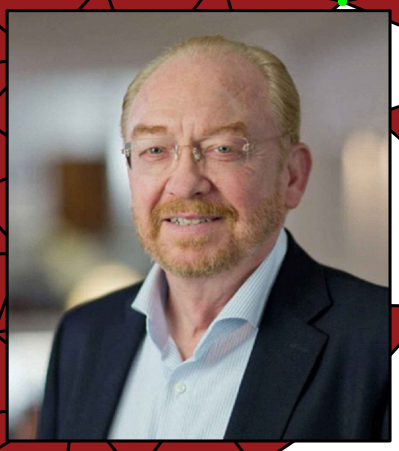

DIPARTIMENTO DI INGEGNERIA CIVILE, EDILE E AMBIENTALE
DEPARTMENT OF CIVIL, ENVIRONMENTAL AND ARCHITECTURAL ENGINEERING

Seminar

June 12 2024

Archivio Antico, Palazzo Bo, Padova

14.00	Opening
14.30	**Fracturing of fully and partially saturated porous media based on a TPM-Phase-field approach** *Prof. Emeritus Wolfgang Ehlers, Institute of Applied Mechanics, University of Stuttgart, Germany*
16.30	Closure

https://maps.app.goo.gl/DtSiZDLXuEL1hrkd9

Fracturing of fully and partially saturated porous media based on a TPM-Phase-field approach

Wolfgang Ehlers, Institute of Applied Mechanics, University of Stuttgart, Germany

The well-known phase-field approach applied to fracturing solids has recently been embedded in the Theory of Porous Media for the description of dynamic hydraulic fracturing scenarios based on fully saturated porous media. This method has further been enhanced by the introduction of a crack-opening indicator to distinguish between open and closed cracks accompanied by a switch between Darcy-type and Navier-Stokes-type flow situations in the unbroken porous domain and in fully broken areas. Based on these achievements, the presentation extends the challenging matter of fully saturated media by the introduction of partially saturated scenarios, where the pore space contains both a liquid, such as water or oil, and a pore gas, such as air or natural gas. Proceeding from the Theory of Porous Media, the setup of the model is based on first principles of continuum mechanics, while the numerical study proceeds from the Finite-Element Method, where coupled problems of fracturing multi-component and multi-phasic media are treated by a monolithic solution strategy provided by a solver for coupled problems. By use of this procedure, it can be shown by comparison of fully and partially saturated porous media that the existence of pore gas slows down the fracture evolution. It is furthermore pointed out that the existence of closed pre-cracks combined with external loads does not only lead to opening and evolving fractures, but also to fractures that do not open as a result of compressive boundary conditions.

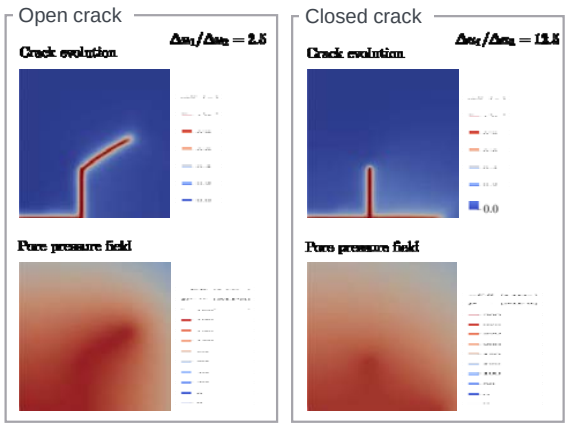

Figure: Crack evolution in a pre-cracked area at different confining pressures.

To set an example for the above, the left-hand figure exhibits a fracture scenario, where a fracking liquid is pressed into a horizonal notch at the bottom of the displayed partially saturated domain with a vertical pre-crack. Depending on the compressive stresses yielding a ratio of 2.5 or 12.5 of the horizontal versus the vertical displacement, the pre-crack is either open or closed. In both cases, the fracking fluid extends the notch towards a horizontal fracture that reaches the pre-crack. Then, depending on the compression ratio, the fracking fluid either enters the pre-crack and furthermore builds up a wing-like fracture (left scenario) or it continues straight through the pre-crack towards the right edge of the domain (right scenario). In the left case, the displacement ratio leaves the pre-crack open, while it closes it in the right case. The lower figures display the corresponding pore pressures combining the liquid and the gaseous parts of the local pore content.

Directly allocatable literature:

W. Ehlers & C. Luo: A phase-field approach embedded in the Theory of Porous Media for the description of dynamic hydraulic fracturing. Computer Methods in Applied Mechanics and Engineering, 315 (2017), 348-368.

W. Ehlers & C. Luo: A phase-field approach embedded in the Theory of Porous Media for the description of dynamic hydraulic fracturing. Part II: The crack-opening indicator. Computer Methods in Applied Mechanics and Engineering 341 (2018), 429-442.

A. Sonntag, A. Wagner & W. Ehlers: Dynamic hydraulic fracturing in partially saturated porous media. Computer Methods in Applied Mechanics and Engineering 414 (2023) 116121, 34 pages.