FOUNDATION

SUPPORTWORKS®

HELICAL SOIL NAILS

STABILITY. SECURITY. INTEGRITY.

Foundation Supportworks® offers a complete line of helical products for use as new construction helical piles, retrofit piers, soil nails and tiebacks.

Helical Soil Nails

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About FOUNDATION SUPPORTWORKS®


Omaha, Nebraska


Seymour, Connecticut

Foundation Supportworks®, Inc. (FSI) is a leading manufacturer of helical pile systems, hydraulically-driven push pier systems, wall anchoring and wall bracing systems, and supplemental crawl space support systems. FSI was founded on the principles of ***integrity, quality*** and ***service*** and it is our mission to provide the industry with innovative solutions that are appropriately designed and tested, expertly installed and dependable to perform as promised.

Foundation Supportworks' commitment to its network of installing contractors and, ultimately, the end consumer, is apparent by employing a team of customer service and dealer support staff unparalleled in the industry. Our staff of full-time employees includes a professional corporate trainer, geotechnical and structural engineers, and entire graphics and website development departments.

With major dealer support facilities in Omaha, Nebraska and Seymour, Connecticut, Foundation Supportworks® operates with a long-term vision.

ENGINEERING

Foundation Supportworks® has both geotechnical and structural engineers on staff for product design, quality assurance of products and support to our network of installing contractors. Our in-house engineers are available to assist with preliminary designs and provide technical support to engineers, architects, building departments and general contractors. Our engineers are experts in the industry and routinely present technical information at industry trade conferences, engineering and architectural meetings and conferences, as well as to contractors and home inspectors.

HELICAL SOIL NAILS

Soil nailing is a method of earth retention that relies on reinforcing strands or members installed within a soil mass to create an internally stable gravity wall/retaining system. A helical soil nail typically consists of square shaft lead and extension sections with small diameter (6 to 8 inches) helix plates spaced evenly along the entire shaft length. The helical soil nail is installed by application of torque, similar to the installation of a helical tieback. The helical soil nail is a passive bearing element, which relies on movement of the soil mass and active earth pressures to mobilize the soil shear strength along the nail. In contrast, a tieback is pre-tensioned to mobilize the soil shear strength around the helix plates. Excavation, soil nail installation, and application of wall facing is completed in steps from the top of the wall downward.

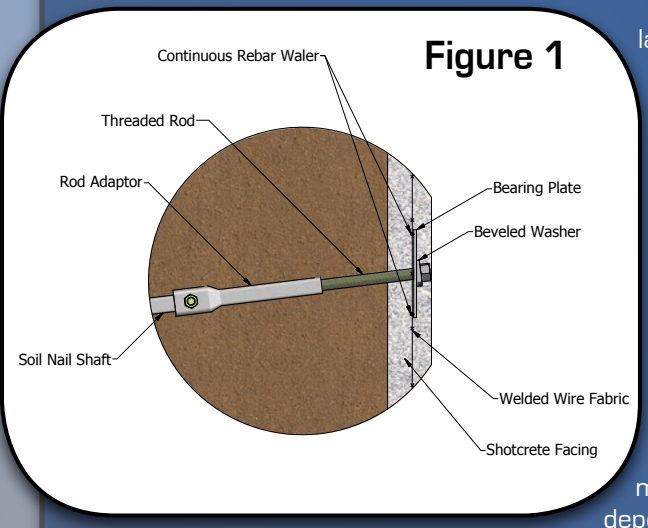
DID YOU KNOW?

Soil nail wall technology began in Europe with use of the New Austrian Tunneling Method in rock formation in 1961. The technology then carried over to applications involving unconsolidated soil retention, primarily in France and Germany. Soil nails walls were first used in North America for temporary excavation support in the late 1960's and continued to gain recognition and acceptance during the 1970's and 1980's for higher profile projects including highway applications. Much of the soil nail wall research performed in North America was funded by the Federal Highway Administration (FHWA) and other state highway agencies during the 1990's. Although helical piles have been used as tiebacks since the early 1950's, helical soil nails are a relatively new alternative to their grouted counterparts.

