Analysis of a consolidation under embankment

Program: Settlement

File: Demo_manual_11.gpo

In this engineering manual, we are going to explain how to analyze a consolidation under a constructed embankment.

Introduction

Soil consolidation considers the settlement time (calculation of earth deformation) under the effect of external (constant or variable) loads. The surcharge leads to an increase in the earth's formation stress and the gradual extrusion of water from pores, i.e., soil consolidation.

Primary consolidation corresponds to a situation in which there is a complete dissipation of pore pressures in the soil; secondary consolidation affects the rheological processes in the soil skeleton (the so-called "creep effect"). This is a time-dependent process influenced by many factors (e.g., soil permeability and compressibility, length of the drainage paths, etc.). With regards to the degree of the consolidation, we distinguish the following cases of ground settlement:

- final settlement corresponding to a 100% consolidation from the respective surcharge

- partial settlement corresponding to a given degree of consolidation from the respective surcharge

In order to calculate settlement time, it is necessary to specify the coefficient of permeability " k " or the coefficient of consolidation," C_v ", which determines the speed of consolidation. This parameter can be obtained on the basis of oedometer tests (according to Casagrande or Taylor).

Assignment

Determine the settlement value under the center of an embankment constructed on impermeable clay one year and ten years after its construction. Perform the analysis using CSN 73 1001 standards (using oedometric modulus), consider the limit of the influence zone using the coefficient of the structure strength.
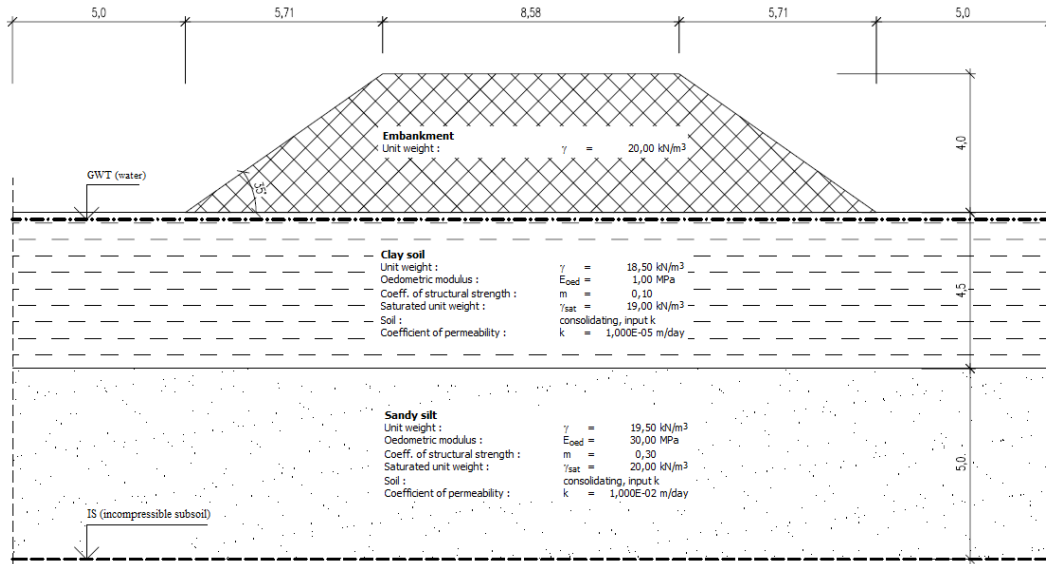

Scheme of the assignment – consolidation

Solution

We will use the GEO 5 Settlement program to solve this task. We are going to model this example step by step:

- 1st construction stage – interface modeling, calculation of the initial geostatic stress,

- 2nd construction stage – adding a surcharge by means of an embankment,

- 3rd up to 5th construction stages – calculation of an embankment consolidation at various time intervals (according to the assignment),

- Evaluation of the results (conclusion).

Stage 1

First of all, check the "Perform consolidation analysis" checkbox in the bottom right corner of the "Settings" frame. Then click on "Select settings" and choose setting No. 8 "Czech republic – old standards CSN". This setting describes the analysis method for the calculation of the settlement and the restriction of the influence zone.
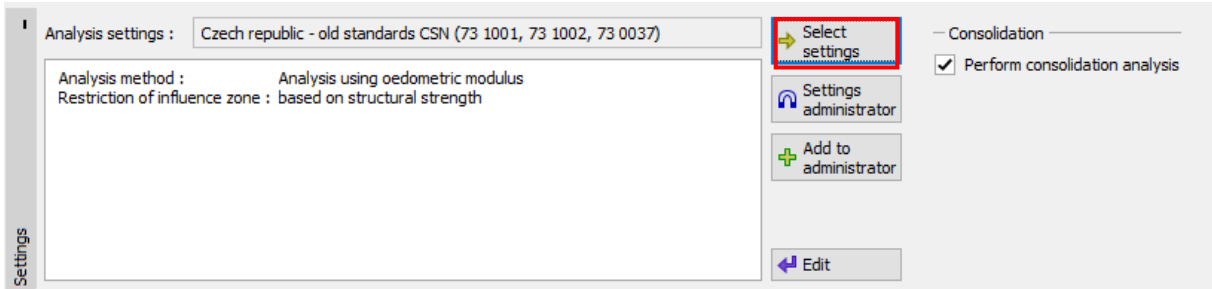
"Settings" Frame

