YAYASAN PENDIDIKAN DAYANG SUMBI
INSTITUT TEKNOLOGI NASIONAL
LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT
Jl. PHH Mustapa 23, Bandung 40124 Indonesia, Telepon: +62-22-7272215 ext 157, Fax:022-720 2892
Web site: http://www.itenas.ac.id., e-mail: lpp@itenas.ac.id

SURAT KETERANGAN

MELAKUKAN KEGIATAN PENGABDIAN KEPADA MASYARAKAT
INSTITUT TEKNOLOGI NASIONAL
No. 020/C.02.01/LP2M/I/2020

Yang bertanda tangan di bawah ini,

Nama	: Dr. Tarsisius Kristyadi, S.T., M.T.
Jabatan	: Kepala
Unit Kerja	: LP2M-Itenas JL. P.K.H. Mustafa No.23 Bandung

Menerangkan bahwa,

No.	Nama	NPP	Jabatan
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2	Ikhya, S.T., M.T., M.M.	20020117	Anggota Tim
3	Desti Santi Pratiwi, S.T., M.T.	20190804	Anggota Tim

Telah melakukan kegiatan Pengabdian kepada Masyarakat sebagai berikut:

Nama Kegiatan	:	Indonesian Advanced Course on Computational Geotechnics 2019
Tempat	:	Nusa Dua, Bali
Waktu	:	09 - 13 Desember 2019
Sumber Dana	:	Peserta Pelatihan

Demikian surat keterangan ini dibuat untuk dapat dipergunakan sebagaimana mestinya.

Bandung, 10 Januari 2020

Lembaga Penelitian dan Pengabdian kepada Masyarakat (LP2M) Itenas
Kepala,

itenas
LPPM

Dr. Tarsisius Kristyadi, S.T., M.T.
NPP 960604

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Form SPPP

SURAT PERINTAH PERJALANAN

PEGAWAI AKADEMIK

344/F.06/BSDM/ITENAS/XII/2019

1. Pejabat yang berwenang memberi perintah : Wakil Rektor Bidang Keuangan dan Umum

2. Pegawai yang ditugaskan

Nama	Unit Kerja	Jabatan
Dr. Techn. Indra Noer Hamdhan, MT.	Teknik Sipil	Lektor
Ikhya, S.T., M.T., M.M.	Teknik Sipil	Asisten Ahli
Desti Santi Pratiwi, S.T., M.T.	Teknik Sipil	Tenaga Pengajar
Suwarno	Teknik Sipil	Tenaga Kependidikan

3. Tujuan Perjalanan : Pelatihan PLAXIS tahun 2019

4. Tempat : Nusa Dua Bali

5. Lama Perjalanan : 5 (Lima) hari

   a. Berangkat Tanggal : 09 Desember 2019

   b. Kembali Tanggal : 13 Desember 2019

Yang Menugaskan,	Verifikasi Kehadiran, Seminar, Lokakarya.
Wakil Rektor Bidang Keuangan dan Umum,	Panitia Penyelenggara,dll.
Tanggal, 06 Desember 2019	Tanggal, 13 - Desember 2019
itenas INSTITUT TEKNOLOGI NASIONAL	Bali Tropic Resort & Spa Nusa Dua - Bali
(Yuniar, S.T., M.T.)	(Wayan Suambara General Manager.) Nama jelas dan cap penyelenggara

*) *SPPP ini harap dikembalikan ke BSDM setelah dibubuhi tanda tangan dan cap penyelenggara.*

INDONESIAN ADVANCED COURSE ON COMPUTATIONAL GEOTECHNICS 2019

Bali - Indonesia, 9 - 13 December 2019

Organized by :

Pre-Course Day : Sunday, 08 December 201					
15:00	-	16:00	CG-A	Introduction to PLAXIS 2D 2019	Dr. Cheang
16:00	-	17:00	CG-B	Introduction to PLAXIS 3D 2018	Dr. Cheang

Day 1 : Monday, 09 December 2019					
08:30	-	09:15	CG 01	Introduction to Finite Element Modelling	Prof. Schweiger
09:15	-	10:00	CG 02	Introduction Plasticity/Mohr-Coulomb	Prof. Schweiger
10:00		10:15	Tea Break		
10:15	-	12:00	CG 03	Exercise 1 : Elastoplastic Analysis of a Footing	Dr. Cheang
12:00	-	13:00	Lunch		
13:00	-	13:30	CG 04	Nonlinear Computations	Prof. Schweiger
13:30	-	14:30	CG 05	Critical State Soil Mechanics Plaxis Soft Soil Model	Prof. Schweiger
14:30		14:45	Tea Break		
14:45	-	16:00	CG 06	Hardening Soil Small Model	Prof. Schweiger
16:00	-	17:30	CG 07.a	Exercise 2 : Calibration of HS Model	Dr. Tschuchnigg
			CG 07.b	Appendix A : Parameter Determination	Dr. Tschuchnigg
17:30			End		

Day 2 : Tuesday, 10 December 2019					
08:30	-	09:15	CG 08	Structural Elements in Plaxis	Dr. Cheang & Dr. Indra
09:15	-	10:30	CG 09	Undrained Behaviour and Consolidation	Prof. Schweiger
10:30		10:45	Tea Break		
10:15	-	12:00	CG 10.a	Exercise 3 : Excavation of Building Pit (MC-Model)	Dr. Tschuchnigg
			CG 10.b	Exercise 3 : Excavation of Building Pit (MC-Model) Result	Dr. Tschuchnigg
12:00	-	13:00	Lunch		
13:00	-	14:00	CG 11	Modelling of Groundwater in PLAXIS	Dr. Cheang
14:00	-	14:45	CG 12	Concrete Model	Prof. Schweiger
14:45		15:00	Tea Break		
15:00	-	16:00	CG 13	Deep Excavation in 2D and 3D	Prof. Schweiger
16:00	-	17:30	CG 14	Exercise 4 : Excavacation of Building Pit (HS-Model & HSS-Model)	Dr. Tschuchnigg
17:30			End		

Day 3 : Wednesday, 11 December 2019					
08:30	-	10:00	CG 15	Initial Stresses andv Phi-C-Reduktion Slope Stability Analysis	Prof. Schweiger
10:00	-	10:15	Tea Break		
10:15	-	12:00	CG 16	Exercise 5 : Slope Stability for a Road Costruction Project	Dr. Indra
12:00	-	13:00	Lunch		
13:00	-	14:00	NCG Lecture :		Prof. Masyhur
				Development of the National Seismic Hazard Maps 2017 and Their Applications For Distribution	
14:00	-	14:30	CG 17	Embedded Beam (3D) and Embedded Beam Row (2D) Elements	Dr. Tschuchnigg
14:30	-	15:15	CG 18	Modelling Of Deep Foundations	Prof. Schweiger
15:15		15:30	Tea Break		
15:30	-	16:00	CG 19	Modelling of Ground Improvement	Prof. Schweiger
16:00	-	17:30	CG 20.a	Exercise 6 : Modelling of Pile Foundation in 3D	Dr. Tschuchnigg
			CG 20.b	Apendix : 3D Exercise	Dr. Tschuchnigg
17:30			End		

Day 4 : Thursday, 12 December 2019					
08:30	-	09:15	CG 21	Fundamental Concepts of Dynamic Analysis	Prof. Pestana
09:15	-	10:00	CG 22	Material Properties for Dynamic Analyses	Prof. Pestana
10:00	-	10:15	Tea Break		
10:15	-	10:45	CG 23	Dynamic Analysis in Plaxis	Prof. Pestana
10:45	-	12:00	CG 24	Exercise 7 : Generator On An Elastic Foundation	Prof. Pestana
12:00	-	13:00	Lunch		
13:00	-	14:00	CG 25	Geotechnical Earthquake Engineering Analysis	Prof. Pestana
14:00	-	15:15	CG 26	Modelling Dynamic Problems	Prof. Pestana
15:15		15:30	Tea Break		
15:30	-	16:15	CG 27	Modelling Liquefaction in PLAXIS	Prof. Pestana
16:15	-	17:30	CG 28	Exercise 8 : 1D_Nonlinear Site Rresponse Analysis	Prof. Pestana
17:30			End		

Day 5 : Friday, 13 December 2019					
08:30	-	09:30	HATTI Lecture :		Prof. Widjojo
				Earthquake Induced Lateral Earth Pressure on Basement Walls with Different Depth	
09:30	-	10:15	CG 29	Rock Models	Prof. Schweiger
10:00	-	10:15	Tea Break		
10:30	-	11:15	CG 30	(NATM) Tunnelling and Face Stability	Prof. Schweiger
11:15	-	12:00	CG 31	Exercise 9 : Modelling Of Rock Slope with Generalized Hoek-Brown Soil Model	Ikhya, ST., MT., MM.
12:00	-	13:00	Lunch		
15:00	-	16:00		Quiz	

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PLAXIS

Bentley
Advancing Infrastructure

TU Graz
Graz University of Technology

INDONESIAN ADVANCED COURSE ON COMPUTATIONAL GEOTECHNICS 2019

THIS CERTIFICATE IS PRESENTED TO

Dr.techn. Indra Noer Hamdhan

AS LECTURER

Bali - Indonesia

9 - 13 December 2019

Prof. Helmut F. Schweiger
Computational Geotechnics Group
Institute for Soil Mechanics & Foundation Eng.
Graz University of Technology - Austria
(Course Leader)

Dr. Imam Aschuri, M.T.
Rector of Itenas Bandung

Andi Kartawiria, S.T., M.T.
Head of HATTI JABAR

Dr. William WL Cheang
Principal Consultant & Technical Trainer, Geotechnics
Design Integration Analysis
Bentley Systems

INDONESIAN ADVANCED COURSE ON COMPUTATIONAL GEOTECHNICS 2019

Bali - Indonesia, 9-13 December 2019

Organized by:

Institut Teknologi Nasional

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Graz University of Technology

CG 16

Exercise 5 :

Slope Stability for a Road Costruction Project

Dr.techn. Indra Noer Hamdhan

Sponsored by:

SLOPE STABILITY FOR A ROAD CONSTRUCTION PROJECT

INTRODUCTION

On the North Island of New Zealand a new road section has to be constructed along the shore line of a tidal bay, see figure 1.

