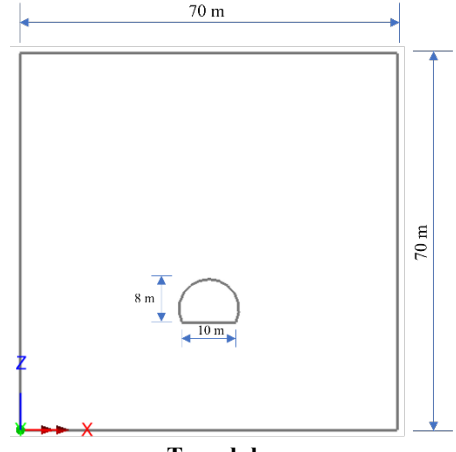
Analysis of Tunnel Excavation

For LUSAS version:	24.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear

Problem Description

This example investigates the stability analysis of a tunnel excavation in a rocky stratification. The excavation of the tunnel is accompanied with the installation of a tunnel lining and rock bolts, The lining has a thickness of 160mm and the bolt length is 3m. The construction process can be divided into construction stages that simulate the excavation and supporting process, with the same steps being repeated as tunnelling progresses.

The tunnel has a horseshoe shape with a height of 8m and a width of 10m, as depicted in the 2D view below.



Tunnel shape

Keywords

Tunnel, Bolts, Lining, Construction Stages

Associated Files

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

- **Analysis_of_tunnel_excavation.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

- Modelling of the tunnel boring process with supporting structural elements; lining and rock bolts.
- Analysis of stability of the tunnel during construction stages and at the final stage.

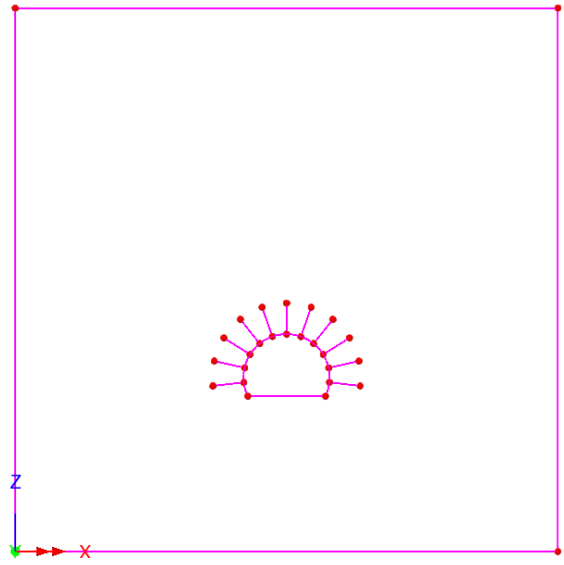
Modelling overview

We create a new model, set the Analysis category as 3D, and specify the model units as kN,m,t,s,C.

Feature Geometry

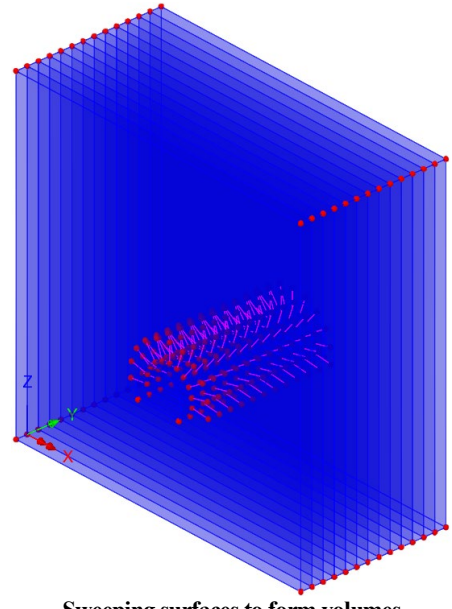
The front side of the model can be created through point and line features.

The tunnel shape is generated using the command **Geometry > Line > Arc/Circle > From Coords/Points**.



