AIR/W Tutorial – Getting started

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Introduction

The idea of using compressed air in the construction of subaqueous tunnels dates back to the late 19th century. The Blackwall Tunnel in London, England, for example, was constructed under the River Thames in the 1890's using a tunneling shield together with compressed air. Also, compressed air caissons were used in the construction of the pier foundations for the Brooklyn Bridge in New York in the 1870's (Wikipedia, The Free Encyclopedia).

The compressed air helps with controlling the ingress of water and mud into the tunnel during construction. The objective of this introductory example is to illustrate how the AIR/W product of GeoStudio can be used to simulate this effect by the compressed air.

Numerical Simulation

Figure 1 shows the configuration of a tunnel in homogenous ground with a natural water table that is 2 m below the ground surface. The tunnel has a diameter of 6 m. There are two analyses present in the Analysis Tree for the Project (Figure 2). The first analysis is a water transfer analysis without the presence of compressed air within the tunnel. In the second analysis, the Air Transfer process is added to the water transfer analysis (Figure 3) to simulate the compressed air within the tunnel.

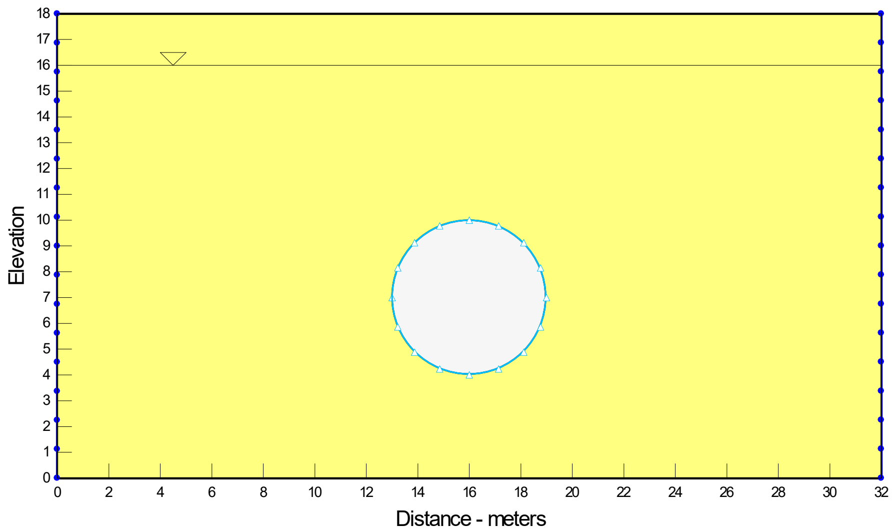

Figure 1. Problem configuration.

Figure 2. Analysis Tree for the Project.

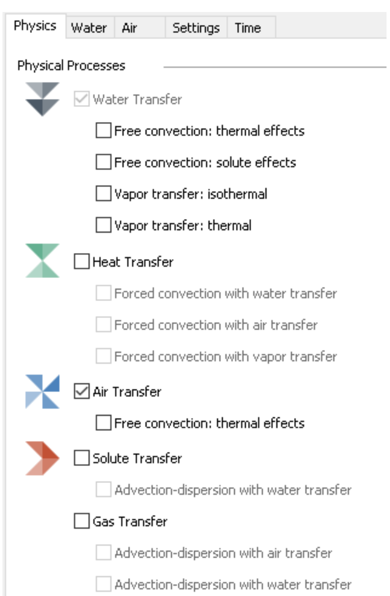

Figure 3. Physics tab to simulate both the water and air transfer processes on the same domain.

The water transfer processes in both analyses are defined with a constant hydraulic head boundary condition set to 16 m on the left and right far-field domain boundaries. The tunnel surface also has a potential seepage face boundary condition applied, allowing water to flow out of the domain if the pressure exceeds 0 kPa. The air transfer processes are defined in the second analysis with a constant atmospheric pressure boundary condition of 0 kPa along the surface of the domain, with a constant tunnel pressure of 50 kPa applied to the tunnel surface.

