DESIGN PROCEDURE FOR LAUNCHED SOIL NAIL SHALLOW SLOUGH TREATMENT

Soil Nail Launcher Carrier (Hydraulic Excavator)

Soil Nail Launcher

Nail

Stabilizer Tube

Barrel Breech

Guide Barrel

Barrel Shroud

GEOTECHNICAL DESIGN PROCEDURE
GDP-14

GEOTECHNICAL ENGINEERING BUREAU

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I. DESCRIPTION AND PURPOSE

Launched soil nailing is a technique developed for the reinforcement of locally unstable existing soil masses. Launched soil nails are long steel or fiberglass rods installed to reinforce or strengthen the existing ground. Soil nails are inserted using high-pressure air approaching 2500 psi (17.2 MPa) by a launcher that can be mounted on a hydraulic excavator. As the soil nail passes into the soil, the ground around the nail is displaced by compression at the nail tip. This forms an annulus of compression which reduces the soil drag on the nail. As the nail comes to rest, the soil rebounds onto and bonds with the nail. The soil nails reinforce the locally unstable soil mass by transferring the nail’s tensile and shear resistance through the failure plane of the sliding soil. The nails maintain the resisting force because they are anchored beyond the slip plane.

This treatment is intended for shallow slope sloughs where the slip plane is within the minimum three meter soil nail embedment depth.

Applications of the installation method include the ability to work beneath most overhead utilities, a relatively rapid installation process (approximately 80 linear ft. (25 m) of road per day for a two-row installation), minimum ground disturbance, single lane closure for mobilization, and installation from the top of the affected slope. The installation method is not appropriate for use in very compact soils or soils containing a significant quantity of boulders and/or cobbles. Underground utility mark-out is required to avoid damage by the installation process.

The purpose of this document is to provide a method for the selection of launched soil nail spacing used to stabilize shallow embankment sloughs.
II. SITE SELECTION

Using 20 ft. (6 m) long nails, launched soil nailing is limited to shallow soil sloughs where the depth from the slope surface to the estimated slide plane is approximately 10 ft. (3 m).

The design process includes an assessment of the cause of failure and collection of field data. The required design information can be gathered from a visual assessment of the site and preparation of a field-developed cross section.

Figure 1 Field Data Form for Launched Soil Nails should be used to note the general soil, rock, vegetation, drainage, grade, and apparent utilities at the site, and provide information regarding the consequence of additional slope movements. Site dimensions can be recorded on the plan or cross-section and on the dimension list, DI through D4, X', H, and HW on the front of the form, X can be projected from the depth of cracks and the toe of the slide.

Sizes and percentages of rock inclusions should be estimated. Include the maximum depth of the distressed area. Note all physical features such as areas of seepage or wet soil, large trees, overhead utility lines, and other potential obstructions. Note if the soil appears to be cementitious.

Figure 2 Site Factor Checklist for Launched Soil Nails contains site factors to adjust the nail spacing for local conditions. The site factor evaluation is based on local conditions, the confidence in the site condition assessment, and the consequence of continued slope movement. Generally the High site condition deserves a more critical design review than the Low site condition.

The site factor checklist can also be used to determine the overall feasibility of correcting the slough with launched soil nails. If the site factors are all in the High condition, then other repair alternatives may be required. Whenever the site condition is High, or when the consequences of additional sliding are High, then more in-depth site investigations and slope stability analyses should be performed before selecting a final repair alternative.
Figure 1 Field Data Form for Launched Soil Nails
# Site Factor Checklist for Launched Soil Nails

<table>
<thead>
<tr>
<th>Site Factors</th>
<th>Evaluation**</th>
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<tbody>
<tr>
<td>Steepness of Slope (Slope Ratio)</td>
<td>Low Med High</td>
</tr>
<tr>
<td>Depth to Failure Surface, D1</td>
<td>2:1 1.5:1 1:1</td>
</tr>
<tr>
<td>Soil Moisture at time of slide</td>
<td>5' 5'-10' 10'-15'</td>
</tr>
<tr>
<td>Decayed Logs or Slash Within Fill</td>
<td>None Some Many</td>
</tr>
<tr>
<td>Soil Type*a</td>
<td>Sand Silt Clay **</td>
</tr>
<tr>
<td>Consequence of Add'l Failure(s)b</td>
<td>Low Med High</td>
</tr>
<tr>
<td>Potential for Accident or Injury</td>
<td>Low Med High</td>
</tr>
</tbody>
</table>

*Unified or AASHTO Classification.
**Design charts were developed for Medium Site Condition (Site Factor of Safety, f_{n} = 1.1).
1 Relates to the probability of failure.
2 Relates to the consequence of failure.