Note: This calculation considers the so-called primary consolidation (dissipation of pore pressure). Secondary settlement (creep), which may occur mainly with non-consolidated and organic soils, is not considered in this example.

Then we input the layer interface in the "Interface" frame. It is necessary to enter two layers. Consolidation is performed between these two layers. Firstly, we define the task dimensions using the "Setup ranges" button.
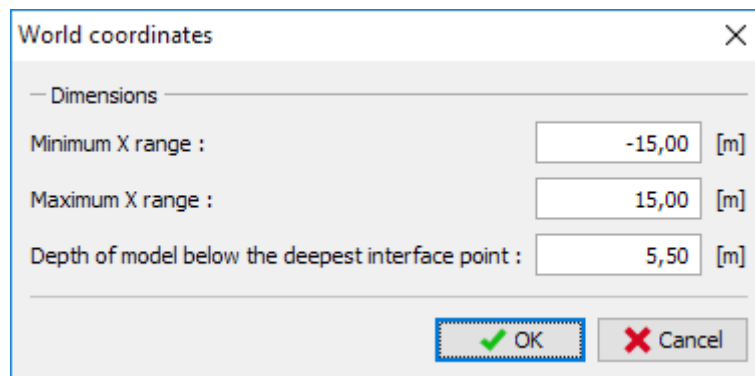
Task dimensions

Then we define an interface between soil layers at a depth of 4,5 m using the "Add interface" button and adding its points textually.

Adding interface 1

Adding interface 2

Note: If there is a homogenous soil, then to calculate the consolidation, it is necessary to enter a fictitious layer (using the same parameters for the two soil layers that are separated by the original interface), preferably at the depth of the deformation zone.

Then we'll move to the "Incompressible subsoil" frame, where we'll input a new incompressible subsoil at a depth of 10 m using the "input incompressible subsoil" button and adding the subsoil points in a similar way that interface points are inputted . No settlement takes place under the incompressible subsoil.


"Incompressible subsoil" Frame

In the next step, open the "Soils" frame, where soil parameters are entered. For soils, which are consolidated, it is required to specify either the coefficient of permeability "k" or the coefficient of consolidation "c_v". Approximate values can be found in the program help (F1).

Table with the soil parameters

| Soil (Soil classification)	Unit weight $\gamma \left[kN/m^3\right]$	Poisson´s ratio $v\left[-\right]$	Oedometric modulus $E_{oed}\left[MPa\right]$	Coeff. of structural strength $m\left[-\right]$	Saturated unit weight $\gamma \left[kN/m^3\right]$	Coeff. of permeability $k\left[m/day\right]$
Clayey soil	18,5	0,35	1,0	0,1	19,0	$1{,}0 \cdot 10^{-5}$
Embankment	20,0	0,3	30,0	0,3	20,0	$1{,}0 \cdot 10^{-2}$
Sandy silt	19,5	0,3	30,0	0,3	20,0	$1{,}0 \cdot 10^{-2}$

