

Cut and cover tunnel construction – two anchor level (Using permanent cast-in-place diaphragm wall)

Advanced nonlinear tunnel and geotechnical FEA features:

- *Moving traffic load analysis under nonlinear conditions (linear is also performed).*
- *Geotechnical stability ultimate state ("Jordbrott").*
- *Staged construction analysis for excavation, tunnel and anchors.*
- *Mohr–Coulomb nonlinear soil model is used for nonlinear conditions.*
- *Initial horizontal stresses based on Rankine at-rest earth pressure (K_0).*
- *Nonlinear tunnel–soil interface elements to handle slip resistance.*
- *Comparison of linear and nonlinear soil behaviour.*
- *Multiple soil layers.*
- *Prestrained anchors.*
- *Lowering of water pressure.*

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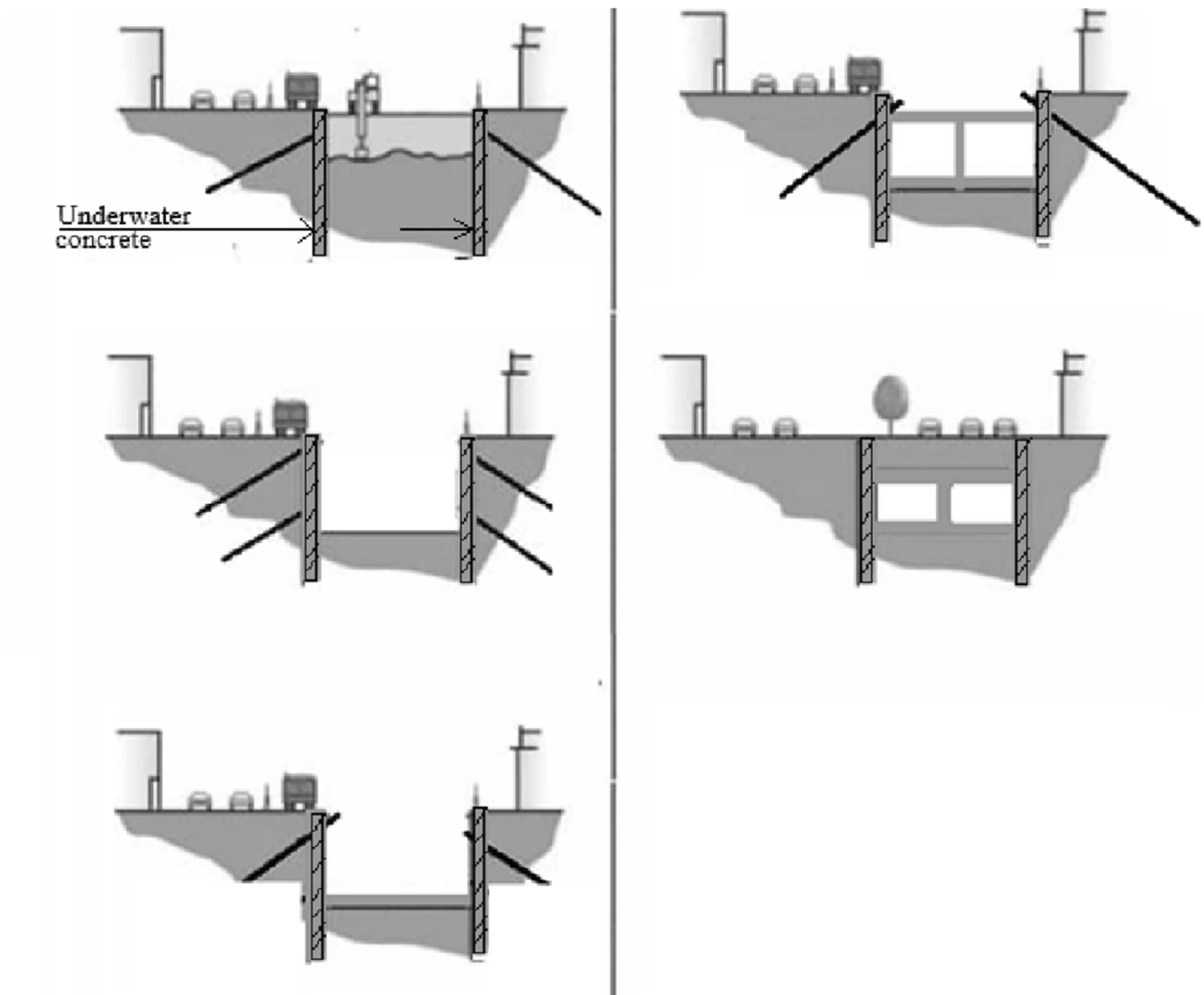
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Appendix

1. Input receipt (FEM-program)

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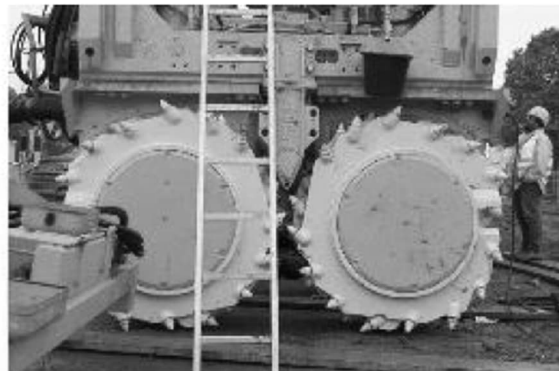
0. PREFACE



Principal sketch Overview



Excavation Fine grained soil



Excavation Bouldery soil

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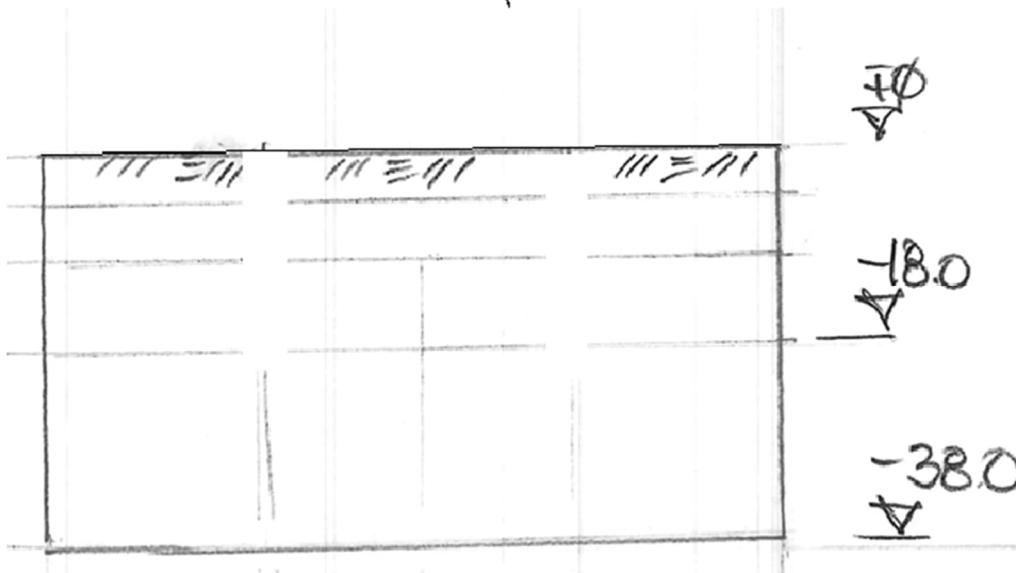
1. GENERAL

Below is a description of varying stages of design.

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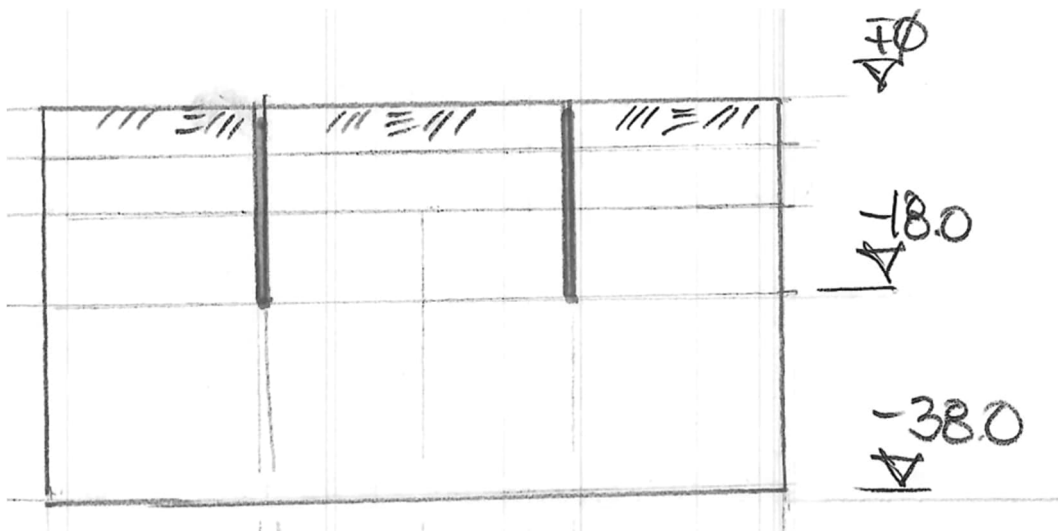
1.2 CONSTRUCTION STAGES

There are a total of 9 construction stages as seen on sketches below.



ELEVATION

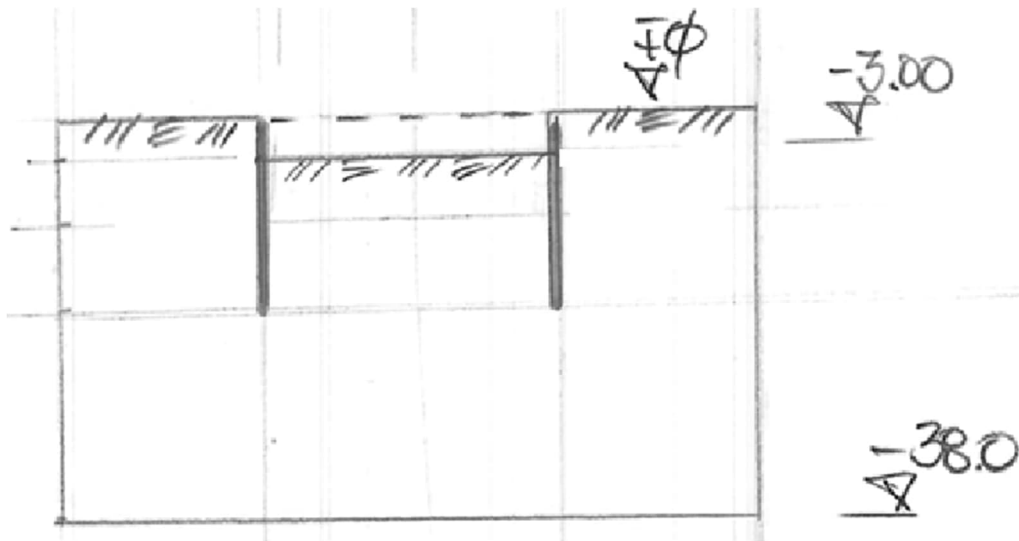
Stage 1: Initial conditions.



ELEVATION

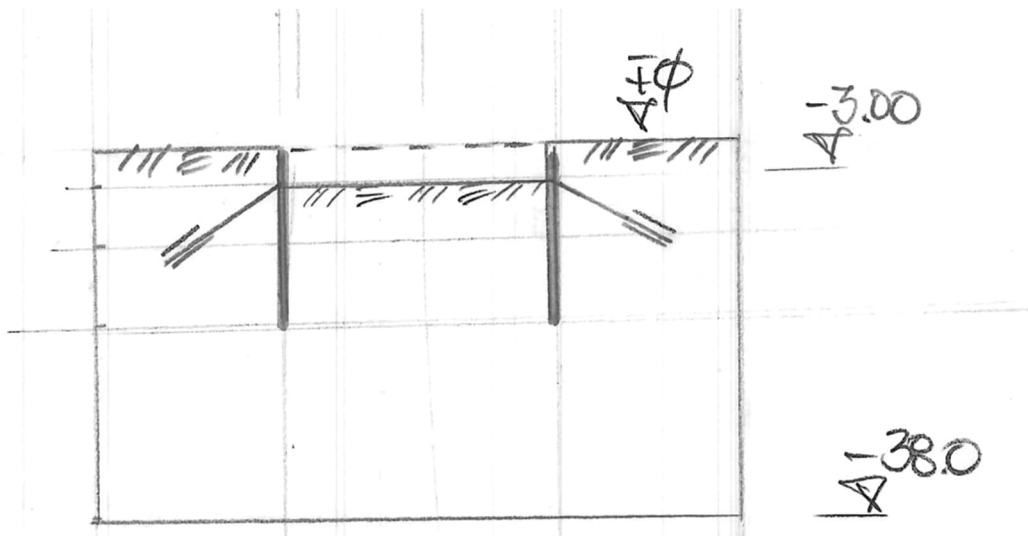
Stage 2: Installation diaphragm-walls.

