Soil nail support of excavation

For LUSAS version:	21.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear

Problem Description

A 10m deep excavation is modelled using soil nails and facing to stablise the soil [S1]. The soil nail is constructed by drilling a 100mm hole, inserting a 20mm diameter steel rod and then filling with grout. The problem geometry is shown in figure 1.

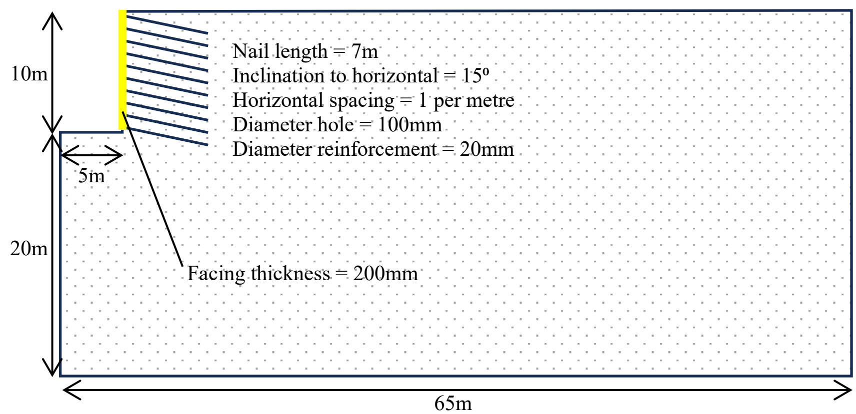

Figure 1: Problem geometry

Two solution methods are considered. The first separates the excavation from the installation of the facing and soil. The second considers the excavation and the installation of the facing and soil nail as simultaneous events. By considering the excavation first a much lower factor of safety is found in the critical prior to the installation of the soil nail and facing.

In addition, the effect of not allowing the soil to carry tension is considered on the overall solution and of the critical factor of safety.

Keywords

Activation/deactivation, phi-c analysis.

Associated Files

Associated files can be downloaded from the user area of the LUSAS website.

- ❑ **soil_nail.lvb** carries out automated modelling of the example.

- Use **File > New** to create a new model of a suitable name in a chosen location.
- Use **File > Script > Run Script** to open the lvb file named above that was downloaded and placed in a folder of your choosing.

Objectives

- Calculate factor of safety before the installation of the final soil nail and facing
- Calculate factor of safety after the installation of the final soil nail and facing
- Compare maximum displacement, maximum axial force and the safety factor with PLAXIS analysis [S1].

Preparing the Model Features

Units of kN, m, t, s, C

Feature Geometry

The surfaces and lines defining the problem are shown in figure 2.

A circular section with a diameter of 100mm is used for the soil nail geometry.

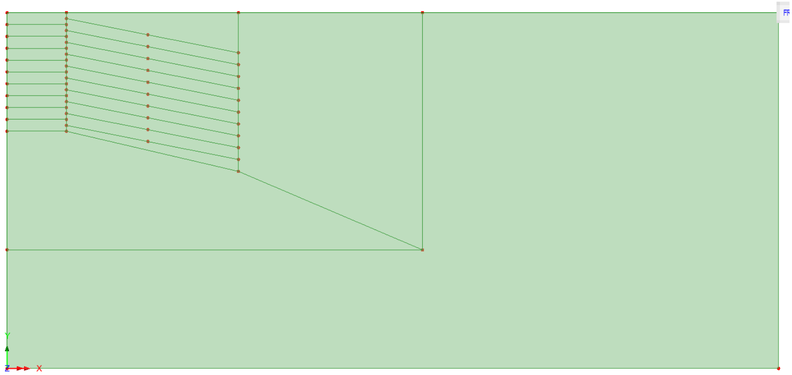

Figure 2: Problem modelled with surfaces and lines

Preparing the Model Attributes

Defining the Mesh

The model is meshed with triangular plain strain elements, TPN6, with a length of 1.5m close to excavation and 3m further away (figure 3). The facing is modelled using quadratic plane strain beams, BMI3N, and the soil nails by thick beams BMI3.

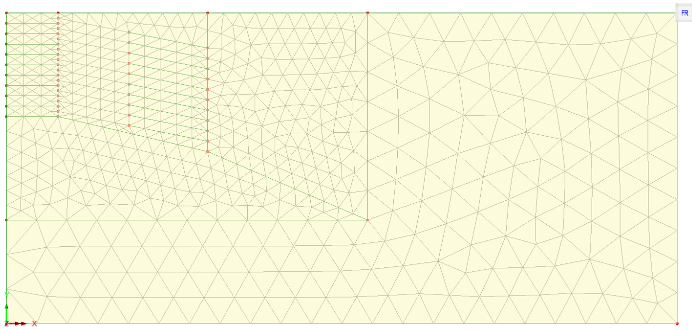

Figure 3: Mesh

Defining the Materials

The soil is modelled using a Modified Mohr-Coulomb (MMC) with Rankine cut-off material. Two materials are detailed in table 1. One with a tensile cut-off close to the Mohr-Coulomb apex and the second with a cutoff at zero. Linear elastic (LE) properties for the nail reinforcement, grout and facing are also detailed.