Then move to the "Assignment" frame, where we assign the soils to the profile as follows:
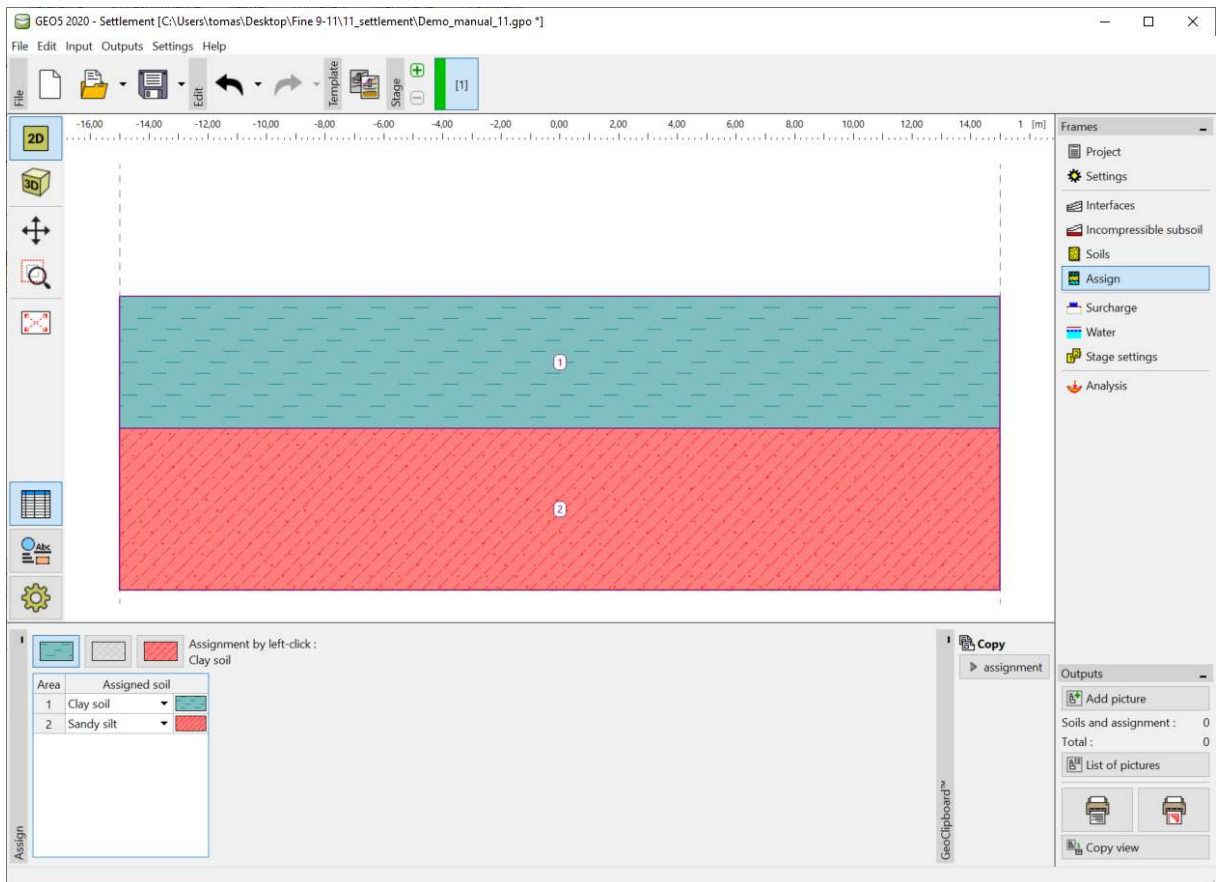

"Assignment" Frame

The "Surcharge" frame is not taken into consideration in the 1st construction stage since in this example, it will be represented by the actual embankment body (in stages 2 to 5).

In the next step, open the "Water" frame, where we enter the groundwater table (hereinafter the "GWT") by adding the interface points textually, in our case, at the ground level.
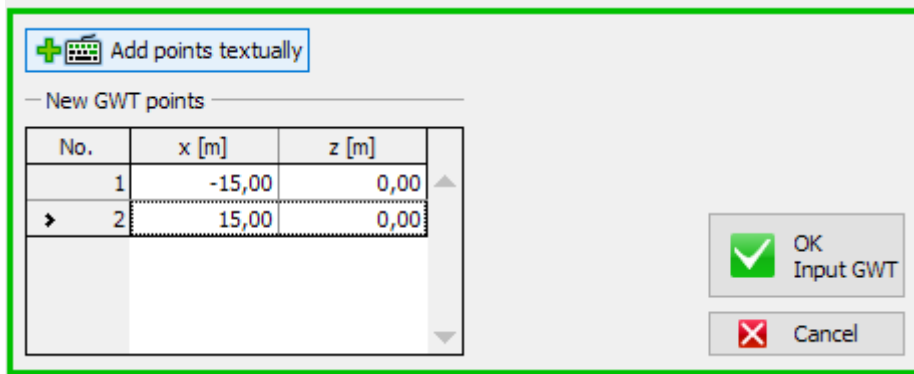