DESIGN CONSIDERATIONS

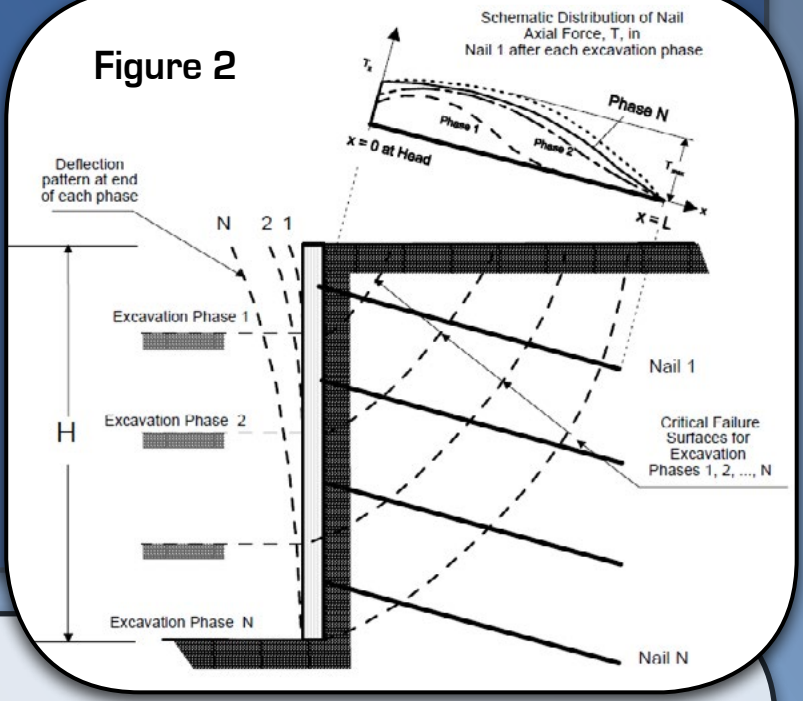
Helical soil nails are passive bearing elements which rely on movement of the soil mass to mobilize the soil shear strength along the nail. As a result, soil nail walls typically experience more lateral movement than tieback walls of similar height. By allowing this movement, the highest stress in the soil nail is near the failure plane, centered between the opposing tensile forces. Conversely, the highest stress in a tieback is at the wall face. Therefore, soil nails have less nail head force than tiebacks for a similar size wall, which results in potential cost savings by using soil nails due to reduced wall thickness requirements (See Figure 1).

Figure 1



As the construction of the wall progresses, the upper soil nails become less important for the stabilization of the soil mass, and depending upon wall height, may not contribute to the global stability at the final excavation phase. However, the upper soil nails are instrumental in providing stability during the early phases of excavation and contribute to limiting wall deflections. Figure 2 illustrates the tensile force distribution along the top soil nail as construction continues through the various excavation phases. Phase N in the upper schematic does not reflect the maximum soil nail tensile force since additional loading occurs after construction to reach long term equilibrium of soil nail forces.

Figure 2



DETERMINATION OF CAPACITY

The bearing capacity of a helical soil nail may be calculated using the traditional bearing capacity equation:

$$Q_u = \sum [A_h (cN_c + q'N_q)]$$

Where,
- Q_u = Ultimate Pile Capacity (lb)
- A_h = Area of Individual Helix Plate (ft^2)
- c = Soil Cohesion (lb/ft^2)
- N_c = Dimensionless Bearing Capacity Factor = 9
- q' = Effective Vertical Overburden Pressure (lb/ft^2)
- N_q = Dimensionless Bearing Capacity Factor