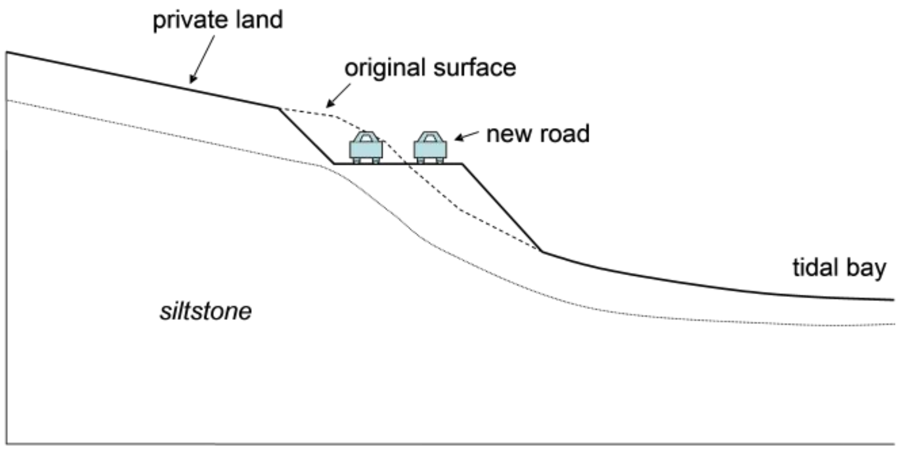


Figure 1: Situation overview for the newly constructed road

Though the easiest solution would have been to construct the road at a larger distance from the bay as the slope gradients are easier there, this is not possible as the upper land is privately owned which for historic reasons cannot be changed. The new road therefore had to be constructed along the steeper gradient just next to the shore line of the tidal bay.

The hillside is mainly siltstone, weathered at the surface but intact at certain depth. Construction will take place in summer when the ground water level is low. However, in winter the hillside side almost fully saturates due to heavy rainfall, which has a significant influence on the stability. For the construction of the new road part of the slope was excavated. The excavated material is crushed and mixed with sand and gravel to make fill material to support the road.

During the first winter after the road construction the road started to tilt towards the tidal bay and after assessing the winter situation the factor of safety was considered too low. The decision was taken to stabilize the fill and hillside below the road using so-called launched soil nails: long steel reinforcement bars that are shot with high speed into the ground.

Main goal of the analysis

- Determine the factor of safety of the original hillside
- Construct the new road under dry (summer) conditions and calculate its factor of safety
- Simulate wet (winter) conditions and calculate its factor of safety
- Apply stabilising soil nails and calculate the factor of safety in wet conditions

INPUT

Project properties

Start a new project and select appropriate *Dimensions* according to the size of the geometry (see figure 2). After closing the *Project properties* window, open the *Snapping options* and make sure to use a snap distance of 0.25m.

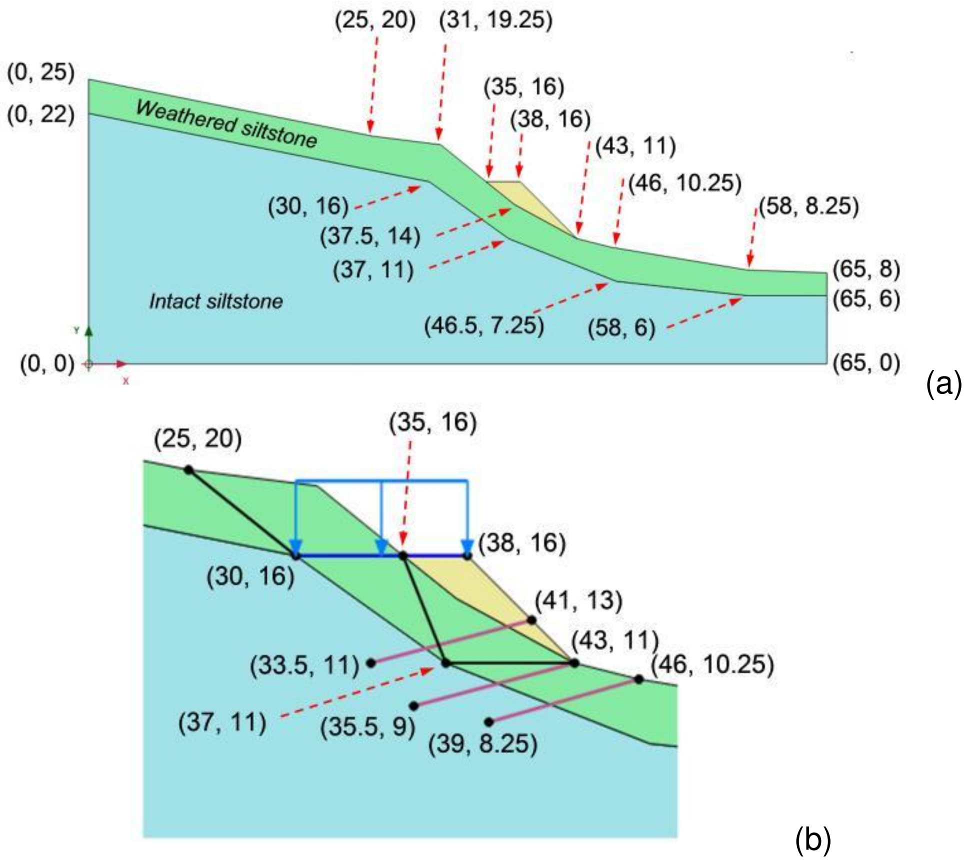


Figure 2: Soil model (a) and position of the road surface, construction details and soil nails (b)

Soil mode

Due to the complexity of the model the geometry will not be defined using boreholes, but through soil polygons in *Structures mode.* Therefore, move directly to *Structures mode*.

Structures mode

- First the intact siltstone is modelled.

- Select the *Create soil polygon* button () and from the submenu that opens, select the *Create soil polygon* option.
- Now draw a soil polygon starting from (x y) = (0 0) and then to (0 22), (30 16), (37 11), (46.5 7.25), (58 6), (65 6) and finally to (65 0).

• Secondly, the weathered siltstone layer will be added. As the bottom of weathered siltstone layer coincides with the top of the intact siltstone layer it's not needed to draw the complete soil polygon.

- From the *Create soil polygon* submenu now select the option *Follow contour*.
- Click at (x y) = (0 22) and draw a line to (0 25), (25 20), (31 19.25), (35 16), (37.5 14), (43 11), (46 10.25), (58 8.25), (65 8) and finally to (65 6).
- Now right click to end the drawing. A soil polygon will be created from the line that was just drawn and the upper contour of the intact siltstone layer below.

• The last part of soil missing is the new fill that will be constructed for the road.

- Select again the *Create soil polygon* option and draw a soil polygon from (x y) = (35 16) to (38 16), (43 11) and (37.5 14)

• Now some additional lines must be specified in order to model the construction sequence.

- From the *Create line* menu choose the option *Create line*.
- Draw a line from (x y) = (25 20) to (30 16)
- Draw a line from (x y) = (35 16) to (37 11) and finally to (43 11)

• The road must be added, including the traffic load:

- From the *Create line* button choose the option *Create plate*.
- Draw a plate from (x y) = (30 16) to (38 16).
- Choose the *Select* button () in order to stop drawing plates.
- Right-click on the just created plate and from the popup menu select the option *Create* → *Line load*
- In the *Selection explorer,* make sure the line load *Distribution* is set to *Uniform* and $q_{y,start,ref}$ = -10 kN/m/m to create a vertical line load of 10 kN/m downwards, per meter out-of-plane.

• And finally the 3 soil nails are added as well:

- From the *Create line* button menu choose the option *Create embedded pile row*.
- Insert 3 embedded pile rows according to the coordinates given in figure 2.

Material properties

Soil

- Enter the material properties for the three soil data sets specified in table 1.
- After entering all properties for the three soil types, drag and drop the properties to the appropriate clusters, as indicated in figure 2.

Table 1: Soil material set parameters

Parameter	**Symbol**	***Intact siltstone***	***Weathered siltstone***	***Reinforced fill***	**Units**
Material model	Model	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	
Type of behaviour	Type	Drained	Drained	Drained	
Dry weight	γ_{unsat}	16.0	16.0	19.0	kN/m^3
Wet weight	γ_{sat}	17.0	17.0	21.0	kN/m^3
Young's modulus	E'	12000	12000	20000	kN/m^2
Poisson's ratio	υ'	0.3	0.3	0.3	–
Cohesion	c'_{ref}	12	10	8	kN/m^2
Friction angle	φ'	35	19	30	$^\circ$
Dilatancy angle	ψ	0	0	0	$^\circ$
Permeabilities	k_x, k_y	$1{\cdot}10^{-3}$	0.01	0.1	m/d
Tension cut-off	Tension cut-off	Disabled	Enabled	Enabled	

Road surface

The road surface is modelled with a plate element. Therefore, create a new plate material set using the parameters as specified in table 2 and assign it to the plate representing the road surface.

Table 2: Properties of the road surface (plate)

Parameter	**Symbol**	***Road surface***	**Unit**
Material model	Model	Elastic	–
Isotropic		Yes	–
End-bearing		No	–
Axial stiffness	$EA_1,\ EA_2$	$2.5{\cdot}10^5$	kN/m
Flexural stiffness	EI	500	kNm^2/m
Weight	w	3.0	$kN/m/m$
Poisson's ratio	ν	0.0	–

Soil nails

The 3 soil nails are modelled using embedded pile row elements. Hence, create a new embedded pile row material set with parameters as specified in table 3 and assign the material to all 3 soil nails.