GWT input

In the "Stage settings" frame, you can only modify the layout and the refinement of the holes. In this case, we will leave the standard settings on.
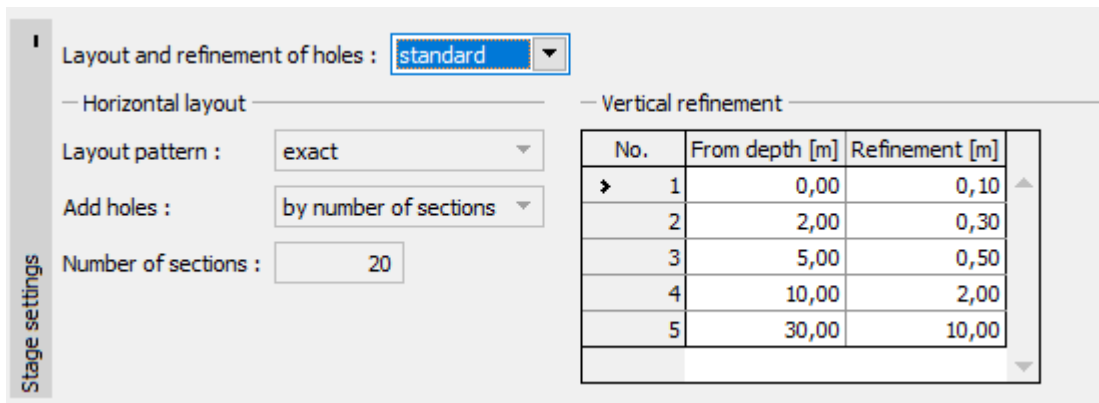
"Stage settings" Frame

The first stage represents the geostatic stress at the initial construction time. However, it is necessary to specify the basic boundary conditions for the consolidation calculation in further stages. Input the top and bottom interface of the consolidating soil as well as the direction of the water flow from this layer – i.e. the drainage path.
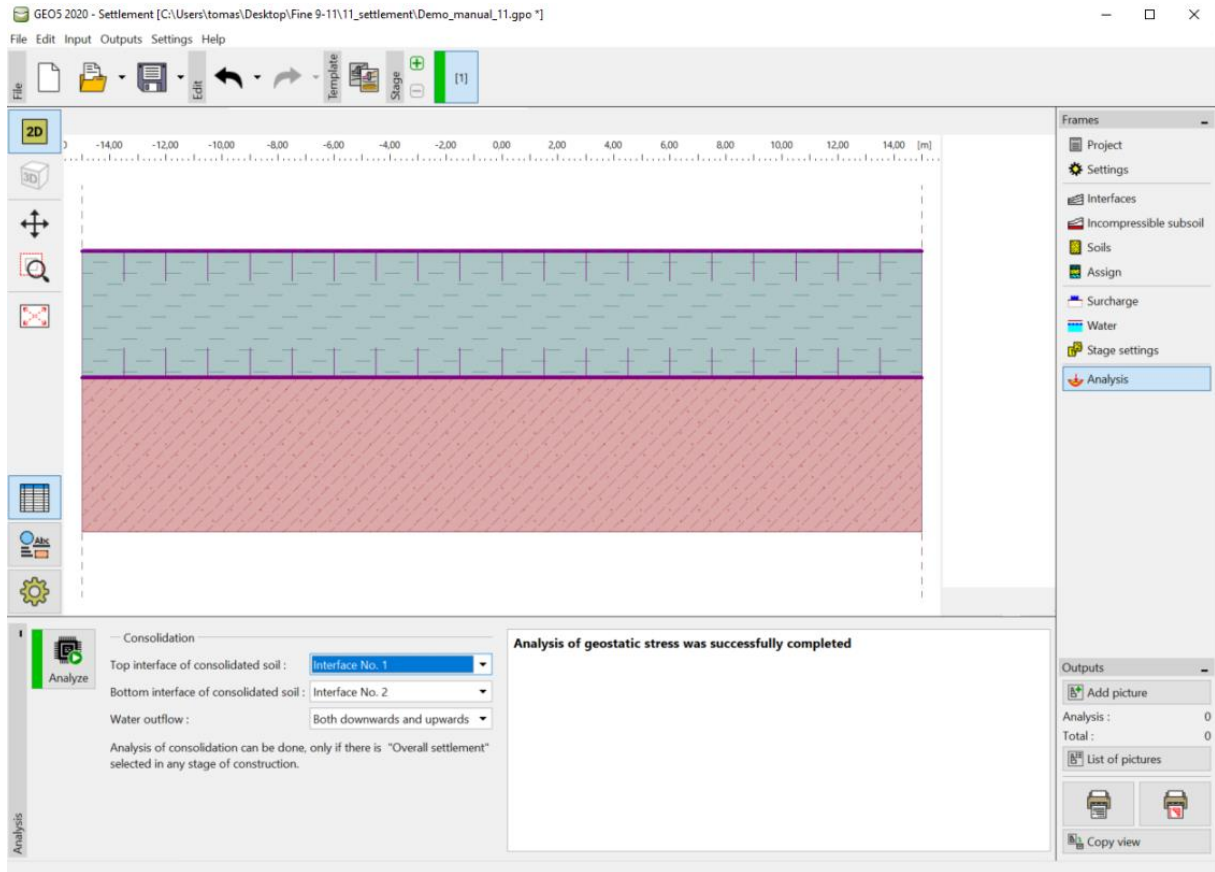
"Analysis" settings – Construction stage 1