Table 1: material properties

	Allow tension	No tension	Nail reinforcement	Grout	Facing
Material type	MMC	MMC	LE	LE	LE
Young's modulus	20E3 kPa	20E3 kPa	200E6 kPa	22E6 kPa	22E6 kPa
Poisson's ratio	0.3	0.3	-	-	0.2
Density	1.733 t/m^3	1.733 t/m^3	-	-	2.4 t/m^3
Angle of friction	31.5°	31.5°	-	-	-
Angle of dilation	0°	0°	-	-	-
Cohesion	4.0 kPa	4.0 kPa	-	-	-
Cutoff stress	6.0 kPa	0.0 kPa	-	-	-
K_0	0.478	0.478	-	-	-

The Rankine cutoff stress of 6 kPa is set to be very close to the Mohr-Coulomb apex stress, σ_{apex}, which is calculated from the cohesion, c, and angle of friction, ϕ

$$\sigma_{apex} = c\ cot\phi$$

giving σ_{apex} = 6.53 kPa. The second set of material properties sets the Rankine cutoff stress to zero.

The equivalent Young's modulus for the soil nail, E_{nail}, is calculated using the rule of mixtures from

$$E_{nail} = E_{grout} + \frac{d_{reinf}^2}{d_{hole}^2}\left(E_{reinf} - E_{grout}\right)$$

where d_{hole} and d_{reinf} are the diameters of the hole and reinforcement bar respectively whilst E_{grout} and E_{reinf} are the Young's moduli of the grout and reinforcement, which gives E_{nail}= 29.1E6 kPa.

Defining the Supports

The model is restrained in X and Y directions along its base and in the X direction on the lateral sides as shown in the figure 4.

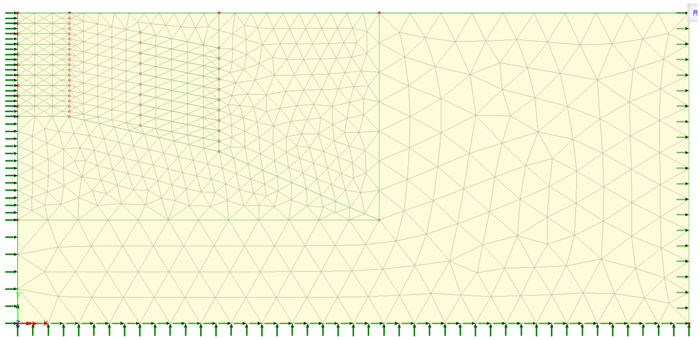

Figure 4: Boundary conditions

Defining the Loads

Gravity loading is used throughout.

Defining Other Attributes

A Deactivate attribute is required to deactivate the facing and nails at the start of the analysis. It is also used to deactivate the soil layers as the excavation progresses.

An Active attribute is used to activate the soil nail and facing.

A phi-c attribute is required for the phi-c reduction analyses.

Running the Analysis

Initial Phase

The initial stresses in the soil are established (figure 5).

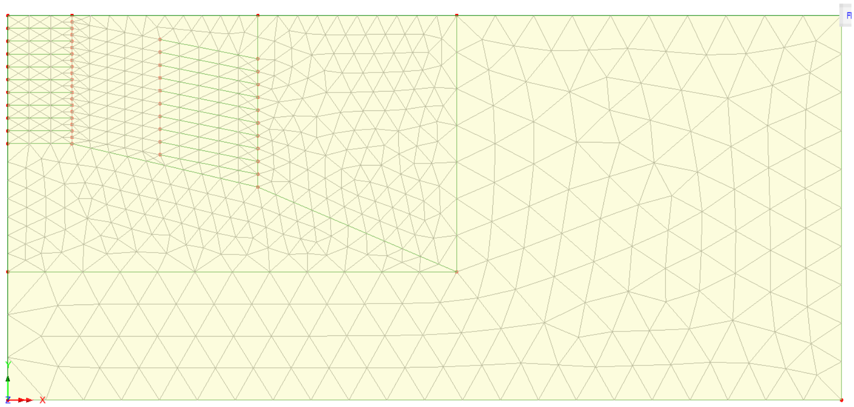

Figure 5: Establish initial stresses

Excavate 1

Excavate first 1 metre layer of soil by deactivation of elements (figure 6).

