GeoStudio Example File
Sequential Tailings Placement

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Introduction

Modeling the sequential placement of mine tailings is analogous to a sedimentation problem. The weight of the added tailings causes excess pore-water 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-water 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.

Numerical Simulation

Three sets of analyses are included in the GeoStudio Project to model the following cases: 1) sequential tailings placement; 2) sequential tailings placement with an under drain; and, 3) under-drained sequential tailings placement with a reduction in hydraulic conductivity due to volumetric compression.

The 1-D column shown in Figure 1 is the model domain used in all three scenarios. The process starts with 3 m of sediment 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.

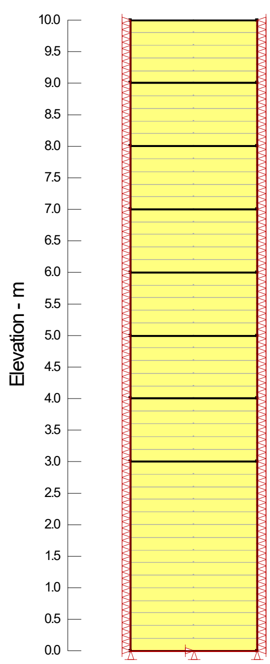

Figure 1. Problem configuration.

The analysis-tree is similar for all three branches of analyses and is presented in Figure 2. After each layer is added, some, but not all, of the excess pore-water 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-water pressure is allowed to dissipate towards the long term steady-state condition. In this illustrative example, a new layer is placed every 30 days until the surface is at Elevation 10 m.

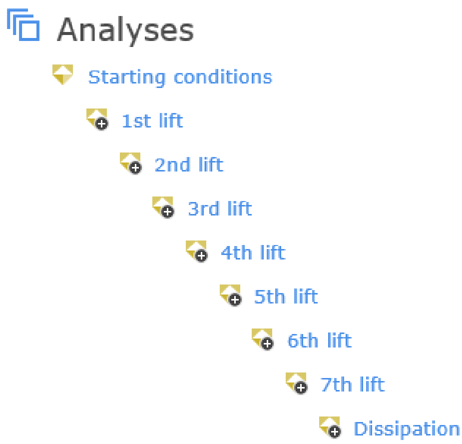

Figure 2. The analysis tree.

An *In situ* analysis using the Gravity Activation procedure is conducted to establish the initial conditions at the start of each branch. This analysis type does not require hydraulic materials or boundary conditions. An initial water table is drawn on the domain for this Parent analysis to define the pore-water pressure conditions. Subsequently, there are eight consolidation analyses in each branch to model the time-dependent pore-water pressure response.

The tailings is defined using a Linear Elastic material model with an effective elastic modulus of 5,000 kPa, a soil unit weight of 20 kN/m^3, an Initial Void Ratio of 0.6, and a Poisson's ratio (v) of 0.334. In a consolidation analysis, the Response Type of the material is ignored because all materials participate in groundwater flow. A Saturated-only material model is used on the Hydraulic Tab. The saturated hydraulic conductivity has been set to 1.16×10^{-9} m/sec.

A very important part of this analysis is that the hydraulic boundary condition representing the water table at the top of each tailings lift. The boundary condition is specified as a pore-water pressure of 0 kPa 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.

Each layer is prevented from moving in the x direction on the left and right boundaries with the Fixed X boundary condition. Both x and y displacement is prevented using the Fixed X-Y boundary condition on the bottom boundary.

The second analysis branch (Sequential tailings underdrain) is a repeat of the above analysis, but with the assumption that there is an under-drain; that is, the excess pore-water 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.

Lastly, in the third analysis branch (Sequential tailings K reduction), the hydraulic conductivity is altered during consolidation using a modifier function (Figure 5). The modifier function is defined as a modifier factor verses a void ratio increment. During solve time, the hydraulic conductivity at each gauss point is calculated as K_{sat} x Modifier. The function is defined verse void increment, instead of void ratio, such that the same function could be used for other materials with a different initial void ratio. In this case, the hydraulic conductivity decreases one order-of-magnitude with a 0.01 decrement in void ratio.

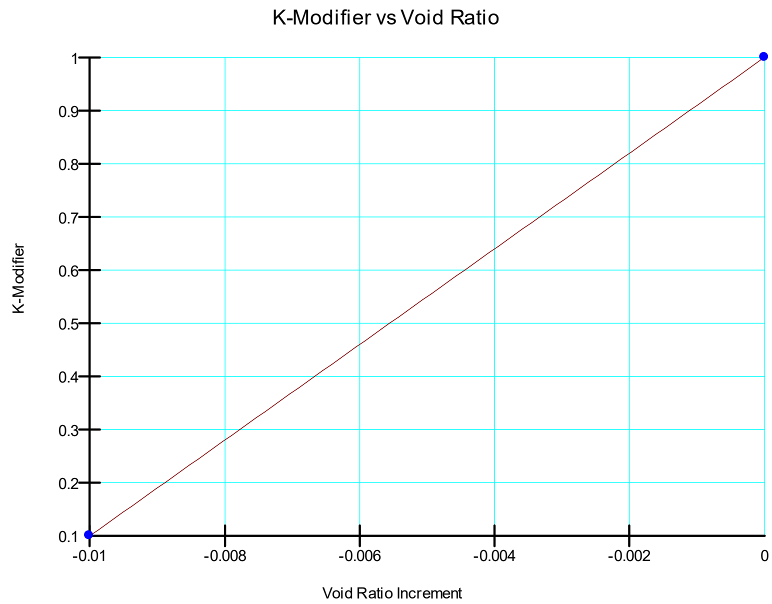

Figure 5. Hydraulic conductivity modifier function.