Stages 2 to 5

Let's now add the 2nd construction stage using the toolbar at the top of the screen.
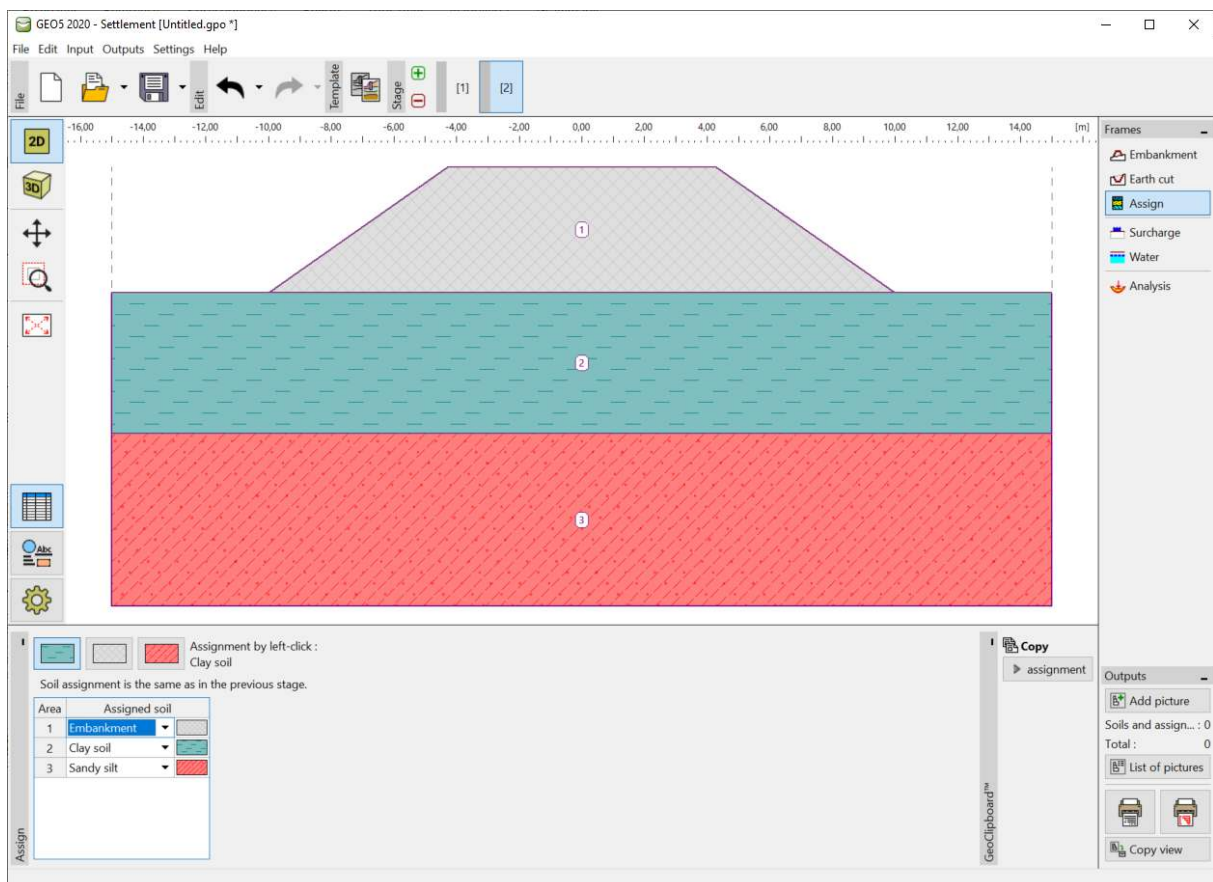

"Construction stage" Toolbar

In the second stage, we will define the embankment by entering the coordinates of its points in the "Embankment" frame:

- Point No. 1: $x = -10,0\,\text{m}$ $z = 0,0\,\text{m}$

- Point No. 2: $x = -4,29\,\text{m}$ $z = 4,0\,\text{m}$

- Point No. 3: $x = 4,29\,\text{m}$ $z = 4,0\,\text{m}$

- Point No. 4: $x = 10,0\,\text{m}$ $z = 0,0\,\text{m}$

Then move on to the "Assign" frame, where the "Embankment" soil type is assigned to the embankment.


"Stage 2 – Embankment + Assignment"

Note: The embankment acts as a surcharge to the original ground surface. It is assumed that a well-executed (optimally compacted) embankment theoretically does not settle. In practice, some settlement may occur (poor compaction, soil creep effect), but the Settlement program does not address this.