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ELEVATION

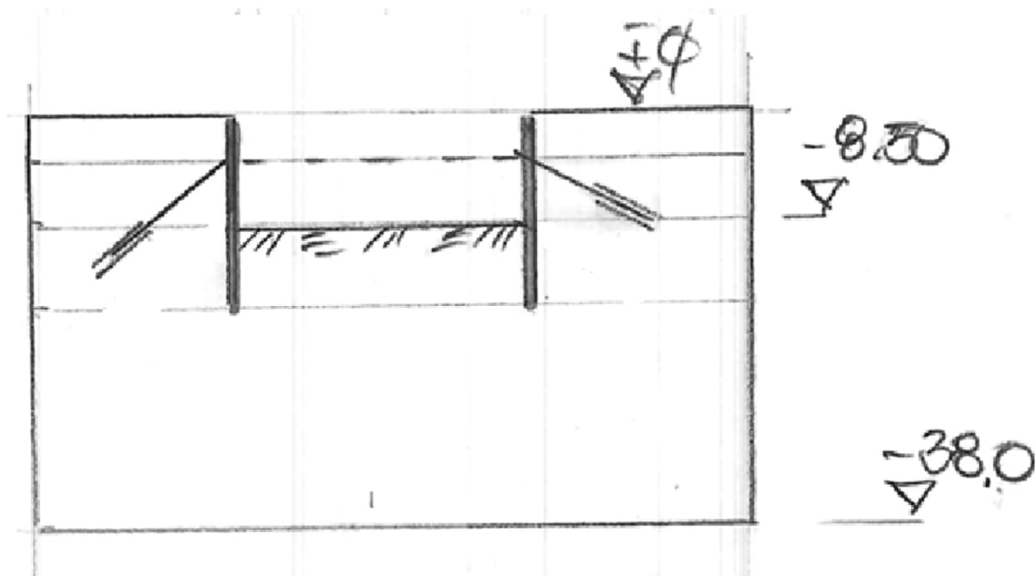
Stage 3: Excavation 1.



ELEVATION

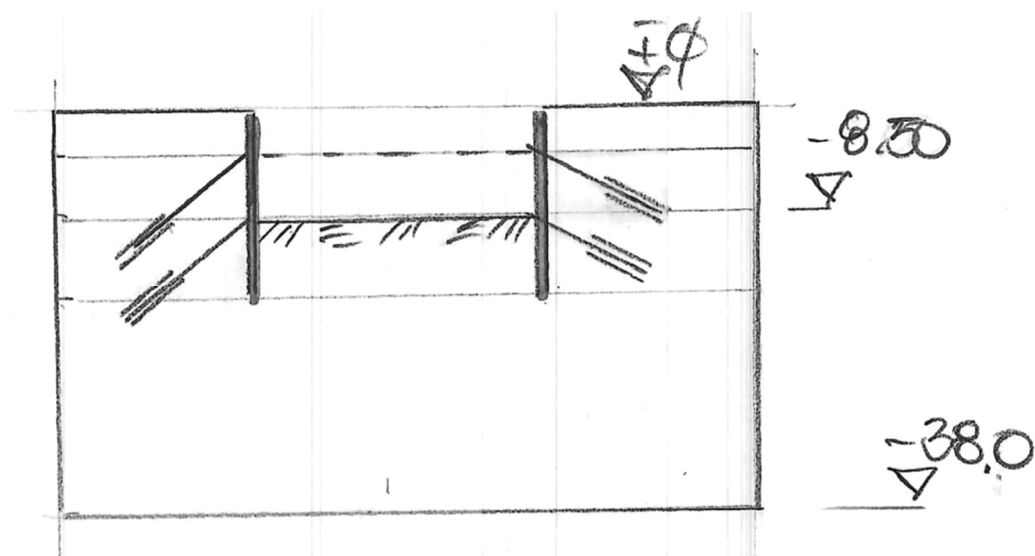
Stage 4: Installation of anchors at level 1.

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ELEVATION

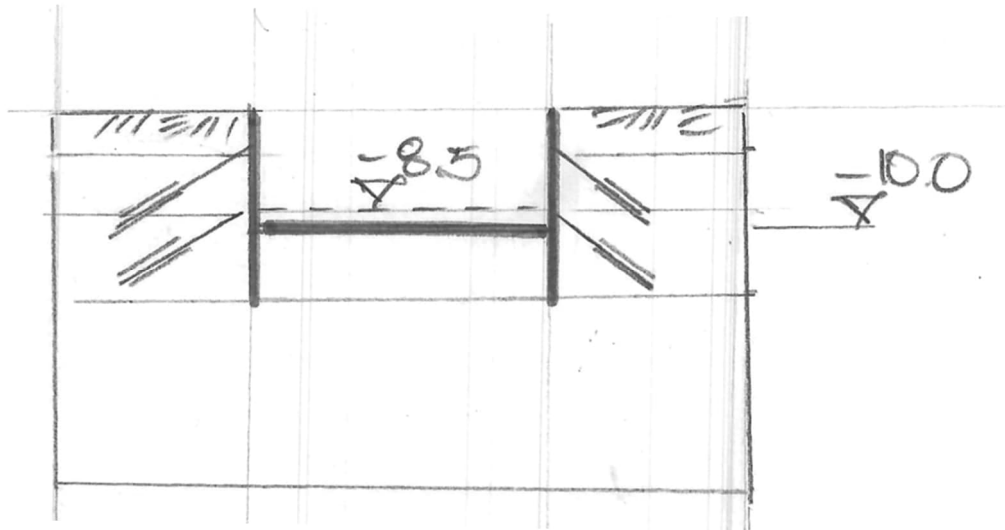
Stage 5: Excavation 2.



ELEVATION

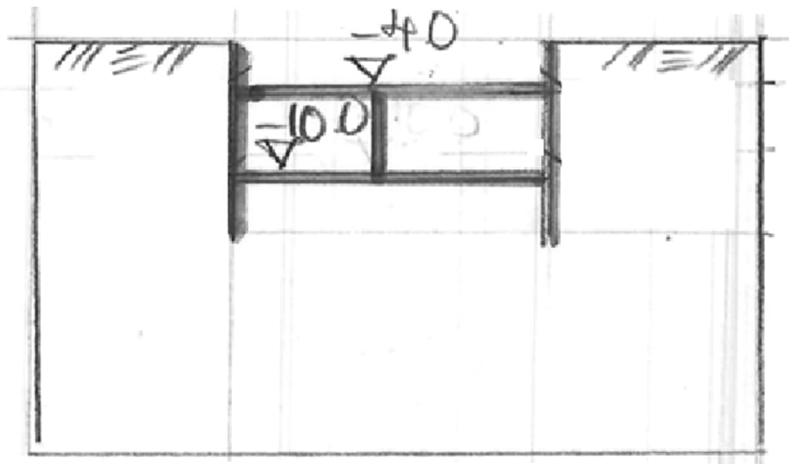
LC 6: Installation of anchors at level 2.

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ELEVATION

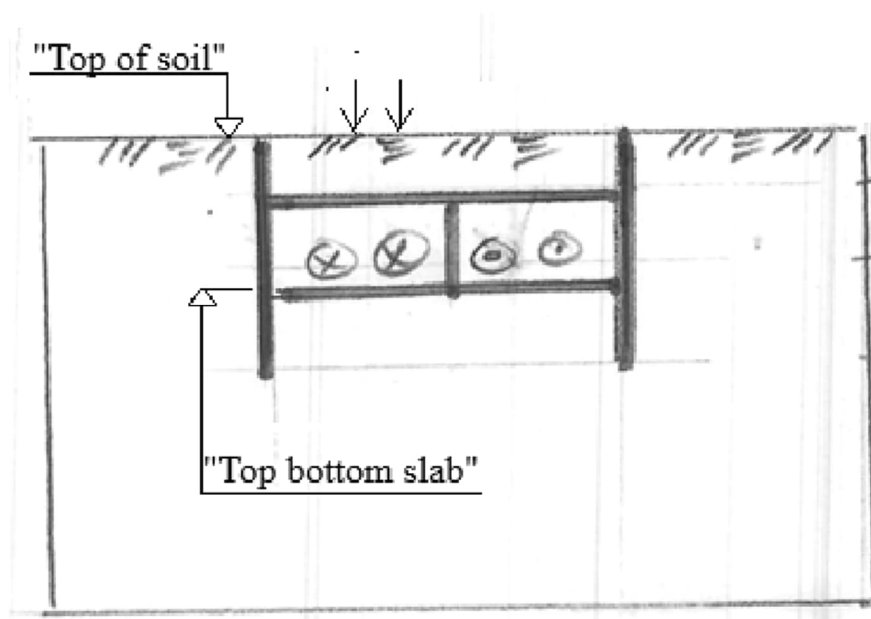
Stage 7: Excavation 3



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Stage 8: Construction tunnel

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ELEVATION

Stage 9: Filling on top of tunnel

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1.3 SOIL PROPERTIES

1.3.1 Ground water

Ground water level is assumed lower than level ± 0 .

1.3.2 Soil material

Geotechnical parameters:

Material	Level	ρ	ρ'	ϕ_k	E_k
"Fill"	$\pm 0 \rightarrow -4.0$	20	11	30	8
"Sand"	$-4.0 \rightarrow -18.0$	20	11	34	30
"Silt"	$-18.0 \rightarrow -38.0$	19	11	29	20
"Rock"	± 0	-	-	-	-
-	m	kN/m ³	kN/m ³	deg	MPa

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2. SYSTEM ANALYSIS

2.1 GENERAL

There are 9 construction stages (∴ Stage 1-9) that are analysed using nonlinear analysis. During each construction stage varying structural parts and soil material is activated or deactivated due to excavation and construction of structure.

The soil material is modelled using a elasto-plastic model *Mohr-Coulomb* (called model 65) that is used for soil and rocks.

Soil is modelled using plain strain surface elements (QNP8).

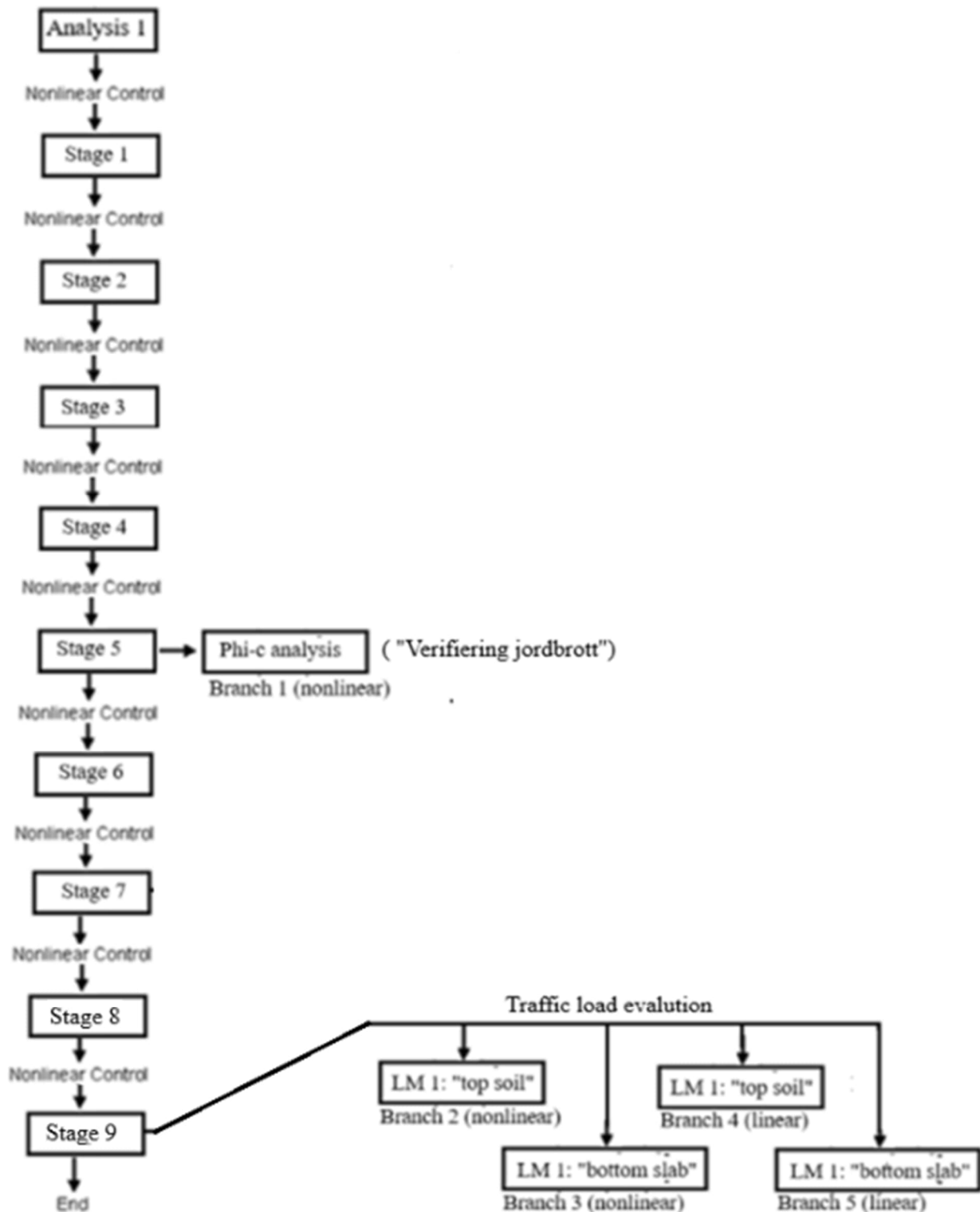
All structural parts of tunnel including diaphragms are modelled as thick beam elements (BMI3).

Analysis using "branches" (∴ Branch 1-5) is used to perform nonlinear analysis. Each "branch" is a sub-analysis has completed. Using braches means start and end of the previous sub-analysis are indepnendent sub-analysis. Every branch is defined using single loadcases, thus load ing occur 'simultaneously', not 'sequentially'.

