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Computational Geotechnics 2

Course work 2: Widening of road embankment

Given to: Juho Mansikkamäki via Moodle

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Contents

1. Initial data

Design process

Traffic capacity of Highway VT3 (E12) in Pirkkala is being enhanced. The existing road will be widened by one new lane on the southern side of the road. Construction outputs large masses of excavated soil, which will be used in new noise barrier embankment beside the road. Excavated masses must be tested to have sufficient strength parameters in further use.

Designed constructs are based on dimensions and soil parameters in the pole 750. All new construct must stay inside the road border.

Existing road, widening and noise barrier are modelled in Plaxis 2D program in every construction stage. Stresses, settlements and slope stability are calculated in service limit state. Settlements causes declination under new lane in the road cross-section, which will be compared into permitted maximum deflection in percent's during the defined time lapse after the construction.

Settlements must be monitored in excavation and new constructs during construction because most of the displacements will occur during construction time.

There are not any existing constructs besides the road.

New lane

The existing road built in 1980's will be widened for 5,0 metres. New lane causes settlements both under the new and existing constructs. An available building time for the widening is 12 months. Light gravel will be used in widening as lightening material to decrease settlements and increase the slope stability.

Noise barrier

Noise barrier embankment is located between chainage 670 and 770. The available building area is 40 metres wide and its length is 100 metres. The purpose of embankment is to store land fill as much as possible. An available building time is 24 months.

Maximum calculated dimensions of the barrier are presented in the image below. The whole theoretical volume is approximately 6300 cubic meters of fill. This equates 500 metres of excavated soil according to the cross-section in pole 750.

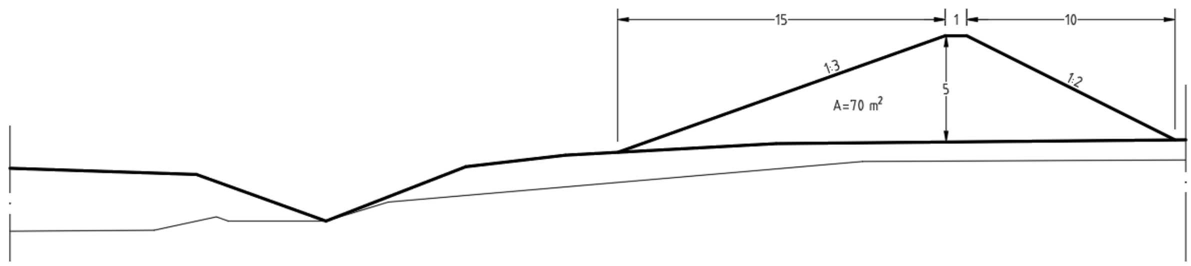


Image 1: Shape of the landfill barrier

Construction Stages

New lane and noise barrier are designed to be built simultaneously. Excavated soils will be massed straight into the barrier.

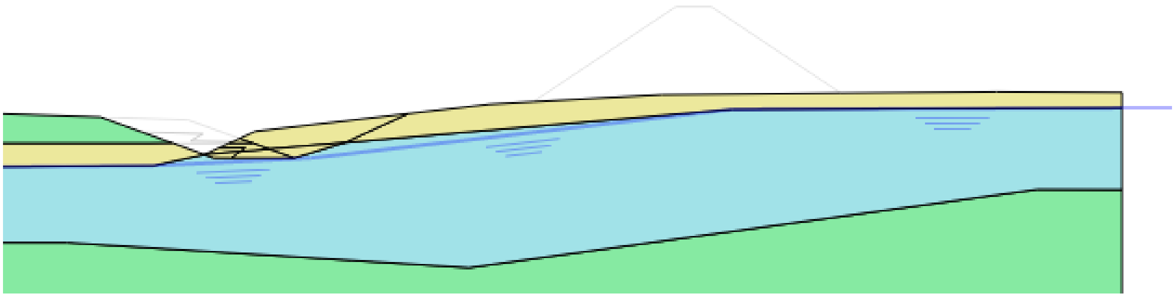


Image 2: Initial stage, existing ground level.