In the "Analysis" frame, enter the time duration of the **2nd stage** (30 days) corresponding to the actual embankment construction time. The actual calculation of the settlement cannot be performed

yet, because when determining consolidation, it is necessary to know the whole history of the earthwork structure loading first, i.e., all the construction stages. Since the embankment is built gradually, we are considering **linear load growth** in the 2nd construction stage.
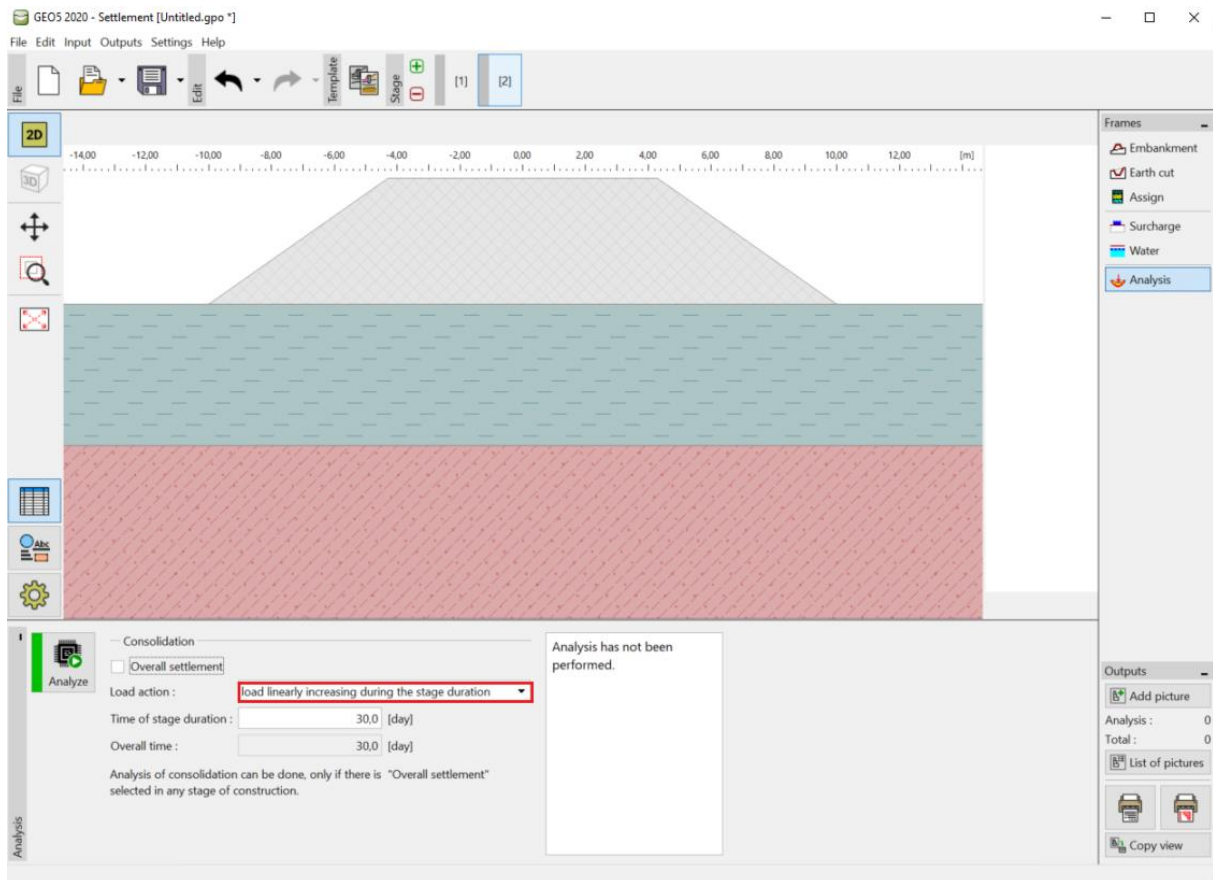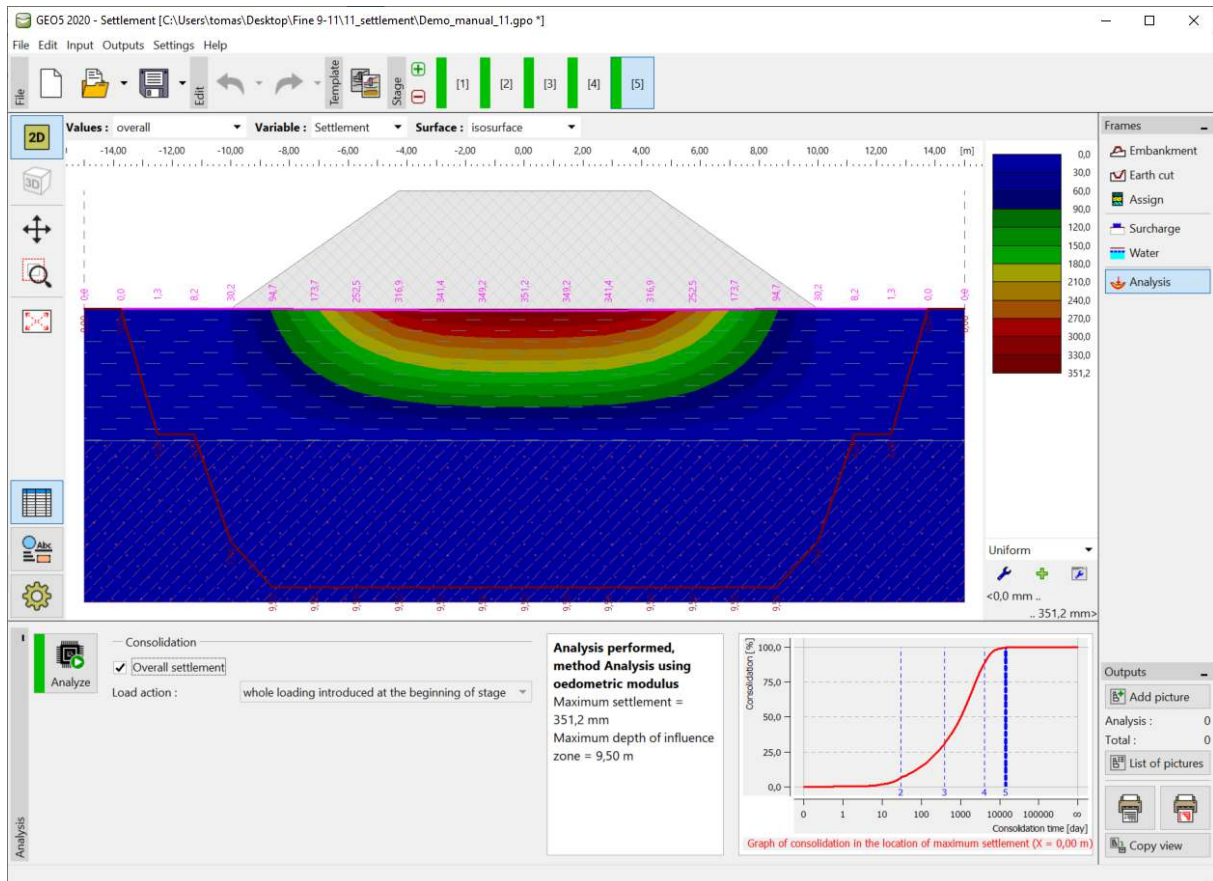

