Elastic regions (regions with no plasticity)

Program: FEM

Files: Demo_manual_34.gmk

Introduction

Upon loading the stress developed in the soil may exceed the yield stress which causes the onset of permanent strains present in the soil body even upon unloading. Such a permanent strain is also termed the plastic strain and its evolution can be described with the help of standard constitutive models such as the Mohr-Coulomb or Drucker-Prager model or adopting more advanced models such as the Cam clay model.

As described next, we may wish to suppress the development of such strains within a certain region at a given calculation stage. This can be accomplished by exploiting the function *Elastic regions*.

When to activate *Elastic regions*

To suppress the evolution of plastic strains may appear useful when:

- Excessive plastic strains developed in a certain, typically small, region do not affect the behaviour of the analyzed structure but may cause the loss of convergence of the nonlinear numerical analysis.
- Simplifications adopted in the computational models cause the onset and evolution of unrealistic plastic strains. This may appear for example at the tow of sheeting wall or in the node which ties the anchor root.
- We wish to determine how the plastic strains influence the overall displacements and stresses by comparing the elastic-plastic analysis with a purely elastic response of the analyzed structure.

Which material models are applicable with *Elastic regions*

Function *Elastic regions* can be used with the following models.

- Mohr-Coulomb
- Modified Mohr-Coulomb
- Drucker-Prager

The behaviour of other models is not affected by activating *Elastic regions*.

Soil properties in *Elastic regions*

Elements in the Elastic region keep their properties determining the material elastic stiffness, i.e. Young's modulus, Poisson's ratio, shear modulus. However, the soil strength parameters, i.e. the cohesion and angle of internal friction, adopt such values so that the stress can never reach the yield surface and therefore no plastic strains will develop.

The enforced elastic behaviour takes effect only in the stage in which the elastic region is specified. Within this calculation stage the elements in the elastic region will experience no evolution of plastic strains thus keeping their current values.

What to be aware of when using *Elastic regions*

When using Elastic regions, we should keep in mind that in the selected elements the yield condition can never be violated. This means that the global slip surface, which may cause the overall loss of stability, cannot pass through this region.

How to define *Elastic regions*

Elastic region is specified in the selected calculation stage as a polygonal region through points inputted on the screen. All elements, which at least partially fall within this region, are highlighted.
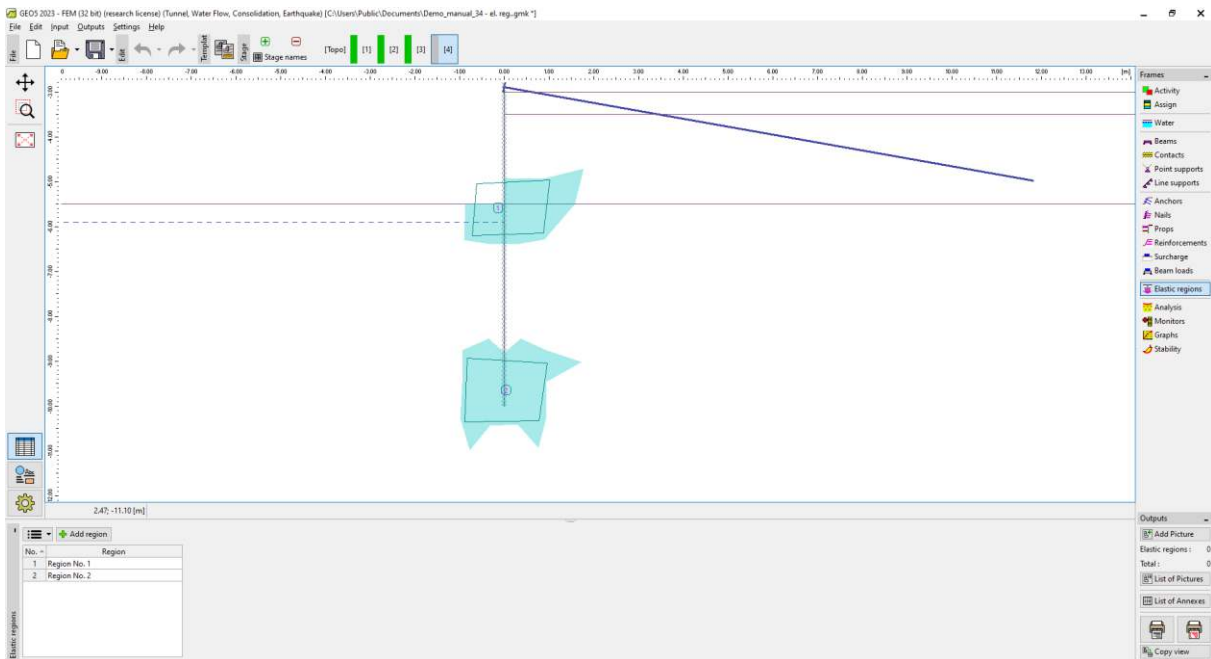
Definition of Elastic regions