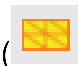
Table 3: Properties of the soil nails (embedded pile rows)

Parameter	**Symbol**	***Grout body***	**Unit**
Modulus of elasticity	E	2.1*10^8	kN/m^2
Material weight	γ	60	kN/m^3
Pile type	Pile type	Predefined	-
Predefined pile type	Predefined pile type	Massive circular pile	-
Diameter	Diameter	0.032	m
Spacing	$L_{spacing}$	1.0	m
Skin resistance	$T_{top,max}$, $T_{bot,max}$	1000	kN/m
Base resistance	F_{max}	0	kN
Interface stiffness factor		Default values	-

Mesh mode

The road surface and the soil nails are automatically refined. However, as possible failure would be expected in the weathered siltstone layer, this layer has to be refined as well.

The *Coarseness factors* as specified in figure 3 should be applied to the indicated areas. This can be done in 2 ways:

1. From the vertical toolbar select the *Refine mesh* button () and click on the areas to be refined. For every click on an area or object its coarseness factor will become 70% of it's current value. Hence, to reach a coarseness factor of 0.5 it's necessary to click twice on the area, for a coarseness factor of 0.35 one has to click 3 times on the same area.

2. Select the areas and in the *Selection explorer* directly enter the appropriate coarseness factors.

Now select the *Generate mesh* button () and make sure the *Element distribution* is set to *Medium*. After mesh generation, view the mesh (see figure 4)

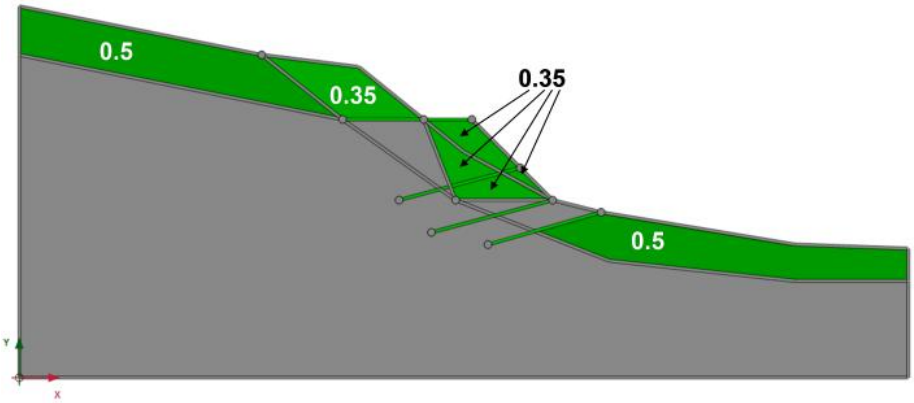


Figure 3: Areas of the mesh to be refined

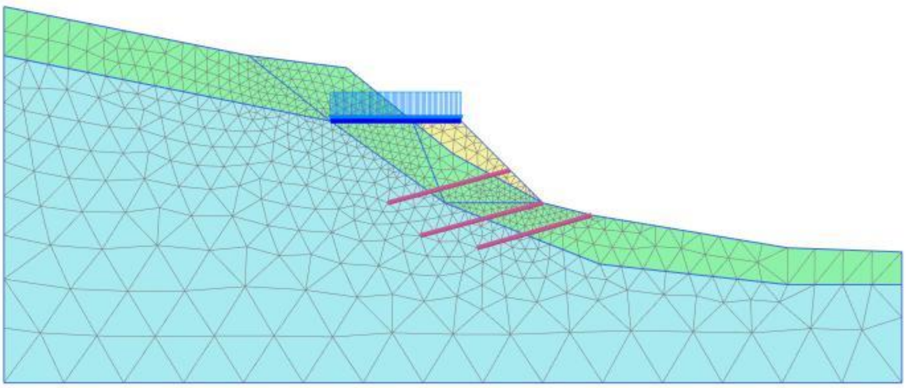


Figure 4: Generated mesh with refinement

Water conditions mode and Staged construction mode

The calculation consists of the initial phase and 12 calculation phases more in order to model the proper construction sequence and the determination of the factors of safety at key moments in the construction process.

Initial phase

The initial situation consists of the intact hill side and a phreatic level representing typical summer conditions as construction starts in summer. In order to define the initial situation, follow these steps:

- Water conditions mode
  - From the vertical toolbar select the *Create water level* button ( ) and then the option *Create water level.*

- Draw a water level from (x y) = (-1 10) to (66 10). This water level will automatically become the global water level.

- Staged construction mode
  - The geometry has a non-horizontal soil layering, hence the K_0-procedure cannot be used.
    Open the *Phases* window and for the initial phase set the *Calculation type* to *Gravity loading*.
  - Make sure only the clusters representing the original hillside are activated. Hence, switch off the parts of reinforced soil.

Phase 1 - Stability prior to the construction

Before the construction is started the factor of safety is determined of the initial situation

- Staged construction mode
  - Open the *Phases* window and change the *Calculation type* of this phase to *Safety*.

Phase 2 - Road excavation

The road excavation should continue from the initial situation and not from the results of the safety factor determination. To do so:

- Select the Initial phase.

- Select the *Add phase* button (). A new phase (phase 2) will now be created that starts from the initial phase.

Now we will define the phase:

- In Staged construction mode
  - In the *Phases* window, set the *Calculation type* to *Plastic* of loading type *Staged construction*.
  - In order to discard the displacements during gravity loading make sure the option *Reset displacements to zero* is selected under the *Deformation control parameters.*
  - Switch off the upper part of the road excavations, see figure 5.

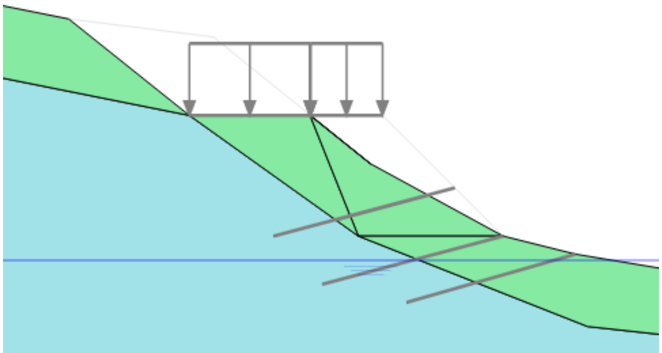


Figure 5: Phase 2, road excavation

Phase 3 - Construction of the fill

- This calculation phase that starts from Phase 2 is again a *Plastic* calculation, loading type *Staged construction*.
- In Staged construction mode
  - Switch on the additional fill
  - Assign the “reinforced fill” material set to the 4 clusters of the fill area, see figure 6.

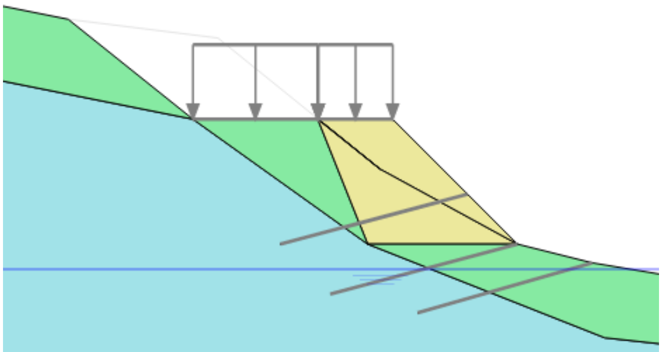


Figure 6: Phase 3, Construction of the fill

Phase 4 - Construction of the road

- This calculation phase that starts from Phase 3 is another *Plastic* calculation, loading type *Staged construction*.
- In Staged construction mode
  - Switch on the plate representing the road. Make sure the distributed load representing the traffic load remains switched off.

Phase 5 - Apply the traffic load

- Again a *Plastic* calculation of loading type *Staged construction*.
- In Staged construction mode
  - Switch on both parts (left ánd right) of the distributed load representing the traffic load. The plate representing the road surface remains switched on.

We are now finished with the road construction.

Phase 6 - Factor of safety of the road in summer conditions

- In order to determine the factor of safety directly after constructing the road use a *Safety* phase starting from Phase 5.

Phase 7 - Winter conditions

In winter, the water level inside the hill gradually increases due to rainfall. Only the highest water level in winter will be modelled, for which a steady-state groundwater flow analysis must be performed.

The increase of water level should occur after finishing the road construction and not after determination of the factor of safety of this situation:

- Select Phase 5 and press the *Add phase* button ( ). Now Phase 7 will be created, starting from Phase 5.
- In Water conditions mode
  - Select the *Create water level* button and draw a new water level from (x y) = (-1,20) to (5,20) and further to (20,10) and (66,10).
  - Choose the *Select* button ( ) in order to stop drawing water levels.
  - Right-click on the newly created water level and select the option *Make global* to make this new water level the global water level.
  - Select the bottom boundary of the model, and in the *Selection explorer* set the *Behaviour* of the boundary conditions to *Closed*.
  - Now right-click on the bottom boundary and in the menu that pops up select the option *Activate* in order to activate the closed boundary.
- In Staged construction mode
  - Open the *Phases* window and in the *General* section set the *Pore pressure calculation type* to *Steady-state groundwater flow.*

Phase 8 - Factor of safety of the road in winter conditions

- In order to determine the factor of safety directly in winter conditions create a *Safety* phase starting from Phase 7.

Phase 9 - Apply top level soil nails

In winter conditions the factor of safety appears to be rather low and therefore it is decided to improve stability by applying launched soil nails.

- The application of the first level of soil nails should occur after calculating winter conditions and not after determination of the factor of safety of this situation : select phase 7 and create a new phase
- Staged construction mode
  - Switch on the topmost soil nail, see figure 7.