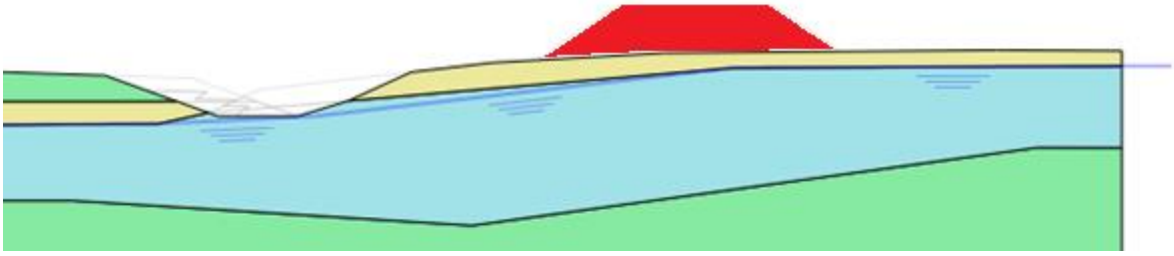


Image 3: Stage 1, soil is excavated beneath the widening, barrier is constructed only partly (50% of total height) to avoid slope failure. Shape of the barrier is only referential.

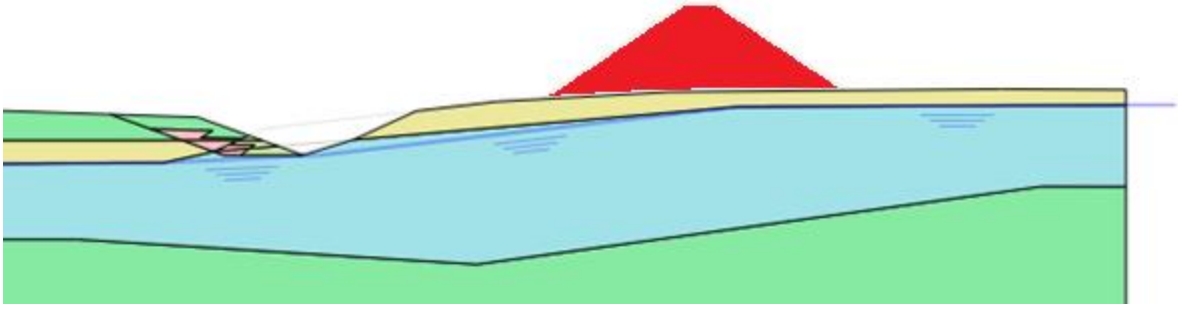
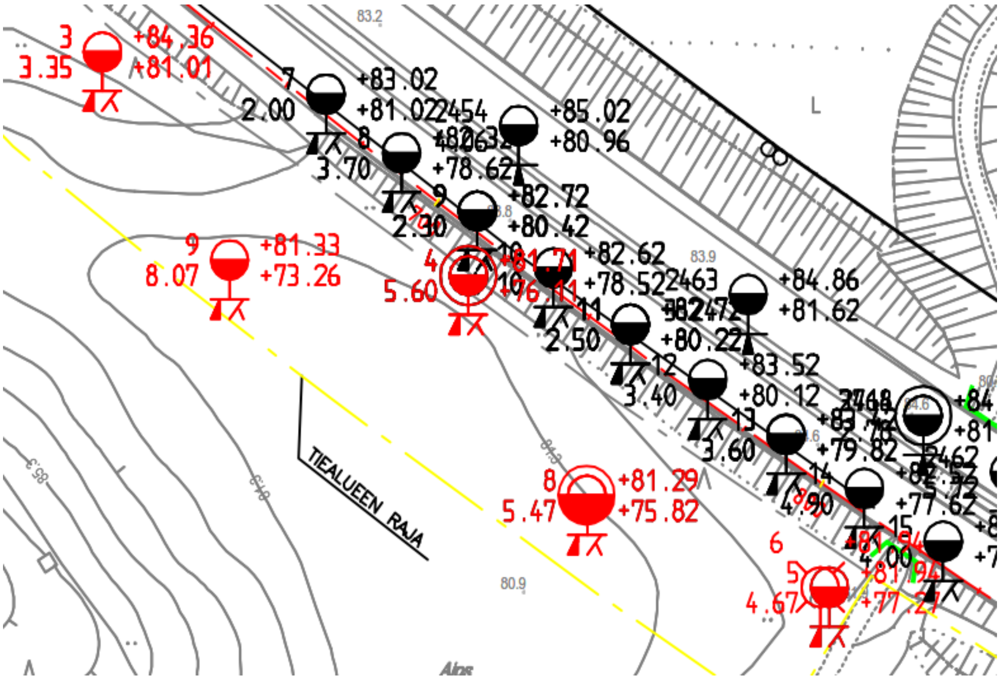


Image 4: Stage 2, widening is constructed, barrier is finished.