Note: When defining an elastic region, it appears useful to display the finite element mesh by checking Drawing settings -> Finite element mesh -> Edges, see Figure.
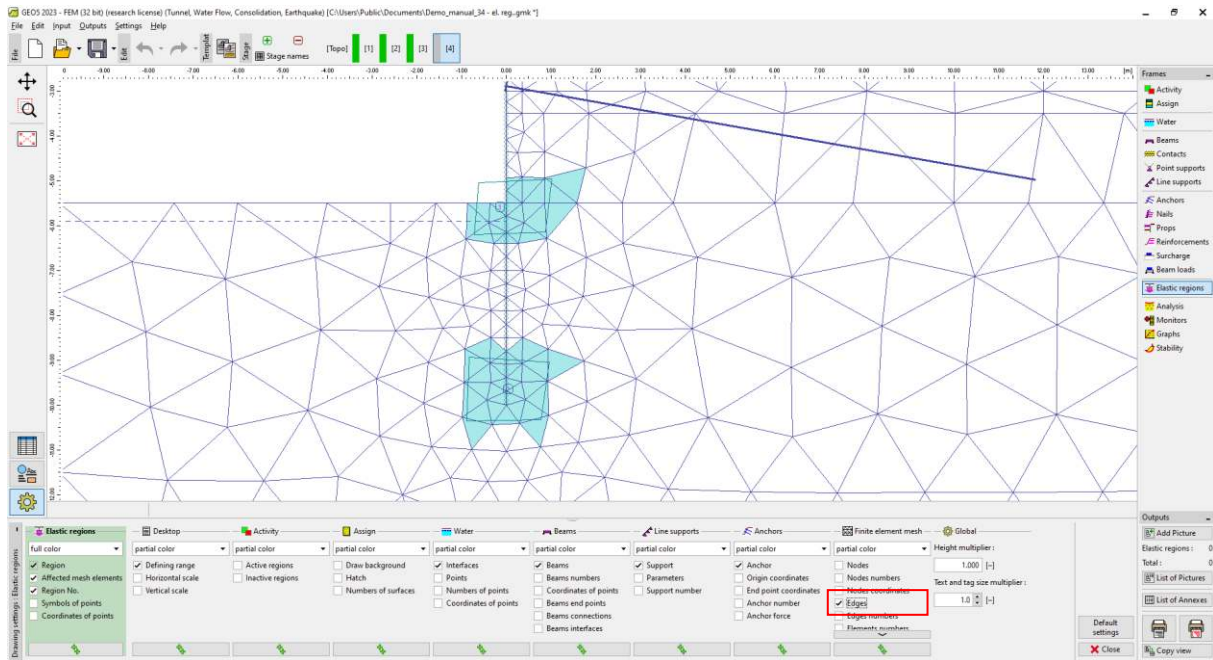
Setting finite element mesh visualization

The elastic region remains active also in subsequent stages, but it can be deactivated. Removing the elastic region in the subsequent calculation stage allows again for the evolution of plastic strains in respective elements. This means that removing an elastic region results in the stress redistribution and consequently in increase of plastic strains even if no loading is specified.

## Example of application of Elastic region

Application of elastic regions can be illustrated on the analysis of anchored sheeting wall. Geometry, soil profile and calculation stages are specified in the Demo_manual_34.gmk file. The first stage serves to determine the geostatic stress. In the second stage we introduce the beam element enhanced by interface elements and perform excavation of soil in the construction ditch by deactivating respective elements up to the level of anchors. The anchors are introduced in the third calculation stage and the excavation of the soils up to the final bottom is performed in the fourth stage.