The hydraulic material parameters are defined using the saturated/unsaturated material model type. The volumetric water content function was estimated using the silty clay sample material type with a saturated water content of 0.47 (Figure 4). The hydraulic conductivity function was estimated using this volumetric water content function with a saturated hydraulic conductivity of 1 x 10^{-2} m/sec and a residual water content of 0.05 (Figure 5).

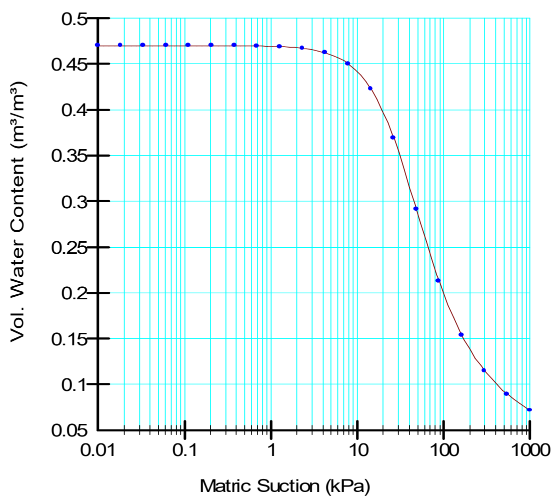

Figure 4. Volumetric water content function for the silty clay material.

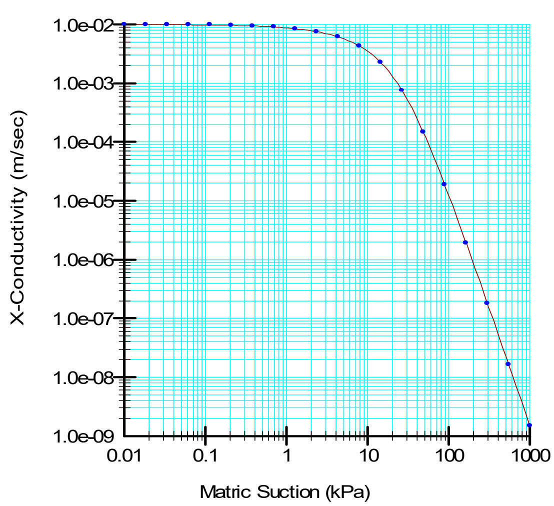

Figure 5. Hydraulic conductivity function for the silty clay material.

The air parameters were estimated using the dual phase material model. The air conductivity function was estimated using the silty clay volumetric water content function above. Here, the dry air conductivity was set to 1 m/sec (Figure 6).

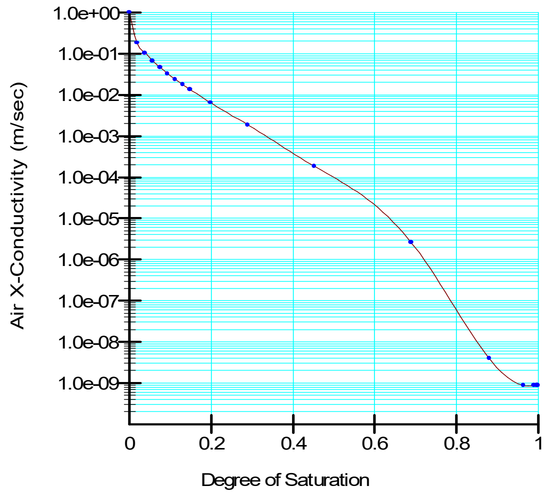

Figure 6. Air conductivity function for the silty clay material.

The global mesh size has been set to 1 m, with refinement of the element size on the tunnel perimeter set to a 0.5 ratio of the default size (Figure 7).