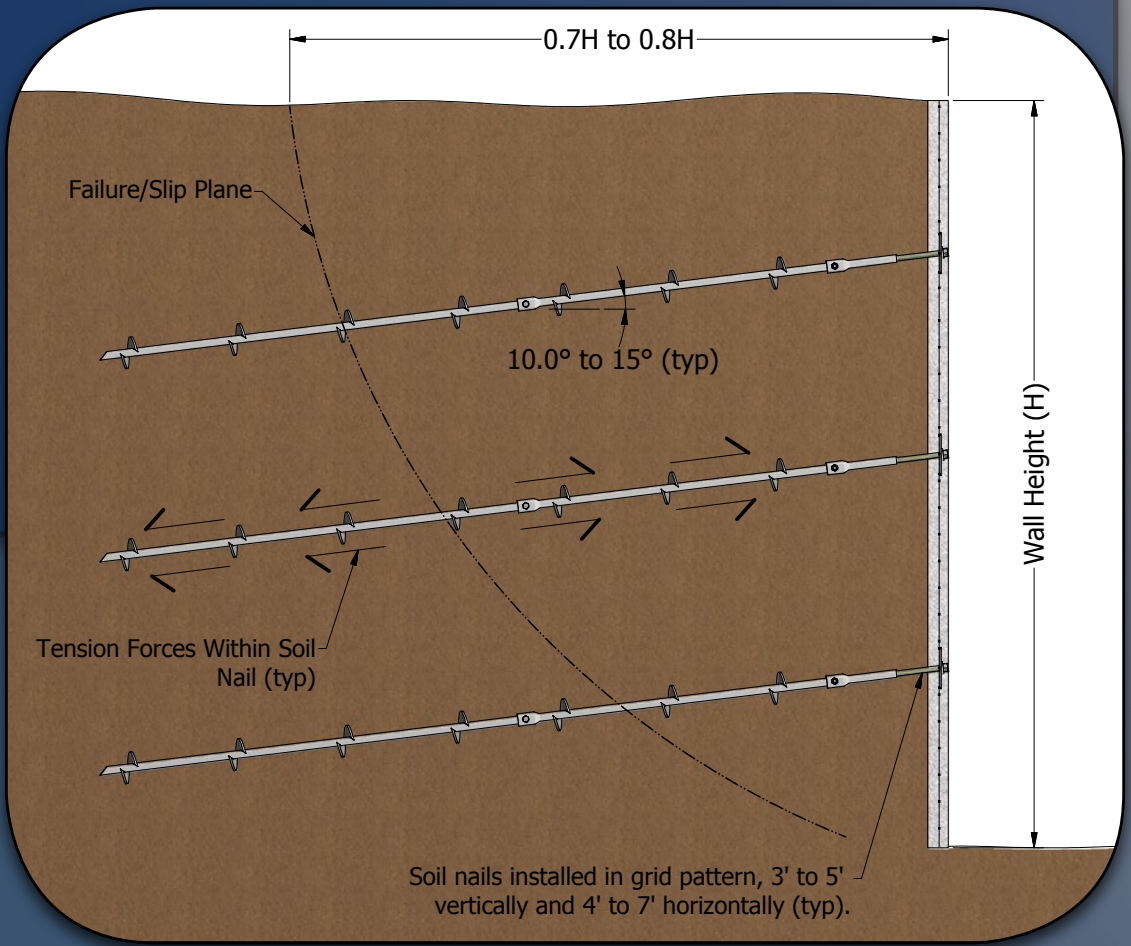
The design procedure for helical soil nails is similar to that for grouted nails. For a helical soil nail, the bond stress with the soil is assumed to act along a cylindrical surface area defined by the outside edge of the helix plates. Bearing capacity of the soil nail is determined using the Individual Bearing method (shown above) and is correlated to bond stress by:

$$q_u = \frac{Q_u}{L \pi D_h FS}$$

Where,
- q_u = Bond Stress (psi)
- Q_u = Bearing Capacity of Helical Soil Nail by Individual Bearing Method (lb)
- L = Soil Nail Length (in)
- D_h = Helix Diameter (in)
- FS = Factor of Safety for Uncertainties in Soil Conditions (Typically 1.5 to 2.0 Based on Quality of Soil Information)

The following should be considered when designing soil nail walls:

