GeoStudio Example File
Tie-back Wall

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Introduction

This example simulates the sequential construction of a sheet-pile shoring wall tied back with pre-stressed anchors. The purpose is to demonstrate the steps involved in modeling a soil-structure interaction problem like this.

Numerical Simulation

Figure 1 presents the problem configuration. The height of the wall is 9 m with anchors at the 1/3 points on the wall.

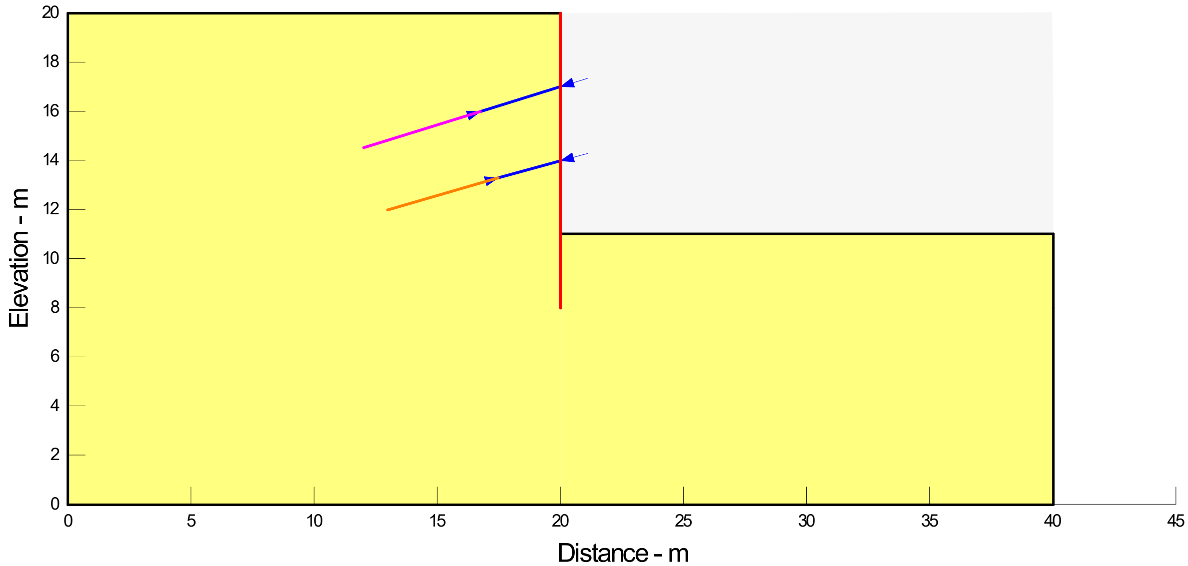

Figure 1. Problem configuration.

The construction sequence is as follows:

- Establish the initial *in situ* stress conditions;
- Install sheet-pile wall; in numerical modeling terminology, this is often referred to as "wishing the wall in place" which means the wall just appears at a certain stage in the analysis;
- Excavate the upper 4 m;
- Install the upper anchor and then pre-stress to 100 kN;
- Excavate another 3 m;
- Install the lower anchor and then pre-stress to 100 kN; and
- Excavate the last 2 m.

The SIGMA/W analysis tree is shown in Figure 2. There are six different finite element analyses, where each analysis, except the first one, gets its initial conditions from the previous analysis. In SIGMA/W terminology, each analysis gets its initial conditions from its "Parent".

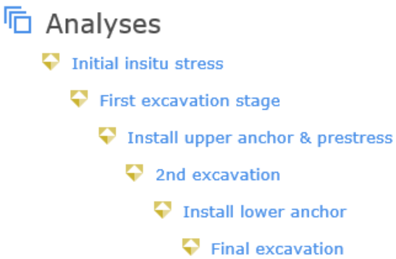

Figure 2. Sequential analysis tree for the Project.

Simple Linear-Elastic soil properties are used here for this illustrative example. The homogeneous sandy soil has been defined with a total E-modulus of 5,000 kPa and a unit weight of 20 kN/m^3. The Poisson's ratio (ν) has been defined as 0.334.

Eight-noded higher order elements are used as shown in Figure 3. The higher order elements offer superior performance in a stress-strain type of analysis. Eight-noded elements are used here for demonstration purposes.

Notice the geometric Regions and the geometric Lines. Some of the Regions are required to simulate the excavation (region deactivation). The geometric Lines are required to apply the beams and bars representing the grouted or bonded anchor length and the free or un-bonded length.