When applying gravity load at stage 1 (∴ before excavtion") deformations arisies which do not occur since have allready been "consolidated" over time. These are historic deformation are used by resting formations av stage 1 but maintaining stress.

Safety factor analysis is performed using function *Phi-c Reduction* to determine the most dangerous situation. Considered to arise at Stage 5.

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Schematic sketch

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Analysis 1:

Stage #	LC name	Excavation	Loading	Deactivate	Activate
1	Before excavation	Before excavation	Gravity soil*	Tunnel & anchors	-
2	Wall installation	Before excavation	Gravity wall	-	Wall
3	Excavation:1	After excavation 1	-	Excavation:1	-
4	Install anchor:1	After excavation 1	Anchor load:1	-	Anchor:1
5	Excavation:2	After excavation 2	-	Excavation:2**	-
6	Install anchor:2	After excavation 2	Anchor load:2	-	Anchor:2
7	Excavation:3	After excavation 3	-	Excavation:3	-
8	Construct tunnel	After excavation 2	Gravity tunnel	Anchors	Tunnel
9	Filling top tunnel	After filling top slab	Filling top tunnel	-	Soil top slab

* = Reset deformation is applied to remove historic deformations.

** = Phi-c analysis to determine geotechnical stability ("Jordbrott").

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2.2 NONLINEAR ANALYSIS

Nonlinear analysis is performed using increments using Newton_Raphson numerical procedure.

Max number of iterations:

For each load increment if convergence is not achieved.

Residual force norm:

The limit for the sum of the squares of all residual forces as a percentage of the sum of the squares of all external forces, including reactions (rdnrm). By default only translation degrees of freedom are considered. So for a value of 0.1 the convergence of the solution at each load increment will be achieved when the out of balance forces are as less than 0.1% of the reactions.

Displacement norm:

The limit for the sum of the squares of the iterative displacements as a percentage of the sum of the squares of the incremental displacements (DTNRM). Only translation degrees of freedom are considered.

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Stage #	LC name	Control	Branch	Incrementation
1	Before excavation	Nonlinear	-	Automatic
2	Wall installation	Nonlinear	-	Automatic
3	Excavation:1	Nonlinear	-	Automatic
4	Install anchor:1	Nonlinear	-	Automatic
5	Excavation:2	Nonlinear	-	Automatic
”	”_”_	”_”_	Branch 1	Automatic
6	Install anchor:2	Nonlinear	-	Automatic
7	Excavation:3	Nonlinear	-	Automatic
8	Construct tunnel	Nonlinear	-	Automatic
9	Filling top tunnel	Nonlinear	-	Automatic
”	”_”_	Nonlinear	Branch 2	Automatic
”	”_”_	Nonlinear	Branch 3	Automatic
”	”_”_	Linear	Branch 4	-
”	”_”_	Linear	Branch 5	-

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Incrementation as chosen to be performed *Automatic* with chosen parameters in dialogue box.

The only load is horizontal anchor load that is increased by load factors 1, 2,... 9 & 10.

Nonlinear & Transient

Incrementation

☒ Nonlinear

Incrementation
Automatic

Starting load factor
0.1

Max change in load factor
1.0

Max total load factor
1.0

☒ Adjust load based on convergence

Iterations per increment
4

Advanced...

☐ Time domain

Two Phase

Initial time step

Total response time

☐ Automatic time stepping

Advanced...

Solution strategy

☒ Same as previous loadcase

Max number of iterations
12

Residual force norm
0.1

Displacement norm
0.1

Advanced...

Incremental LUSAS file output

☒ Same as previous loadcase

Output file
1

Plot file
1

Restart file
0

Max number of saved restarts
0

Log file
1

History file
1

☐ Save a restart at the end of this control

Common to all

Max time steps or increments
20

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 17
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2.3 SAFETY FACTOR ANALYSIS

A nonlinear safety factor analysis is performed using function *Phi-c Reduction* with starting values seen below. This analysis is performed at stage 5 which is considered most dangerous.

Phi-c Reduction

	Value
Starting value for safety factor	1.1
Minimum change in safety factor	0.01
Maximum number of steps to use	40

Name
Phi-c1
(1)

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2.4 SKETCH SYSTEM ANALYSIS

To describe geometry first POINTS are defined.

Beam elements are defined by applying attributes to LINES.

Shell elements are defined by applying attributes to SURFACES.

All coordinates needed to describe POINTS are found in attachment 1.

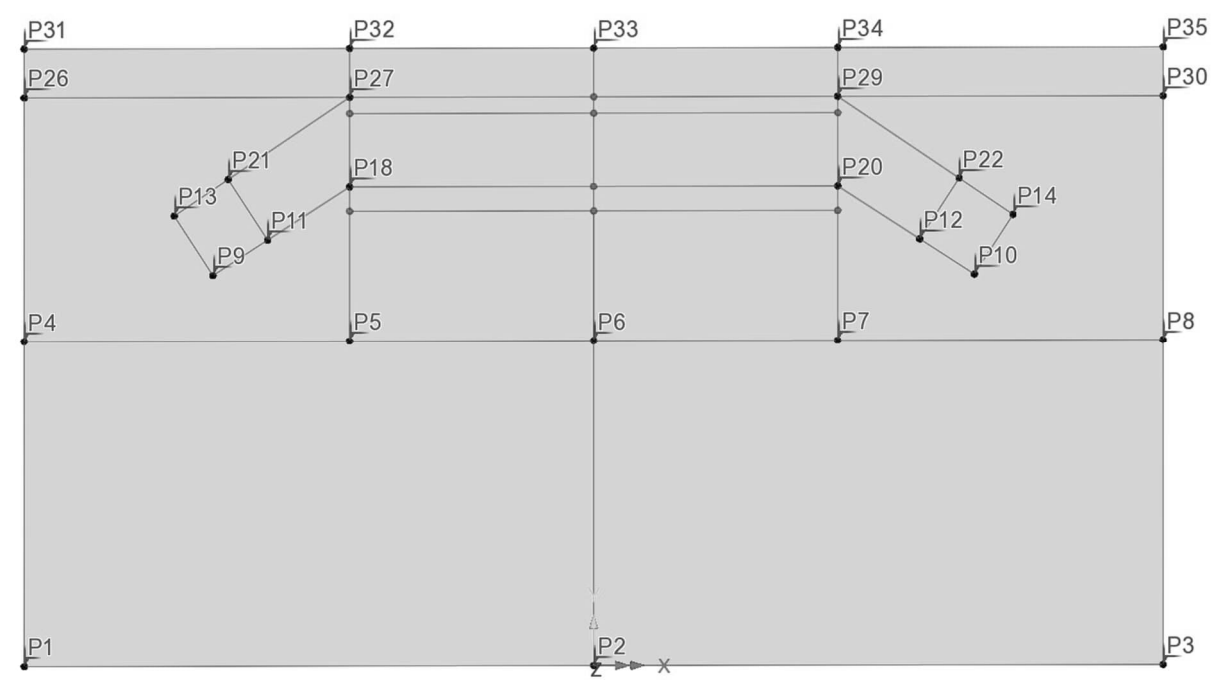
All POINTS needed to describe LINES are found in attachment 1.

All LINES need to describe SURFACE are found in attachment 1.

Sketches are generated by using POINTS, LINES and SURFACES.

