Coupled versus uncoupled HM modelling

Coupled in 2 directions
Uncoupled or coupled in 1 direction

March 2020

Problem description

Excavation of a cavity under axisymmetric conditions.

- Initial conditions
  The initial state of stresses is, for vertical stress: -11 MPa and, for horizontal stress: -8 MPa. The initial pore pressure is 4.3 in average. These values correspond to a certain depth of the domain.
- Boundary conditions
  Pore pressure and temperature are imposed on top and bottom boundary. Stress is also imposed on the top boundary to 11 MPa. Lateral displacements on the vertical external surface is not permitted. Lateral surfaces are impermeable.
- Gravity effects are included, and will modify the initial stress and pore pressure slightly.
- Properties
  Porosity is 0.02, intrinsic permeability is 10^{-20} m^2, elastic modulus is 25000 MPa and Poisson's ratio is 0.3.

Excavation induces pressure variations in the rock by two processes:

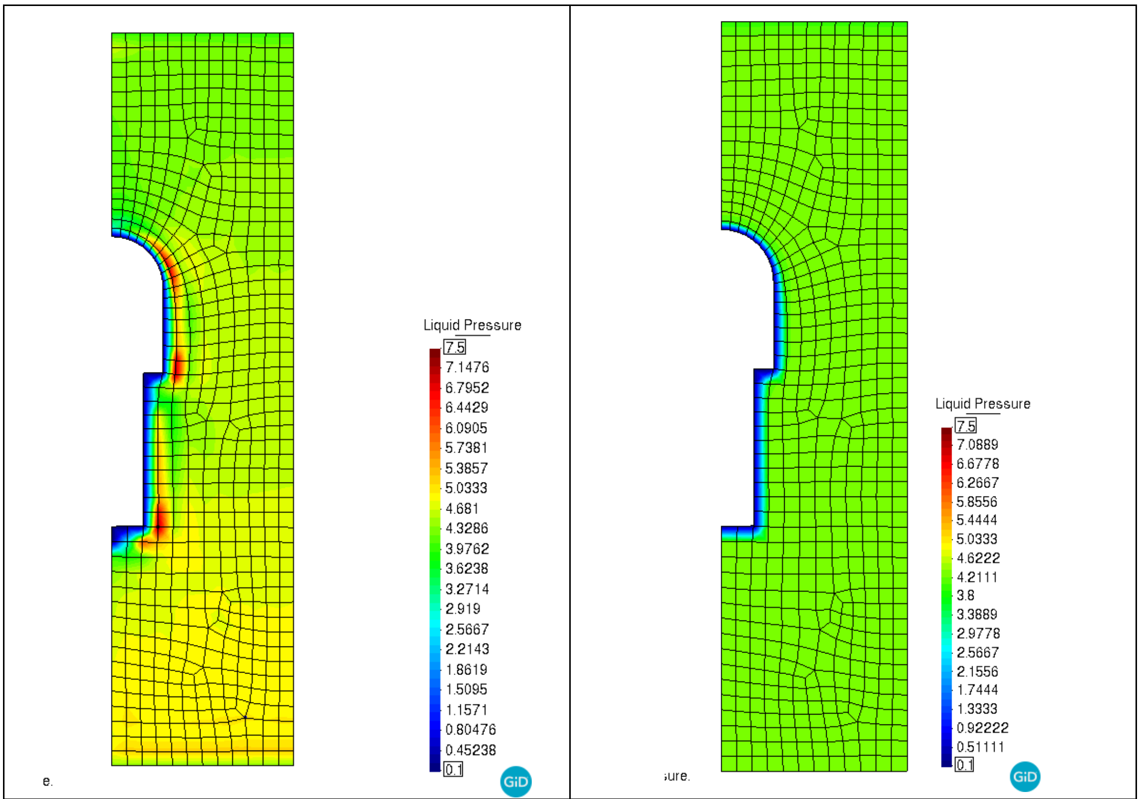
- Volumetric deformation in the rock leads to increments of pore pressure
- Cavity wall drainage induces reduction of pore pressure

Results

Figure 1 shows the pore pressure generation immediately after excavation.