The approximate global mesh size is specified as 1 m. The mesh is refined along the grouted lengths of the anchors by making the element size half of the global size.

The grouted or bonded portion of the anchors is modeled with beam elements. The free or un-bonded portion is modeled with bar elements. The sheet-pile wall is included as beam elements.

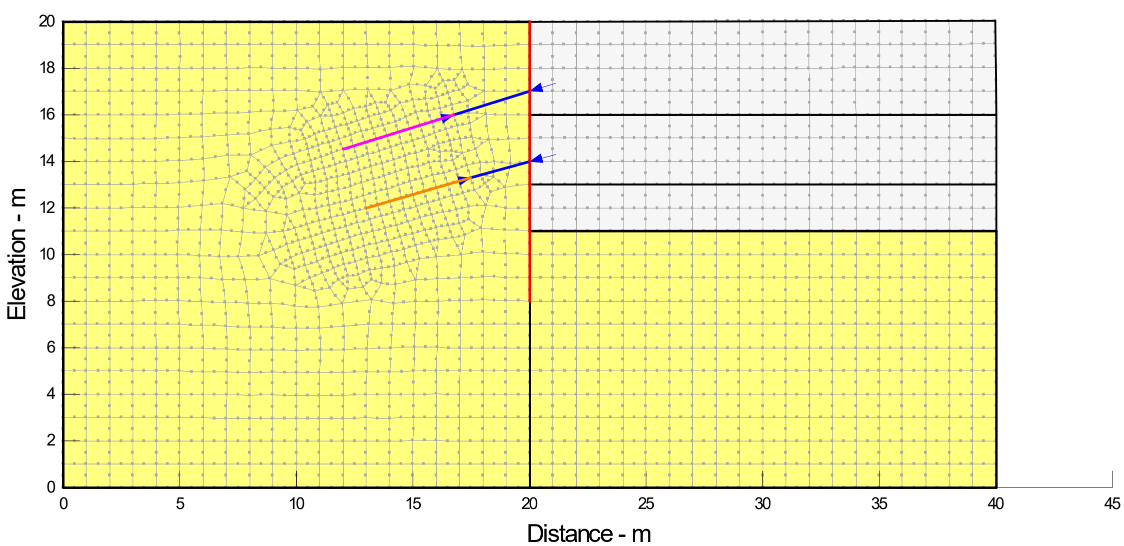

Figure 3. Finite element mesh view.

As discussed in the SIGMA/W Reference Book, the excavation face becomes a stress boundary when a region is deactivated. The excavation, in essence, simulates the removal of the initial *in situ* stresses. The stresses acting on the wall are directly related to the *in situ* conditions, particularly the *in situ* horizontal stresses.

Results and Discussion

Figure 4 shows the lateral deflection of the wall and the ground under the wall. The maximum deflection occurs at the lower tip of the sheet-pile wall. This occurs because of the rebound of the soil due to the removal of the excavated soil. Also, note that the pre-stressing of the upper anchor pulls the wall toward the anchor (load step 2).