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2.4.1 Geometry: Points



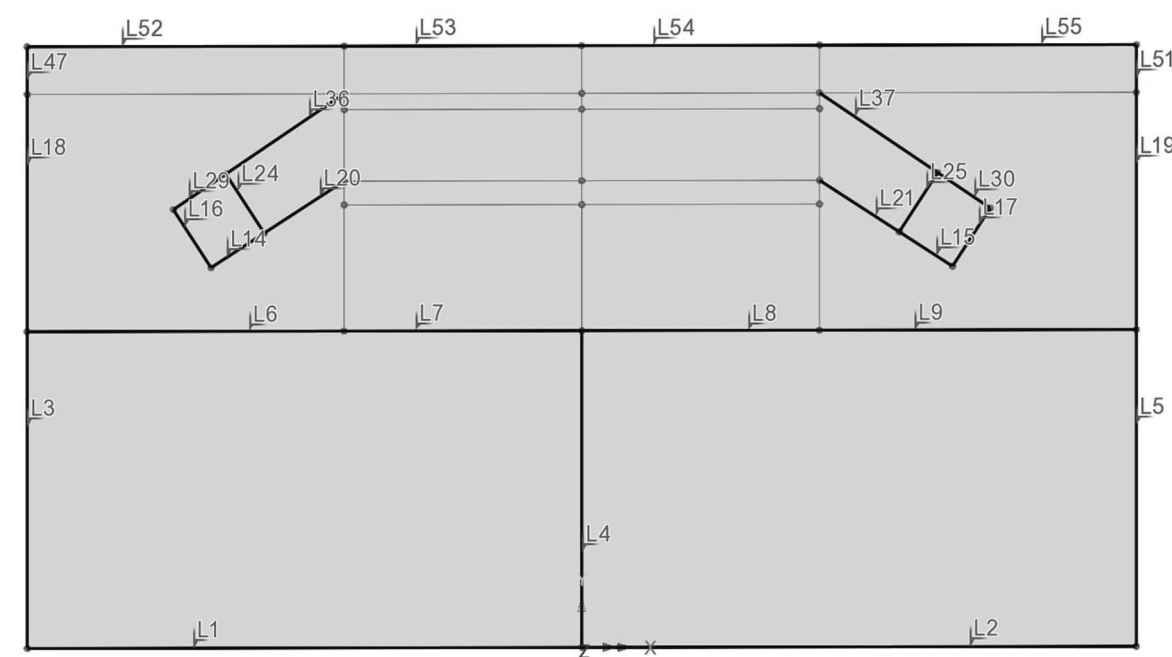
ELEVATION
Overall



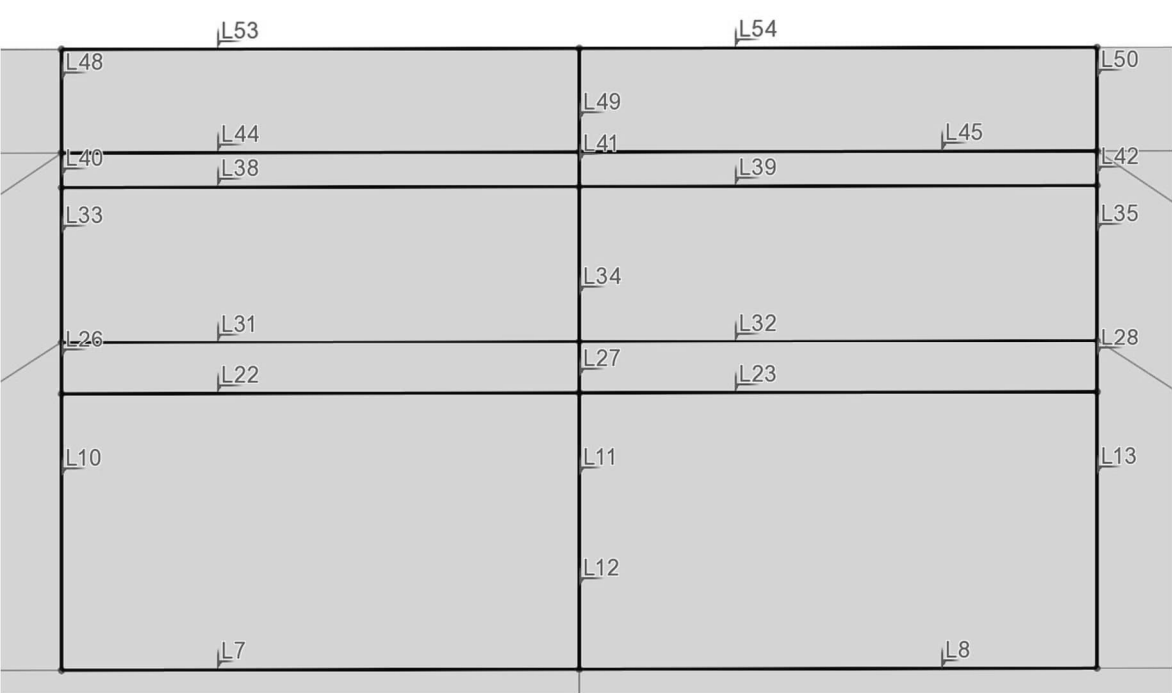
ELEVATION
Detail

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2.4.2 Geometry: Lines



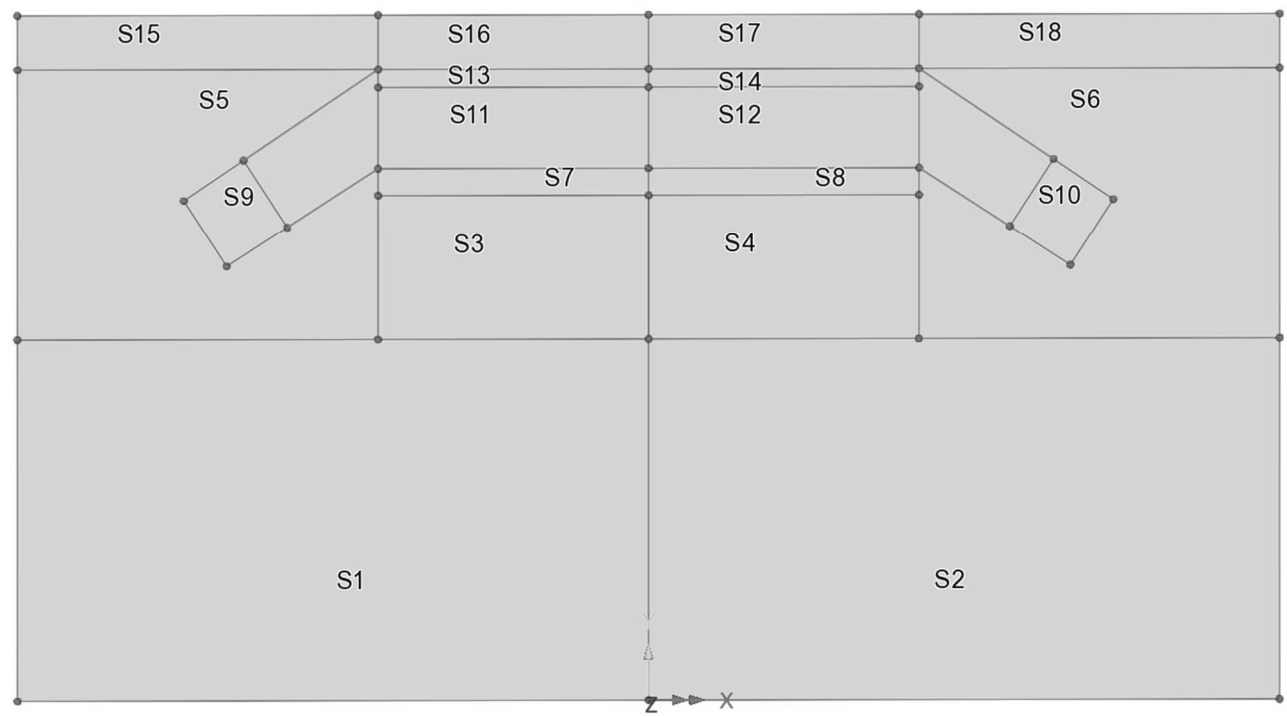
ELEVATION
Overall



ELEVATION
Detail

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2.4.3 Geometry: Surfaces

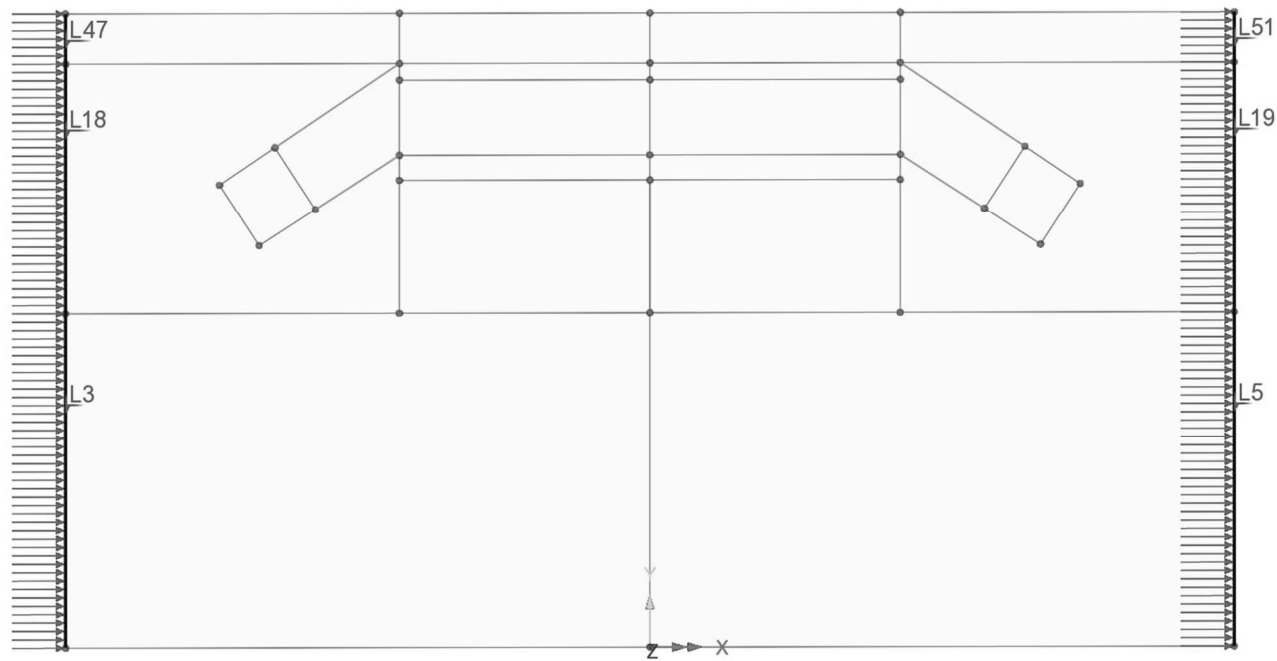


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2.5 BOUNDARY CONDITIONS

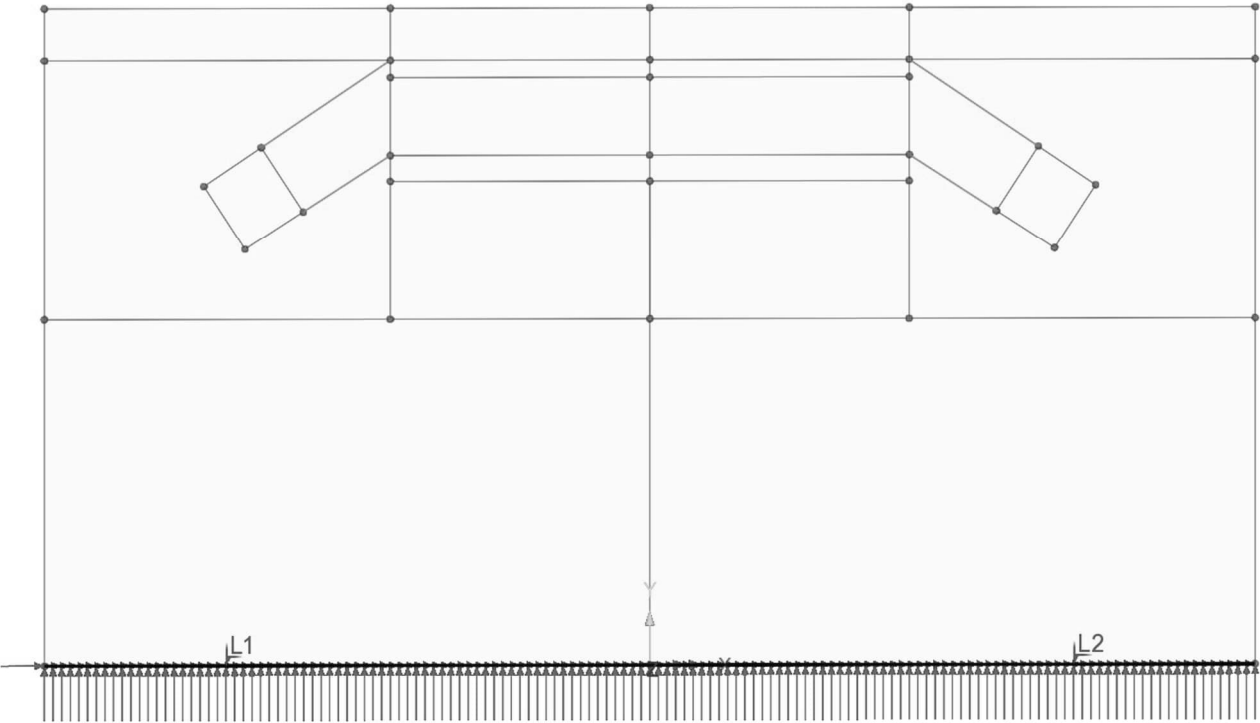
2.5.1 Horizontal boundary soil: Fixed X



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2.5.2 Vertical boundary soil: Fixed XY



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Overall

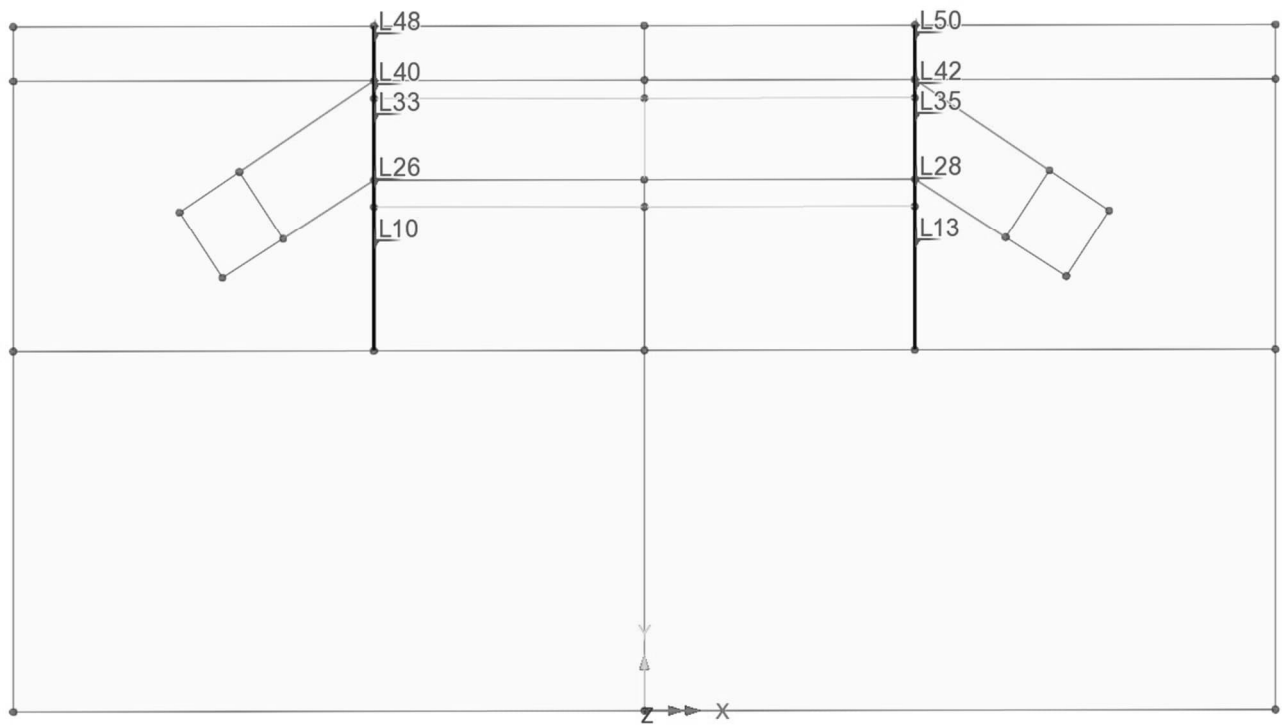
	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 24
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2.6 MESH

2.6.1 Diaphragm: Plain strain beam element (BMI3N)

Diaphragms seen below with two dimensional long structures retaining walls for which the plane strain assumption is appropriate.

Name	Element type	Element length	Order element
BMI3N	Plain strain beam	1.0	Quadratic



ELEVATION

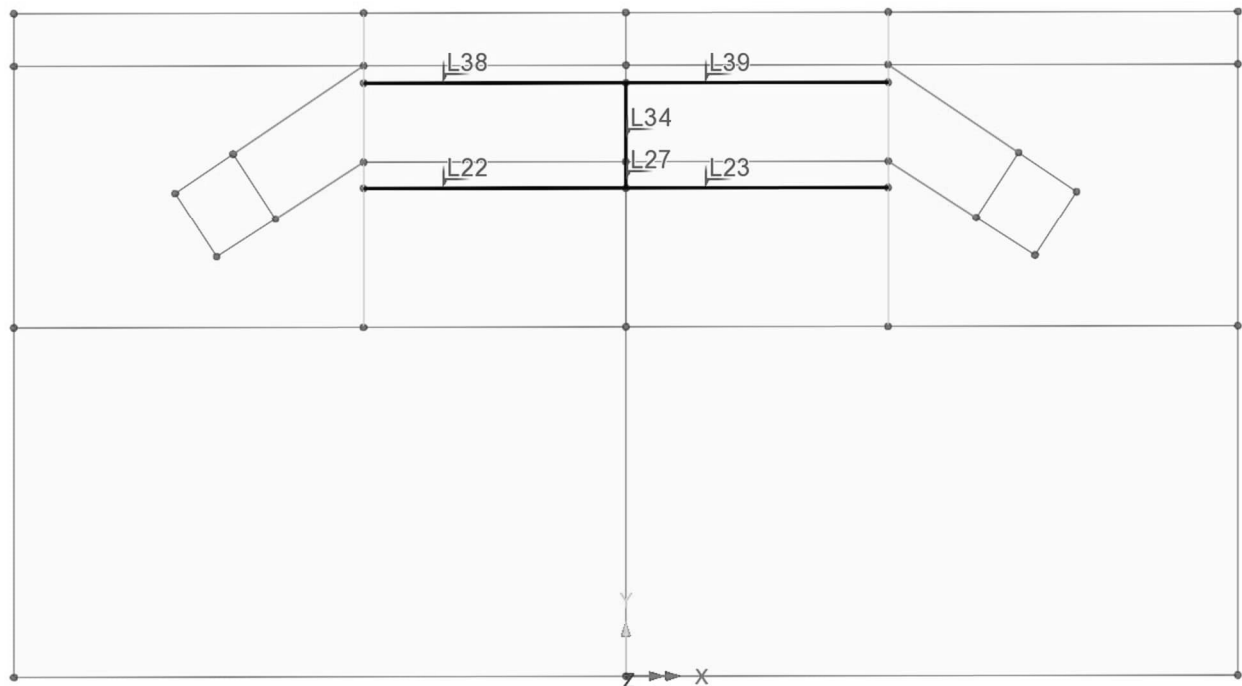
Overall

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2.6.2 Tunnel: Plain strain beam element (BMI3N)

Diaphragms seen below with two dimensional long structures retaining walls for which the plane strain assumption is appropriate.