Front side of the tunnel

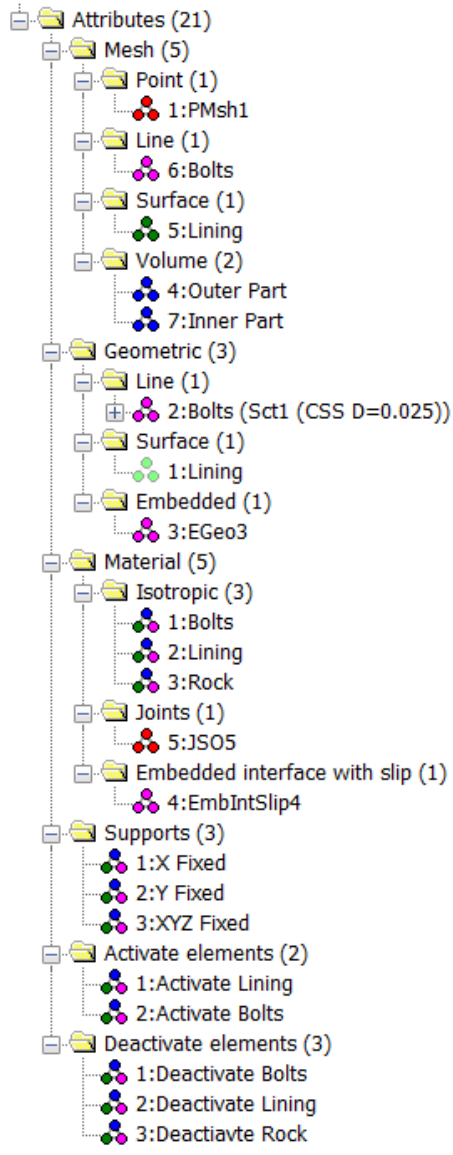
Volumes are formed by sweeping the surfaces in Y direction by the command **Geometry > Volume > By Sweeping**.



Sweeping surfaces to form volumes

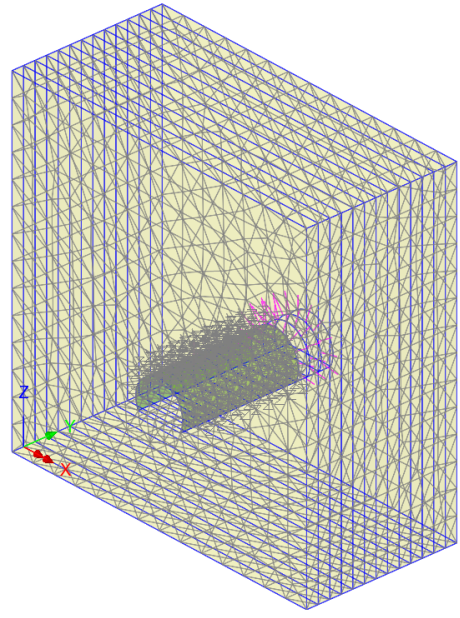
Attributes

Model attributes (mesh, material, geometric properties, etc.) are defined and assigned to the model. The adjacent image shows the attributes of model.

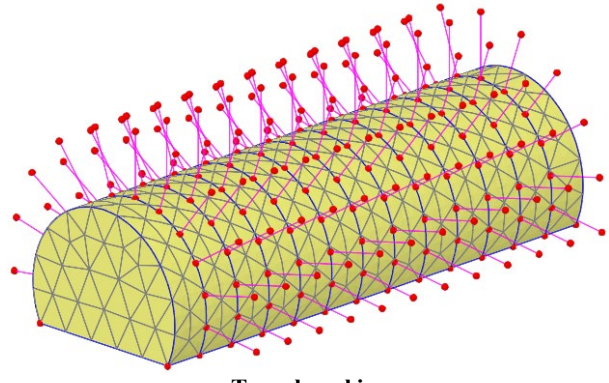


Mesh

Tetrahedral quadratic stress elements (TH10) are used to mesh the volume parts, while triangular thick shell elements (TTS6) are used for the lining and quadratic embedded bar elements with interface behaviour are used for the bolts. An embedded point joint is assigned to the bolt tops to model the connection with the lining.