Excavation site and material parameters

- Old road embankment, coarse gravel 1,5 m
- Top soil is dry crust 0,5…1,0 m
- Loamy silt 5…7 m
- Bottom moraine
- Groundwater level is below the dry crust

Ground parameters are based on the (paino) soundings and oedometer and triaxial tests from soil samples at investigation point #8 at the deep of 2,40 metres.



		Dry crust	Loamy silt	Bottom moraine
Material model		Mohr-Coulomb	Soft soil	Mohr-Coulomb
γ_{unsat}	*kN/m3*	16,0		20,0
γ_{sat}	*kN/m3*	17,5		22,0
Drainage		Drained	Undrained	Drained
Void ratio				
Young's modulus	*MPa*	100		1000
Cohesion c'	*kN/m2*	0	0	0
Friction angle		28	28,5	38
Dilatancy angle		0	0	8
Flow k	*m/day*	0,121	0,248	0,600
λ			0,100	
κ			0,011	

		Road embankment	Light gravel	Fill (Barrier)
Material model		Mohr-Coulomb	Mohr-Coulomb	Hardening soil
γunsat	*kN/m3*	20	4	18
γsat	*kN/m3*	22	6	20
Drainage		Drained	Drained	Drained
Void ratio				
Young's modulus	*MPa*	1000	50	25
Cohesion c'	*kN/m2*	0	0	1
Friction angle		38	37	30
Dilatancy angle		8	7	0

Silts stiffness parameters are based on the curve of the oedometer tests and Plaxis soil test program.

Noise barrier's fill material is limited to loamy sand, silt or dry crust, when the materials friction angle is at least 30 °.

Settlements are estimated to occur quickly, because flow parameters are high in silt and coarse materials.

Design method

Stresses and settlements are calculated in service limit state.

External Loads

Equally distributed traffic load 20 kPa is used on the road embankment in stability analysis.

2. New lane - Plaxis results

Settlements

Settlement are calculated on the top of the old and new road embankment for both the normal and the lightened construct.

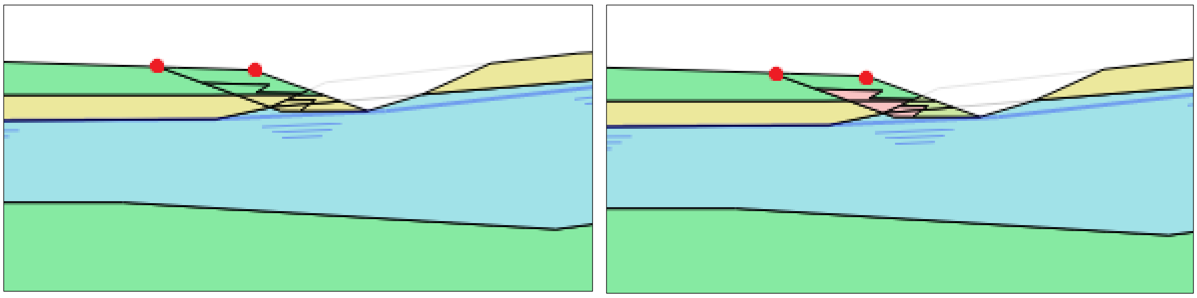


Image 5: Points to calculate settlement – old and new top of the embankment – normal and lightened structure.

The deformation for the normal embankment was only managed to calculate for the first 0,2 days after the loading. Lightened embankment was calculated for the first 30 days, which was enough to give the ultimate deformations for rather coarse silt.

Results still gave a reason to estimate the settlement of the normal embankment to be too high (2 times higher) as compared in to lightened embankment and the allowed deformations.