- Not all soil conditions are suitable for construction of helical soil nail walls. Excavations are generally made in 3 to 5-foot steps, depending upon soil type and strength, and the soil should be able to stand unsupported for a period of at least one day after the vertical cut is made.
- A failure plane generally develops at the top of the wall at a horizontal distance of about 0.7 to 0.8 times the height of the wall away from the wall face (Lazarte, Elias et al. 2003). This distance may be reduced by battering the wall face. Any structure, utility, roadway, etc. that would be impacted by the wall movement and/or failure plane should be considered during the design phase.
- Top of wall lateral movements on the order of 0.2% to 0.3% of the wall height should be expected with soil nail lengths to wall height ratios between 0.7 to 1.0, negligible surcharge loading and design including a global factor of safety of at least 1.5. As a general guide, the soil mass located between the failure plane and the wall facing may slump approximately 1/8-inch laterally and 1/8-inch vertically for each 5-foot depth of excavation.
- Soil nail walls may be designed with a slight batter rather than vertical to account for anticipated lateral wall movement.
- There may be restrictions to the design soil nail lengths, including property lines, right-of-way (ROW), underground utility corridors, bridge abutments or existing structures.
- Consider temporary and/or permanent surcharge loads from adjacent structures, roadways, construction equipment, fill placement, etc.
- Maximum wall heights for helical soil nails walls are practically limited to 20 to 30 feet. Increased heights may be considered with a stepped wall design.
- Helical soil nails are typically installed in a grid pattern, spaced 3 to 5 feet vertically and 4 to 7 feet horizontally.
- Helical soil nails are typically installed at an angle of 10 to 15 degrees downward from horizontal, although a batter is not required. The downward installation angle is a carryover from grouted nail design where an angle is required to prevent wet grout from flowing out of the hole.
- Soil nails may be installed with consistent lengths for all rows, or be longer at the top of the wall, becoming shorter with successive rows toward the bottom. Nail length determination depends upon soil strength parameters, location of the failure plane, and design for strength and service limit states.



Additional soil nails installed below previous rows of soil nails embedded in shotcrete wall

Helical Soil Nails

ADVANTAGES

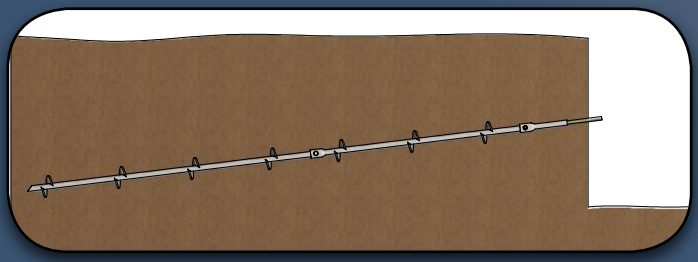
- Soil nail walls are more economical than conventional concrete gravity walls and are often more economical than tieback walls due to reduced wall facing requirements. There would likely be more soil nails than tiebacks for a given project, but this additional cost for the nails is outweighed by the difference in cost of a shotcrete facing versus a more substantial soldier pile, sheet-pile, or reinforced concrete wall detail.
- Soil nails are typically shorter than tiebacks for similar wall heights so there will be reduced right-of-way (ROW) requirements.
- There is less impact to adjacent structures since soil nails are not installed with vibratory energy like solider piles or sheet-piles.
- Overhead clearance requirements are less than driven soldier pile or sheet-pile wall construction. Soil nail walls can therefore be installed easily below bridges or other structures.
- There is no need to embed structural elements below the proposed ground surface elevation on the low side of the soil nail wall. Soldier pile and sheet-pile walls require minimum embedment depths for wall stability.
- Soil nail wall construction is typically quicker than other earth retention methods.
- Soil nails walls can be constructed in remote areas with smaller equipment.
- Soil nail walls have performed well during seismic loading events due to the overall system flexibility.