Name	Element type	Element length	Order element
BMI3N	Plain strain beam	1.0	Quadratic



ELEVATION

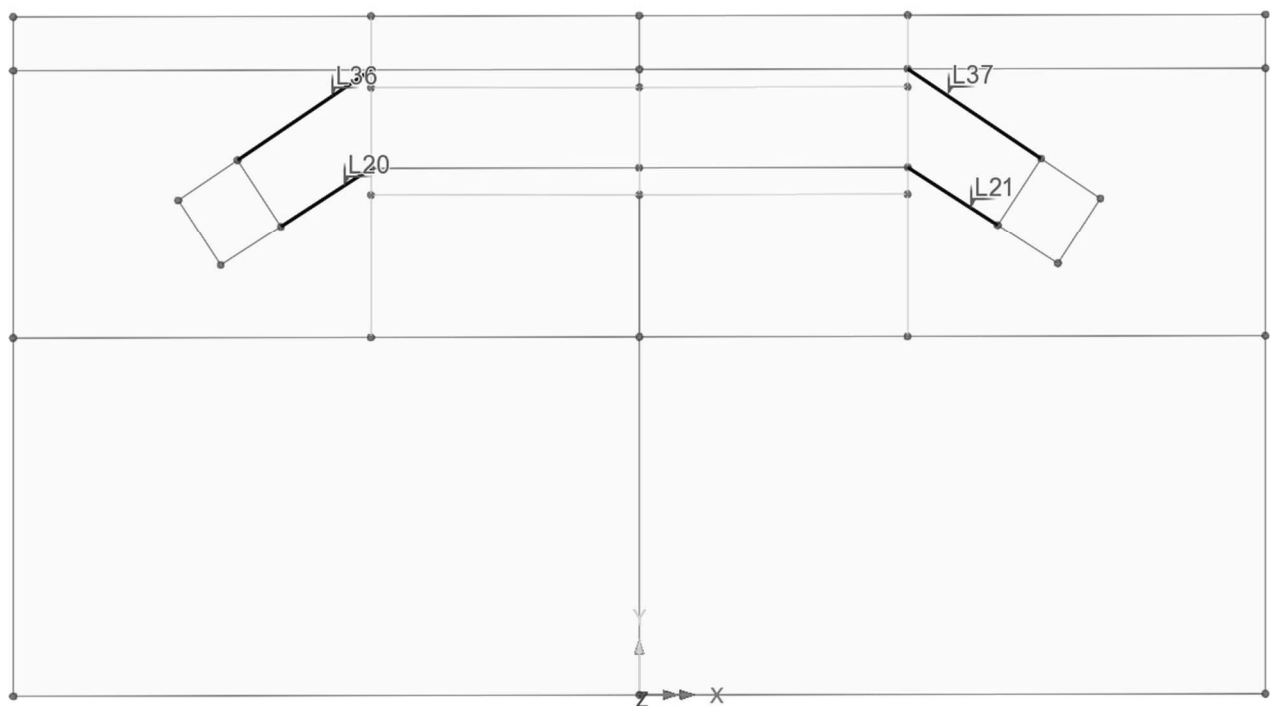
Overall

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2.6.3 Anchor rod: Bar element (BAR2)

Anchor rods are modelled as seen below. This element is not connected to nodes in soil thus the rod is defined by only one element. More elements than one would create a failure due mechanism.

Name	Element type	Number of divisions	Order element
BAR2	Bar	1	Linear



ELEVATION

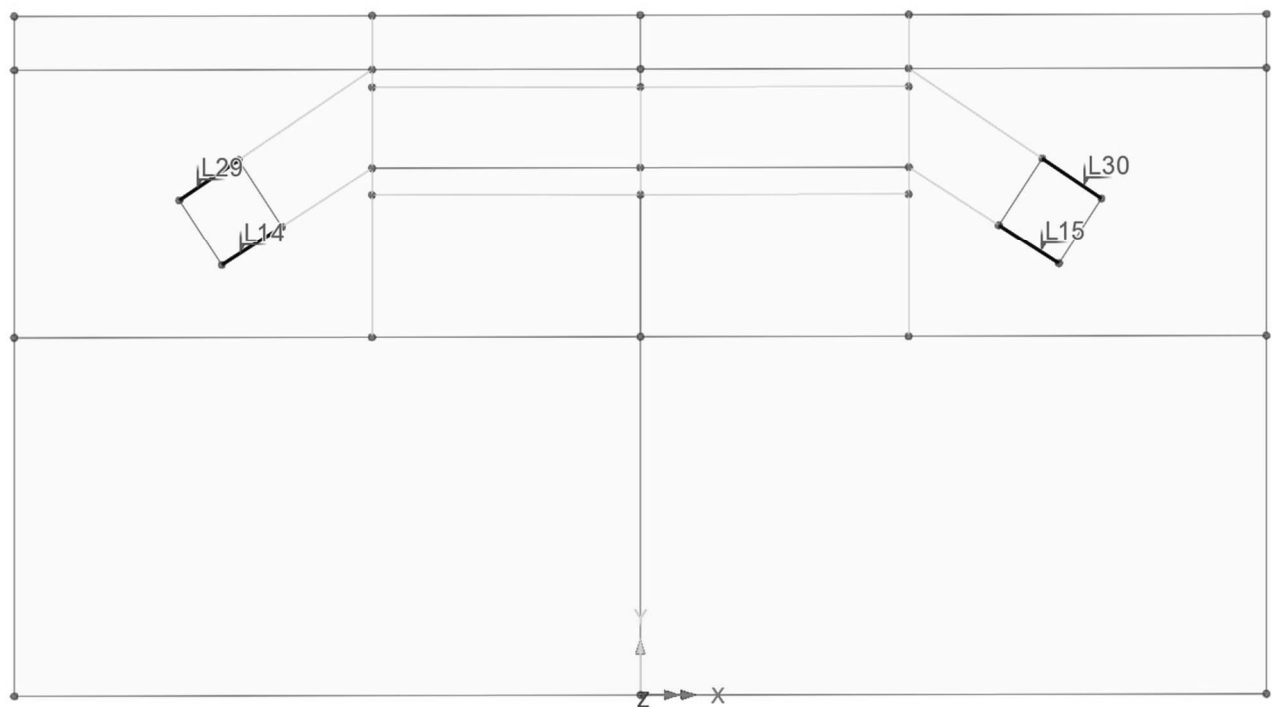
Overall

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2.6.4 Anchor grout : Bar element (BAR3)

Anchor grouts are modelled as seen below. These elements are connected to nodes in soil.

Name	Element type	Element length	Order element
BAR3	Bar	1	Quadratic



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Overall

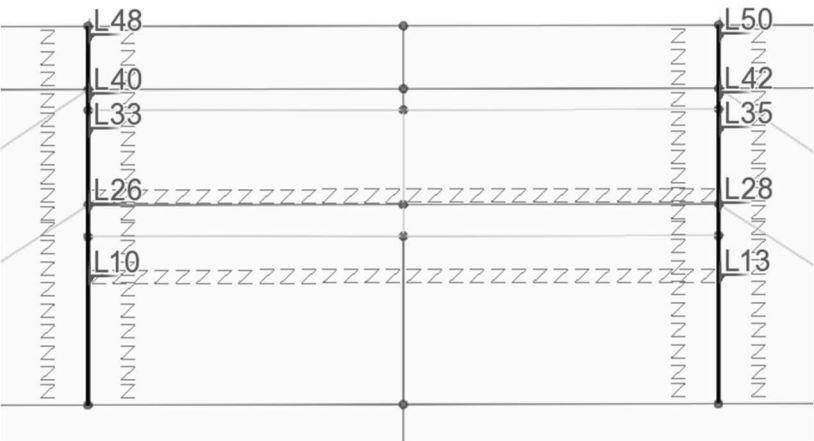
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2.6.5 Interface element between tunnel and soil: Interface plain strain (IPN6)

The interface between soil and wall is modelled as seen below.

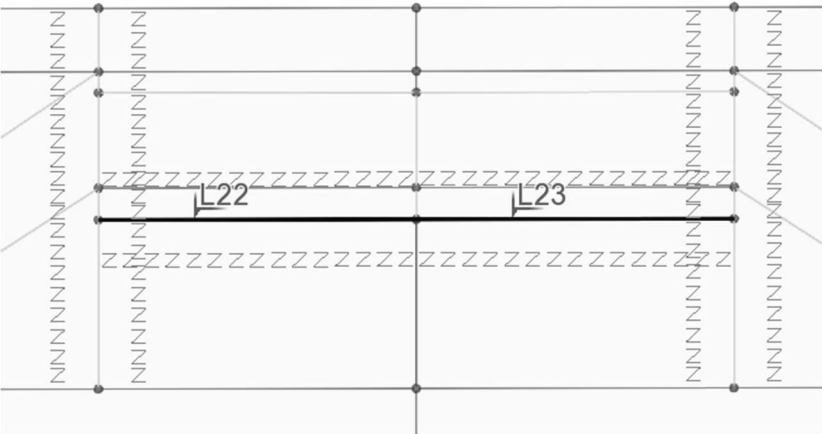
The element is used for modelling standard Mohr-Coulomb friction contact in soil/structure interactions.

Name	Element type	Element length	Assignment type	Order element
IPN6	Interface: vertical	1 m	Single feature (automatic)	Quadratic
IPN6	Interface: horizontal	1 m	Single feature (automatic)	Quadratic



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Interface: vertical



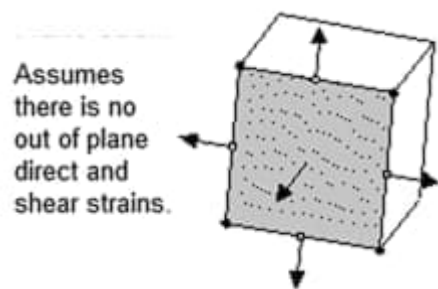
ELEVATION

Interface: horizontal

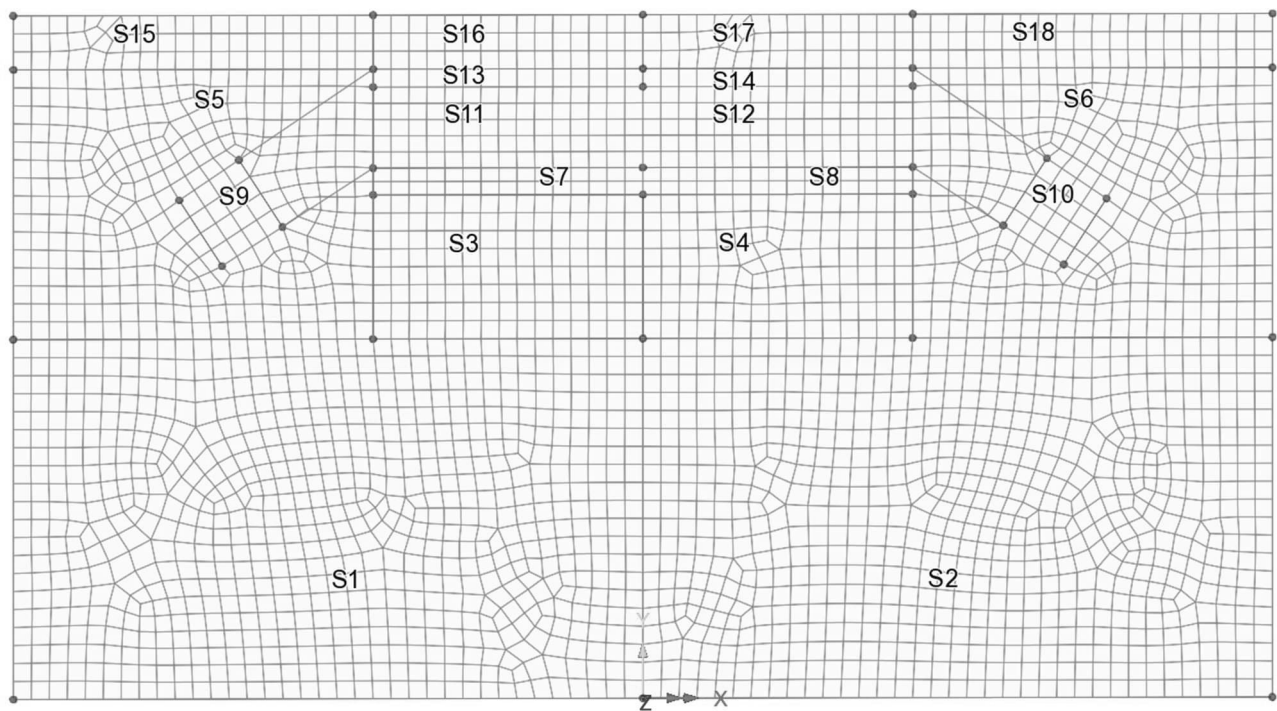
	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 29
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2.6.6 Soil: plain strain surface elements (QPN8)

Soil is modelled using surface elements as seen below. The element type plain strain.



Name	Element type	Element size	Order element	Mesh
QPN8	Plain strain two phase	1 m	Quadratic	Irregular



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2.7 MATERIAL

2.7.1 Linear elastic material: retaining wall, anchors rods & grouting

Retaining wall:

The retaining wall is assumed to be isotropic concrete C40/50.