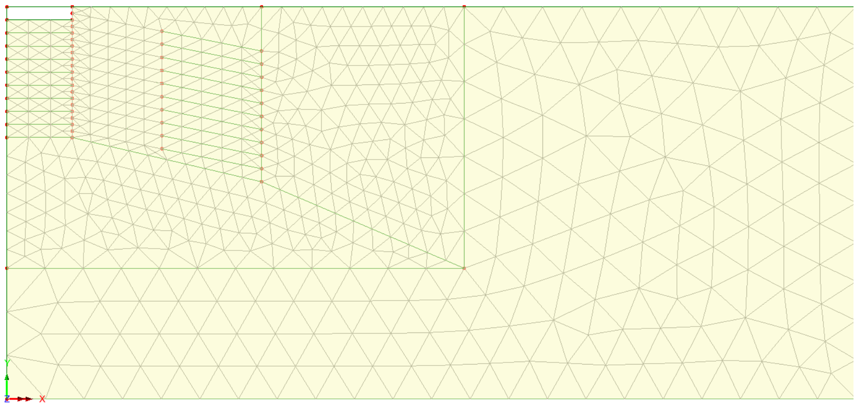

Figure 6: Deactivate 1st layer

Install nail 1

The facing and nail corresponding to layer 1 are activated.

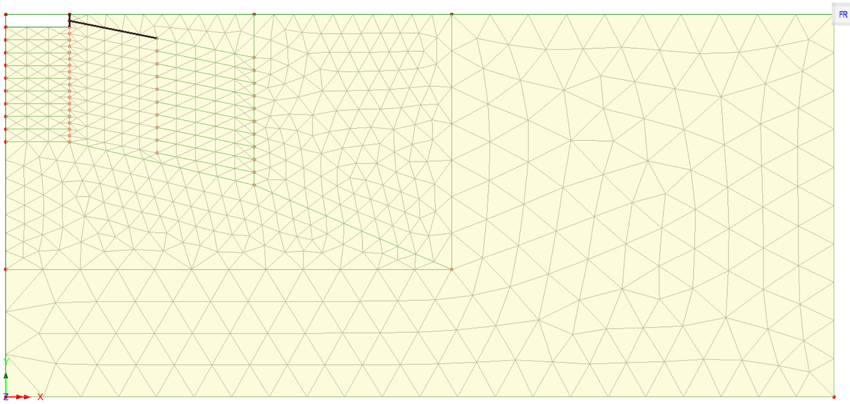

Figure 7: Install nail and facing

The process of excavation and then activation of the facing and soil nail is repeated to the end of the excavation.

PLAXIS – ALL-IN-ONE ANALYSIS

Initial Phase

The initial stresses in the soil are established.

Excavate level 1

Excavate first layer of soil by deactivation of elements and activate facing and soil nail (figure 8).

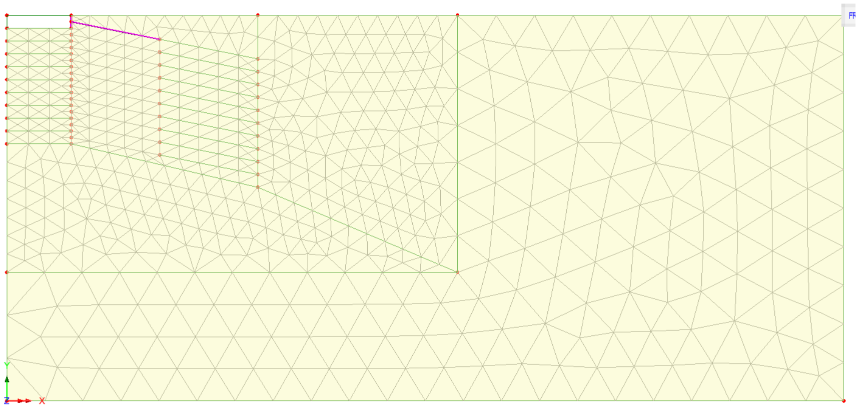

Figure 8: Excavate and install facing and support in one go

The process of excavation and activation of the facing and soil nail is repeated to the end of the excavation.

Viewing the Analysis

In figure 9 the horizontal displacements are shown for the analyses, with and without tension allowed. The analysis without tension produces a slightly larger displacement.

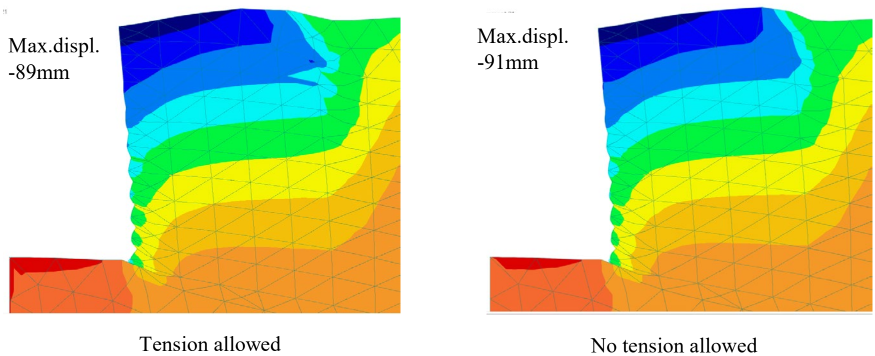

Figure 9: Horizontal displacements after installing final nail

Figure 10 shows the effective strain after the placement of the final nail. Again, there is little difference caused by the limit on the tensile stresses.