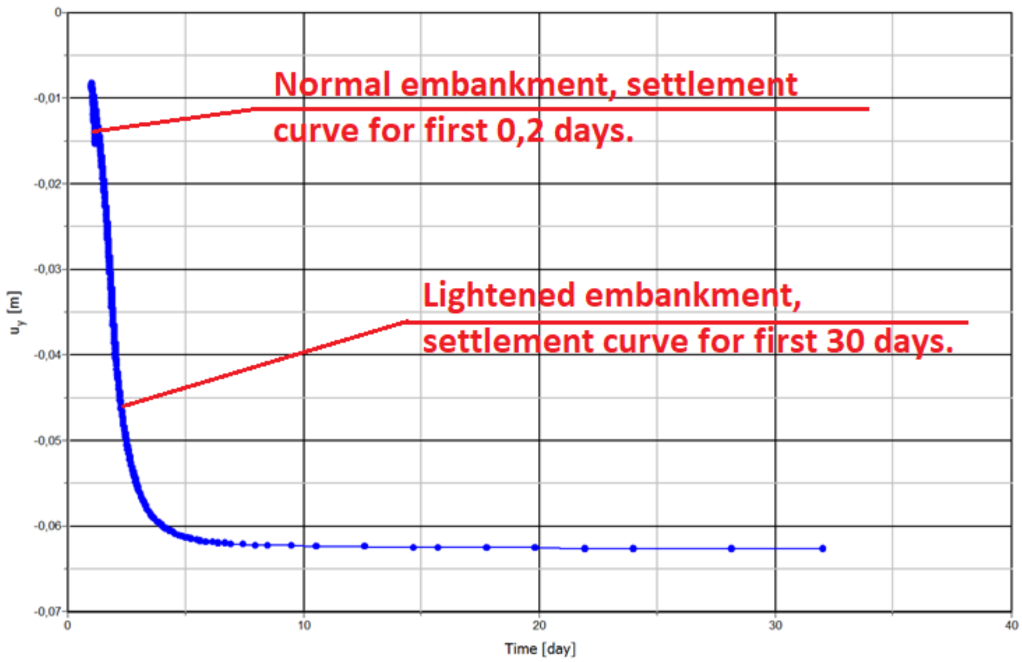


Image 6: Settlement, old top of the embankment.

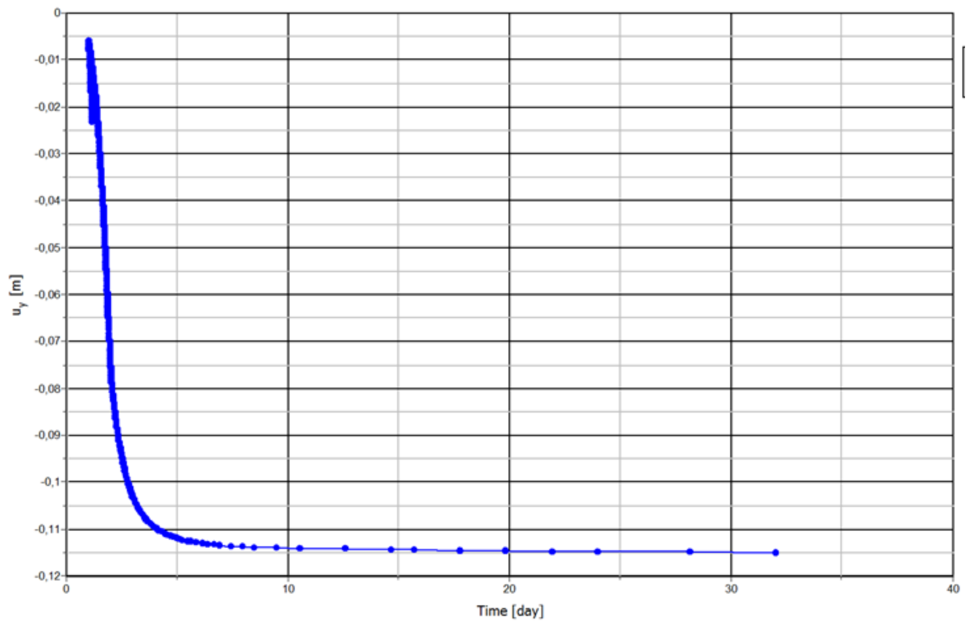


Image 7: Settlement, new top old the embankment, lightened embankment.

