# Sequential Tailings Placement

## 1 Introduction

Modeling the sequential placement of mine tailings is analogous to a sedimentation problem. The weight of the added tailings causes excess pore-pressures to develop in the previously placed tailings. In this sense it is like a consolidation test, but with continually moving boundary.

In the case where there is no under drainage, the problem is further complicated by the fact that a portion of the excess pore pressure is converted into long-term hydrostatic pressures.

Furthermore, the hydraulic conductivity changes with time, as the sediments consolidate.

This example illustrates how SIGMA/W can be used to model this type of problem.

## 2 Problem description

The 1-D column shown in Figure 1 is used here to illustrate the techniques and procedures. The process starts with 3 m of sediments under static conditions with the water table at the surface. Seven one-metre layers are then added over time, with the water table always being at the deposition surface.

File name: Sequential tailings placement.gsz

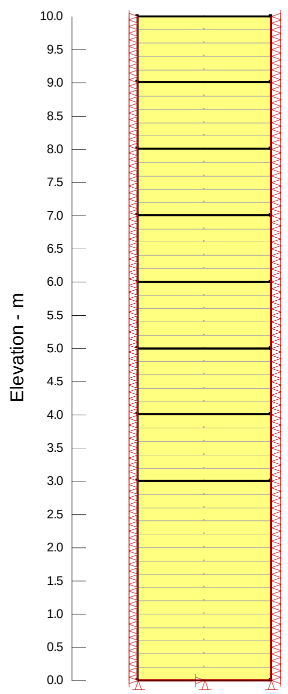


**Figure 1 Problem configuration**

After each layer is added, some but not all of the excess pore-pressure is allowed to dissipate, with the result that there is a net accumulation with time. Finally, after the last layer has been added, the excess pore-pressure is allow to dissipate and migrate towards the long term steady-state conditions.

The same material is used throughout and the properties are completely arbitrary, selected only for demonstration purposes. The material properties can be viewed and inspected by opening the corresponding data files.

The analysis-tree is presented in Figure 2.

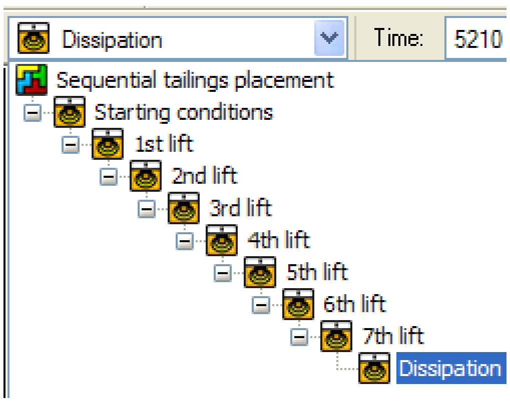


**Figure 2 The analysis tree**

A very important part of this analysis is that the hydraulic boundary condition representing the water table has to move with the tailings surface. The boundary condition is specified as a pressure equals zero boundary condition, and is moved to the surface as each layer is added. In addition, the pressure boundary condition is removed once a previous surface is covered with a new layer. You should look at each of the analyses to see how this is done, because it is critical to this case.

## 3 Data files

For this example it was decided that it is easier to create three different data files instead of doing more than one scenario in the same data file. The three different data files and cases are:

- Case 1: Sequential tailings placement
- Case 2: Sequential tailings under drain
- Case 3: Sequential tailings K reduction

## 4 Case 1

Case 1 has no under drain and involves the dissipation of the excess pore-pressure back to a hydrostatic condition. The initial pore-pressure profile through the existing 3 m of soil is hydrostatic. When one-metre of tailings is added, the pore-pressure at the base of the column increases by about 20 kPa, as indicated in Figure 3. Within the one-metre tailings added, the pore-pressure increases from zero at the surface to 20 at the base of the added layer (actually it is not exactly 20 kPa, due to some dissipation during the 3 days the layer was added). Then the excess pore-pressure dissipates over the next 27 days, as shown on the right in Figure 3. Before the excess pore-pressure has had a chance to completely dissipate, another layer is added.