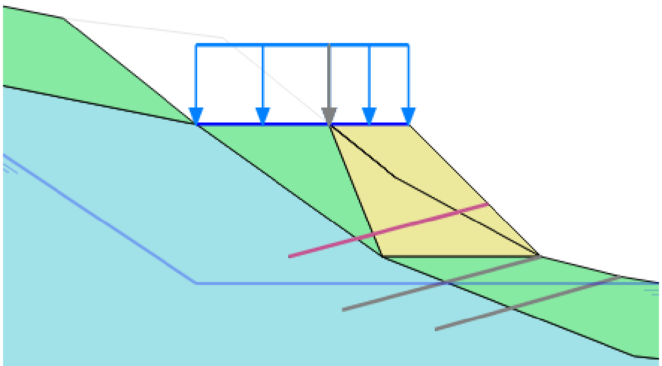


Figure 7: Phase 9, Road construction with traffic load and topmost level of soil nails

Phase 10 - Factor of safety in winter conditions with top level soil nails

- In order to determine the factor of safety directly in winter conditions with the topmost level of soil nails installed create a *Safety* phase. Keep all default settings

Phase 11 - Apply additional soil nails

- The application of the first level of soil nails should occur after installing the top level of soil nails and not after determination of the factor of safety of this situation. Therefore, create a phase starting from Phase 9
- In Staged construction mode
  - Switch on the 2 other soil nails

Phase 12 - Factor of safety in winter conditions with all soil nails installed

- In order to determine the factor of safety directly in winter conditions with the all soil nails installed create a final *Safety* phase.
- For this *Safety* phase, set in the *Phases* window the amount of calculation steps (*Max steps*) to 200 in the *Numerical control parameters* section.

Load-displacement curves

Before starting the calculation choose some points for node-displacement curves. In order to check failure for the phi/c reduction phases the chosen points should be in the expected failure zone. As there are several possible slope instabilities, chose at least points at (25,20), (35,16), (38,16) and (43,11).

Now save the project and start the calculation by pressing the *Calculate* button.

SUCTION

Beforehand, it was estimated that the factor of safety of the slope before construction should be in the order of 1.5 as there is no history of significant deformation for either low water table (summer) and high water table (winter).

However, after the calculation it appears that the factor of safety before construction in summer conditions is just over 1.2 and it is doubted that the factor of safety in reality is indeed that low. Therefore the possibility of present suction is taken into account, as suction generally leads to an increased factor of safety.

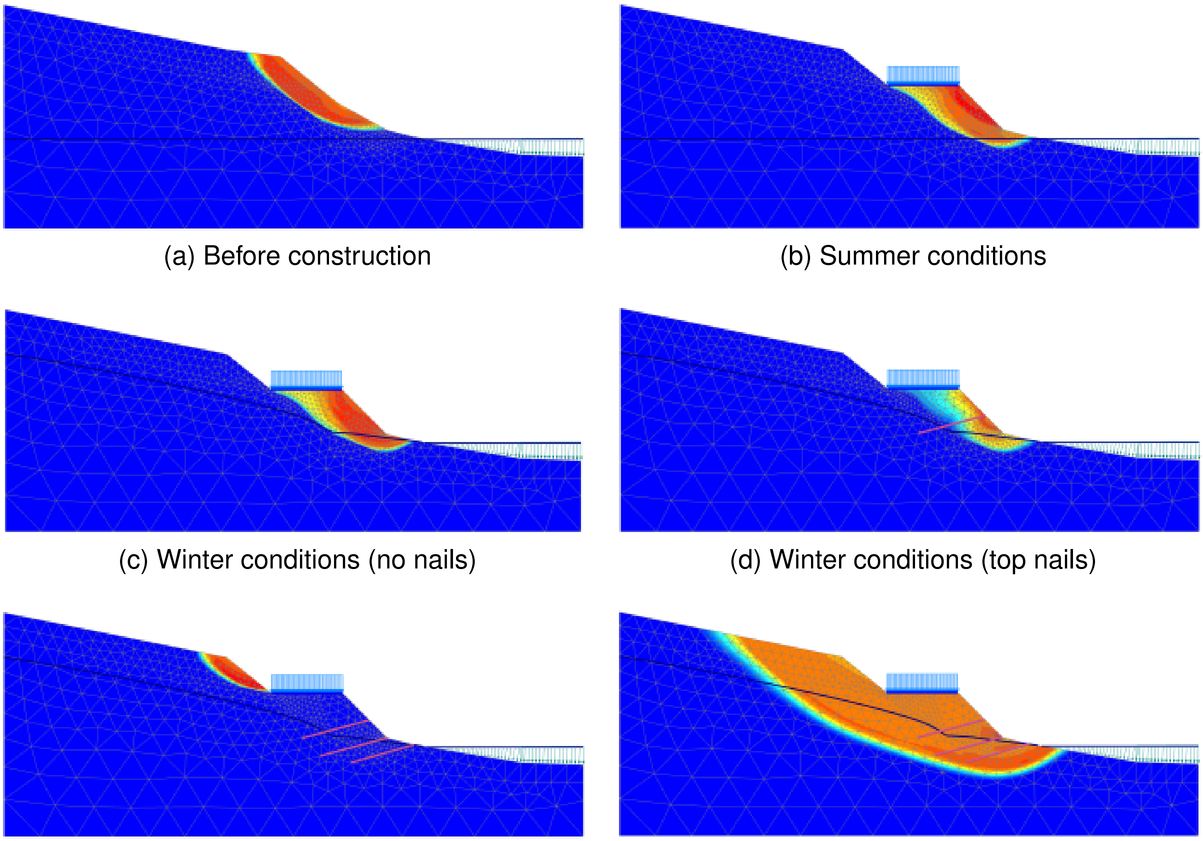
- Save the project under a different name
- Open the *Phases* window and for all phases uncheck the option *Ignore suction* in the *Deformation control parameters.* Hence, we will allow for suction in all phases,
- Mark all phases to be calculated.

Now recalculate the project

OUTPUT

Failure mechanisms

Figure 8 shows the failure mechanisms for all 5 conditions. Note that only for the winter condition with all soil nails installed, the failure mechanism is different depending on whether suction was taken into account. For all other conditions the failure mechanism is the same with or without suction, though the actual factor of safety is different.



(a) Before construction

(b) Summer conditions

(c) Winter conditions (no nails)

(d) Winter conditions (top nails)

(e) Winter conditions (all nails, no suction)

(f) Winter conditions (all nails, with suction)

Figure 8: Incremental displacements showing failure mechanisms

Factors of safety

In order to check the factors of safety, strength reduction curves (ΣMsf vs. displacement of a control point) must be made in the Curves module. As can be seen from figure 8 it is not possible to use the same control point for all 6 factors of safety in case we ignore suction, as the failure mechanisms are in different locations for different situations. Therefore we choose the control points as:

- (x y) = (25 20) for the winter conditions with all nails installed

- (x y) = (35 16) for all other conditions.

To create the curve as shown in figure 9 follow these steps:

- Open the Curves manager ( ) and choose to start a new chart.
- Set the x-axis values to the total displacement of point (x y) = (35 16) and the y-axis values to the *Project* multiplier ΣMsf.
- Right-click on the chart and choose the option *Settings.*
- In the *Settings* window, on the tabsheet representing the curve, click the *Phases...* button and in the *Select phases* window that opens, deselect phase 12 (factor of safety of the winter conditions with all nails installed) so that it will not appear in the graph. To clean up the graph a bit more, one can decided to deselect all phases that are not Safety phases as well.
- Close the *Select phases* window but do not close the *Settings* window.
- In the *Settings* window now select the *Add curve* button and then from the popup menu select *From current project*.
- Add a new curve, but now with the total displacements of point (x y) = (25 20) on the x-axis. The y-axis values remain the *Project* multiplier ΣMsf.
- Back in the *Settings* window, on the tabsheet representing the newly added curve, click again the *Phases...* button. Now deselect all phases but keep phase 12 selected.
- Close the *Phases* window
- Addittionally, on the *Chart* tabsheet of the *Settings* window one can set the scaling of the axes. For instance the x-axis from 0 to 2 m. Press the *Apply* button to confirm this.

We now have a graph with the strength reduction curves for point (x y) = (25 20) for the final phases and for point (x y) = (35 16) for all other calculation phases.

Please note that in case we do calculate with suction, all graphs can be created from point (x y) = (35 16) as this point is in the failure zone for all situations (see figure 10).

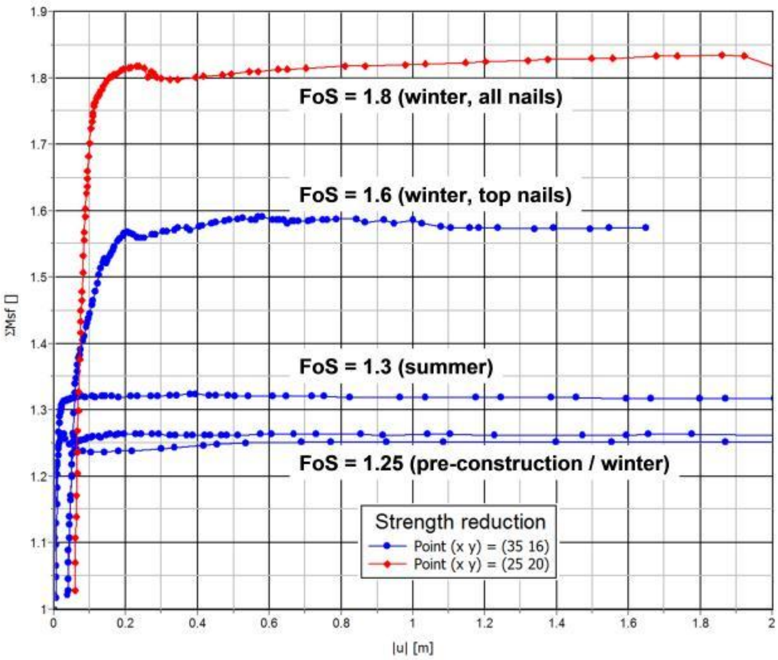


Figure 9: Factors of safety for key moments in the project without taking into account suction.