Settlements and the inclination of the lightened embankment are calculated below:

	Old top	New top	Δu
Settlement [mm]	63	115	52
	Widening	5	m
	Inclination	1,04	%

Tien vaatimusluokka	*Pituuskaltevuuden muutos 0…50 v (2)* *pksall 0/50≤* *[%] yksikköä*	*Kokonaispainuma 50 v aikana(1)* *Ssall50v ≤* *[mm]*	*Sivukaltevuuden muutos 50 v aikana(2)* *sksall50v ≤* *[%] yksikköä*	*Sivukaltevuuden muutos 10 v aikana(2)* *sksall10v≤* *[%] yksikköä*
V1	*0,6*	*300*	*± 1,5*	*-1,0 tai +1,0*

Image 8: Allowed deformations for highways.

Allowed inclinations for highway according to Liikennevirasto is presented in the guideline Tien geometrinen suunnittelu. Allowed inclination in the road cross-section is 1,5 percent. Deformations in silt are so quick, that most of the deformations can be re-shaped during the construction. That's why lightening is not necessary due to settlements, but slope stability failure demands still lighter embankment.

Stability

Stability has been calculated for 30 days after the construction of new widening. Equally distributed traffic load 20 kPa is set on the lightened embankment.

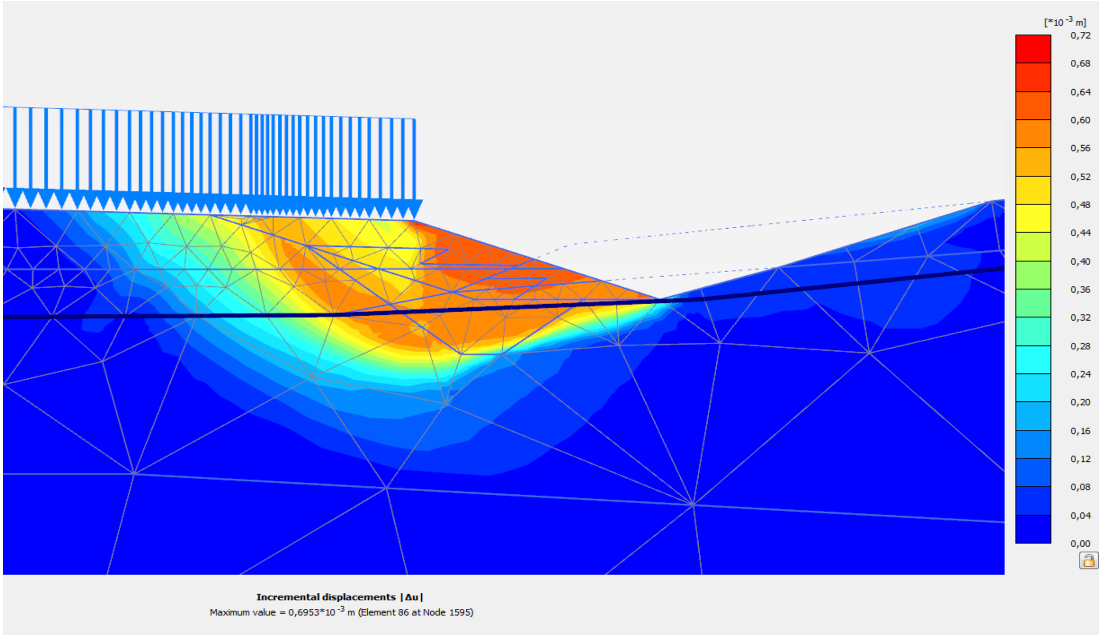


Image 9: Incremental displacements of the lightened embankment.