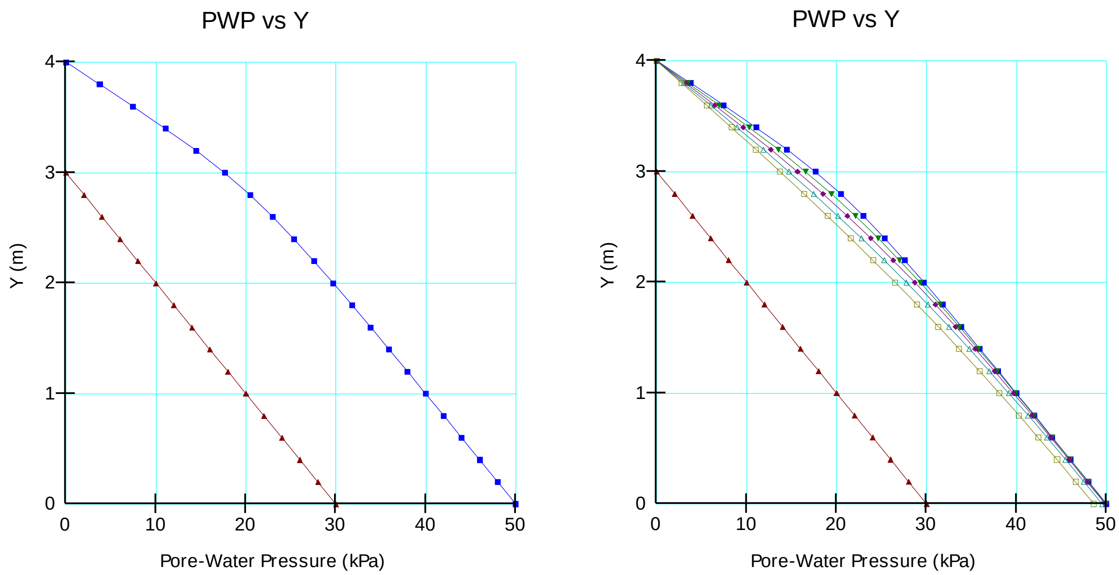


**Figure 3  Pore-pressure increases and dissipations with placement of first layer**

In this illustrative example, a new layer is placed every 30 days until the surface is at Elevation 10 m. The resulting pore-pressures are as shown in Figure 4. The maximum pore-pressure at the base is about 150 kPa. Had there been no consolidation during the placement, the maximum pore-pressure would have been 170 kPa.

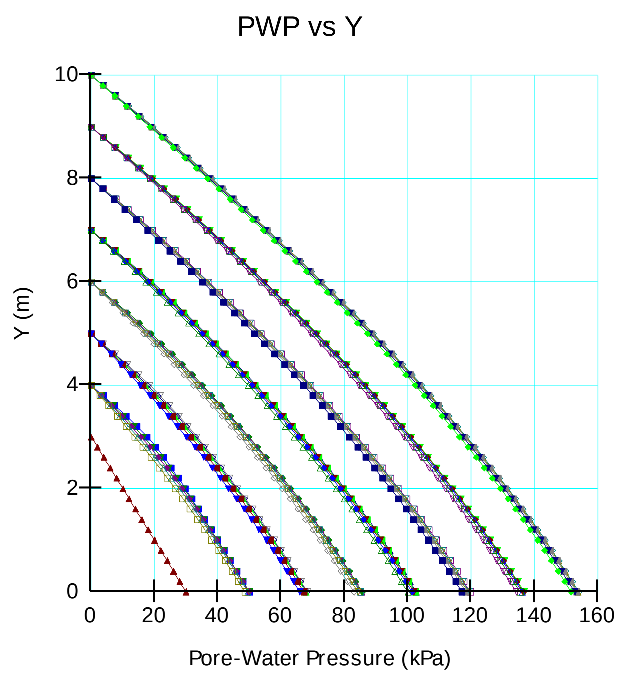


**Figure 4  Pore-pressure build-up during tailings placement**

Finally, if the system is allowed to remain undistributed, the excess pore-pressure will ultimately dissipate and become hydrostatic, as shown in Figure 5. Ultimately, the pore-pressure at the base should be 100 kPa, as is the case in Figure 5.

Of significance here is that the final pore-pressure moves towards a hydrostatic condition. The excess pore-pressure moves toward zero, as in Figure 6, but the actual pore-pressure in the ground is hydrostatic with depth.