Soil nail walls are constructed from the top down where the excavation proceeds as shown in Figure 4. The construction sequence for a typical helical soil nail wall includes:

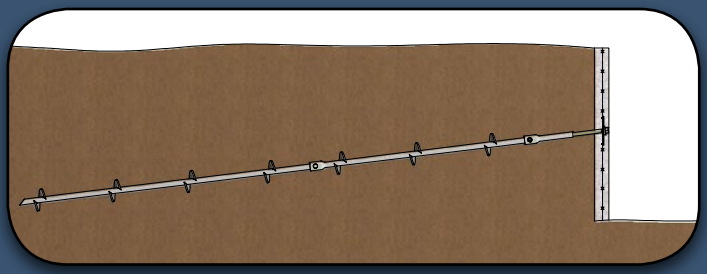
- Initial excavation about 3 to 5 feet deep depending upon design parameters and soil conditions
- Installation of the first row of helical soil nails to the required inclination angle, torque and embedment length
- Placement of drainage medium (if required)
- Placement of wall reinforcement and bearing plates
- Placement of shotcrete to the required design wall thickness
- After shotcrete has cured, repeat sequence for successive rows of soil nails; Continue process to final design depth (wall height)

STEP 1
Initial Excavation

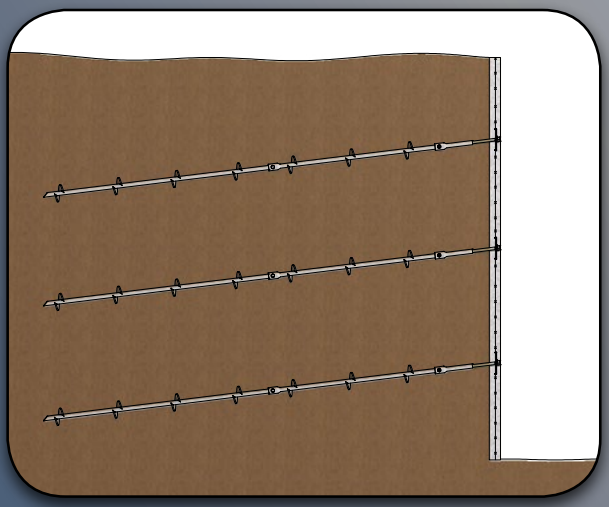
STEP 2
Install top row of soil nails



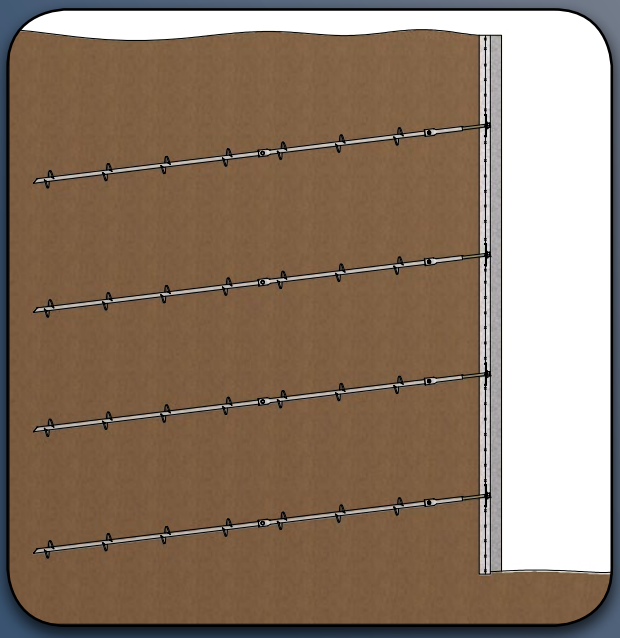
STEP 3
Install drainage strips, reinforcing steel and anchor plates, and apply initial shotcrete layer.



STEP 4
Repeat steps 1 through 3 to bottom of wall.



STEP 5
Apply final or permanent wall facing if required.



