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Failure of the intervertebral disc.

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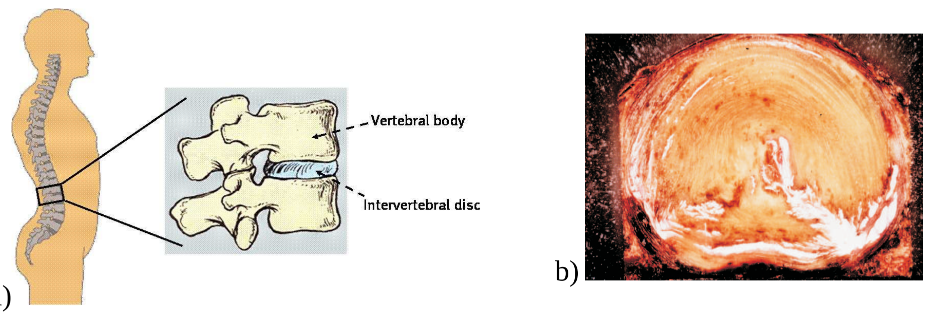
ABSTRACT

In ionized porous media, such as shales, clays and biological tissues, localization or even crack formation during swelling or shrinking can take place. This can lead to for example earthquakes, borehole instability and intervertebral disc (IVD) herniation. The goal is to study the effect of swelling on the failure mechanism. Currently, there is no numerical framework which includes osmotic swelling and fractures. To test the hypothesis a 2D plane-strain finite element framework for saturated osmotically swelling porous media is developed, which is verified by an analytical solution.

The intervertebral disc (IVD) is a cartilaginous tissue situated in the spine between the vertebrae (figure 1a). The presence of ions in the solid structure (fixed charge) and in the liquid (free ions) in the intervertebral disc causes an osmotic pressure and gives the IVD its capacity to acts as a shock absorber and provides the body its range of motion. The high osmolarity of the IVD tissue provides a strong protection against crack propagation. During degeneration the disc undergoes changes in fibre contents and loss of fixed charges causing a decrease in osmotic pre-stress. In this period it is also seen that fractures arise virtually independent of loading. An example of a patent crack is given by figure 1b. Wognum and al. [5] showed by a numerical model that while the global stress decreases, the stress at the crack tip increases. This is multi-scale by nature.



a) b)

Figure 1: *a) The IVD is situated in the spine between two vertebrae. b) Macro fracture in an intervertebral disc (courtesy of T. Videman).*

In this work the numerical framework is elaborated and crack propagation is introduced. Since the cracks are discrete, a discrete FE method is used based on the Partition of Unity principle. [1]. This is applied on Lanir's model for biphasic osmotically swelling media [3], which assumes immediate equilibrium and incompressible constituents. The displacements are treated like in solid fracture mechanics [4] by the introduction of a displacement jump.
For the fluid part firstly a jump in chemical potential is introduced, where the jump approximates a strong gradient. The implementation has been checked partly by analytical solution for pure shear mode without propagation. [2] Since a jump in chemical potential is physically infeasible the modeling is improved by introducing a weak discontinuity for the chemical potential. In both cases mass balance at the crack is introduced as boundary conditions. An example of calculated delamination is figure 2.

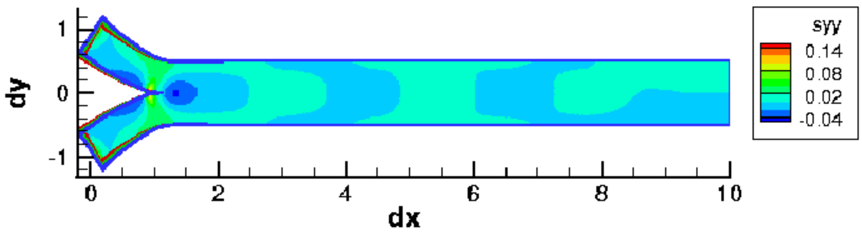


Figure 2: *Calculated stress distribution during delamination of a porous medium (small strains at crack-tip). Growth takes place.*

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