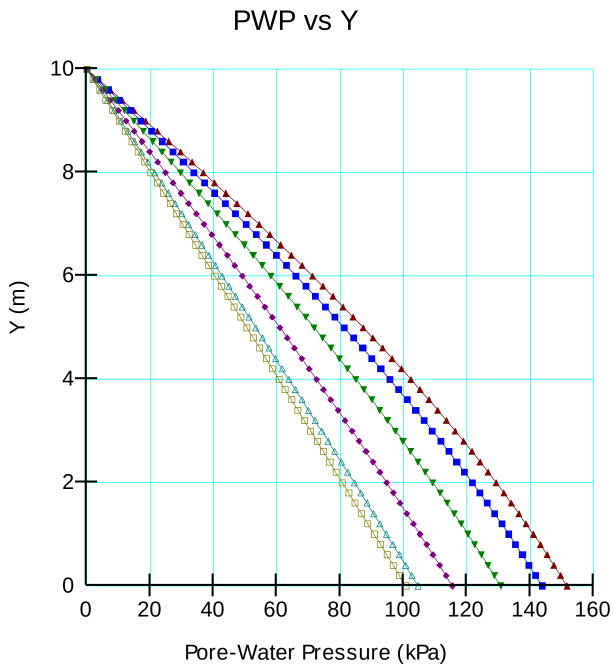


**Figure 5 Final pore-pressure dissipation**

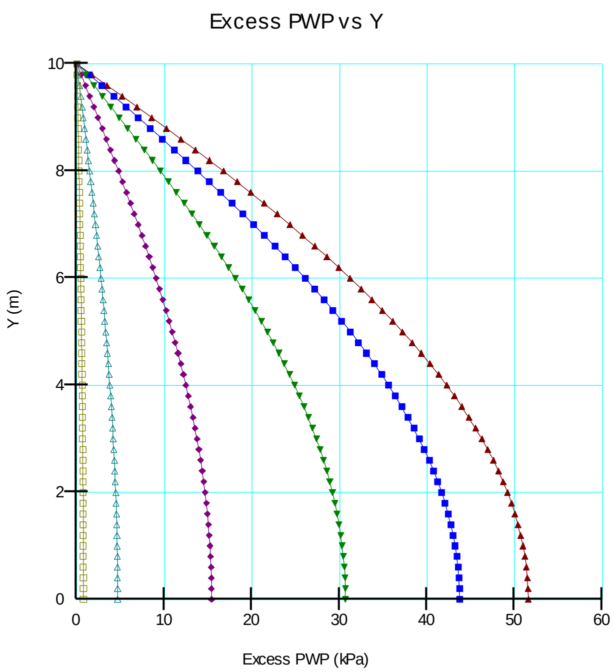


**Figure 6 Dissipation of excess pore-pressure**

## 5 Case 2

The analysis is repeated here, but with the assumption that there is an under drain; that is, the excess pore-pressure remains zero at the base. The drainage condition is simulated by applying a pressure head = 0 m boundary condition at the top and bottom of the column.

For this case it was considered easier to save the data file under a different name rather than repeat all the different analyses within the same data file. The associated file name is:

*Sequential tailings underdrain.gsz*

Figure 7 shows that the pore-pressure increases as the layers are added, and then the final dissipation.

