Experimental validation of the numerical model for the crack propagation in poroelastic media

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Introduction

Numerical simulations of the crack propagation in homogeneous poroelastic media reveal a stepwise propagation for both Mode I and Mode II [1]. The tracing of the simulated flow across the crack and the simulated pressure before and after a propagation step demonstrates that a consolidation process occurs between each step of propagation.

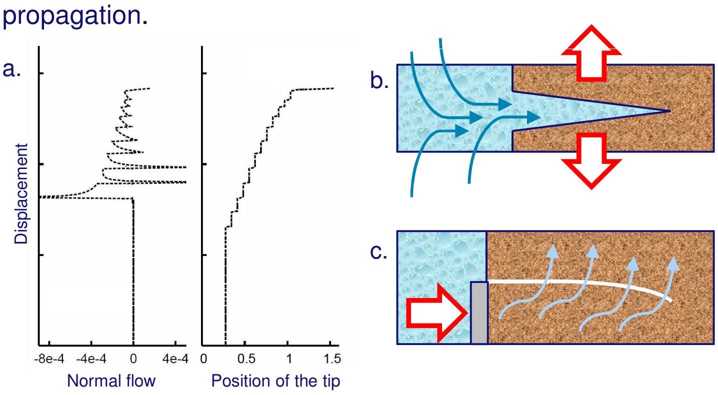


Fig. 1: a. Crack growth causes a peak in flow. b. In Mode I the fluid is sucked inside the crack. c. In Mode II the fluid flows through the crack.

Aim of the study

Using hydro-gels we want to demonstrate that the stepwise propagation behavior is a physical process and not only a numerical artifact.

Results: Mode II

From the preliminary tests it was possible to distinguish 4 different main phases (see Fig. 2): 1) linear behavior and formation of a shear band (yellow line), 2) first macro crack, 3) growth of a dry area under the piston, 4) failure of the sample.

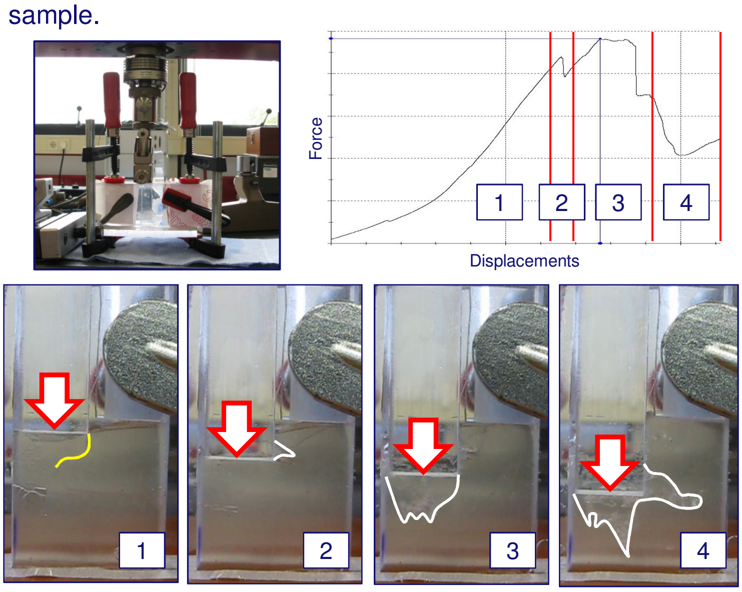


Fig. 2: Top left: set up of the experiment for Mode II. Top right and bottom: the four different behaviors observed.

Results: Mode I

When the crack opens there is a change of volume of the gel in an area next to the tip (Fig. 4b-d) due to a softening and visco-elastic behavior. Then the crack propagates till the fictitious tip (Fig. 4c-e, hardening behavior) and repeats this stepwise pattern till failure. This behavior has been observed for different loads and different stiffness of the hydrogel.

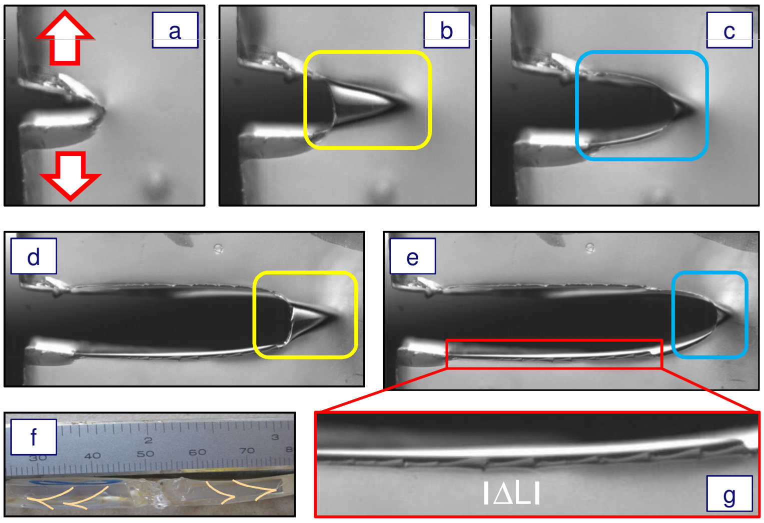


Fig. 4: Stepwise scheme for Mode I. a. Opening of the crack, b.-d. Formation of the plastic zone (softening), c.-e. Step till the fictitious tip (hardening), f. Shape of the plastic zone, g. Steps on the lip of the discontinuity.

Discussion

The results for the Mode II show interesting analogies with the consolidation process of the soil under a foundation plinth [2].
For Mode I it has been found that the time (Δt) of the propagation step (ΔL) is well approximated by the 1D Terzaghi's consolidation law [2].

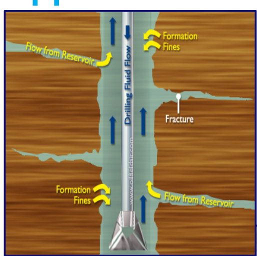
$k = 0{,}28 \cdot 10^{-3}\ \mathrm{mm^4/Ns}$, $E = 2\ \mathrm{Mpa} = 2 \cdot 10^4\ \mathrm{N/mm^2}$, $\Delta L = 0{,}92\ \mathrm{mm}$

$$\Delta t = \frac{(\Delta L)^2}{k\ E}$$

	Δt [s]
Numerical result	0,16
Experimental result	0,24

Applications

Oil companies are interested in new ways to extract oil. For this, it is important to understand the physical behavior of crack propagation. Moreover, confirming the existence of the stepwise motion may help to understand the connection between slow slip quakes and deep tremors.



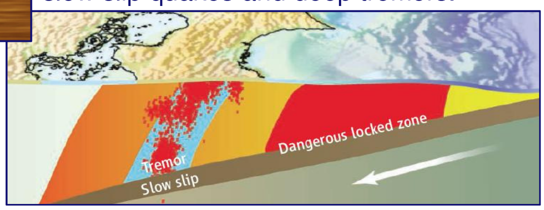


Fig. 5: Top: Cracks are forced to propagate from the borehole to the reservoir. Right: perspective view of the subduction of the Philippine Sea Plate under southwest Japan [3].

/ Orthopaedic biomechanics

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