# Supplementary Material

1 FINITE ELEMENT SOURCE CODE

Source code and input files: Source code and three exemplary input files for cyclic loading, compression relaxation and indentation tests used to obtain the results presented in the main text. The `deal.ii` code provided here is an extension of the one made available by Comellas et al. 2020.

2 SUPPLEMENTARY RESULTS FIGURE

Fluid may locally flow outwards when overall fluid is entering the sample (see Figure 4, bottom left), as observed in Figure **??**.
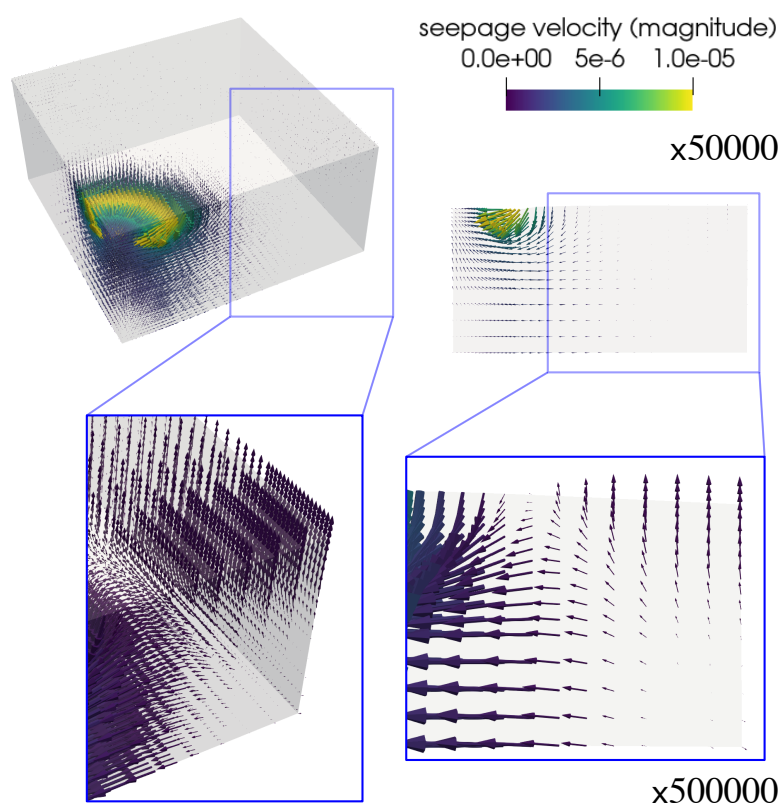
Figure S1. Finite element results showing the seepage velocity for an indentation test with an indentation depth of $50\,\mu$m at $t = 14\,$s for $\mu_\infty^0 = 0.32\,$kPa, $\mu_1 = 8.4\,$kPa, $\alpha = -8$, $\eta = 14\,$kPa·s and $K_0 = 10^{-10}\,$mm^2. Results are shown for the whole sample and for a vertical cross-section. They demonstrate that even when overall fluid is entering the sample (see Figure 4, bottom left), there can be fluid flowing outwards locally. The depicted arrows are sized proportional to the magnitude of the seepage velocity, given in mm/s, scaled by the factor indicated above the main images and below the insets.

3 FINITE ELEMENT VIDEO RESULTS

3.1 Videos for Figure 5

Finite element results showing the seepage velocity for a compression relaxation test up to 15 % strain over time for $\mu_\infty^0 = 0.32\,\text{kPa}$, $\mu_1^0 = 8.4\,\text{kPa}$, $\alpha = -8$, $\eta = 14\,\text{kPa} \cdot \text{s}$ and different initial intrinsic permeabilities. The depicted arrows are sized proportional to the magnitude of the seepage velocity, given in mm/s, scaled by the factor indicated in the file name. The complete simulated sample (right) and a vertical plane of said sample are shown for the three permeabilities, indicated in the file names.

- Video1_StressRelax_alpha-8_mu1-80_E-08_x600.mp4
- Video2_StressRelax_alpha-8_mu1-80_E-10_x5000.mp4
- Video3_StressRelax_alpha-8_mu1-80_E-12_x200000.mp4

3.2 Videos for Figure 6

Finite element results showing the seepage velocity for an indentation test with an indentation depth of $50\,\mu\text{m}$ over time for $\mu_\infty^0 = 0.32\,\text{kPa}$, $\mu_1 = 8.4\,\text{kPa}$, $\alpha = -8$, $\eta = 14\,\text{kPa} \cdot \text{s}$ and different initial intrinsic permeabilities. Results are shown for a vertical cross-section and the depicted arrows are sized proportional to the magnitude of the seepage velocity, given in mm/s, scaled by the factor indicated in the file name. The three permeabilities are indicated in the file names.

- Video4_FlatPunch_alpha-8_mu1-80_E-08_slice_displ_x10000.mp4
- Video5_FlatPunch_alpha-8_mu1-80_E-10_slice_displ_x20000.mp4
- Video6_FlatPunch_alpha-8_mu1-80_E-12_slice_displ_x200000.mp4

3.3 Videos for Figures 9 and 10

Finite element results for a compression relaxation test up to 15 % strain over time for $\mu_\infty^0 = 0.32\,\text{kPa}$, $\mu_1 = 8.4\,\text{kPa}$, $\eta = 14\,\text{kPa} \cdot \text{s}$ and different nonlinear Ogden parameters as well as initial intrinsic permeabilities. Results are shown for a vertical cross-section and include (left to right, top to bottom) the vertical component of the total Cauchy stress (Pa), vertical component of the "extra" Cauchy stress (Pa), the solid volume fraction, the viscous dissipation rate (nJ/s) , the vertical displacement loading curve (mm), and fluid pore pressure (Pa), seepage velocity (mm/s) and porous dissipation (nJ/s). The depicted arrows representing the seepage velocity are sized proportional to its magnitude scaled by the factor indicated in the file name. The nonlinear Ogden parameter and initial intrinsic permeability are also indicated in the file name.

- Video7_StressRelax_alpha-5_mu1-80_E-08_x800_full.mp4
- Video8_StressRelax_alpha-5_mu1-80_E-10_x5000_full.mp4
- Video9_StressRelax_alpha-5_mu1-80_E-12_x200000_full.mp4
- Video10_StressRelax_alpha-8_mu1-80_E-08_x800_full.mp4
- Video11_StressRelax_alpha-8_mu1-80_E-10_x5000_full.mp4
- Video12_StressRelax_alpha-8_mu1-80_E-12_x200000_full.mp4
- Video13_StressRelax_alpha-13_mu1-80_E-08_x800_full.mp4
- Video14_StressRelax_alpha-13_mu1-80_E-10_x5000_full.mp4
- Video15_StressRelax_alpha-13_mu1-80_E-12_x200000_full.mp4