Isotropic

☐ Plastic

☐ Creep

☐ Damage

☐ Shrinkage

☐ Viscous

☐ Two phase

☐ Ko Initialisation

Elastic

☐ Dynamic properties

☐ Thermal expansion

	Value
Young's modulus	35.0E6
Poisson's ratio	0.15
Mass density	2.4

Name

Wall

(4)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 31
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Anchor rods (c/c 3 m):

The rods are placed c/c 3.0 m out of plain. This can be considered by reducing area of rods or by reducing stiffness corresponding to width 1 m. The later is used thus E-modulus is reduced to 1/3.

Isotropic

☐ Plastic
☐ Creep
☐ Damage
☐ Shrinkage
☐ Viscous
☐ Two phase
☐ Ko Initialisation

Elastic

☐ Dynamic properties
☐ Thermal expansion

	Value
Young's modulus	66.7E6
Poisson's ratio	0.0
Mass density	0.0

Name
Anchor Rod
(5)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 32
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Anchor grouts (c/c 3 m):

The anchor grouts are placed c/c 3.0 m out of plain. This can be considered by reducing area of rods or by reducing stiffness corresponding to width 1 m. The later is used thus E-modulus is reduced to 1/3.

Isotropic

☐ Plastic
☐ Creep
☐ Damage
☐ Shrinkage
☐ Viscous
☐ Two phase
☐ Ko Initialisation

Elastic

☐ Dynamic properties
☐ Thermal expansion

	Value
Young's modulus	83.0E3
Poisson's ratio	0.0
Mass density	0.0

Name
Anchor Grout
(6)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 33
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2.7.2 Nonlinear material: soil

Soil is modelled modified Mohr-Coulomb. This model applies a Rankine tensile cut-off to standard Mohr-Coulomb model.

The standard model would predicts tensile stresses beyond the uniaxial tensile limit of the material, while the modified modell uses tension cut-off stress preventing this.

Definition	Parameter	Fill	Sand	Silt
Elastic	Young's Modulus	8,000 kPa	30,000 kPa	20,000 kPa
Elastic	Poisson's ratio	0.3	0.3	0.33
Elastic	Mass density (Fully Saturated)	2.0	2.0	1.9
Plastic	Friction angle	30.0°	34.0°	29.0°
Plastic	Dilation angle	0 °	4.0°	0 °
Plastic	Cohesion	1.0 kPa	1.0 kPa	8.0°
Plastic (Rankine)	Tensile cut-off stress	0 kPa	0 kPa	0 kPa

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Definition	Parameter	Fill	Sand	Silt
Plastic (Rankine)	Compressive cut-off stress	1E30 kPa	1E30 kPa	1E30 kPa
Plastic (Rankine)	Damping factor	0		
Elastic (once Two-phase tab is selected)	Fully saturated soil density	2.0 tonnes/m ³	2.0 tonnes/m ³	1.9 tonnes/m ³
Two phase (Partially saturated, Saturation)	Bulk modulus of fluid phase	2.1 MPa	2.1 MPa	2.1 MPa
	Porosity of medium	0.4	0.3	0.2
	Hydraulic conductivity in global X, Y, Z	0.5 m/day	1.0 m/day	0.1 m/day
	Density of fluid	1 tonne/m ³	1 tonne/m ³	1 tonne/m ³
	Saturation at residual water content	0.0	0.0	0.0
	Saturation at full water content	1.0	1.0	1.0
(Constant water content)	Permeability factor in partially saturated zone	1x10 ⁻³	1x10 ⁻³	1x10 ⁻³
Ko Initialisation	Coefficient of lateral earth pressure K ₀	0.5	0.441	0.515

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2.7.3 Nonlinear joint material between retaining wall and soil

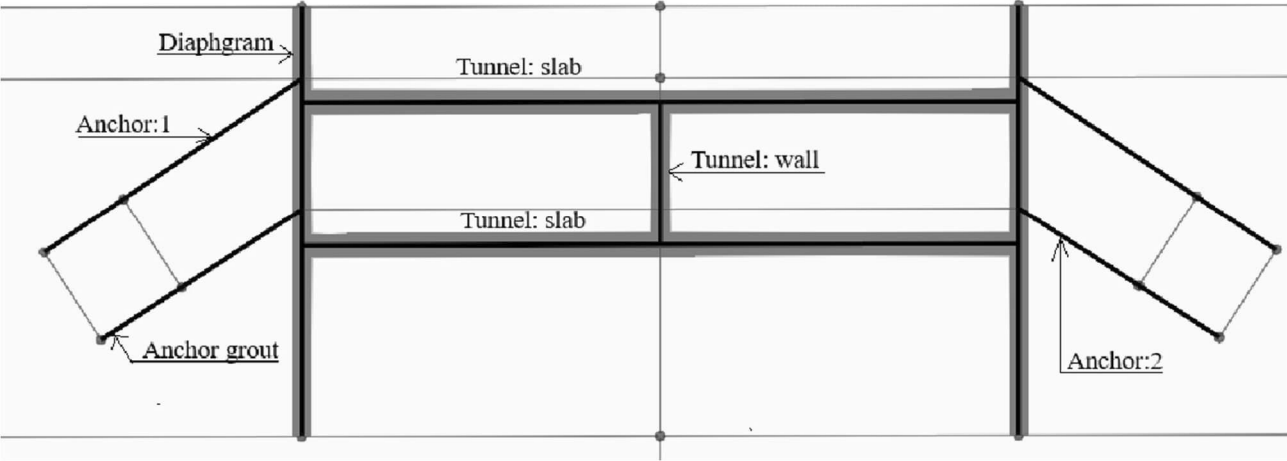
The tangential slip surface is defined as seen below. No leakage is assumed through wall.

Defintion	Parameter	Wall/Fill	Wall/Sand
Soil structure interface (tangential slip)	Angle of friction	20°	24°
Soil structure interface (tangential slip)	Dilatency angle	0	0
Soil structure interface (tangential slip)	Cohesion	0 kPa	0.0 m/s

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2.8 CROSS SECTIONS

Defined cross section properties.



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2.8.1 Diaphragm

Geometric Line

Analysis category2D Inplane

Definition

From library / calculator

Enter properties

UsagePlane Strain Beam

EU Sections

HE Shapes (EN53-62)

HE 1000 M

100%

	Value
In-plane thickness	0.8

Visualise...

Section details...

Name

Diaphragm

(4)

File : Cut and cover tunnel
Datum : 2026-08-11
Tid : 10:01

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 38
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2.8.2 Rod anchor

Rod area is adapted to c/c of anchor rods.

Anchor 1 (c/c 2.3 m):

Geometric Line

Analysis category
2D Inplane

Definition

☐ From library / calculator

☒ Enter properties

Usage
Bar / Cable

EU Sections

HE Shapes (EN53-62)

HE 1000 M

100%

	Value
Cross sectional area (A)	1.37E-3

Visualise...

Section details...

Name
Anchor: 1
(2)

Anchor 2 (c/c 1.35 m):

Geometric Line

Analysis category
2D Inplane

Definition

☐ From library / calculator

☒ Enter properties

Usage
Bar / Cable

EU Sections

HE Shapes (EN53-62)

HE 1000 M

100%

	Value
Cross sectional area (A)	1.53E-3

Visualise...

Section details...

Name
Anchor: 2 & 3
(3)

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2.8.3 Grout anchor

Same grout area is adapted to all grout anchors despite varying c/c of anchor rods. The simplification is considered negligible.

Geometric Line

Analysis category: 2D Inplane

Definition

☒ From library / calculator

☐ Enter properties

Rotation about centroid: 0 °

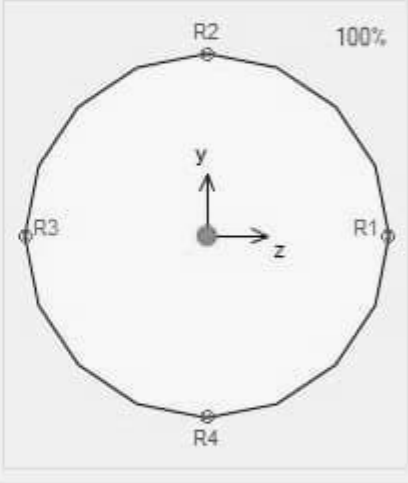
Mirrored about axis: None

ey origin: Centroid

Parametric Sections

Circular Sections

1:Sct1 (CSS D=0.0438)



	Value
Cross sectional area (A)	1.50674E-3
Second moment of area about z axis (Izz)	0.180662E-6
Effective shear area in y direction (Asy)	1.28861E-3
Eccentricity in y direction (ey)	0.0

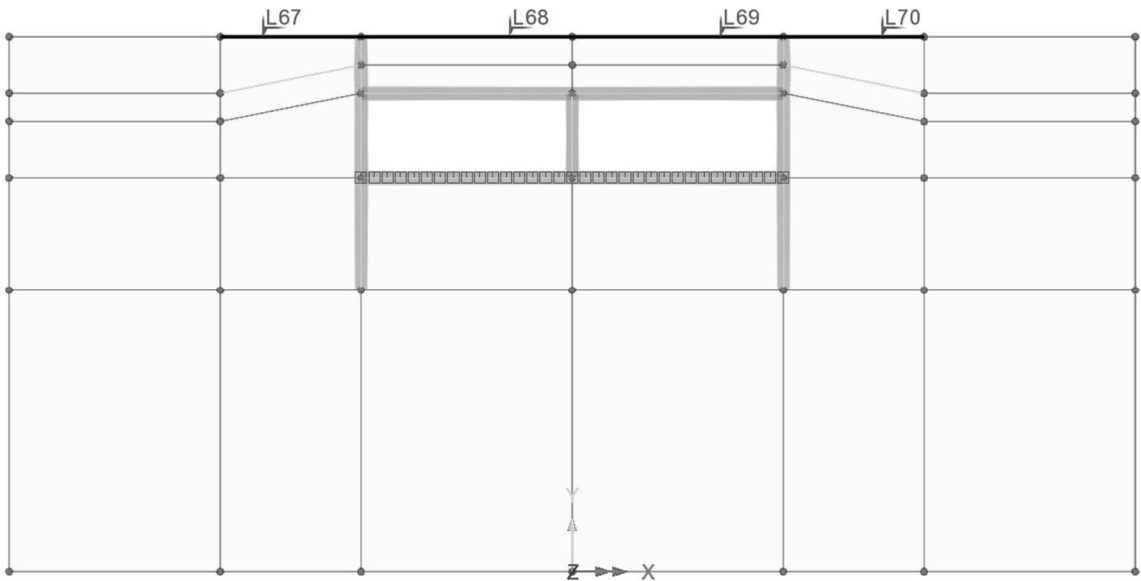
Name: Grout Section (4)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 40
		Date :	Created :

2.9 SEARCH AREA

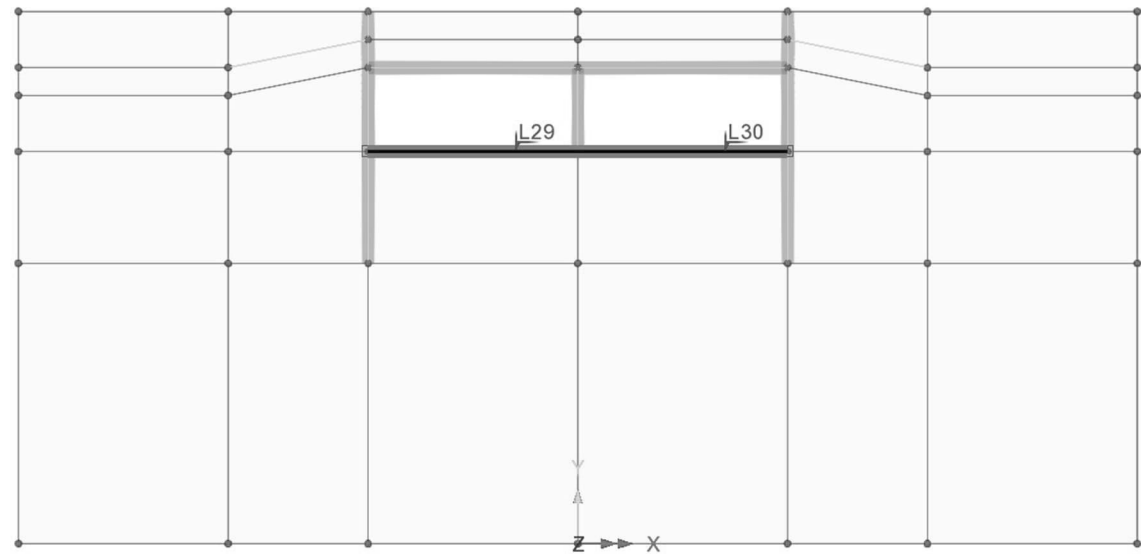
Discrete load can be applied to structure as geometrical load areas. The load areas are termed “Search Area”.