"Analysis Frame – Construction Stage 2"

Add 3 more stages. In the subsequent stages, enter the duration of each stage:

- **3rd stage -** 1 year, i.e. 365 days

- **4th stage** - 10 years, i.e. 3,650 days

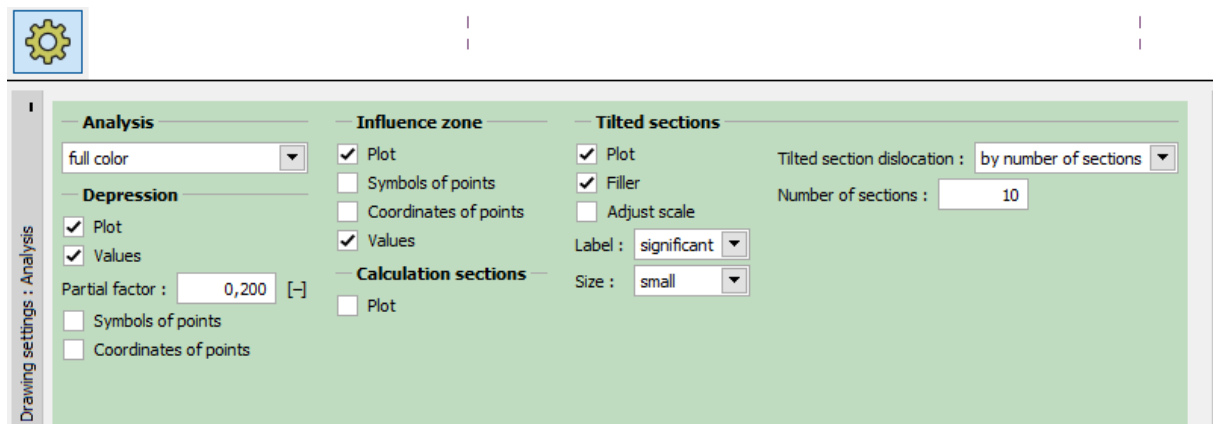- **5th stage** - the overall settlement

The load action is not important in this case (there is no new surcharge added in subsequent stages), so we leave the load action setting as "Whole loading introduced at the beginning of stage".

Perform the analysis in the last 5th construction stage, where the "Overall settlement" option is turned on (the option can be turned on in any construction stage apart from the first one).