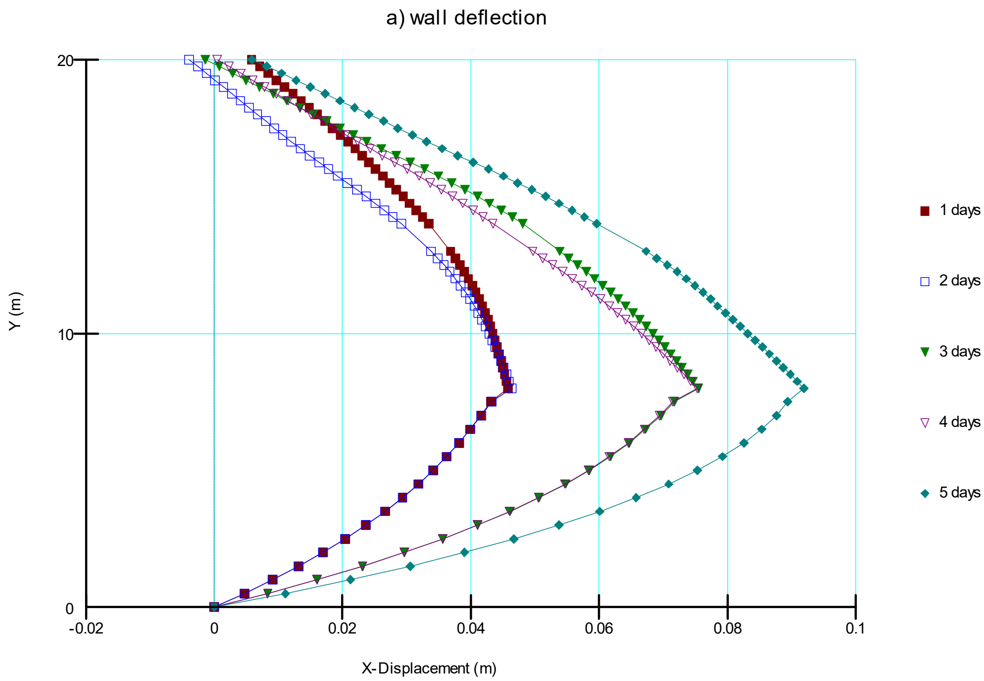

Figure 4. Lateral deflection of the wall.

There is a tendency for users to look at the wall deflections at an exaggerated scale, as on the left in Figure 5. This makes it appear that the deflections are a serious issue. If the deflections are viewed at a reasonable scale, as shown on the right in Figure 5, the wall movements are hardly perceptible.

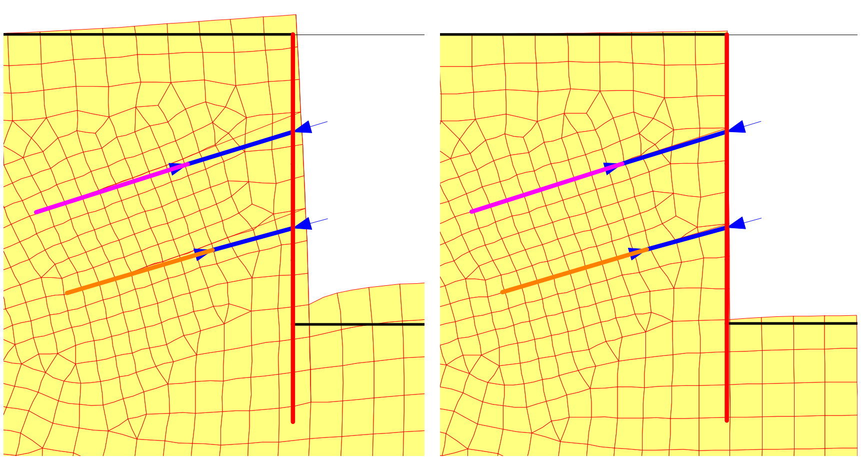

Figure 5. Wall deflection at 5X exaggeration and no exaggeration.

The moment distributions in the sheet-pile wall are presented in Figure 6 and the shear distributions are shown in Figure 7. Ultimately, the purpose of this type of analysis is to ensure that the structural members are not being over-stressed. Including the structural elements in the analysis makes this possible because the soil-structure interaction is analyzed. The structural stiffness affects the soil stresses and the soil stiffness affects the structural stresses.

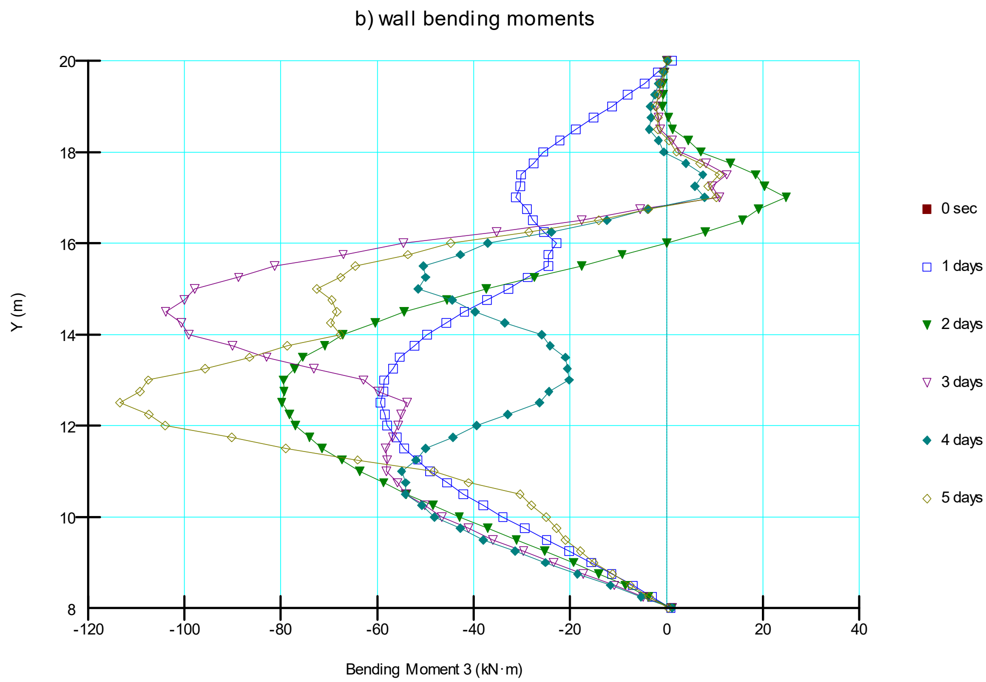

Figure 6. Moment distributions in the wall.