## Site Specific Plan and (Or) Cross-Section

![Site Specific Plan and Cross-Section](image)

*Figure 2 Site Factor Checklist for Launched Soil Nails*
III. DESIGN

Figure 3 *Forces Acting on a Slope Slough* illustrates the interaction of driving and resisting forces in the soil. Figure 4 *Simplified Wedge Forces* illustrates the geometry and forces in the simplified wedge analysis method used to develop the design charts. Figures 5a *Tensile Resistance of Nail* and 5b *Shear Resistance of Nail* illustrate the simple geometry of the tensile and shear resistance of the nail.

The design charts (Figures 6 to 8) provide spacing for correcting small embankment failures using 1 ½ in. (38 mm) nails for a Medium site condition. These charts are based on the assumption that the existing field condition is at limit equilibrium (i.e., existing factor of safety = 1.0).

The design assumes the slope has been in place for several years and can be represented by the consolidated and undrained condition during slope movement.

The design charts do not include groundwater as a variable. Since pore water pressures can have a major effect on site stability, active seepage on the site must be controlled by the appropriate systems to control either groundwater and/or surface run-off in the affected area prior to installation of the launched soil nail system.

If the material is wholly granular, the position of the slip surface is determined by the values x and H, where x is the distance to the projected slide plane surface as indicated in Figure 4 *Simplified Wedge Forces* and H is the vertical distance between the shoulder and the toe of the slide. Where the toe is not visible, the toe of the embankment is assumed to be the toe of the slip.

To ensure full penetration by the soil nails, the soil should not contain a high percentage of cobbles or boulders. Launching nails in soils that are predominantly sands, gravel, silts, and clays, or mixtures of these, have a high chance of success depending on the in situ density. Penetration will be reduced in dense gravels, cementitious soils, and stiff clay.

A nail is rejected if it encounters an obstruction and does not achieve 10 ft. (3 m) of penetration beyond the slope surface. If a nail encounters an obstruction from what may be anticipated as occasional cobbles and boulders, the obstruction can be circumvented and the required penetration can be achieved by adjustment of the nail location within the design grid. The replacement nail should be placed within an 18 in. (450 mm) radius of the obstructed nail. If subsequent nails fail to achieve the minimum penetration, then the Geotechnical Engineering Bureau should be contacted to recommend a course of action.

For granular materials the number of nails N is related to the slope ratio and the value of H.

The design assumes the top nail is 1 m below the road shoulder and additional nails are evenly spaced with offset rows on the slope with no nails closer than 1 m from the toe of the failure.

Figure 9 *Typical Nail Spacing Pattern* shows a plan view of the preferred nail spacing pattern.
Figure 3 Forces Acting on a Slope Slough

Figure 4 Simplified Wedge Forces

Where:

- \( W \) = Mass of sliding wedge
- \( \gamma \) = Unit mass of the soil
- \( X' \) = Distance to visible crack
- \( X \) = Distance to projected slide plane
- \( W = \frac{1}{2} \gamma x H \)
Figure 5a  *Tensile Resistance of Nail*

Figure 5b  *Shear Resistance of Nail*
Figure 6 Number of Nails Required to Stabilize Slope Slough for a 1V on 2H Slope
Figure 7 Number of Nails Required to Stabilize Slope Slough for a 1V on 1.5H Slope
Figure 8 Number of Nails Required to Stabilize Slope Slough for a 1V on 1H Slope
Figure 9 Typical Nail Spacing Pattern
REFERENCES

The following sources of information were used in developing this manual and are sources for further information on the subject matter:

1. Website for launched soil nails found at www.soilnaillauncher.com