Results and Discussion

Scenario 1 has no under drain and involves the dissipation of the excess pore-water pressure back to a hydrostatic condition. The initial pore-water pressure profile through the existing 3 m of soil is hydrostatic. When one-metre of tailings is added, the pore-water pressure at the base of the column increases by about 20 kPa (Figure 6). Within the each new tailings layer, the pore-water pressure increases from zero at the surface to 20 kPa 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-water pressure dissipates over the next 27 days. Before the excess pore-water pressure has had a chance to completely dissipate, another layer is added.

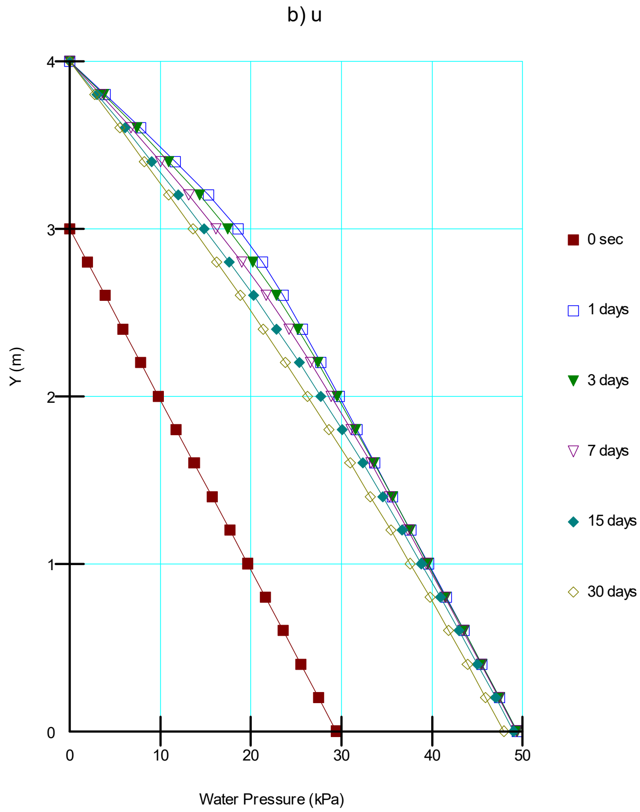

Figure 6. Pore-water pressure increases and dissipates with placement of first layer.

The resulting pore-water pressures after all placements have been added are shown in Figure 7. The maximum pore-water pressure at the base is about 150 kPa. Had there been no consolidation during the placement, the maximum pore-water pressure would have been 170 kPa.

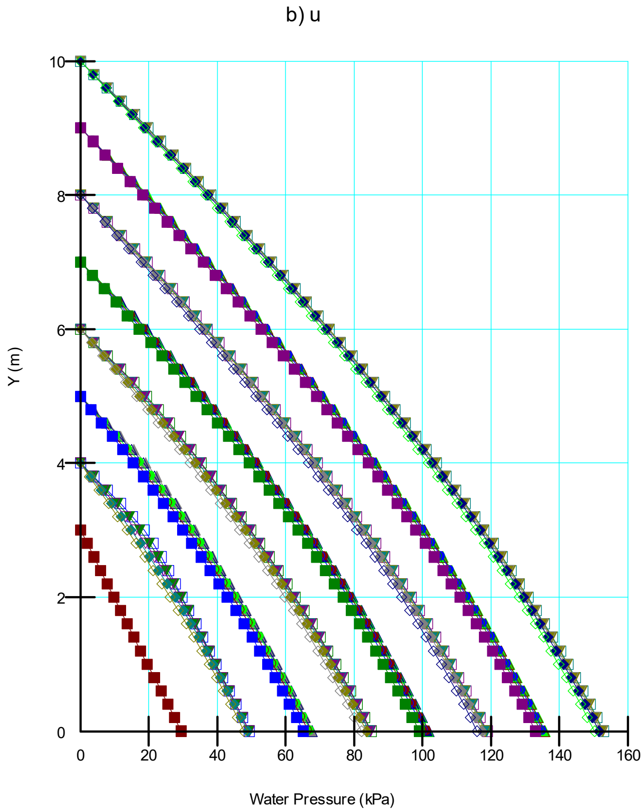

Figure 7. Pore-water pressure build-up during tailings placement.

Finally, if the system is allowed to remain undistributed, the excess pore-water pressure will dissipate and become hydrostatic (Figure 8). Ultimately, the pore-water pressure at the base should be 100 kPa, as is the case in Figure 8.