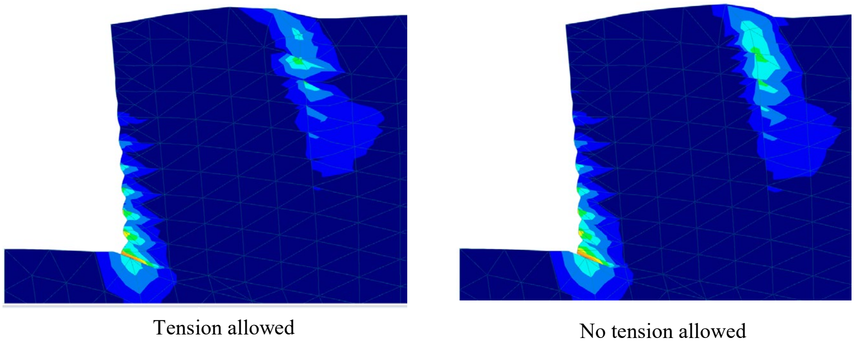

Figure 10: Effective strain after installing final nail

Figure 11 shows the effective strains at the end of the phi-c reduction analyses performed after the excavation but before installing the facing and nail. Restricting the tension in the soil leads to a much lower factor of safety of 1.07 with the soil on the point of failure. The soil fails locally at the foot of the excavation, with the block of soil held together by the soil nails tipping forwards into the excavation.

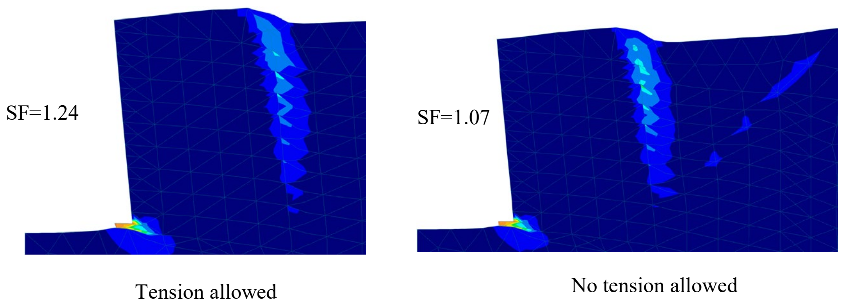

Figure 11: Effective strains for phi-c reduction before installing final facing and nail

In figure 12 the effective strains are shown for the phi-c reductions after the facing and soil nail are installed. The failure mode is the same with the soil block bound by the nails tipping into the excavation, but the factor of safety has increased significantly in both cases to nearly 1.6.

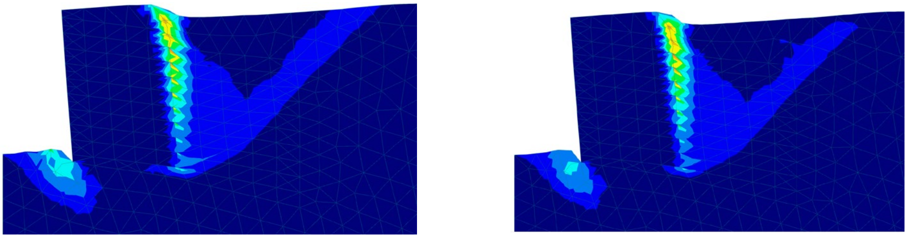

Figure 11: Effective strains for phi-c reduction after installing final facing and nail

Apart from the near failure of the soil before the installation of the final soil nail and facing restricting the tension carried by the soil does not significantly change the results. The most critical phase is after completing the excavation and before the soil nail and facing are fixed.

Comparison with PLAXIS

The results for the analysis with the simultaneous excavation and installation of the facing and soil nail are compared with values from PLAXIS [S1] in table 2. Overall, there is good agreement between the solutions with LUSAS predicting a smaller maximum force in the soil nail.

Table 2: Comparison of PLAXIS and LUSAS results

	PLAXIS	LUSAS
Max.displacement	22.82 mm	23.04 mm
Max.axial force in nail	74.82 kN/m	69.41 kN/m
Safety factor	1.59	1.62

References

S1 Simulation of soil nail structures using PLAXIS 2D, Sivakumar Babu G.L., Singh V.P., PLAXIS Bulletin, Spring Issue 2009, www.plaxis.nl