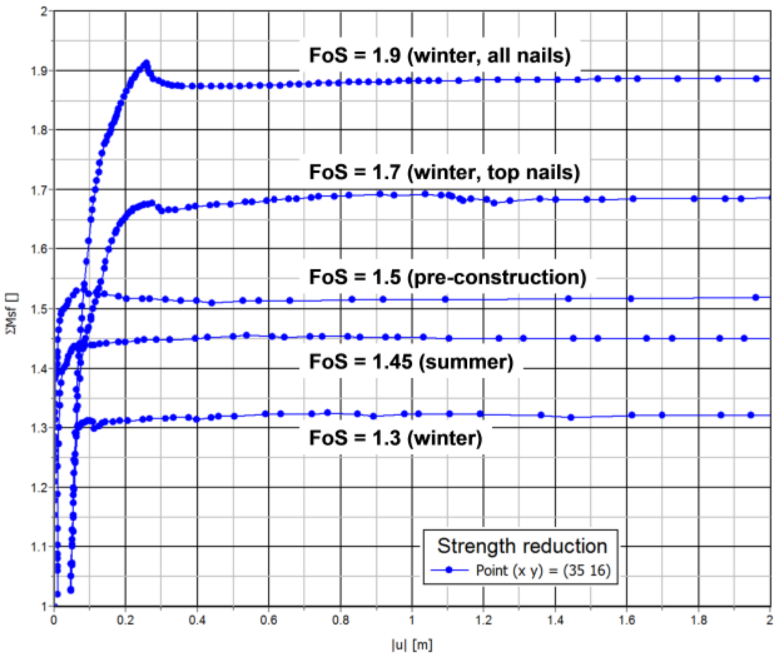


Figure 10: Factors of safety for key moments in the project taking into account suction.

From figures 9 and 10 the effect of installing the nails on the factor of safety can be seen. It can also be seen that taking into account suction gives a factor of safety prior to construction that is more in accordance of the expected value, while suction only has a minor influence on the factor of safety in winter conditions as in winter conditions most of the soil is fully saturated.

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INDONESIAN ADVANCED COURSE ON COMPUTATIONAL GEOTECHNICS 2019

THIS CERTIFICATE IS PRESENTED TO

Ikhya, S.T., M.T., M.M.

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Bali - Indonesia

9 - 13 December 2019

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CG 31

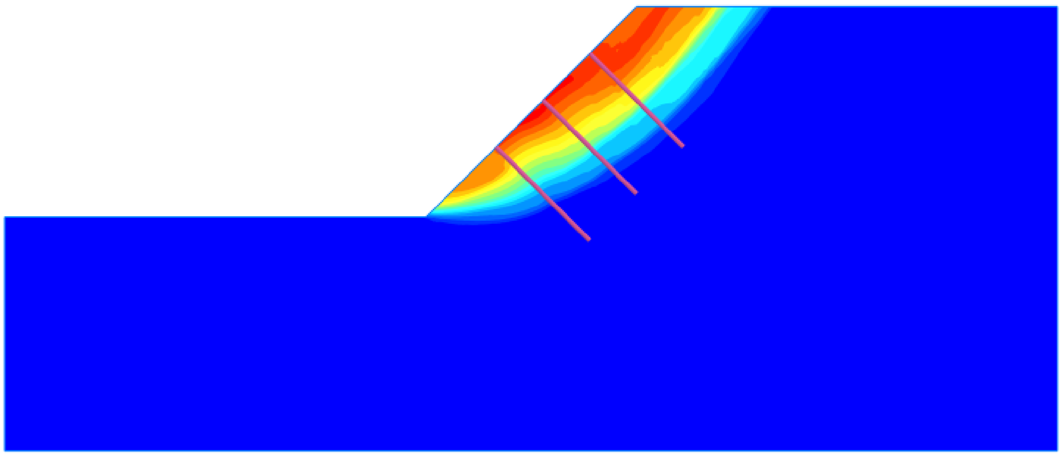
Exercise 9 :

Modelling Of Rock Slope with Generalized Hoek-Brown Soil Model

Ikhya, ST., MT., MM.

Sponsored by:

CG31
EXERCISE 9: Modelling of Rock Slope with Generalized Hoek-Brown Soil Model



Ikhya, S.T., M.T., M.M.

COMPUTIONAL GEOTECHNICS

INTRODUCTION

The exercise concerns in the **analysis to the determination of the factor of safety of rock slope for which strength is modelled by the Generalized Hoek-Brown failure criterion** In order to keep the problem as simple as possible, the model assumed with homogeneus rock slope.

Objectives:
- Safety factor rock slopes
- Safety factor rock slopes with rockbolt

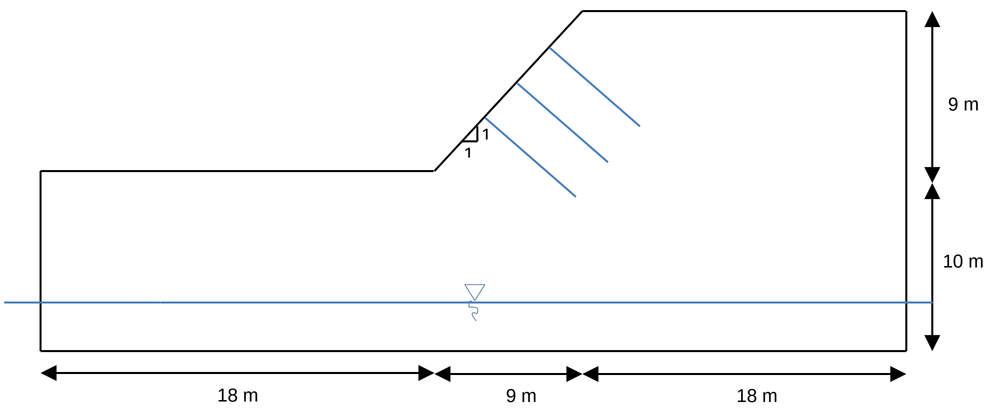


Figure 1: Scheme of the exercise

INPUT

Figure 1 shows a cross section of a **rock slope**. The model slope is have **45.0 m wide** and **19.0 m high**. **The slope** have an inclination of **1:1 with 9.0 m high**. **The model slope** itself is composed of **homogeneous rock**. **The phreatic level** is located **-7.0 m** (at the lowest ground surface).

General settings

- Start the Input program and select Start a new project from the Quick select dialog box.
- In the Project tabsheet of the Project properties window, enter an appropriate title *(Rock Slope with Hoek-Brown Soil Model*).
- In the Model tabsheet make sure that Model is set to **Plane strain** and that Elements is set to **15-Noded**.
- Define the limits for the soil contour as **xmin = -8.0, xmax = 37.0, ymin = −10.0 and ymax = 10.0**.

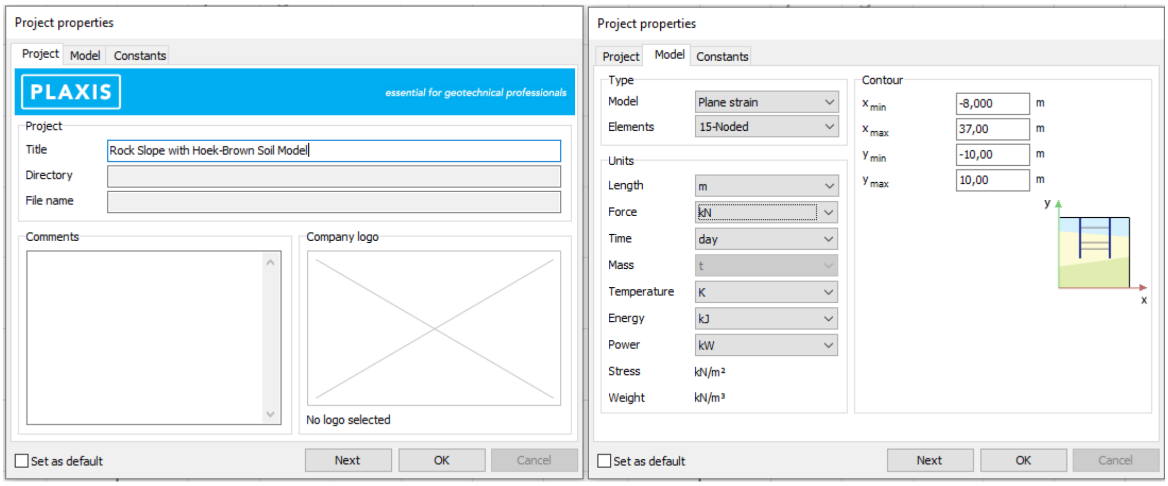


Figure 2: Project tabsheet and Model tabsheet of the Project properties window

Definition of soil stratigraphy

To define the soil stratigraphy:

- **Create a borehole 1** at **x = 10**. The Modify soil layers window pops up.
- **Define single soil layer** as shown in (Figure 3).
- **The water level is located at y = -7.0 m**. In the borehole column specify a value of -7.0 to Head.

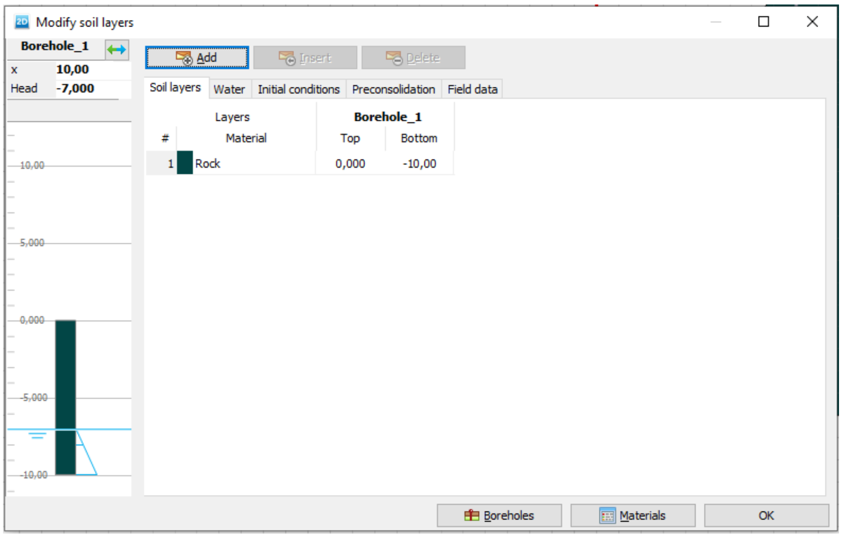


Figure 3: Modify soil layer window.

- **Open the Material sets window.** 
- **Create soil material data set** according to **Table 1** and **assign them to the corresponding layer in the borehole** (Figure 3).
- Next step, **Create again borehole 2, define the x value, depth water level, Top and Bottom soil layer** according to (Figure 4).

