} = 4.60$$

Example Crack Depth Calculation

$$d_{crack} = \frac{2c'_m}{\gamma \tan\left(45 - \frac{\phi'_m}{2}\right)}$$

$$c'_m = \frac{c'}{F}$$

$$\tan \phi'_m = \frac{\tan \phi'}{F}$$

Figure 2: Unreinforced Homogenous Slope with a Crack

$$\gamma = 120 \text{ pcf}$$

$$c' = 300 \text{ psf}$$

$$\phi' = 30^\circ$$

$$F = 1.4$$

$$c'_m = \frac{300 \text{ psf}}{1.4} = 214.3 \text{ psf}$$

$$\tan \phi'_m = \frac{\tan 30}{1.4} = .4124$$

$$\phi'_m = \tan^{-1} .4124 = 22.4^\circ$$

$$d_{crack} = \frac{2(214.3 \text{ psf})}{120 \text{ psf} \times \tan\left(45 - \frac{22.4}{2}\right)} = 5.3 \text{ ft}$$