

Week #11 - excavation of a trench **Solution**

Note: Some clarifications, details and important points to retain from the exercise are added below directly at every question. As a mark-up for you to recognize them as such, those are written in blue (same as this note).

We will model in Optum G2 the step-wise excavation of a trench with a diaphragm wall as support. We sketch the configuration in figure 1 with its different excavation phases.

1 Mesh and initial stresses

We will let you create the mesh for the problem given in figure 1. In order to compare side by side different constitutive model, create a single mesh with 1000 elements, and with the following features: i) a mesh fan at the bottom of the diaphragm wall, 2) enforce a mesh size of 0.1 along the lowest part of the diaphragm wall. In what follows, always use the 6-nodes element in the analysis.

The constitutive relation for the soil will change throughout the exercise. Note that for this, you need to use different type materials for every stage (recommended). The initial water table is given in figure 1 but will eventually change following the excavation.

We actually have different files for the various materials and the combination. Which is not strictly necessary, and you can use it as you want. The mesh creation is the same and performed in a separate stage.

Soil properties Use the default elastic and weight properties for the Mohr-Coulomb (MC) and Modified Cam-Clay (MCC). Use the following strength properties for the MC and MCC:

$$c = 5\text{kPa} \quad \phi = 25^\circ$$

Also use the following for the initial earth coefficient and over-consolidation ratio:

$$K_o = 0.5 \quad OCR = 1$$

2 Excavation analysis: Comparing Mohr-Coulomb and Cam-Clay

Perform the following steps once with Soil 1 = Soil 2 = MC and once with the Soil 1 = Soil 2 = MCC. In a first stage calculate the initial stresses. Use this as the input for the analysis of the excavation of phase 1. The following excavation steps will always take the previous step as initial condition. For step 2 simply excavate half of the phase 2 and 3 soil and perform the same for step 3. Stages 4 and 5 are similar to 2 and 3 but incorporate a simultaneous lowering of the water table. You should finish with having an initial and 5 excavation stages.

2.1 Mohr-Coulomb

You see using the file “MC_excavation.g2x” that we start by introducing a stage to create the mesh. We then use the mesh as an initial condition to calculate initial stresses. The only interesting thing for you to see on the mesh is the imposed mesh fan and the mesh size in the lowest part. You should have the same if you followed the instructions of section 1. Observation of the initial stresses gives you a hydro- respectively lithostatic profile as expected. We then start with the first excavation phase where we prescribe the initial