2.9.1 Search area: Fictive beam



ELEVATION

2.9.2 Search area: Bottom slab

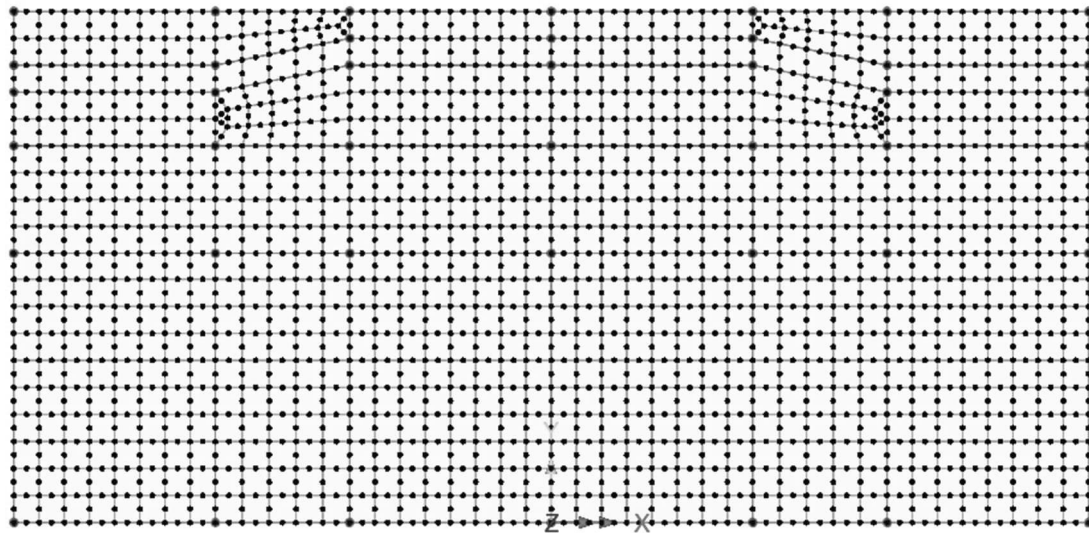
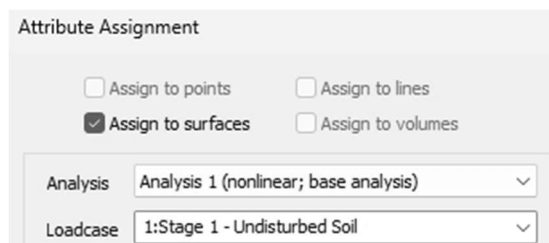


ELEVATION

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 41
		Date :	Created :

2.10 RESET DEFORMATIONS

All node deformations at stage 1 are set to zero.



ELEVATION

Overall

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 42
		Date :	Created :

3. LOADS

3.1 Soil weight (Gravity)

Soil weight is determined material density.

Body Force

Analysis category
2D Inplane

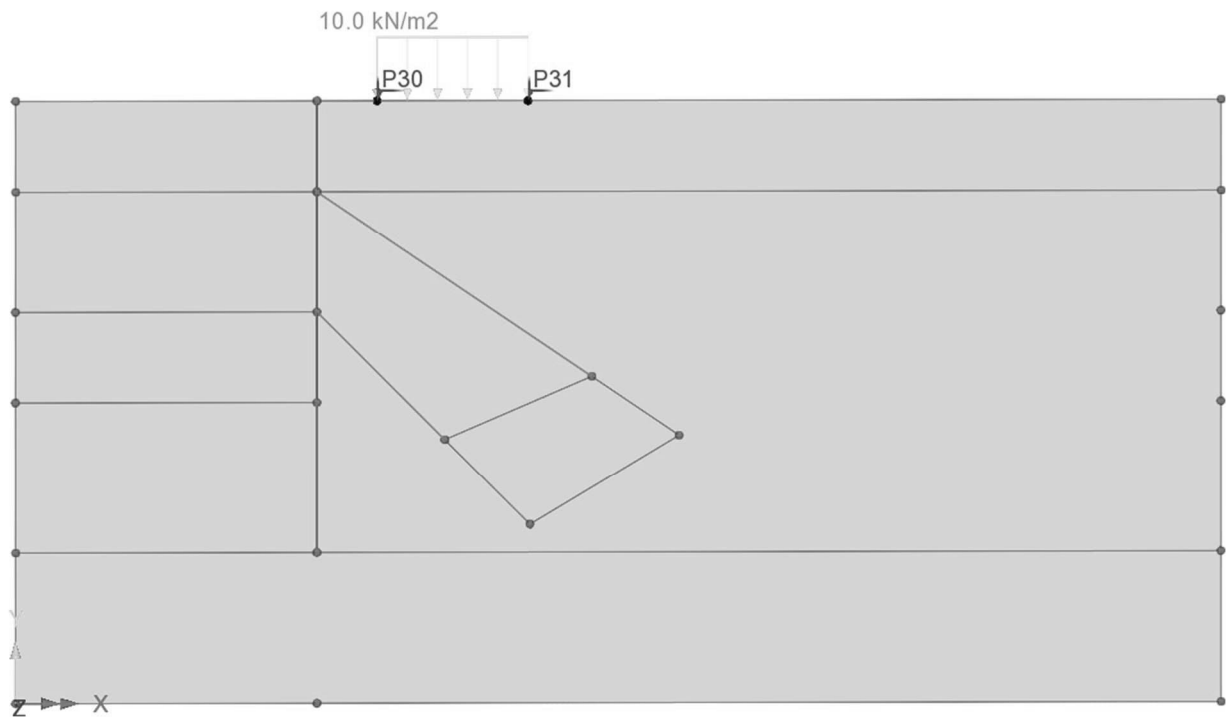
Component	Value
Linear acceleration in X	0.0
Linear acceleration in Y	-10.0
Angular velocity about Z axis	0.0
Angular acceleration about Z axis	0.0

Name
Gravity
(2)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 43
		Date :	Created :

3.2 Surcharge

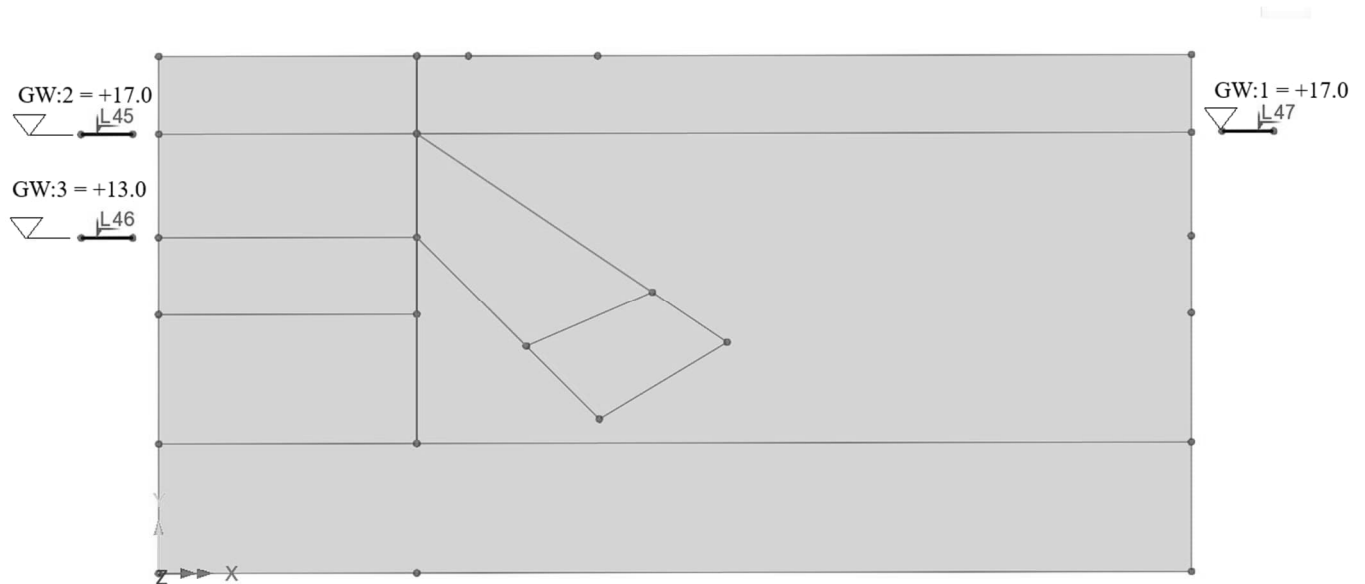
Surcharge ($q = 10 \text{ kPa}$) on top of filling as seen below.



	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 44
		Date :	Created :

3.3 Ground water levels

Free groundwater surfaces (phreatic surfaces) are used to determine acting water pressures, see used levels.



	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 45
		Date :	Created :

3.4 Water pressure

Water pressure varies according to load cases (construction stages).

3.4.1 Water pressure GW:1

Water pressure is associated to GW:1

Water Pressure Distribution

Analysis category: 2D Inplane

Pressure profile:

- ☒ Calculated from phreatic surface: 1:GW:1
- ☐ Assigned to faces

Density of fluid: 1.0

Name: Water pressure GW:1 (4)

This load acts at load cases (stages) seen below.

Before excavation	☒
Install wall	☒
Surface load 10kPa	☒
Excavation:1	☐
Install anchor:1	☐
Set water level GW:2	☒
Reduction to GW:2	☐
Excavation:2	☐
Install anchor:2	☐
Set water level GW:3	☒
Reduction to GW:3	☐
Excavation:3	☐

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 46
		Date :	Created :

3.4.2 Water pressure GW:2

Water pressure is associated to GW:2

Water Pressure Distribution

Analysis category

2D Inplane

Pressure profile

☒ Calculated from phreatic surface

2:GW:2

☐ Assigned to faces

Density of fluid

1.0

Name

Water pressure GW:2

(5)

This load acts at load cases (stages) seen below.

Before excavation	☐
Install wall	☐
Surface load 10kP	☐
Excavation:1	☐
Install anchor:1	☐
Set water level G	☒
Reduction to GW:	☐
Excavation:2	☐
Install anchor:2	☐
Set water level G	☐
Reduction to GW:	☐
Excavation:3	☐

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 47
		Date :	Created :

3.4.3 Water pressure GW:3

Water pressure is associated to GW:3.

Water Pressure Distribution

Analysis category: 2D Inplane

Pressure profile:
☒ Calculated from phreatic surface: 3:GW:3
Density of fluid: 1.0

Name: Water pressure GW:3 (6)

This load acts at load cases (stages) seen below.

Before excavation	☐
Install wall	☐
Surface load 10kP	☐
Excavation:1	☐
Install anchor:1	☐
Set water level G	☐
Reduction to GW:	☐
Excavation:2	☐
Install anchor:2	☐
Set water level G	☒
Reduction to GW:	☐
Excavation:3	☐

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 48
		Date :	Created :

3.5 Reduced pore pressure

3.5.1 Reduced pore pressure:1

Reduction from GW:2 (+17.0 m) to GW:3 (+13.0 m) → -4.0 m

Prescribed Displacement

Analysis category: 2D Inplane

☒ Total ☐ Incremental

	Free	Fixed	Displacement
Translation in Y	☐	☒	-4.0
Pore pressure	☒	☐	

Name: Reduced pore pressure:1 (2)

This load acts at load cases (stages) seen below.

Before excavation	☐
Install wall	☐
Surface load 10kPa	☐
Excavation:1	☐
Install anchor:1	☐
Set water level GW:2	☐
Reduction to GW:2	☒
Excavation:2	☐
Install anchor:2	☐
Set water level GW:3	☐
Reduction to GW:3	☐

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 49
		Date :	Created :

3.5.2 Reduced pore pressure:2

Reduction from GW:3 (+13.0 m) to +10.0 m → -3.0 m

Prescribed Displacement

Analysis category
2D Inplane

☒ Total
☐ Incremental

	Free	Fixed	Displacement
Translation in Y	☐	☒	-3.0
Pore pressure	☒	☐	

Name
Reduced pore pressure:2
(3)

This load acts at load cases (stages) seen below.

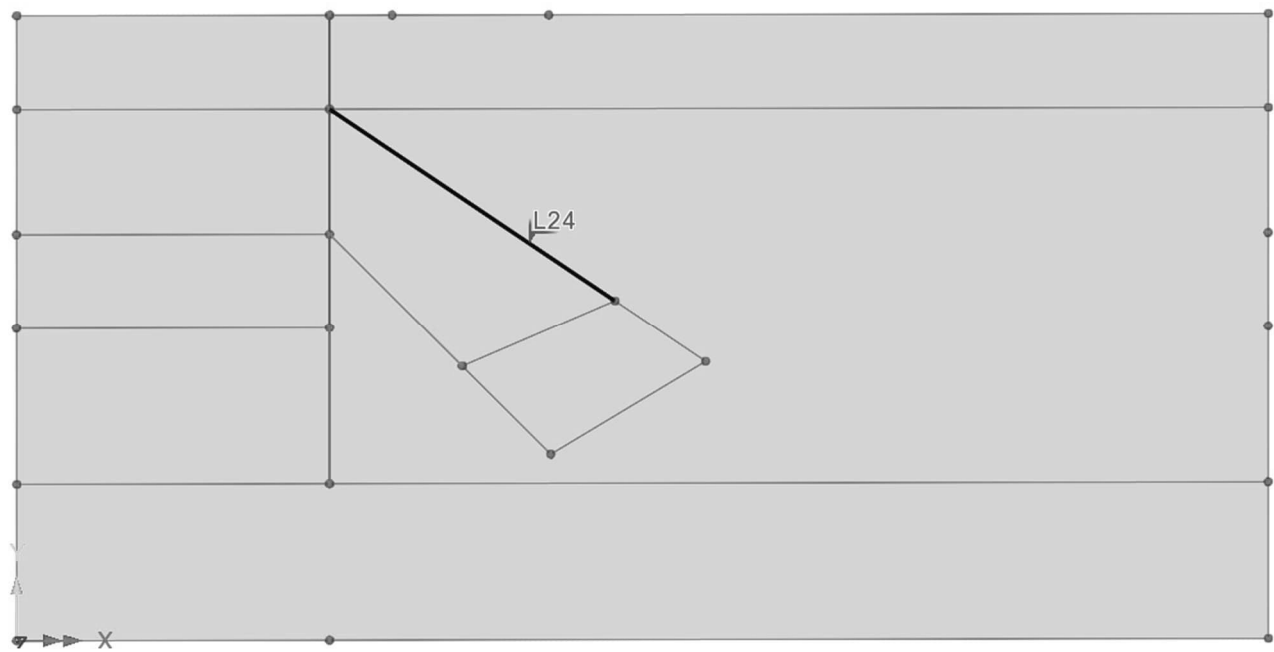
Before excavation	☐
Install wall	☐
Surface load 10kPa	☐
Excavation:1	☐
Install anchor:1	☐
Set water level GW:2	☐
Reduction to GW:2	☐
Excavation:2	☐
Install anchor:2	☐
Set water level GW:3	☐
Reduction to GW:3	☒

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 50
		Date :	Created :

3.6 Anchor loads

3.6.1 Anchor load:1

Total anchor load 360 kN (c/c 3 m) → Fx = 120 kN is applied to L24.