If no action is taken the analysis in the 2nd stage is terminated at the 87.5% of the total load, which is the maximum load for which the equilibrium was achieved. Notice, however, that plastic strains evolve in a few elements only with no further redistribution, see the figure bellow.
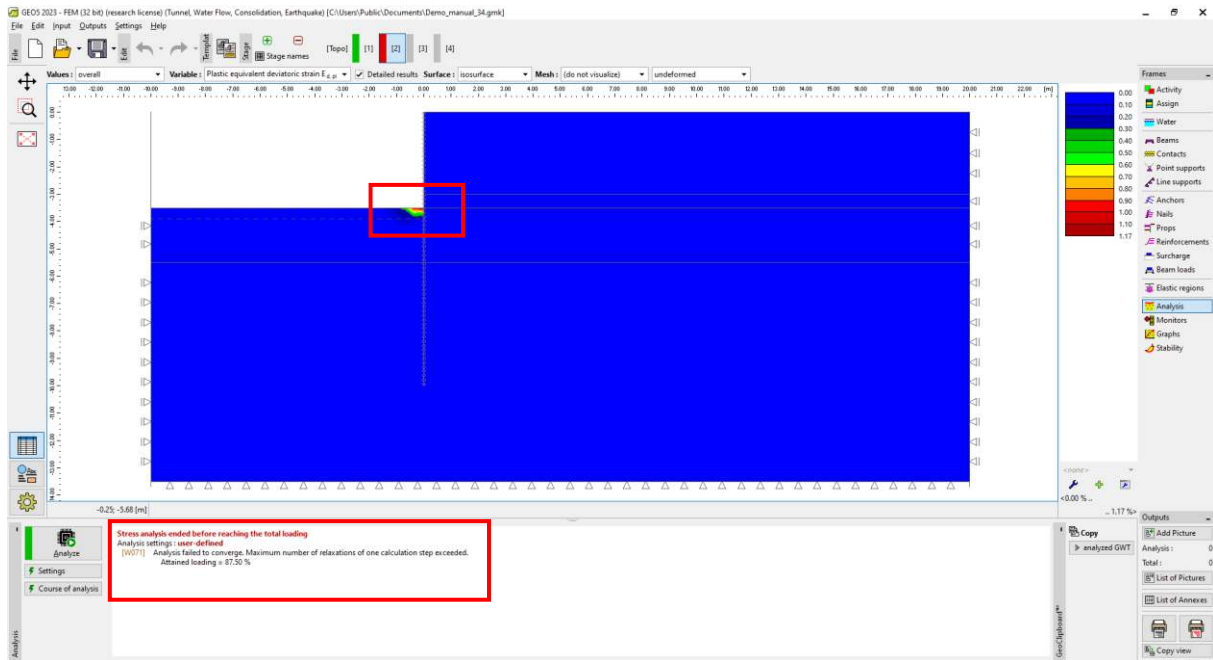
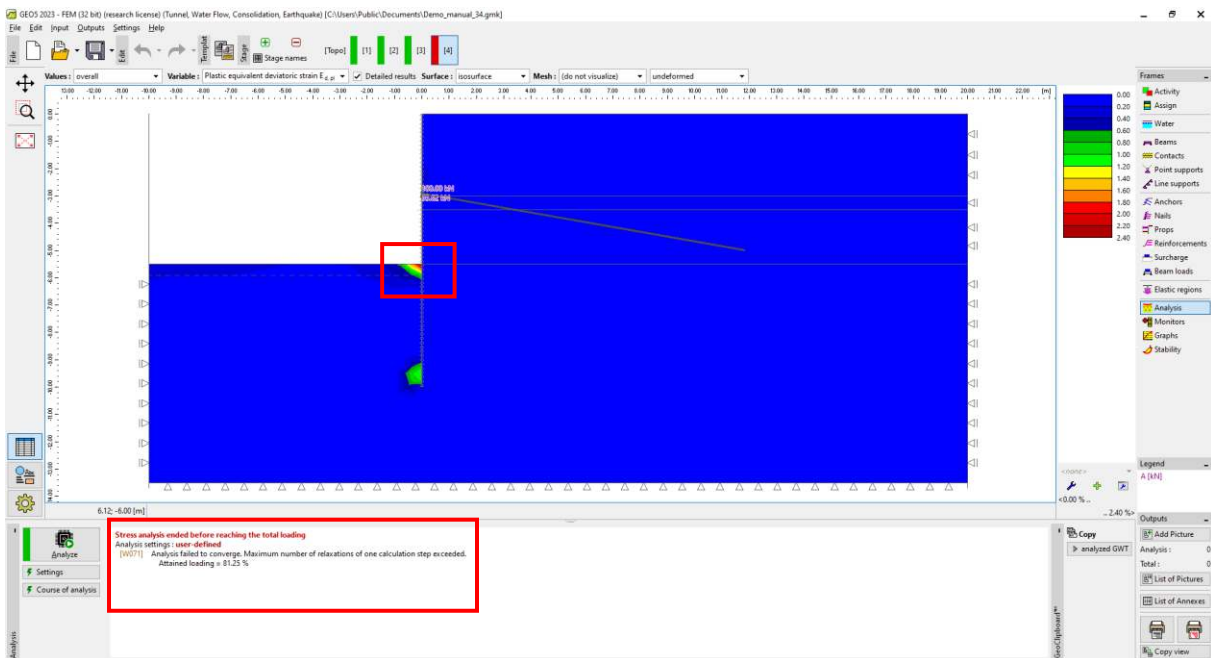*Diverging analysis in the 2nd calculation stage*