TEMPORARY AND PERMANENT WALL FACING

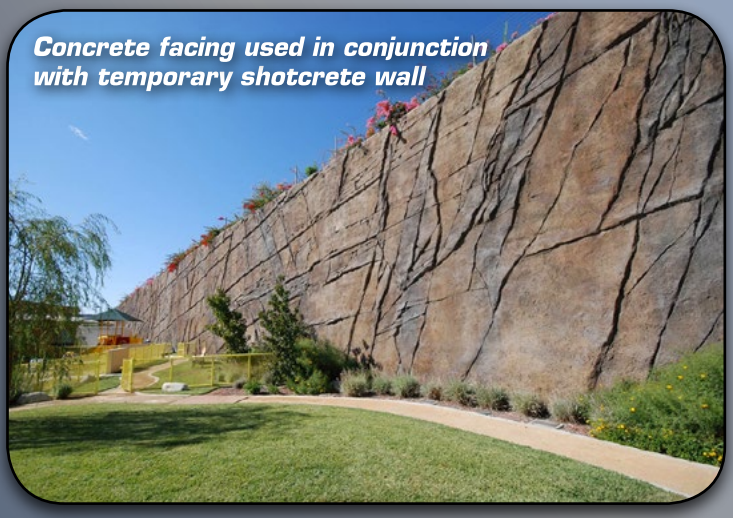
Helical soil nail walls are used most often in temporary shoring applications, with reinforced shotcrete the most common temporary wall facing material. Shotcrete is concrete conveyed through a hose and projected through a nozzle at high velocity onto a working surface. The shotcrete is applied/sprayed in thin lifts until the design thickness requirement is met for the wall. For temporary applications, the shotcrete is typically applied to a thickness of 3 to 4 inches. Internal reinforcement of the shotcrete may consist of welded wire fabric (WWF), steel reinforcing bars, (rebar), or fiber reinforcement. WWF with rebar walers at the nail heads is typically favored due to ease of installation.

Permanent helical soil nail walls may either have an additional thickness of shotcrete applied or another facing attached to the temporary shotcrete layer. For permanent soil nail walls with shotcrete facing, the typical wall thickness varies from 6 to 12 inches, not including the thickness of the temporary facing. Cast in place and precast concrete facings can also be used in conjunction with the temporary shotcrete wall facing. Facings can be attached to the shotcrete wall to form decorative facades.

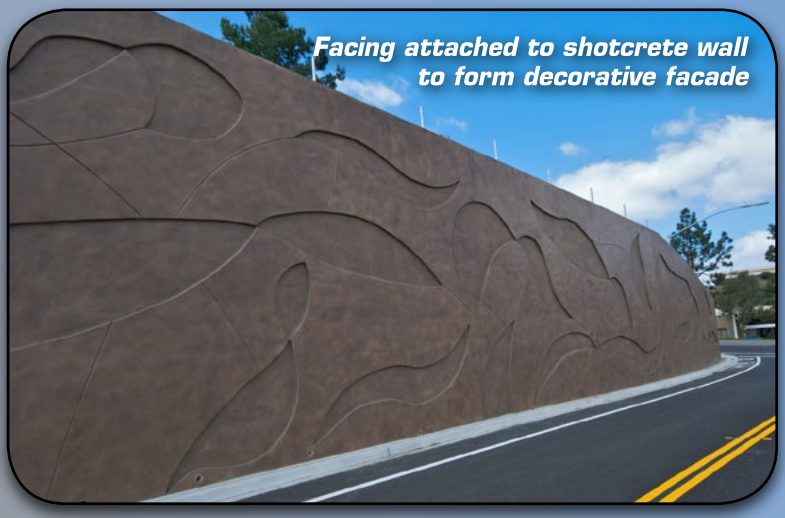
Shotcrete projected at high velocity onto working surface