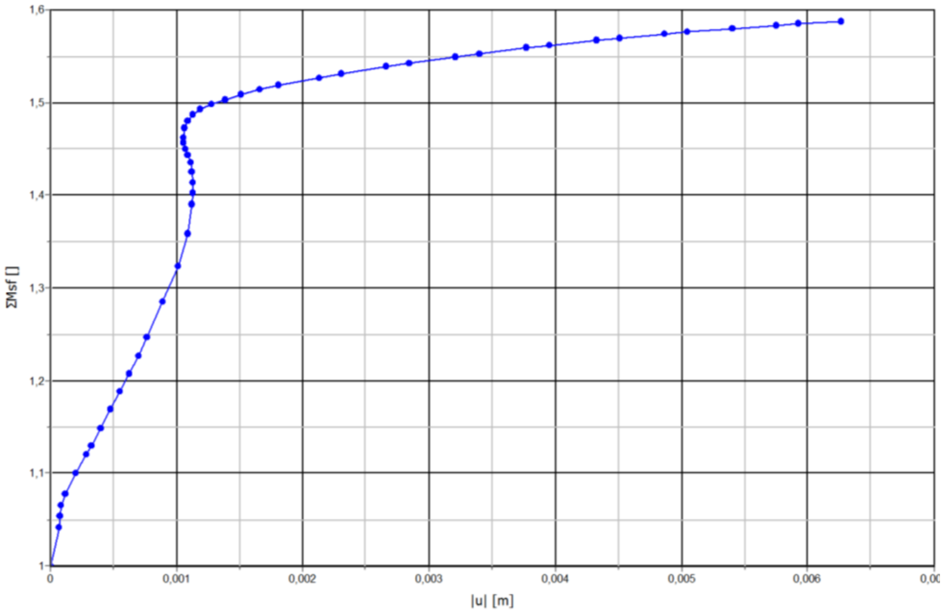


Image 10: Overall stability factor (FOS=1,6) at the toe of new slope.

3. Noise barrier - Plaxis results

Settlements

Noise barriers ultimate settlement, when all the excess pore pressure has been discharged, is calculated to be 0,27 metres. This must be noted if the barrier has requirement for the minimum height and barrier need re-shaping.

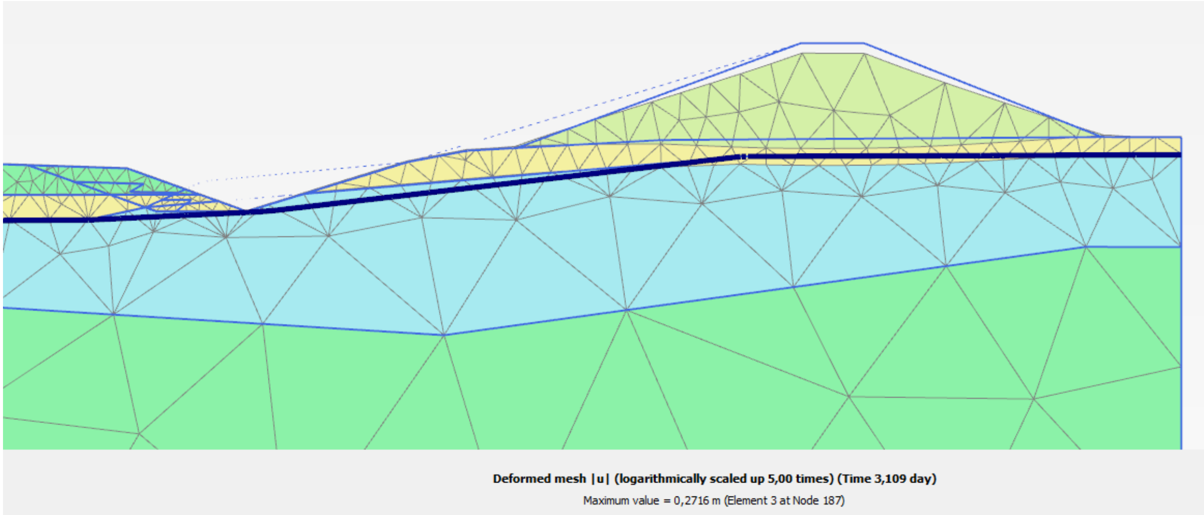


Image 11: Ultimate settlements of the noise barrier

Stability

Noise barriers stability was examined in the phase, where all the pore pressure was discharged.