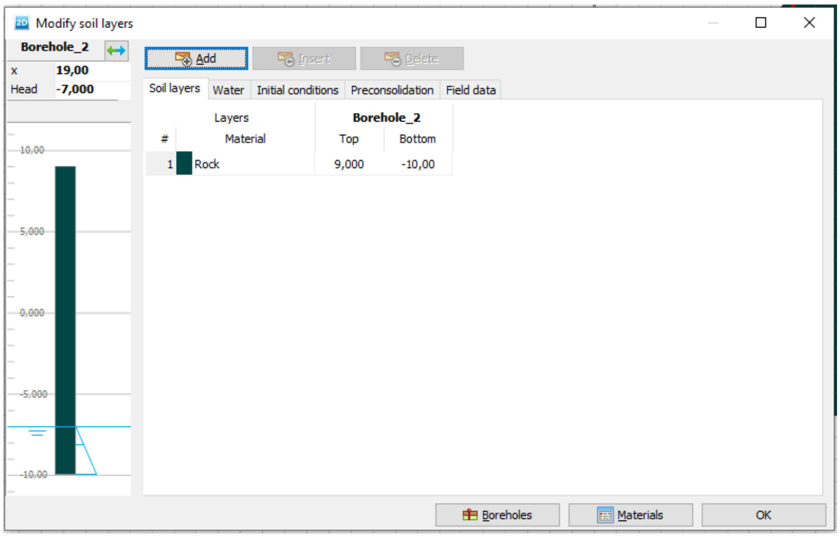


Figure 4: Modify soil layer window (to create borehole 2).

- Close the Modify soil layers window **and proceed to the** to the Structures mode to define rockbolts.

Table 1: Material properties
(Source : Hammah et al, 2004)

Hoek-Brown Soil Model		
Parameter		Rock
Type	Non-Porous	
γ_{unsat}	kN/m^3	25
μ	-	0,3
σ_{ci}	kN/m^2	30000
E	kN/m^2	5000000
ψ	°	0
m_b	-	0,067
m_i	-	2
s	-	2,5 x 10^{-5}
GSI	-	5
a	-	0,619

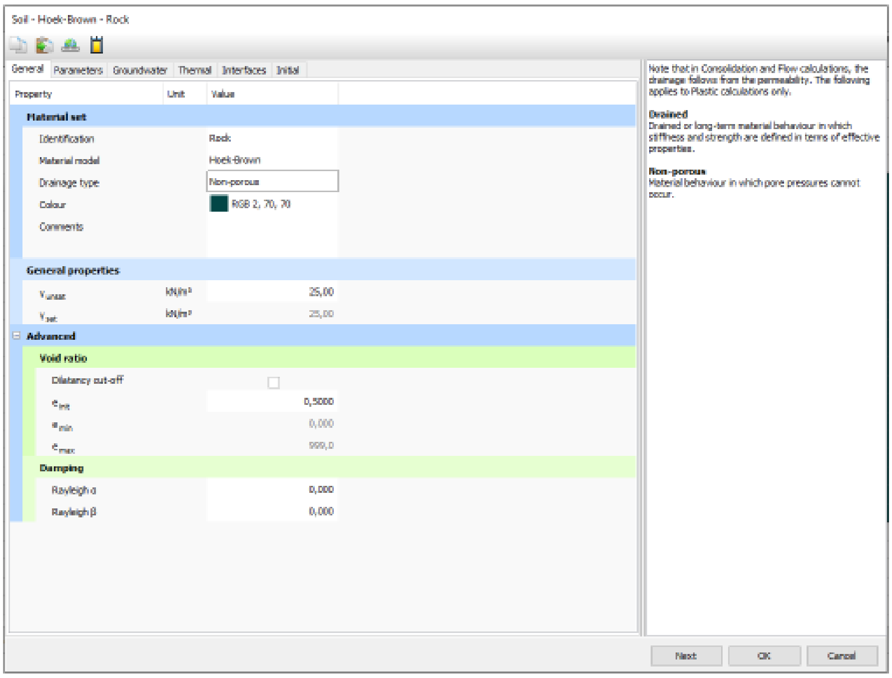


Figure 5: General tabsheet of the soil and interface data set window

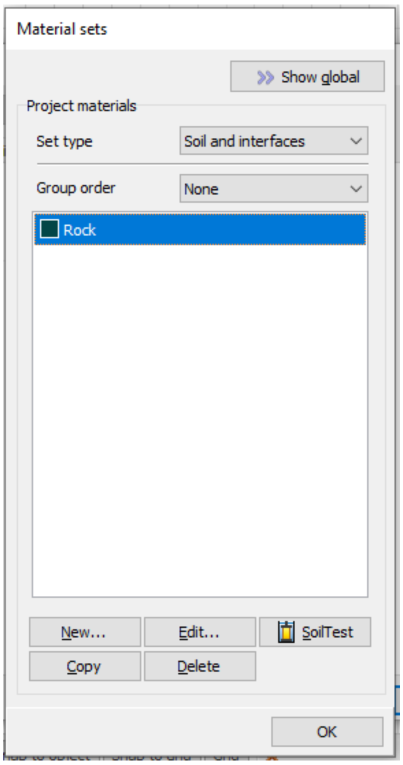


Figure 6: Material sets window.

Definition of Rockbolt

The embankment and **the drains** are defined in the **Structures mode**.
To define the rockbolt:

- **Click the Create line button** in the **side toolbar** and select the **Create embedded beam row** option in the appearing menu. 
- **Define the embedded beam row** in the **draw area** by **clicking on (17.0 7.0), (21.0 3.0), (15.0 5.0), (19.0 1.0), (13.0 3.0) and (17.0 -1.0).**
- **Open the Material sets window**. 
- **Click set type project materials** and select **to embedded beam row,** and then **Create new** (Figure 7) rockbolt data parameter set **according to Table 2.**
- **Right-click** the embedded beam row and **assign the rockbolt data set to the embedded beam row** (Figure 8).

Table 2: Rockbolt parameter **(Embedded beam row)**

Parameter		**Rockbolt**
Type		Elastic
γ	kN/m³	60
E	kN/m²	2,1*10⁸
Diameter	m	0,15
Beam type	-	Predefine (Massive circular beam)
L Spacing	m	1
Skin resistance $T_{top,bot\ max}$	kN/m	1000
Base resistance F_{max}	kN	0
Interface Stiffness factor	-	Default

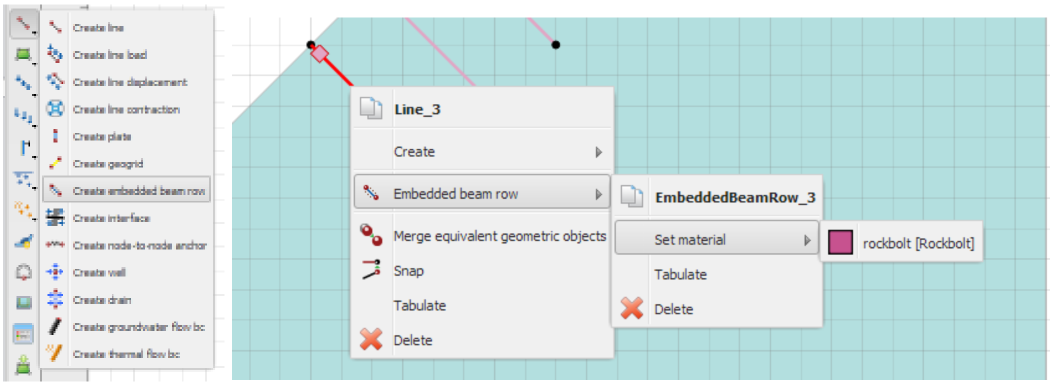


Figure 8: Assignment of a material dataset to rockbolt in the draw area.

- **3 rows rockbolt** will be created in total (Figure 9)

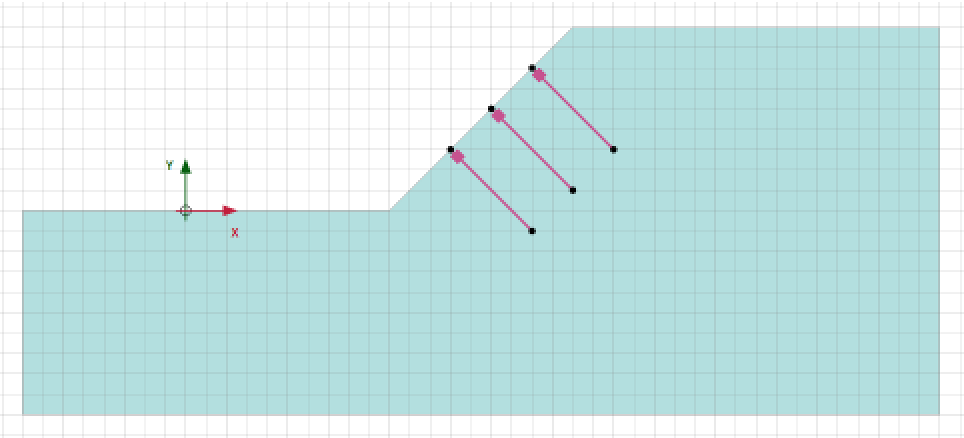
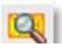


Figure 9: Final geometry of the model

MESH GENERATION

- Proceed to the **Mesh mode**
- Generate the mesh. **Use the very fine** for the **Element distribution parameter**. (Figure 7). 
- **View the generated mesh**. The resulting mesh is shown in Figure 8. 
- **Click on the Close tab** to **close the Output program**.