For coupled conditions, pressure builds up in zones close to the cavity wall. As cavity wall is at atmospheric pressure, the pressure build up dissipates but the duration of the drainage process depends on the permeability. If the host rock is considered elastic, this process may be of no interest. Actually, in real conditions, progressive excavation of cavities may not produce this type of pressure generation. Therefore, this coupled pressure generation may be of little interest. However, depending on the case, it may be numerically demanding. Actually, the case presented here seems to indicate that mesh would have to be refined in order to improve the solution of pressure generation and dissipation.

In constrast, this effect is not observed in the uncoupled case because the volumetric strain term in the water balance equation is not considered. Cavity wall is at atmospheric pressure.

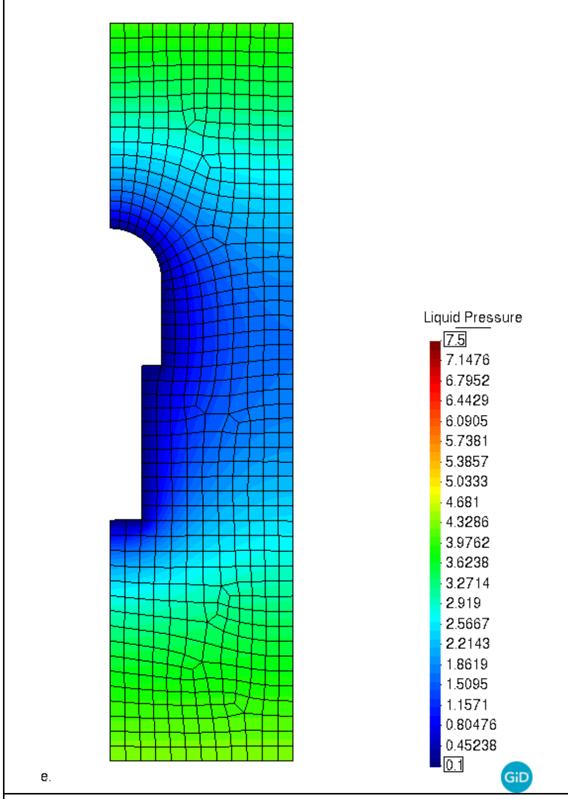


COUPLED	UNCOUPLED

Figure 1. Initial pressure after instantaneous excavation of the cavity. Displacements induced by excavation produce volumetric deformations, which in turn lead to pore pressure development.

Figure 2 shows the pressure after 10 years from excavation. Both models show a distribution of water pressures mainly controlled by the boundary conditions (top, bottom and cavity wall). Top and bottom are not equal because the gravity difference is considered.

The steady flow from top and bottom boundaries towards the cavity has not been reached completely, but it is close. The 10 years interval is considered a time period from excavation to waste emplacement.



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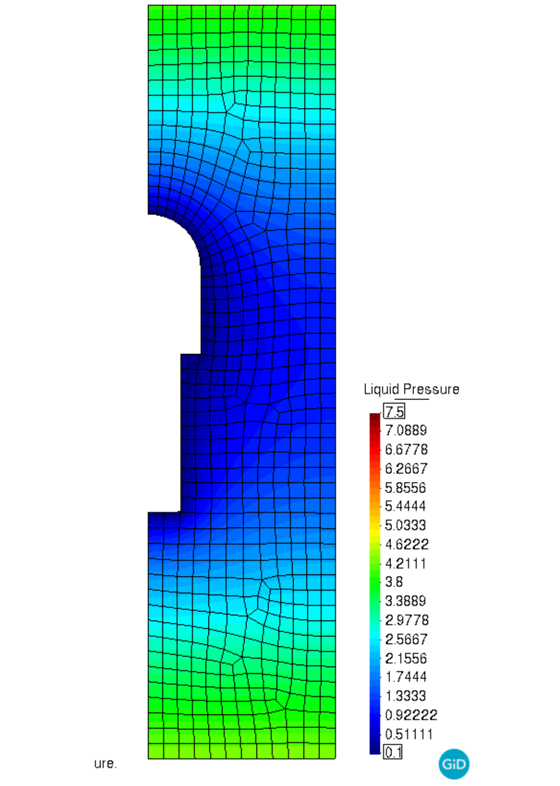