Model meshing

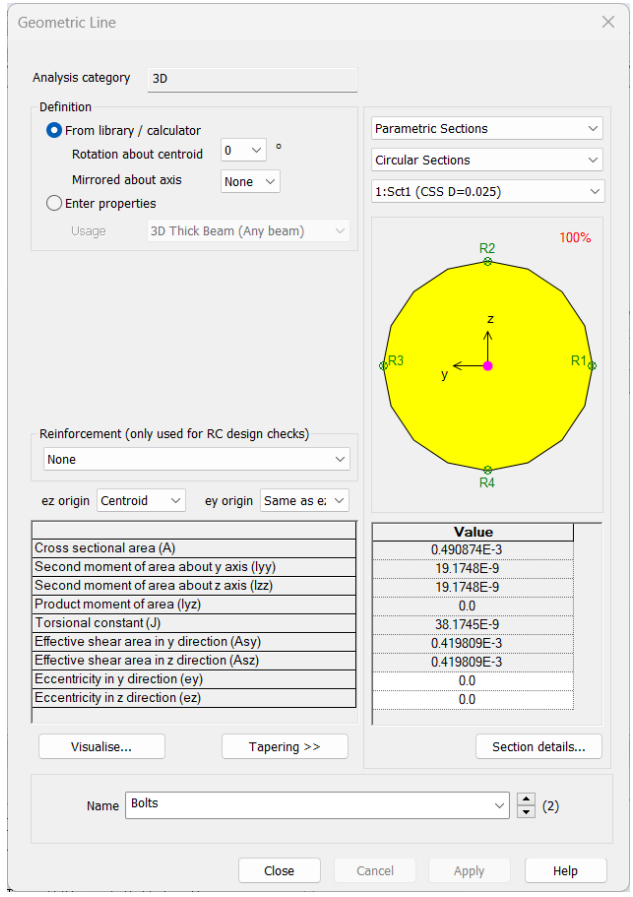


Tunnel meshing

Geometric properties

A geometric surface attribute is assigned to the lining feature with a thickness of 160 mm, while the rock bolt is given the section shown in the following dialog, with a diameter of 25mm.

The elastic embedded interface zone is assigned to the bolts, zone diameter 0.025m.



Rock bolt section

Defining the Materials

The rock material will be modelled using an isotropic nonlinear material with a Modified Mohr-Coulomb failure surface, while the structural elements will be assumed to have elastic behaviour. The initial stress state in the soil is defined by the coefficient for lateral

earth pressure, K_0, of the soil. All material properties are listed in table 1. Interfaces properties are listed in table 2.

Table 1: material properties

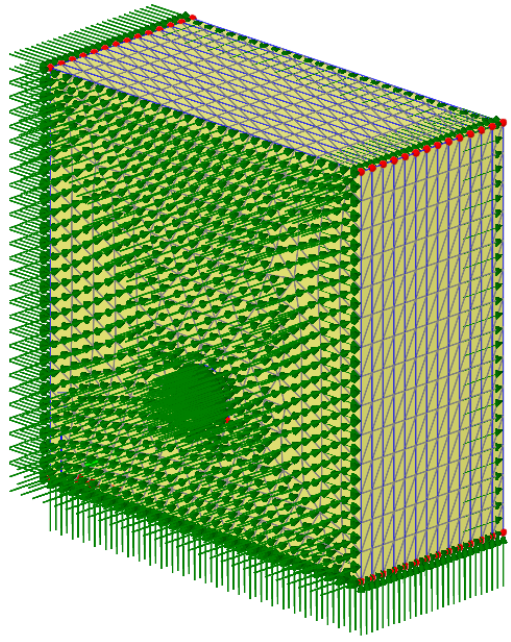
Layer	Mass Density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Cohesion, c	K_0
Rock	2.3 t/m^3	500.0E3 kPa	0.3	36°	400 kPa	0.412
Lining	2.4 t/m^3	5.0E6 kPa	0.2	-	-	-
Bolt	7.85 t/m^3	200.0E6 kPa	0.3	-	-	-

Table 1: Interfaces properties

	Normal stiffness factor	Tangential stiffness factor	Angle of friction, φ	Cohesion, c
Embedded interface with slip	10.0E6	0.15	36°	400 kPa
Embedded point joint	1E12 kN/m	-	-	-

Supports

The model is restrained in X and Y direction, with fully fixed supports assigned to the base



Boundary conditions

Loads

Gravity load is the only load considered.

Other Attributes

Deactivate and Activate attributes are used to simulate the excavation phases of the tunnel and the installation of the lining and bolts.

Analyses considered

We consider the following construction stages.

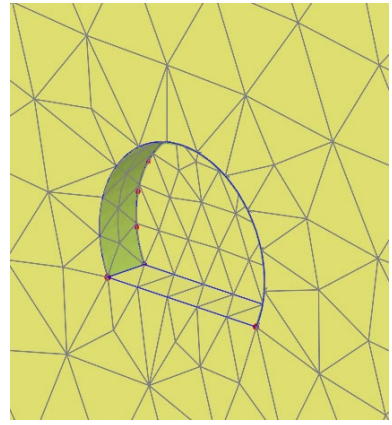
Initial Phase

During this stage, the simulation replicates the starting conditions in which the only load applied is the gravity. The nonlinear analysis control characteristics are established, with all parameters remaining at their default settings.