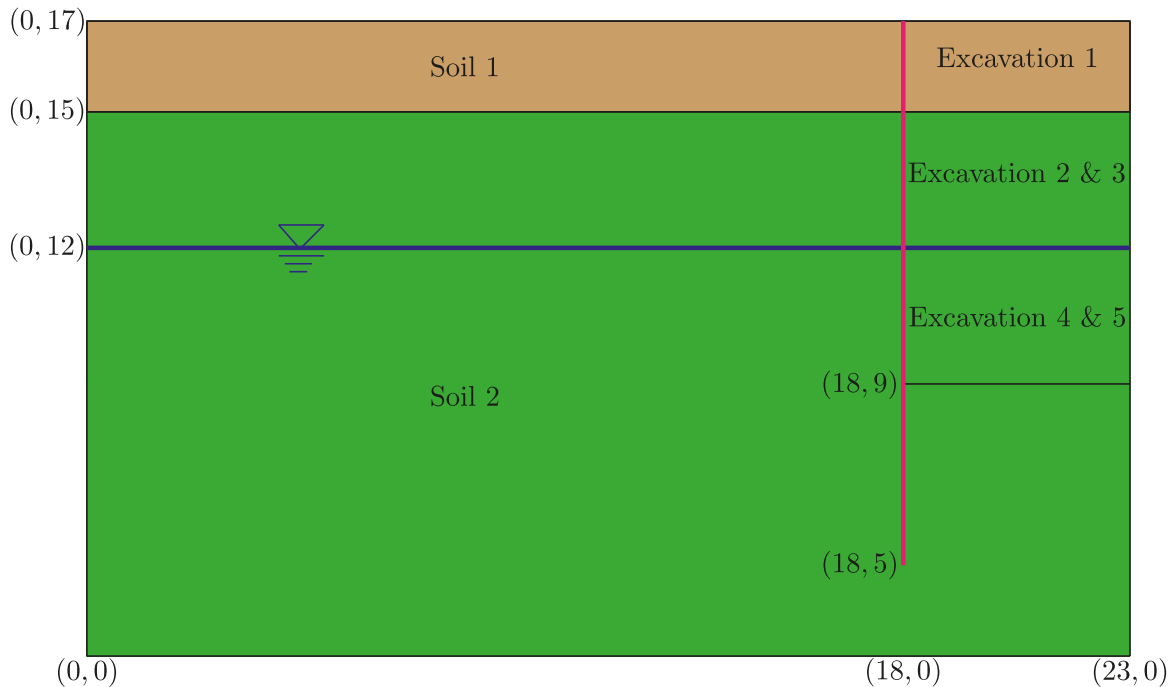


Figure 1: Geometry of the excavation. The affiliations of the two soils will change throughout the exercise. The blue line is the initial water table, the red line corresponds to a diaphragm wall (in Optum modeled with plates where the plus needs to be on the side of the active soil).

stresses as base state. We have done the same thing without prescribing the initial stresses. Observe the difference! In the case of a excavation, we need to prescribe the stresses on the geometry before the excavation. If we do not do this, the geometry of the stage will be used to calculate initial stresses!

We then split phases two and three into two sub-steps of the same height (so half the excavation). You can see that the displacements increase step by step and that the forces in the structure do as well. The resulting displacements of the structure, in the end, are of the order of 1cm and the retaining wall remains stable.

To get a feeling of the importance of the staging, we did an example where the excavation uses initial stresses but directly goes to the final stage (Stage “*Exc Direct*”). You might be surprised, that the maximum displacements are not that different. But look at the forces inside the structure... they are not only different in magnitude but also in the distribution. You could thus economize at the wrong places and your structure could fail. Or on the other hand, you strengthen too much and are too expensive so your company will not get the job...

2.2 Modified Cam-Clay

You can see that for this material parameters the diaphragm wall will fail when advancing the last excavation step. Note that it is a plastic rupture of the soil associated with large displacements whereas the diaphragm still behaves as a rigid body. You can prevent this and achieve reasonable deformations when putting a strut (fixed end anchor in Optum) at the point (18,15) from excavation step 2 on.

We have put the file with the failing structure as “*MC_excavation_noSupport.g2x*” also into the folder. Finally, you see that Optum directly tells you that it does not work. However, you could already anticipate it from the fact that your displacements after stage 4 are already over 11cm.

Using the support we perform again the same calculations and get a total displacement of about 5cm. We perform again an analysis with the same initial conditions but jump directly to the final stage. We will let you investigate the differences on your own this time.

3 Consolidation analysis

For the MCC material we want to get the long term settlements of the excavation. These can be obtained from optum by using a consolidation analysis. Perform this analysis with a target time of 200 days by performing 30 steps.

As you know for these materials the consolidation can be very important. It is thus up to you to know, how such displacements will affect your construction stages. In the current simulation, you observe that the uplift is very important (around 85cm at the center) you thus need to think about how you can stabilize this uplift. One example is to construct the slab such that you have a pressure controlling the uplift. Something that could happen however in this case is that the differential settlements/uplifts will fracture your slab. You thus need to consider this stage carefully.

For the direct calculation, the consolidation in the last stage does not converge and the results can thus not be trusted.

4 Combined soils

For the combined soils the observations remain the same. We will let you investigate the corresponding file "*Mixed_excavation.g2x*" on your own.