"Analysis" Frame – Construction Stage 5"

The variables shown on the screen are selected in the upper toolbar. Special drawing options (e. g. depression, influence zone, and titled sections) can be defined in the drawing settings – using the button with the toothed wheel on the left edge of the desktop.


Drawing settings

Analysis results

Upon the calculation of the overall settlement, we can see the partial consolidation values below the center of the embankment. We have obtained the following maximum settlement values in individual construction stages:

- Stage 1: only geostatic stress – settlement is not calculated.

- Stage 2 (surcharge by the embankment): for 30 days → 29,2 mm

- Stage 3 (unchanged): for 365 days → 113,7 mm

- Stage 4 (unchanged): for 3,650 days → 311,7 mm

- Stage 5: the overall settlement → 351,2 mm

As we are interested in the embankment settlement after its construction, we will switch the results view in the 3rd and 4th stages (the "Values" button) to "compared to stage 2, which subtracts the respective settlement value.
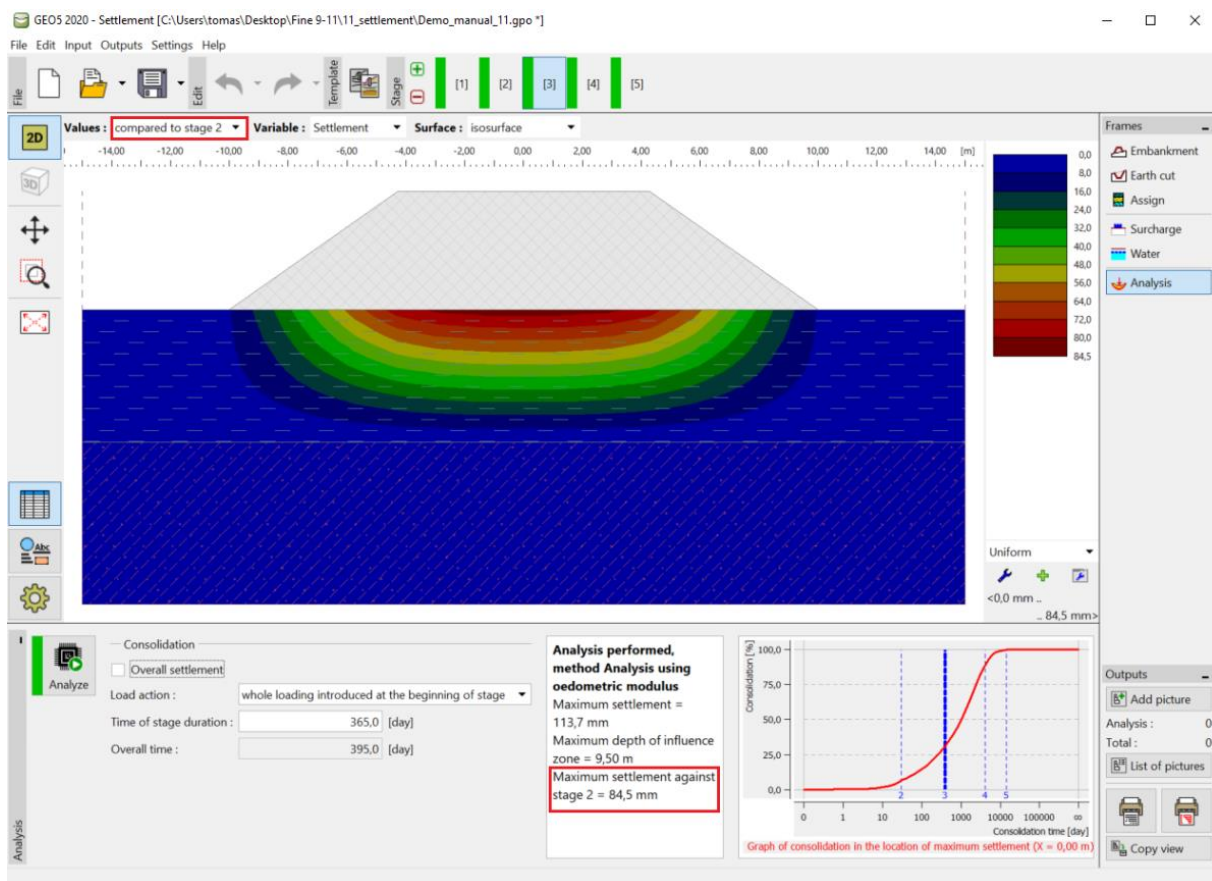
"Analysis" Frame – Settlement (differences compared to previous stages)

Conclusion:

The embankment settlement (under its center) within one year from its construction is 84,5 mm (= 113,7 – 29,2) and after ten years it is 282,5 mm (= 311,7 – 29,2).