Excavation Phases from 1 to 10

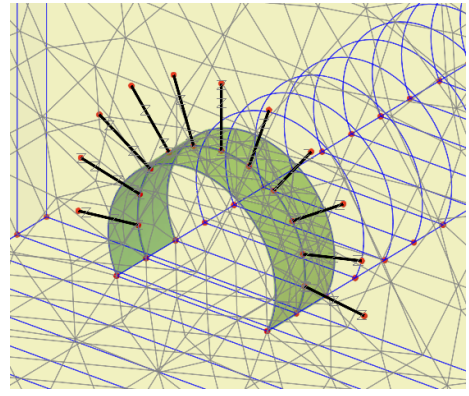
The phases from 1 to 10 simulate the excavation process of the tunnel. The following steps are considered:

- In stages 1, 3, 5, 7, and 9, we turn on the lining and turn off the corresponding excavated part of the tunnel rock material.



Stage 1

- In stages 2, 4, 6, 8, and 10, we turn on both the lining and bolts, and turn off the excavated part of the tunnel.



Stage 2

Running the Analysis

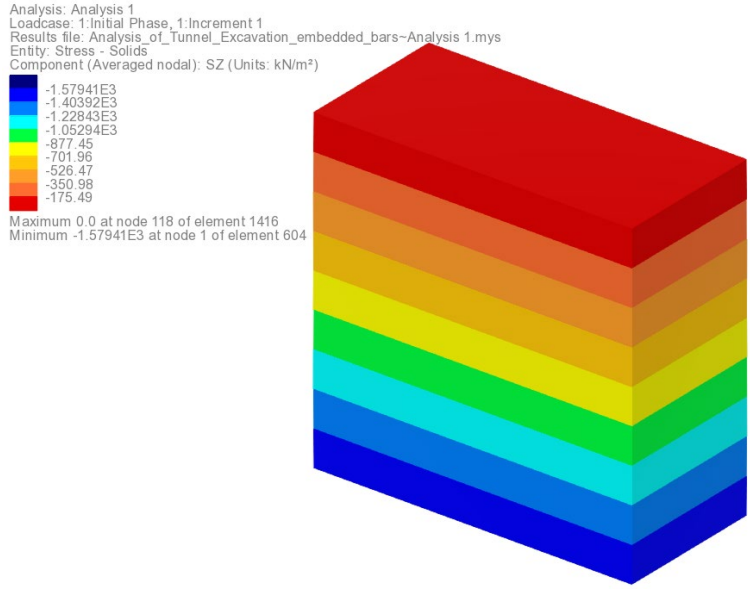
Ensure all analyses are selected and press **OK** to solve.

Viewing the Results

Analysis loadcase results are presented in the Treeview.

Stress

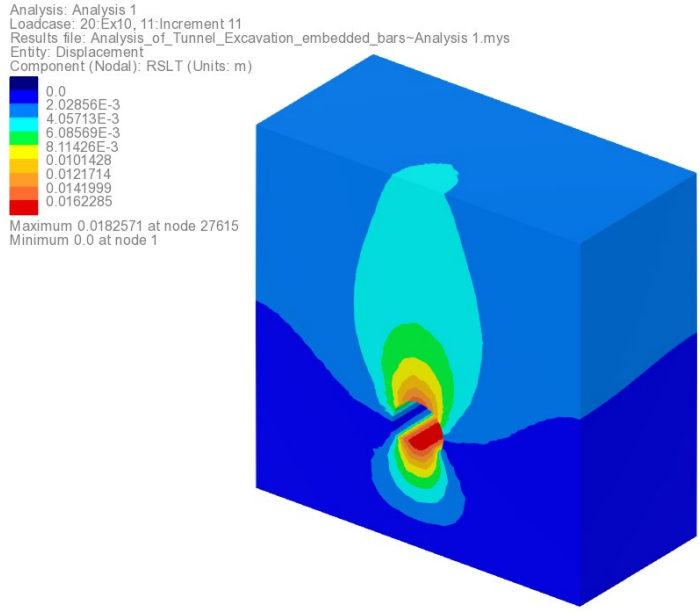
The following image shows the vertical stress at the initial stage.