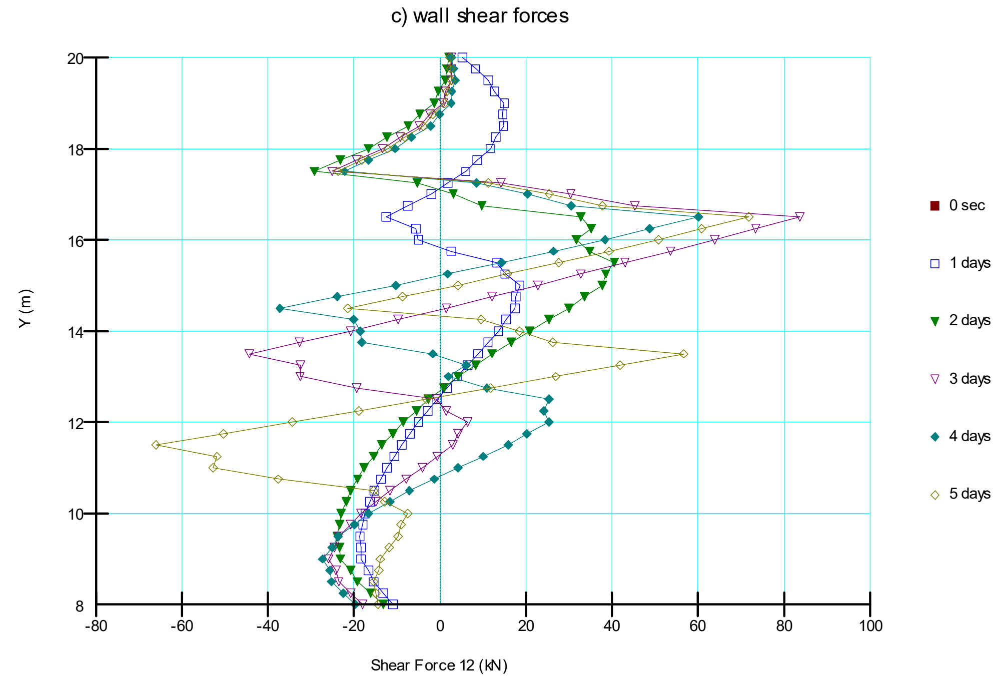

Figure 7. Shear distributions in the wall.

The forces in the upper anchor are presented in Figure 8. The force starts at the prescribed pre-stress of 100 kPa. Then, when the second layer of soil is excavated, the force increases to 150 kPa. The forces then decrease to 123 kPa when the pre-stress of the lower anchor is applied. Finally, the load ends up at 138 kPa after all the soil has been excavated. Of significance is that the maximum force in the upper anchor occurs during construction, not when the excavation reaches its maximum depth.

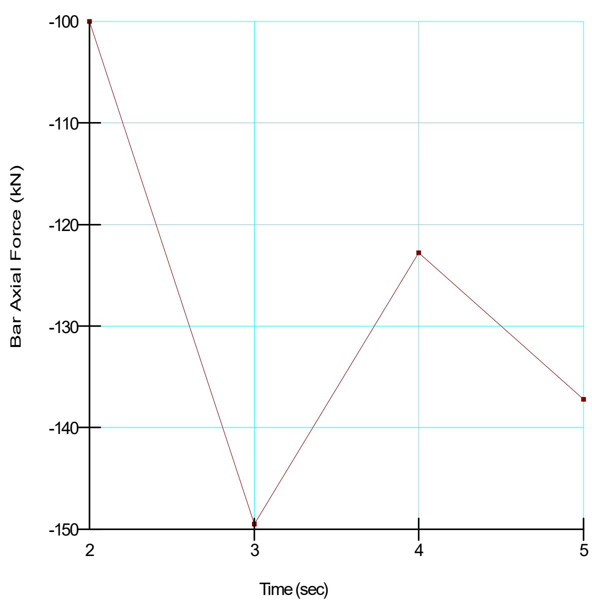

Figure 8. Forces in the upper anchor free length.