Shotcrete applied in thin lifts until design thickness is met

Last row of soil nails installed and prepped for shotcrete



Concrete facing used in conjunction with temporary shotcrete wall

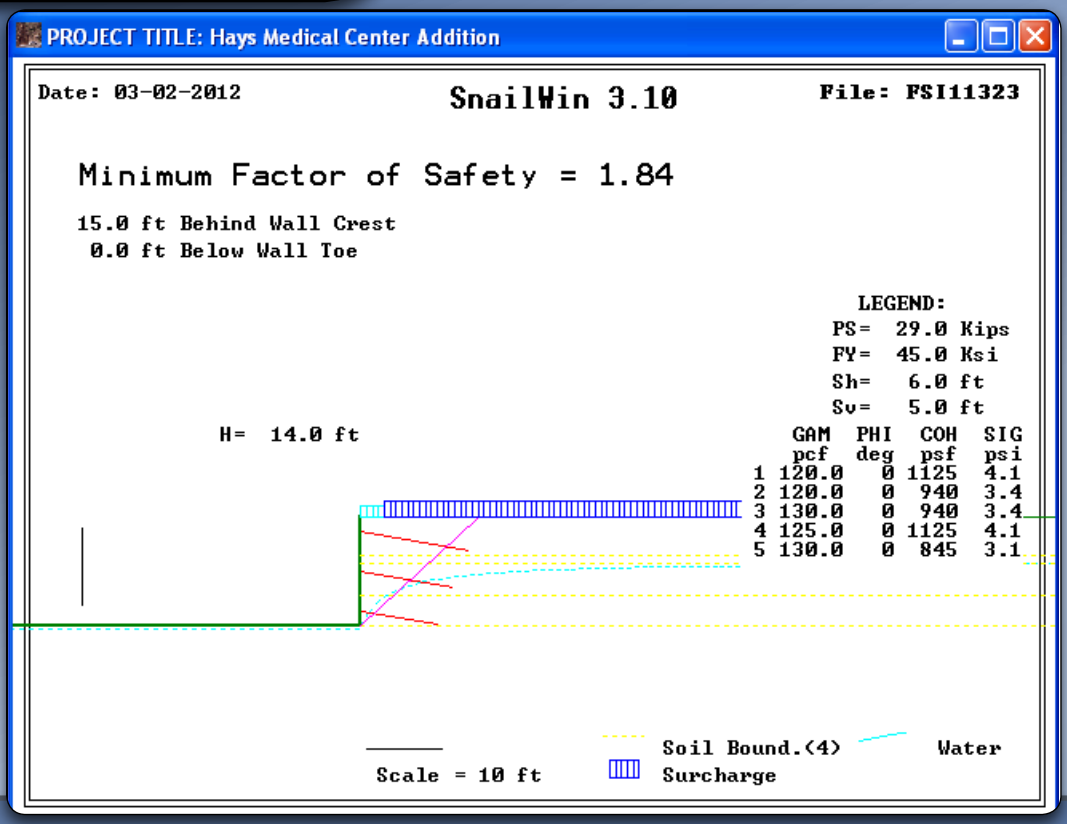


Facing attached to shotcrete wall to form decorative facade

Helical Soil Nails

DESIGN SOFTWARE

FOUNDATION SUPPORTWORKS®



The design of helical soil nail walls should be performed in general accordance with requirements detailed in FHWA Geotechnical Engineering Circular No. 7 (Lazarte, Elias et al. 2003). Several computer programs are available for designing soil nail walls, with the more common programs being SNAIL (CALTRANS 1999) and GoldNail (Golder 1996).

SNAIL is a windows-based program developed by the California Department of Transportation (CALTRANS) and is available free to the public. SNAIL is a two dimensional limit equilibrium program that uses force equilibrium exclusively. Either metric or English units can be used during the design process. Soil nail reinforcement inputs include location, diameter, inclination angle, vertical and horizontal spacing, cross sectional area, yield strength and tensile strength. The soil parameter inputs include soil unit weight, cohesion, friction angle, bond strength and the bond strength reduction factor. The soil strength parameters are modeled with the conventional linear Mohr-Coulomb envelope. The only data entered for the wall facing design must be used for the trial runs. The program allows for consideration of up to seven soil layers and provides inputs for two uniform vertical surcharge loads and an internal or external point load. The program output provides the global factor of safety, an estimated location of the failure plane and the tensile forces for each nail for each of the 10 most critical failure surfaces analyzed.

GoldNail is a windows-based proprietary program developed by Golder Associates which satisfies both moment and force equilibrium. The program can work in one of three modes; design, factor of safety and nail service load. The program allows factored strengths for Load and Resistance Factor Design (LFRD). The soil strength parameters can be modeled with the conventional linear Mohr-Coulomb envelope or using a bi-linear strength envelope. Up to 13 soil layers can be modeled with more complex geometry capability than SNAIL. The program can only model a circular failure surface which must pass at the toe of the wall or above the toe. This limits the ability to evaluate sliding and bearing capacity failure modes. Data input variables and output reports are generally similar to SNAIL.