UNCOUPLED

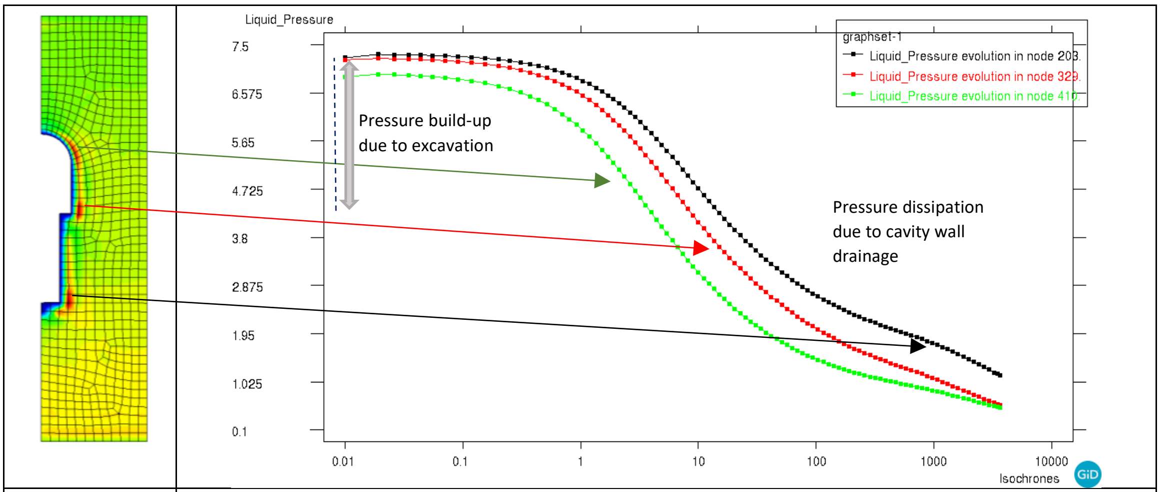
Figure 2. Final pressure (at 3650 days)) after instantaneous excavation of the cavity. Displacements induced by excavation produce volumetric deformations which in turn lead to pore pressure development.

Figure 3 displays the evolution of pore pressure at some selected points.

Initial pressure is in average 4.3 MPa (a vertical gradient exist due to gravity). For the coupled case, pressure develops with an increment of the order of 3 MPa. This is what was observed also in figure 2. The pressure reaches a value close to 7.5 MPa. This pore pressure dissipates in a consolidation type process.

For the uncoupled case, pressure does not increase at the beginning. For uncoupled solution, there is no pressure development due to instantaneous excavation. Therefore, pressure only changes in this case by the effect of drainage through the tunnel wall.

The uncoupled case seems to have finished the transient process of dissipation, and this is not the case of the coupled case. If we look at this problem in terms of a consolidation problem, the coefficient of consolidation (or diffusivity coefficient) is larger in the case of uncoupled because deformability of the rock is neglected (only water compressibility is considered). So the characteristic time for consolidation is shorter in the case of uncoupled solution.



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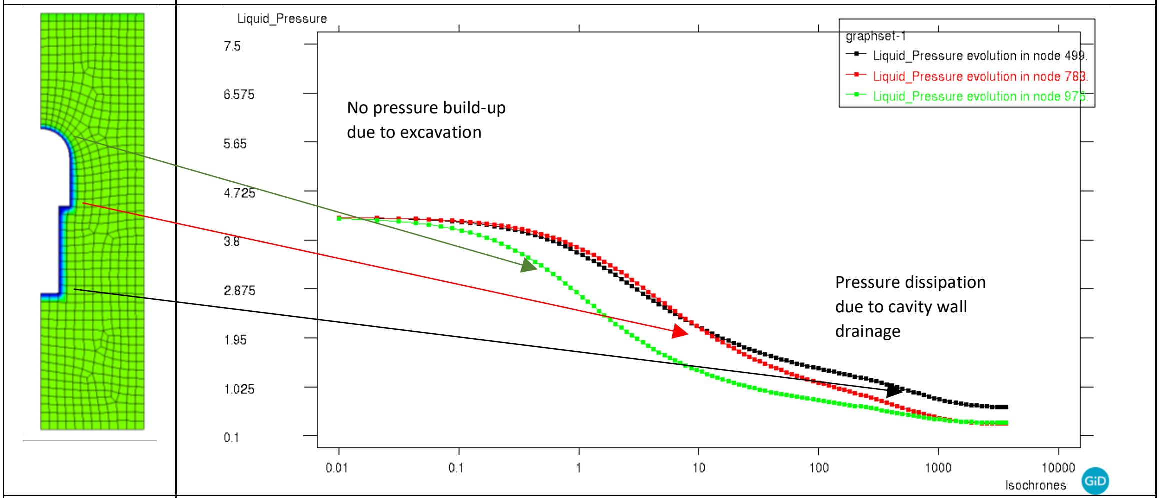
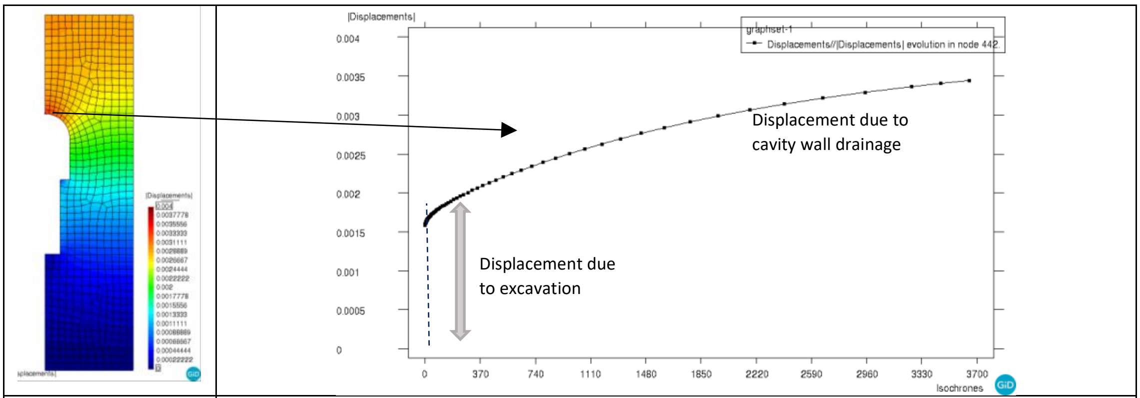