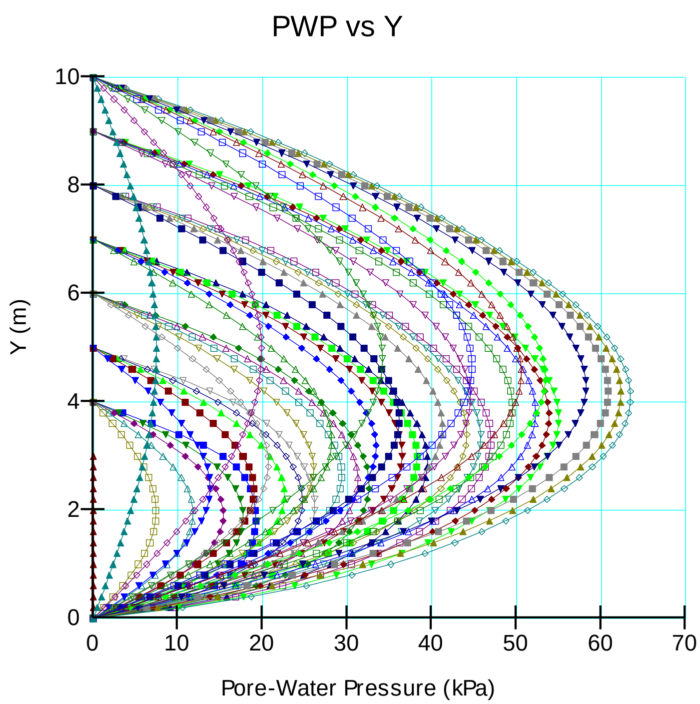


**Figure 7 Pore-pressure increases and dissipation with an under drain**

## 6 Case 3

In the sedimentation process, the hydraulic conductivity obviously changes as the soil consolidates. In SIGMA/W, this change can be accommodated with a K-modifier function, such as in Figure 8. The conductivity *K* changes as the vertical effective stress changes. Indirectly, K changes as the pore-pressure and effective overburden change. The conductivity changes about one order of magnitude over an effective stress change of 90 kPa.

Such data can be determined from an odometer test, as described in the SIGMA/W Engineering Book.

Again, the file was saved under a different name for this case, but it would not have been necessary; a K-modified function could have been specified and then the problem could have been re-run.

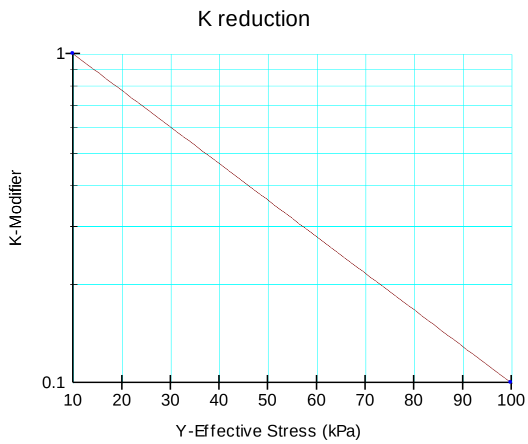


**Figure 8 Hydraulic modifier function**

Figure 9 shows a repeat of the previous case when the conductivity *K* changes as the effectives stress changes. The dissipation is much slower near the bottom of the column where the effective stresses are the highest.

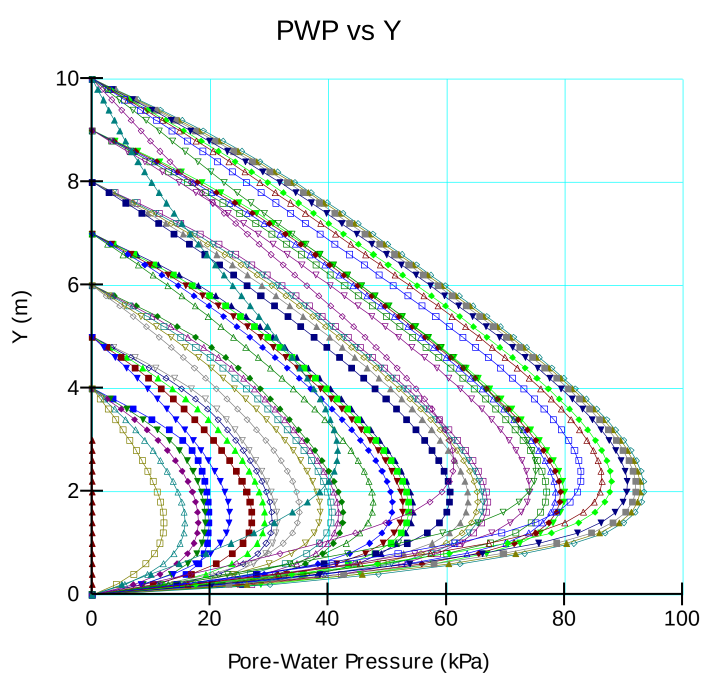


**Figure 9 Pore-pressure increases and dissipation with a K-modifier function**

## 7 Concluding remarks

This example has demonstrated how SIGMA/W can be used to model a sedimentation problem with and without an under drain, and when the hydraulic conductivity *K* changes as the sediments consolidate.