Vertical stress at the initial stage (kN/m^2)

Displacement

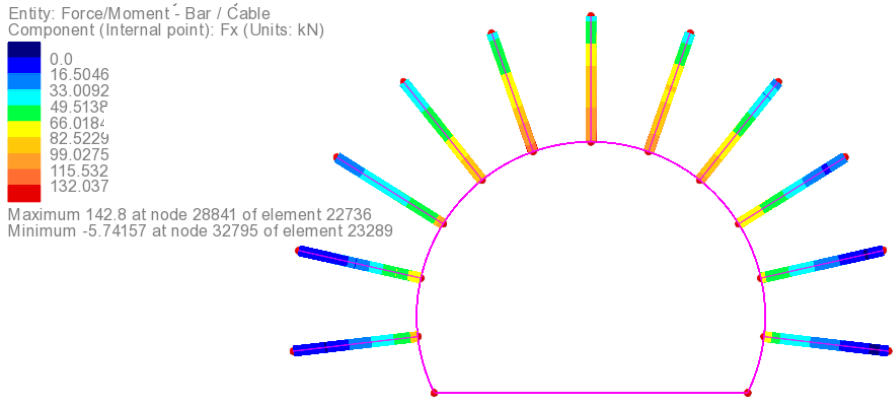
The maximum resultant displacement at the final stage is 18.25 mm. Figure 12 illustrates the displacement contours.



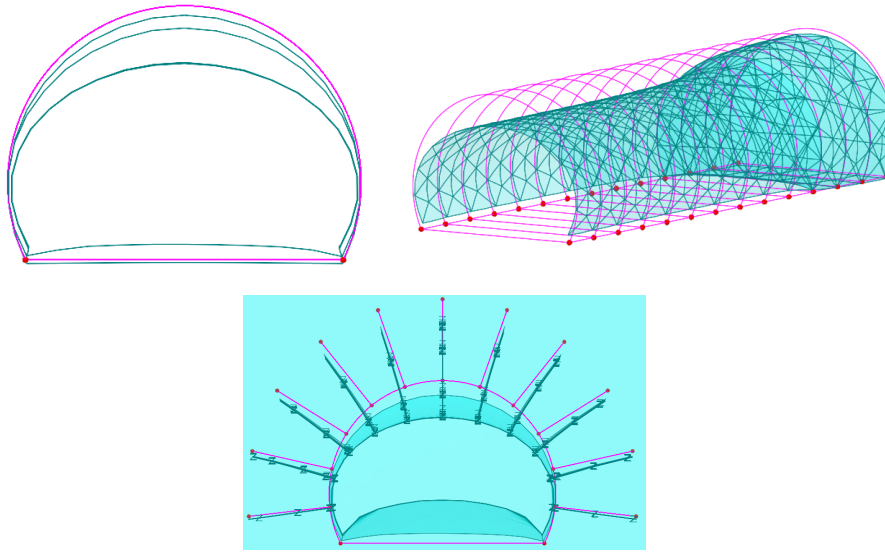
Resultant displacement (m)

Moments and axial forces

LUSAS has the capability of determining the moments and forces for structural elements. The following image shows the axial forces for the first row of rock bolts, where it can be seen the bolt experiencing the highest tensile force is located at the roof of the tunnel.

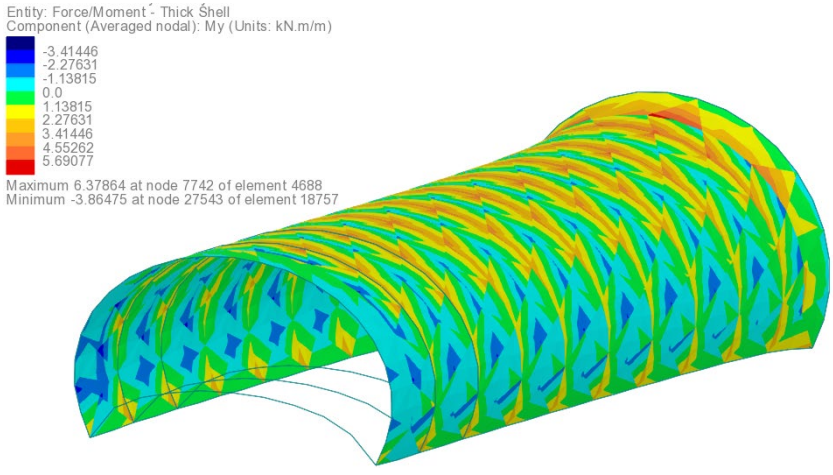


Axial forces for the first row of rock bolts



Tunnel deformation

We can also get the moments My in the lining (shell) as shown below.



Bending moment My in lining along the tunnel

This completes the example.