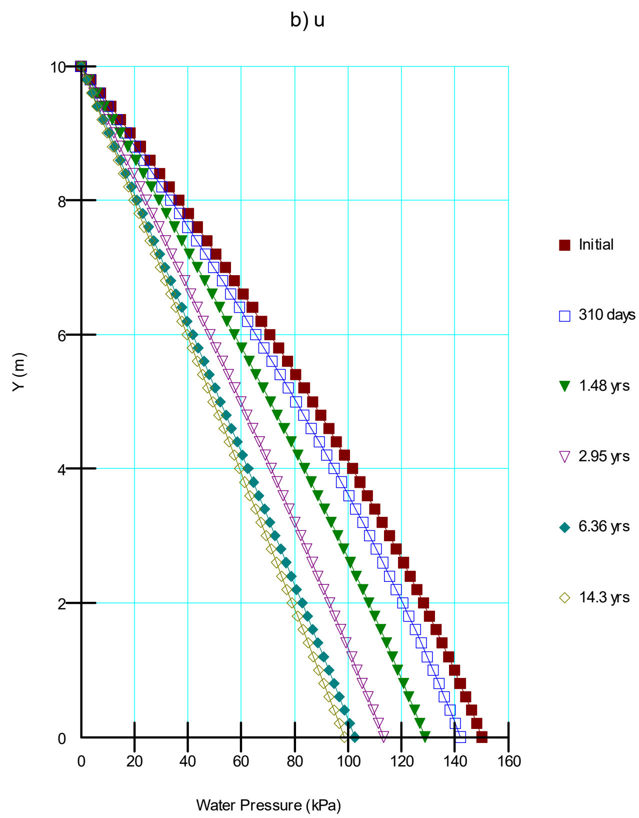

Figure 8. Final pore-water pressure dissipation.

Figure 9 shows that the pore-water pressure increases as the layers are added and then the final dissipation for the second scenario with the under-drain at the bottom of the column.

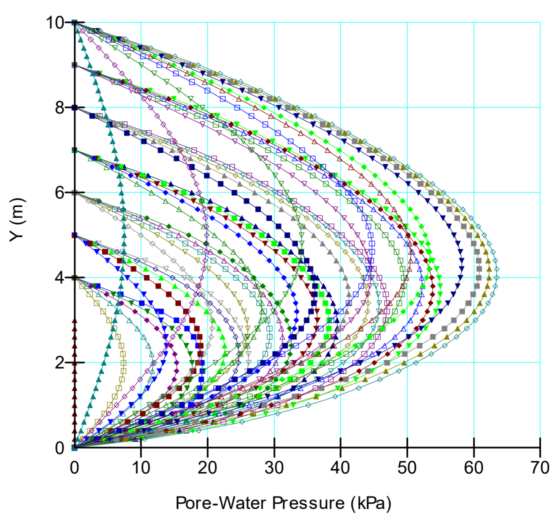

Figure 9. Pore-water pressure increases and dissipation with an under-drain.

Figure 10 the results from scenario 3 in which the conductivity *K* changes as the void ratio decreases due to volumetric compression. The dissipation is much slower near the bottom of the column where the volumetric strain (compression) is highest.

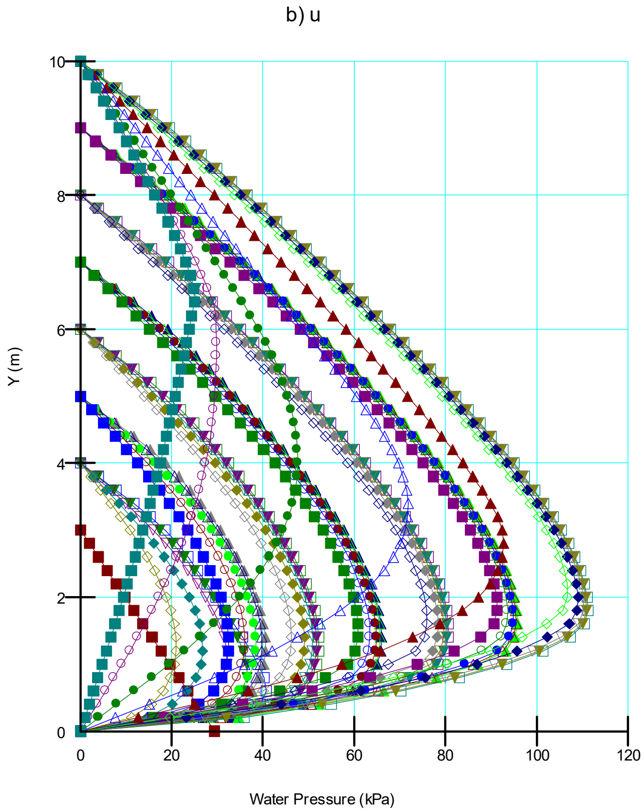

Figure 10. Pore-water pressure increases and dissipation with a K-modifier function.

Summary and Conclusions

This example demonstrates the analysis of tailings deposition with and without an under-drain, and when the hydraulic conductivity *K* changes as the sediments consolidate, using a SIGMA/W consolidation analysis.