Figure 9 shows the axial force in the grouted length of the upper anchor. The highest axial force is at the end where the grouted length connects to the free length (x=16.75) and then diminishes toward the back end of the grouted length as the load is transferred to the soil. Ideally, the total axial force at the far deep end should be zero, but in a discretized environment this is not exactly the case, although the trend is towards zero (left end of curves).

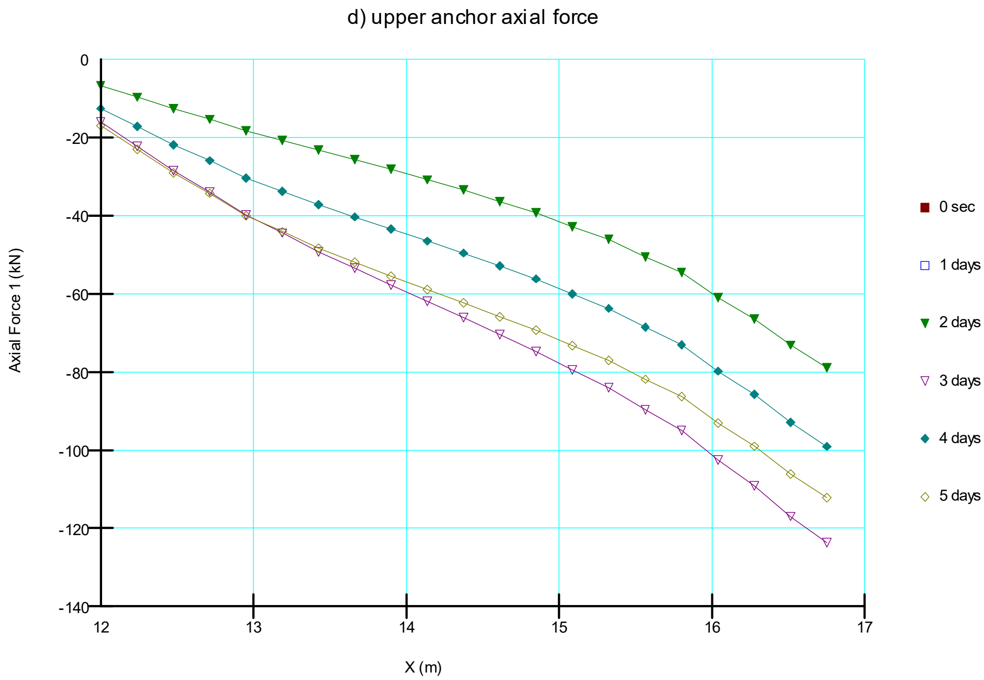

Figure 9. Axial forces in the upper grouted length.

One of the bigger concerns with temporary shoring is always the settlement behind the wall. The results here indicate there will be up-lift instead of settlement which is inconsistent with field observations. The rebound along the excavation base is, of course, not evident at the actual site, since the excavators keep removing materials to the design elevation.

Of more significance and interest is the rebound of the ground surface just outside of the wall. Usually, a major concern is the settlement that often occurs behind the retaining wall. The analysis results seem to suggest that it is not an issue. At a first glance, it would seem that the numerical model has not provided the correct response. Upon further reflection, however, it is reasonable that the soil will rebound when it is unloaded.

One aspect of shoring wall construction that the model does not capture is the loss of ground behind the wall. This can be particularly problematic in a pile-lagging system, where portions of the excavation face are exposed for a period of time before the lagging is installed. Furthermore, there may be some settlement before the lagging picks up the load; that is, slack in the system.

In the case of a carefully constructed diaphragm wall where there is likely little or no loss of ground behind the wall, there may indeed be a slight amount of rebound outside of the wall, but in the field it may be too small to be noticeable.

As a very broad principle in this industry, more expensive shoring systems like diaphragm walls are used in cases where settlement outside the wall is a major concern. Less expensive systems, like piles with lagging, are used when settlement is less of a concern. The point is that the potential for settlement is related to the shoring system behavior and the installation procedures. The modeling, unfortunately, cannot capture this aspect of the shoring behavior.

From a modeling perspective, the results should not be dismissed because of the small rebound behind the wall. The results related to aspects like lateral deflections and structural stresses are nonetheless useful in the shoring design.

Summary and Conclusions

SIGMA/W is used to simulate the staged construction of a tie-back shoring wall in this example. A commentary on interpreting the results is provided. This example is not based on any field case; all properties have been selected for illustrative purposes.