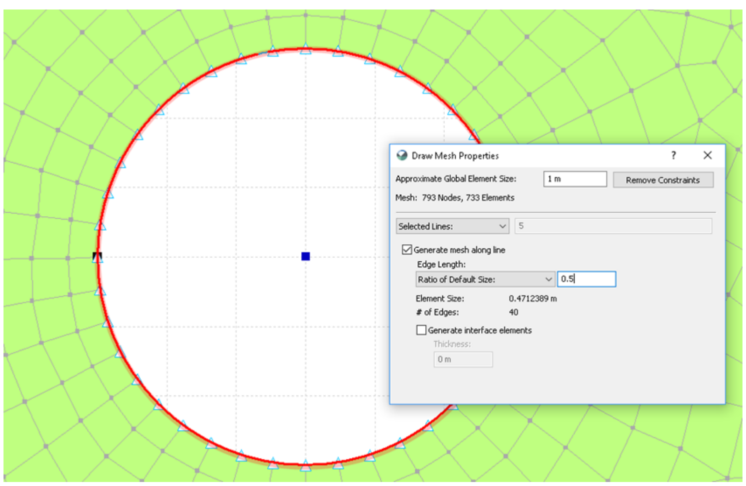

Figure 7. Mesh refinement around the tunnel perimeter.

Results and Discussion

The steady-state water transfer conditions with the tunnel present, but no compressed air, are shown in Figure 8. The drawdown of the water table by the presence of the tunnel is as much as 8 m, which results in significant seepage gradients towards the tunnel and therefore flow into the tunnel. The total water volume rate into the tunnel is -0.172 m^3/s. The negative sign indicates that water is leaving the domain.

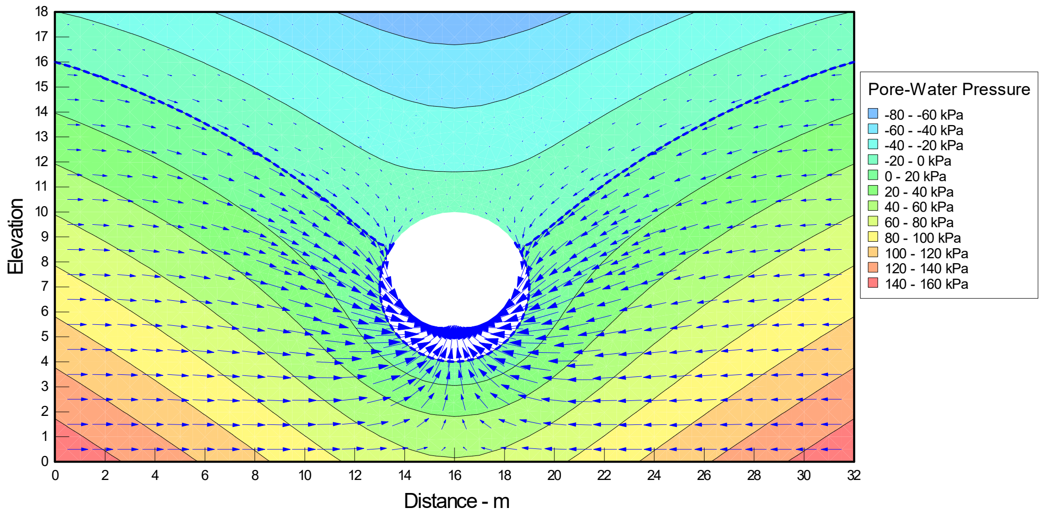

Figure 8. Water transfer analysis results with no compressed air within the tunnel.

Figure 9 shows the pore-water pressure contours and zero pressure isoline that develops when air pressure is applied to the tunnel wall. It is tempting to conclude from the zero pressure isoline that the phreatic surface has lifted above the tunnel; however, the results have to be interpreted in the context of matric suction. Figure 10 reveals that the soil around the tunnel is now in an unsaturated state. The combined effects of the altered pore-water pressure gradients and decrease in hydraulic conductivity reduces the overall water inflow rate to 0.099 m^3/s.