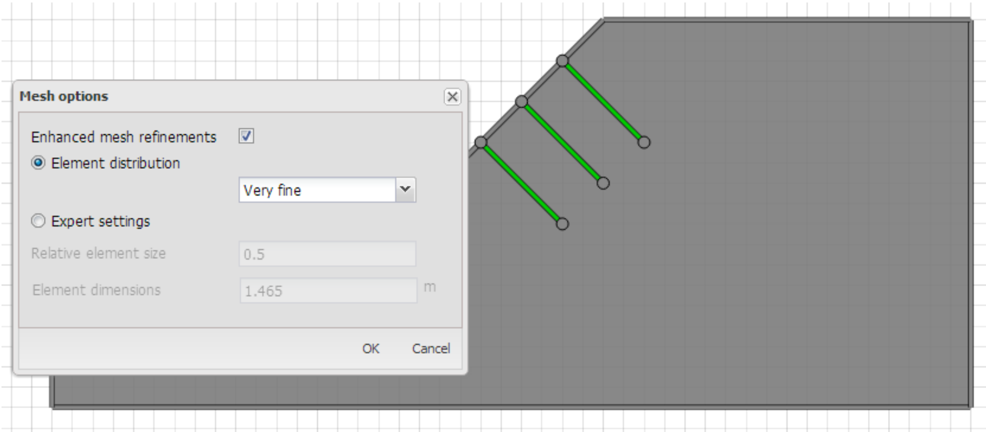


Figure 7: Mesh options window.

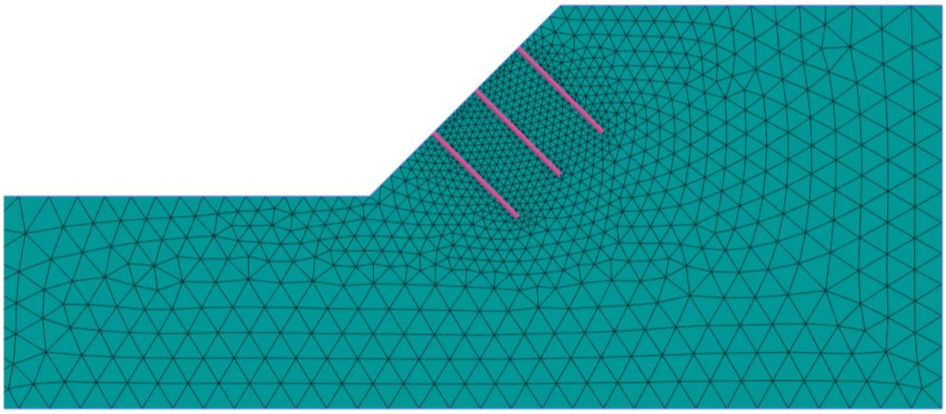


Figure 8: The generated mesh in the Output window.

CALCULATIONS

Once the mesh has been generated, the finite element model is complete. **The calculation phases** to simulate the stages of construction are shown in **Table 2**.

Table 2. Calculation phases

No	Staged Construction
1	*Initial condition*
2	*Safety Factor Existing*
3	*Install rockbolt*
4	*Safety Factor after install rockbolt*

Initial Phase: Initial Conditions

In the **initial situation** to generate the initial stresses, Cause the model slope originally non-horizontal layers, therefore **in the phases window** set the **Calculation type to Gravity Loading** (Figure 9).

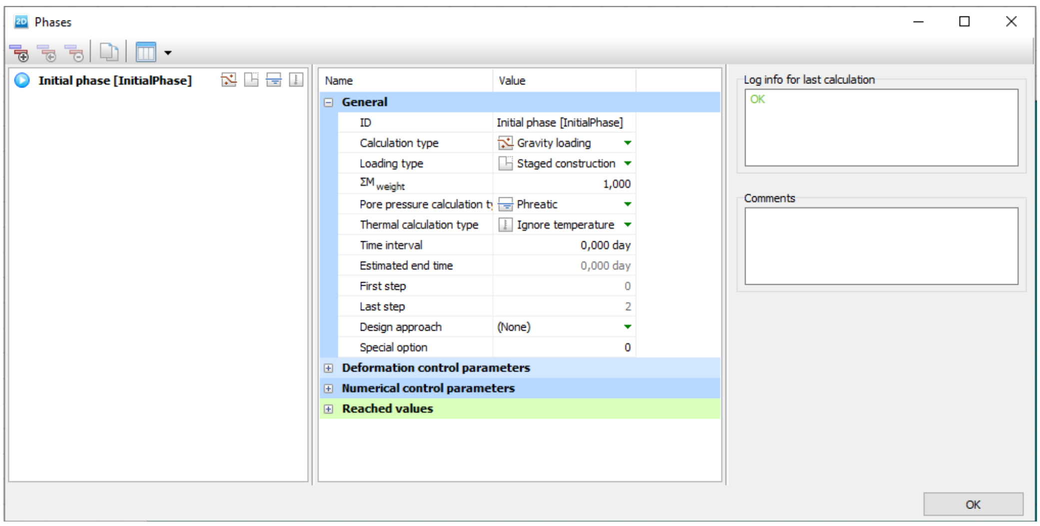


Figure 9: Configuration of the initial phase.

Phase 1: Stability Analysis Existing Condition

The first calculation stage is a **Safety Factor Analysis**, **Staged construction**.

- **Add a new phase**.
- In the Phases window select the **Safety option** from the **Calculation type** drop-down menu in the General subtree (Figure 10).
- Make sure that the **Incremental multipliers** option is selected for the **Loading type**.

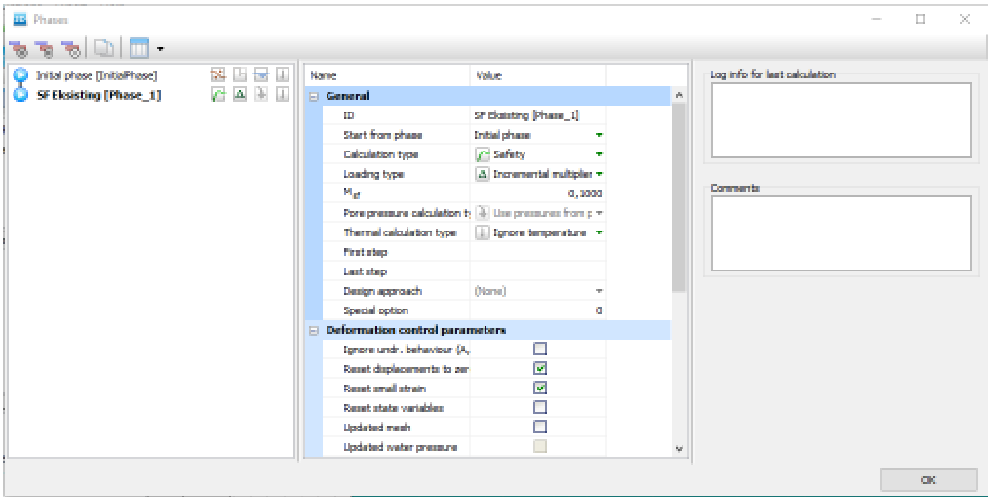


Figure 10: Phase 1.

Phase 2: Install Rockbolt on the model Slope

The second calculation stage is also a **Plastic Analysis**, **Staged construction**.

- **Add a new phase**.
- In the Phases window select the **Plastic option** from the **Calculation type** drop-down menu in the General subtree.
- Make sure this **Phase, start from phase (Initial phase) (**Figure 11).
- And make sure that the **Staged construction** option is selected for the **Loading type.**
- In the **Model explorer** expand the **Embedded beam row subtree** and **activate all the Embedded beam row** (Figure 12).

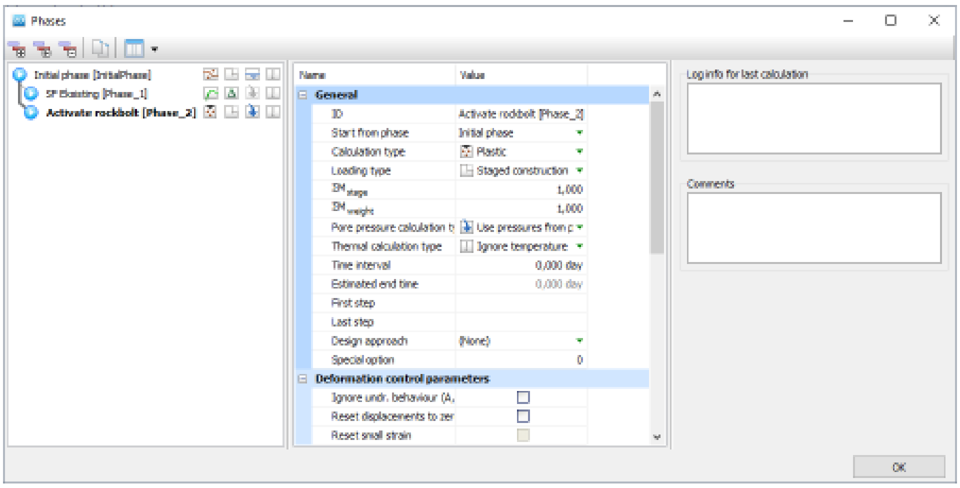


Figure 11: Phase 2.

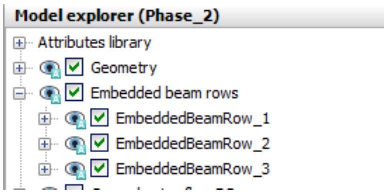


Figure 12: Activate all Embedded beam row.

Phase 3: Stability Analysis after Installed Rockbolt

The third calculation stage is a **Safety Factor Analysis**, **Staged construction**

- **Add a new phase**. 
- Make sure this **Phase, start from phase (phase 2)**.
- In the Phases window select the **Safety option** from the **Calculation type** drop-down menu in the General subtree.
- Make sure that the Incremental multipliers option is selected for the **Loading type**. 

Execution of calculation:

Before starting the calculation, click the Select points for curves button and select the following points (figure 16): 

Point (XY) = (19.0 9.0) will be used to plot the development of vertical displacement.