Stress and Strain

Analysis category

2D Inplane

Usage

Element description

Point

Line

Surface

Volume

Include joints

Bar

Stress and strain type

Target

Initial

Residual (NL only)

	Set	Value
Fx	☒	120.0
Ex	☐	

Name

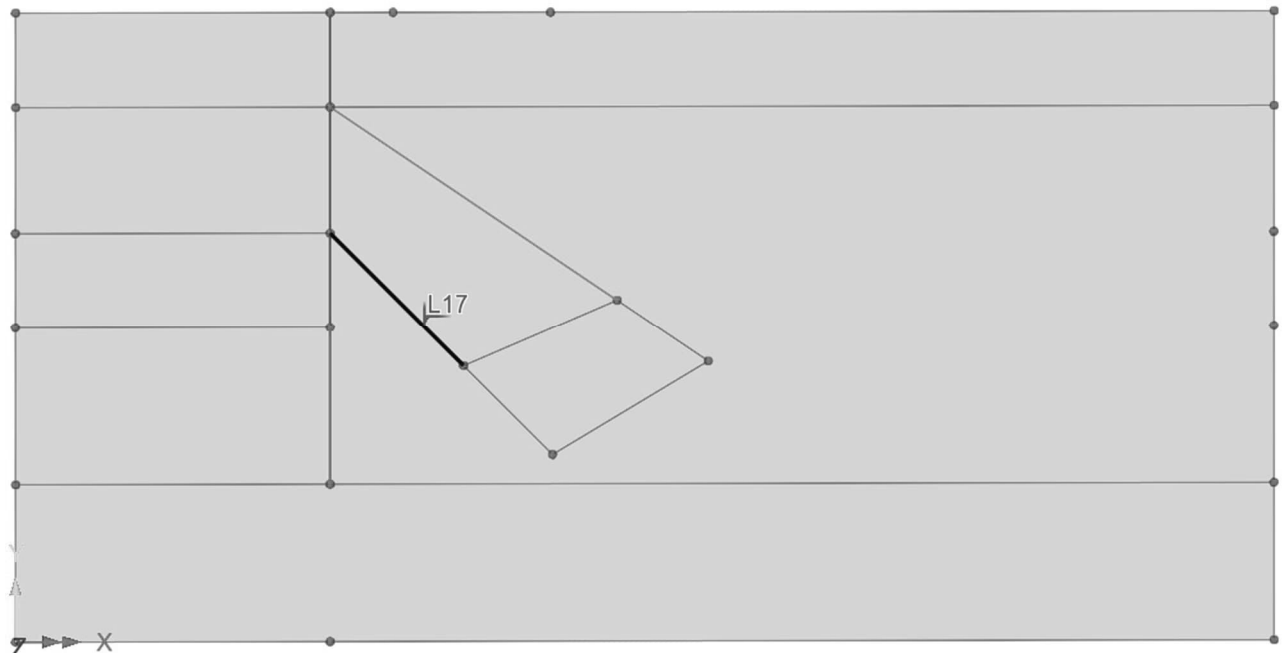
Anchor load:1

(7)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 51
		Date :	Created :

3.6.2 Anchor load:2

Total anchor load 600 kN (c/c 3 m) → $F_x = 200$ kN is applied to L17.



Stress and Strain

Analysis category

2D Inplane

Usage

Element description

☐ Point
☒ Line
☐ Surface
☐ Volume

☐ Include joints

Bar

▼

Stress and strain type

Target

☐ Initial
☐ Residual (NL only)

	Set	Value
F_x	☒	200.0
E_x	☐	

Name

Anchor load:2

▼

▲

▼

(8)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 52
		Date :	Created :

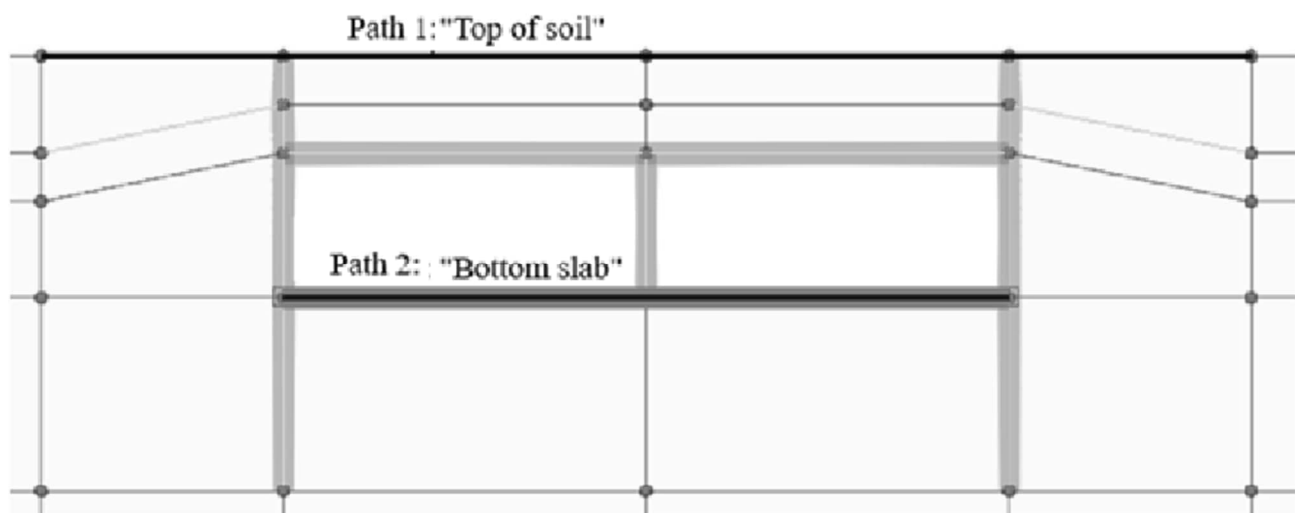
3.7 Traffic load – LM 1

Traffic is applied at two levels, “top of soil” and “bottom slab”.

Since soil is nonlinear analysing moving traffic load is difficult. Another difficulty is principle of load superposition which does not apply.

To verify nonlinear traffic load a linear analysis is also conducted.

Branch #	Level at road	Soil	LC
2	"Top of soil"	Linear	Branch 2: LM 1
3	"Bottom slab"	Linear	Branch 3: LM 1
4	"Top of soil"	Nonlinear	Branch 4: LM 1
5	"Bottom slab"	Nonlinear	Branch 5: LM 1



ELEVATION

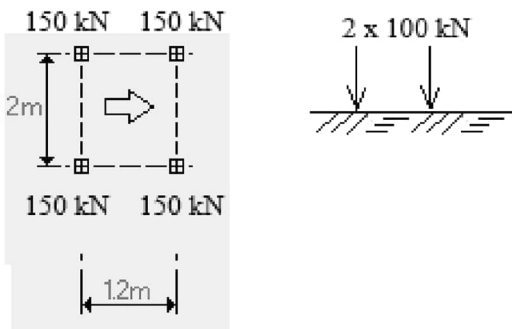
	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 53
		Date :	Created :

3.7.1 Road “Top of soil”

3.7.1.1 Traffic load

Axle load (LM 1:P-T):

Distribution width 3.0 m I assumed in transversal traffic direction.



Point

Analysis category

2D Inplane

Arbitrary

Grid

x

2

y

1

Untransformed load direction

X

Y

Z

XYZ global

XYZ transformable

Surface normal

Projection vector

Project in load direction

X component

0.0

Y component

1.0

Z component

0.0

	X	Y	Z	Load
1	-0.6	0.0	0.0	-100.0
2	0.6	0.0	0.0	-100.0

Name

LM 1:P-T

(3)

File : Cut and cover tunnel
Datum : 2026-08-11
Tid : 10:01

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 54
		Date :	Created :

Surface load (LM 1:q):

Patch

Analysis category
2D Inplane

Patch type

☐ 8 node patch
☐ 4 node patch
☐ Multi-patch
☒ Straight
☐ Curve
☐ Multi-straight

Load direction

☐ X
☐ Z
☒ Y
☐ XYZ global

☐ Patch x
☐ Patch y
☐ Surface normal
☐ XYZ transformable

Projection vector

☐ Project in load direction
☐ Project for prestress

X component
0.0
Y component
0.0
Z component
1.0

Patch load divisions

☒ Use default

Number of divisions in x
0
Number of divisions in y
0

	X	Y	Z	Load
1	-15.0	0.0	-1.5	-9.0
2	15.0	0.0	-1.5	-9.0

Name
LM 1:q
(4)

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 55
		Date :	Created :

3.7.1.2 Linear analysis

Moving Load Analysis (Linear)

Discrete load
LM 1:P-T & LM 1:q

Assignment

☒ Project onto line (2D line beams and frames)

☐ Project over area (grillages, shells, and 3D space frames)

Search area
1: Top of soil

Options for loads outside search area
Exclude All Load

Moments to include
All

Load path definition

Reference path
Path1

Direction of travel
Forward

Path divisions

☒ Move load along path in equal divisions
Divisions
16

☐ Move load by incremental distance along path
Distance
5.5

☒ Create loadcase envelope

Name
Branch 2: LM 1-T

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 56
		Date :	Created :

3.7.1.3 Nonlinear analysis

Moving Load Analysis (Linear)

Discrete load
LM 1-T

Assignment

☒ Project onto line (2D line beams and frames)

☐ Project over area (grillages, shells, and 3D space frames)

Search area
1: Top of soil

Options for loads outside search area
Exclude All Load

Moments to include
All

Load path definition

Reference path
Path1

Direction of travel
Forward

Path divisions

☒ Move load along path in equal divisions

Divisions
16

☐ Move load by incremental distance along path

Distance
5.5

☒ Create loadcase envelope

Name
Branch 2: LM 1-T

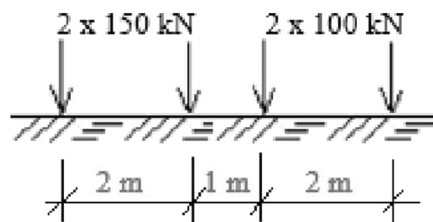
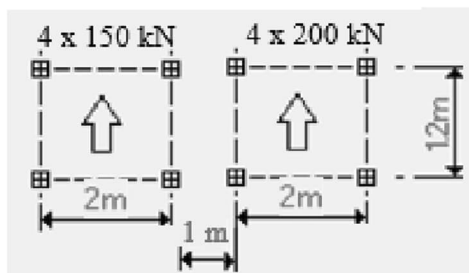
	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 57
		Date :	Created :

3.7.2 Road “Bottom slab”

3.7.2.1 Traffic load

Axle load (LM 1:P-B):

Distribution width 2.0 m I assumed in transversal traffic direction.



Point

Analysis category
2D Inplane

☐ Arbitrary

☒ Grid

x
4

y
1

Untransformed load direction

☐ X
☒ Y

☐ Z
☐ Surface normal

☐ XYZ global
☐ XYZ transformable

Projection vector

☒ Project in load direction

X component
0.0

Y component
1.0

Z component
0.0

	X	Y	Z	Load
1	-2.5	0.0	0.0	-150.0
2	-0.5	0.0	0.0	-150.0
3	0.5	0.0	0.0	-100.0
4	2.5	0.0	0.0	-100.0

Name
LM 1:P-B
(5)

Surface load (LM 1:q):

See page 37.

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 58
		Date :	Created :

3.7.2.2 Linear analysis

Moving Load Analysis(Linear)

Discrete load
LM 1:P-B & LM 1:q

Assignment

☒ Project onto line (2D line beams and frames)
☐ Project over area (grillages, shells, and 3D space frames)

Search area
2: Bottom of slab

Options for loads outside search area
Exclude All Load

Moments to include
All

Load path definition

Reference path
Path 2

Direction of travel
Forward

Path divisions

☒ Move load along path in equal divisions
Divisions
8

☐ Move load by incremental distance along path
Distance
5.5

☒ Create loadcase envelope

Name
Branch 3: LM 1-B

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 59
		Date :	Created :

3.7.2.3 Nonlinear analysis

Moving Load Analysis(Nonlinear & transient)

Discrete load
LM 1:P-B & LM 1:q

Assignment

☒ Project onto line (2D line beams and frames)
☐ Project over area (grillages, shells, and 3D space frames)

Search area
2: Bottom of slab

Options for loads outside search area
Exclude All Load

Moments to include
All

Load path definition

Reference path
Path 2

Direction of travel
Forward

Path divisions

☒ Move load along path in equal divisions
Divisions
8

☐ Move load by incremental distance along path
Distance
5.5

☒ Create loadcase envelope

Name
Branch 5: LM 1-B

	Cut and cover tunnel – two anchor levels (Using permanent diaphragm wall)	Status :	Page : 60
		Date :	Created :

4. **RESULTS (FEM-program)**

Vacant.