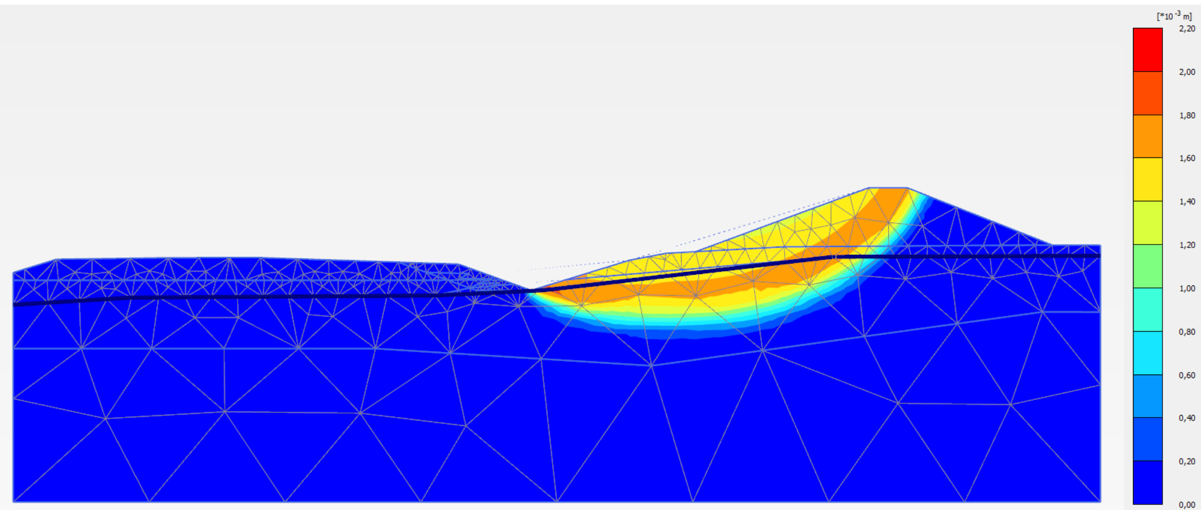


Image 12: Deformations and slope failure curves in barrier.

The critical slope failure path goes through the roads side trench. Overall stability at the bottom of the trench is calculated to be 1,5.

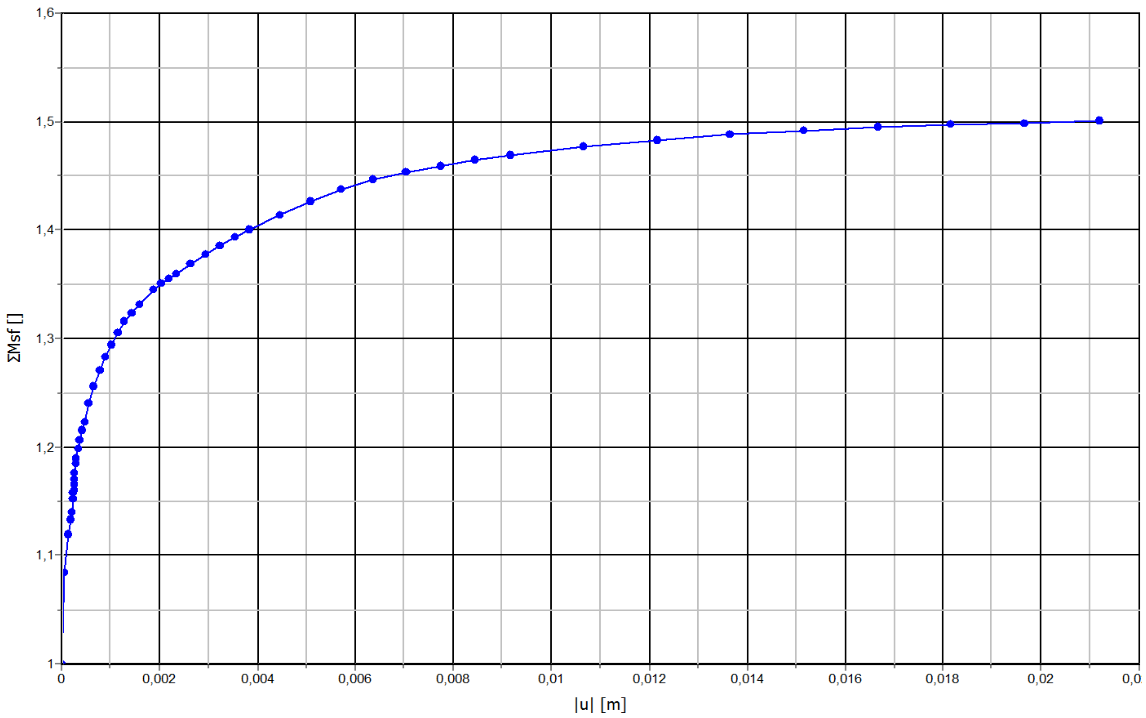


Image 13: Factor of safety for the noise barrier.

Maximum slope stability limits the height of the noise barrier. Failure curve goes through the silt layer so improving the fill material has little effect to the stability.

Noise barrier can be constructed into the height of 2,5 metres during the road excavation (stage 1). After the widening of the road it can be finished into overall height.