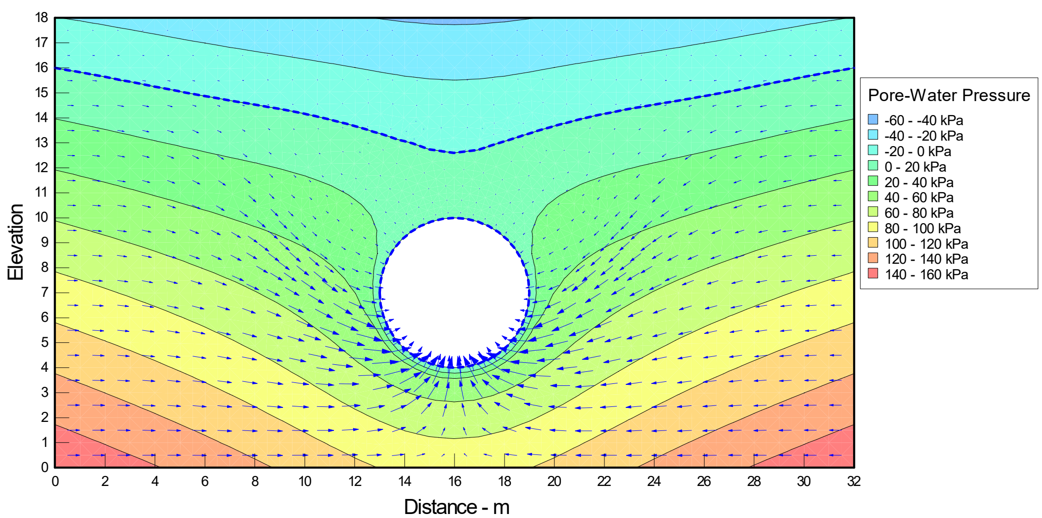

Figure 9. Pore-water pressure contours and zero pressure isoline from the air and water transfer analysis.

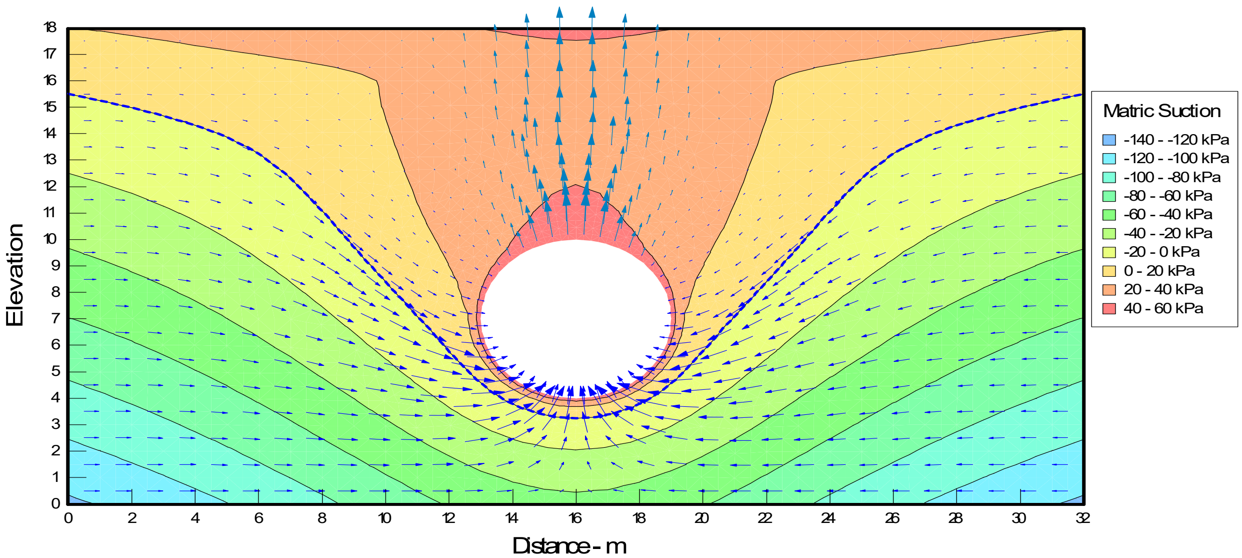

Figure 10. Matric suction contours and zero matric suction isoline from the air and water transfer analysis.

Summary and Conclusions

This illustrative example demonstrates that GeoStudio has the capability of considering the effects of air pressure on water inflow rates into tunnels.