UNCOUPLED

Figure 3. Evolution of pore pressure for points close to cavity wall. Initial pressure is in average 4.3 MPa.

Finally, figure 4 shows the displacement evolution at the cavity roof point. Note that the coupled solution displays more delay in the development of time dependent displacement variation. It has not reached the final value. As indicated before, this is due to the compressibility of the rock leading to lower coefficient of consolidation.

For the uncoupled case, the transient effects have practically finished. From the point of view of the balance of water, the rock appears as rigid.



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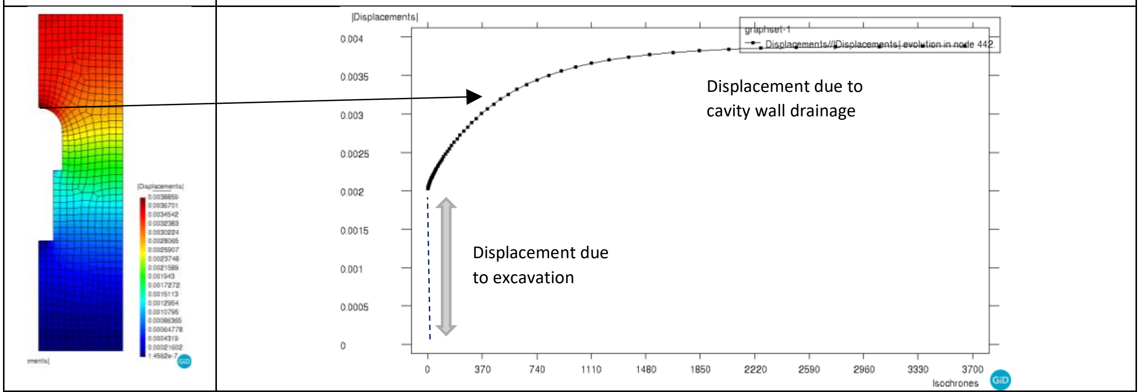

UNCOUPLED

Figure 4. Evolution of maximum displacement.

Conclusions

The option of uncoupled is interesting as it permits to avoid transient processes in a host rock during excavation if the coupling has no interest. The coupled deformation process can be recovered after excavation is simulated.

The uncoupled option can also be useful to eliminate coupling in zero permeability components in a model like the canister or other metallic elements.

This option can also be useful in case of construction or excavation that takes place progressively. In this case, removing the coupling of the specific materials that are constructed or excavated smoothly can be useful to avoid numerical problems in the material that is being constructed or excavated. All the other zones in the model maintain the coupling.

In case of construction, the coupling should be recovered after construction of the specific elements. In case of excavation, the element is no longer active.