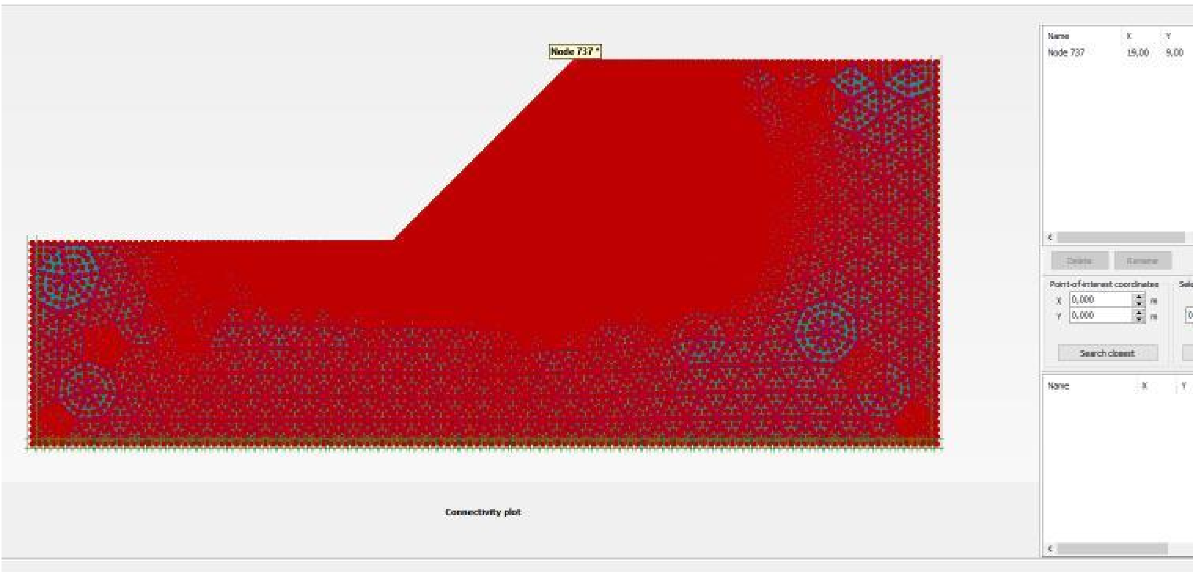


Figure 17: Point (XY)

After selecting these points, start the calculation. 

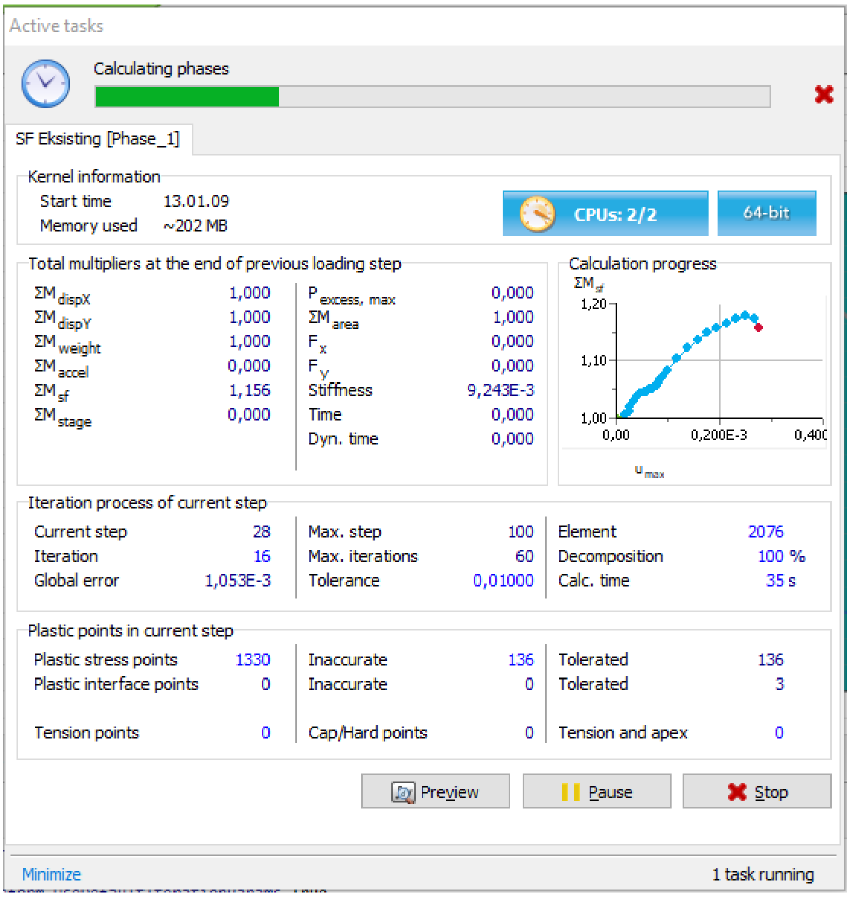
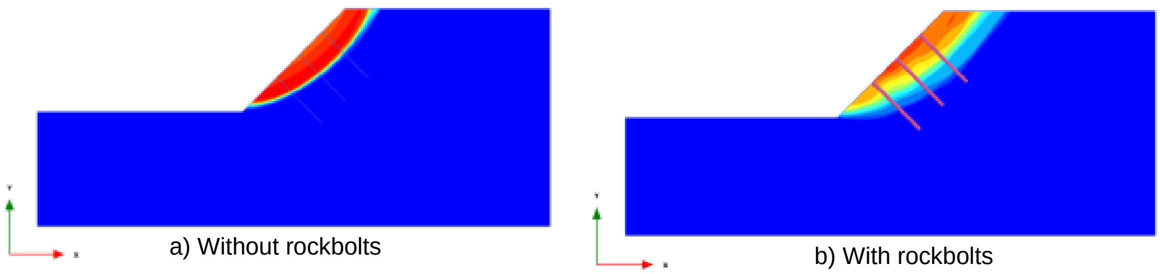


Figure 13: Calculation progress displayed I the Active task window.

RESULTS

After the calculation has finished, **select** the ***'View calculation'* button** that will start the output program.

Figure 14 shows the failure mechanisms for two conditions. One of rockbolts installed and one more is without installed rockbolts.



a) Without rockbolts

b) With rockbolts

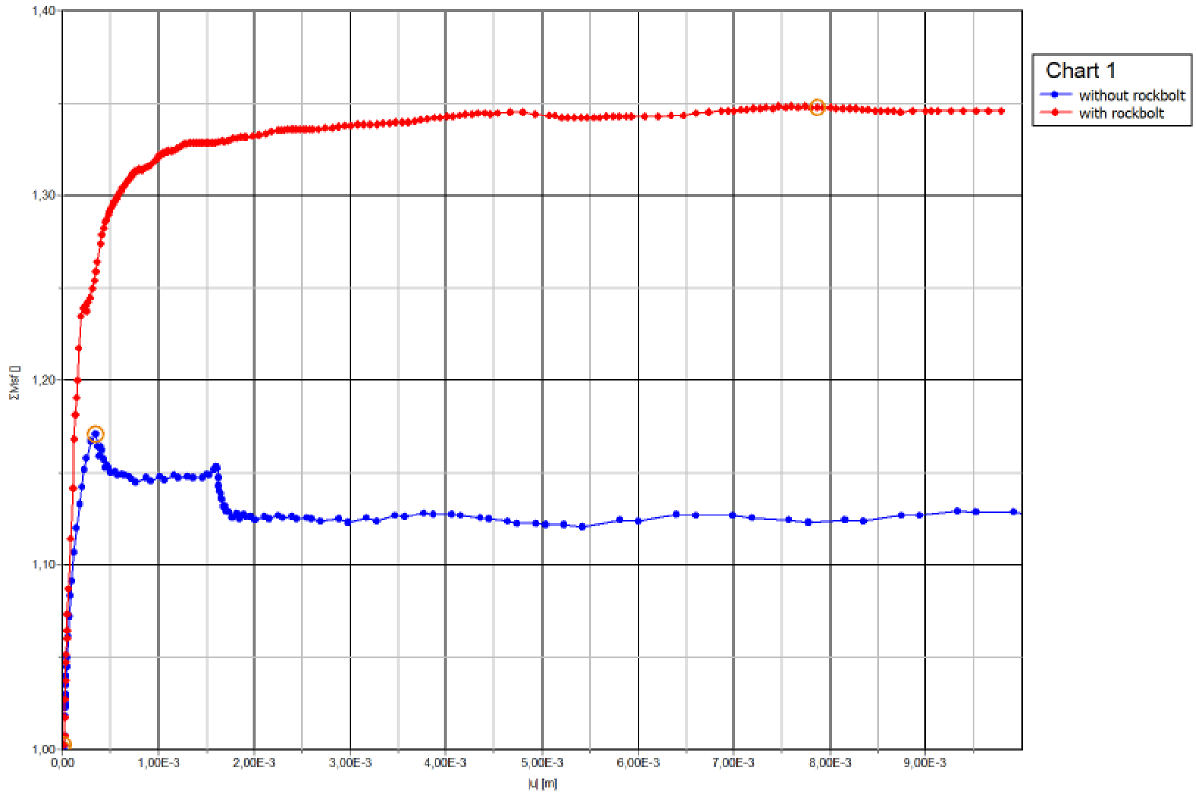
Figure 14: Incremental displacements showing failure mechanisms

In order to check the factors of safety, strength reduction curves ($\Sigma M\ sf$ vs. displacement of a control point) must be made in the Curves module.

To create the curve as shown in figure 9 follow these steps:

- Open the Curves manager ( ) and choose to start a new chart.
- Set the x-axis values to the total displacement of point (x y) = (19.0 9.0) and the y-axis values to the Project multiplier $\Sigma M\ sf$.
- Right-click on the chart and choose the option Settings.
- In the Settings window, on the tabsheet representing the curve, click the **Phases...** button and in the Select phases window that opens, deselect phase 3 (factor of safety with rockbolts) so that it will not appear in the graph. To clean up the graph a bit more, one can decided to deselect all phases that are not Safety phases as well.

- Close the Select phases window but do not close the Settings window.
- In the Settings window now select the Add curve button and then from the popup menu select From current project.
- Add a new curve, Set again the x-axis values to the total displacement of point (x y) = (19.0 9.0) and the y-axis values to the Project multiplier $\Sigma M\ sf$.
- Back in the Settings window, on the tabsheet representing the newly added curve, click again the **Phases...** button. Now deselect all phases but keep phase 3 selected.
- Close the Phases window
- Addittionally, on the Chart tabsheet of the Settings window one can set the scaling of the axes. For instance the x-axis from 0 to 2 x 10^{-3} m. Press the Apply button to confirm this.



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