Since no evolution of global failure surface takes place in the model we may attribute this result to numerical instead of structural instability. As remedy we exploit the *Elastic regions* function. This element is specified as an elastic region and the analysis is run again. In this case, we were able to accommodate the entire load, which was accompanied by the redistribution of plastic strains into neighbouring elements, see Figure.
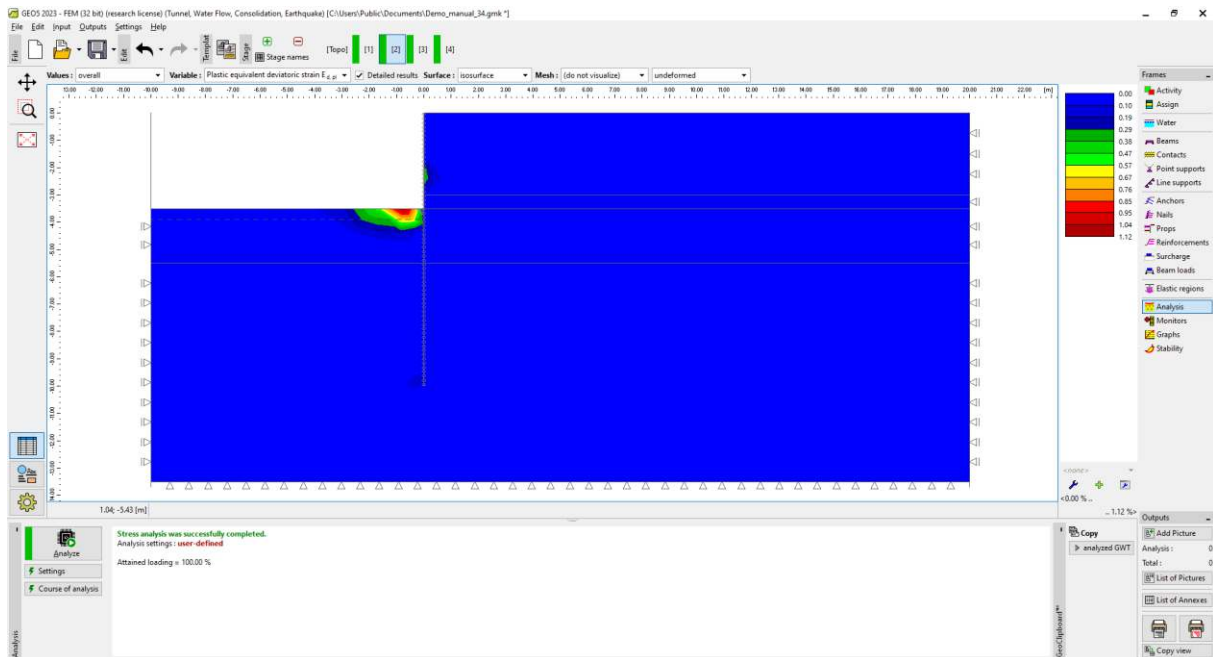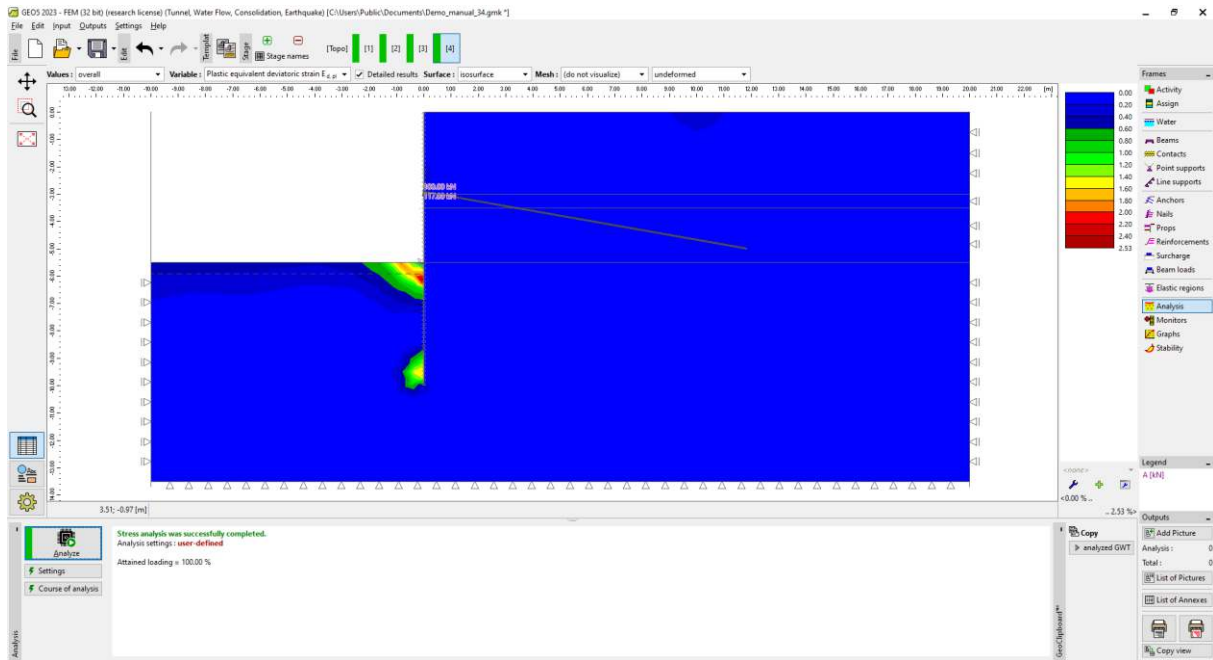

Reaching equilibrium using elastic region containing a single element

![GEO5 logo]

Note: The problematic element is loaded in a horizontal direction (it carries a horizontal reaction of the sheeting wall caused by active pressure in the soil on the right behind the wall). On the other hand, in the vertical direction this element is unloaded. A significant difference between the vertical and horizontal stress causes a significant increase of the deviatoric stress and consequently the onset of equivalent plastic strains.

In the third calculation stage the result is similar – equilibrium for the total load is not achieved because of plastic strains localized into a single element at the bottom of the ditch. This can be avoided again by including this element into an elastic region.

Equilibrium for the total load not reached in the 4th calculation stage – no redistribution of plastic strains takes place, analysis is diverging

Achieving equilibrium in the 4th calculation stage with the help of elastic region

Conclusion

The function *Elastic regions* allows for enforcing an elastic behaviour of soil in the selected elements and as such to suppress evolution of plastic strains in these elements. This ad-hoc approach provides solution in cases when equilibrium cannot be achieved for the specified load. However, this strategy can only be used if the loss of convergence or the occurrence of oscillations is linked to numerical reasons, i.e. the localized plastic strains do not suggest the global loss of structural stability.