Role of fluid flow during crack propagation in porous media

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Introduction

We want to investigate under which conditions a fracture can initiate or propagate in the IVD (Figure 1) and, in general, to understand the role that fluid flow has during crack propagation.

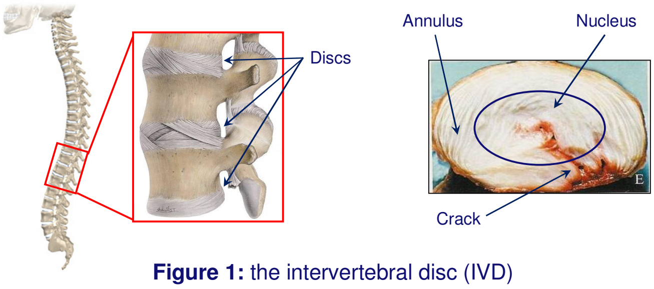


Figure 1: the intervertebral disc (IVD)

Using standard finite element formulations the mass balance is fulfilled only globally (Figure 2). Fluid and solid are strongly coupled, so fluid flow has to be evaluated locally to predict deformations and stresses and with that propagation. Using a mixed formulation this problem is tackled.

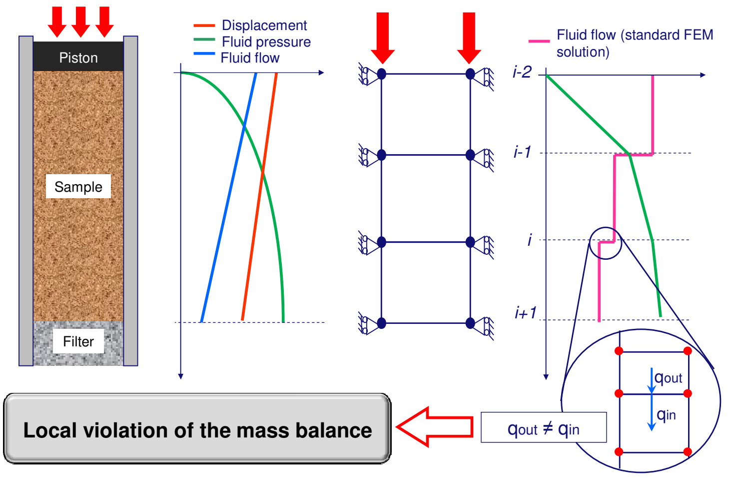


Figure 2: 1D consolidation problem. Left: exact solution. Right: approximated solution with standard finite element.

Objective

To develop a finite element formulation that estimates exactly the fluid flow and permits to put crack in an arbitrary position in the model.

Method

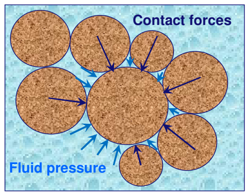
Porous media are modeled by Lanir's biphasic theory [5]. The governing equations are: momentum balance (with a constitutive linear stress-strain relation) and mass balance (with the Darcy's law equation) [2]. The idea behind the hybridization technique is to introduce a Lagrange multipliers λ to enforce the continuity of the normal component of the fluid flow [4].

Momentum equation

$$\vec{\nabla}\cdot\sigma = \vec{0} \qquad \sigma = \sigma_e - pI$$

Mass balance equation

$$\vec{\nabla}\cdot\vec{v} + \vec{\nabla}\cdot\vec{q} = 0 \qquad \vec{q} = -K\vec{\nabla}p$$



Fluid flow "forced" condition

$$\lambda(q_{IN} - q_{OUT})\cdot\vec{n} = f_f \qquad \lambda = \text{Lagrange multiplier}$$

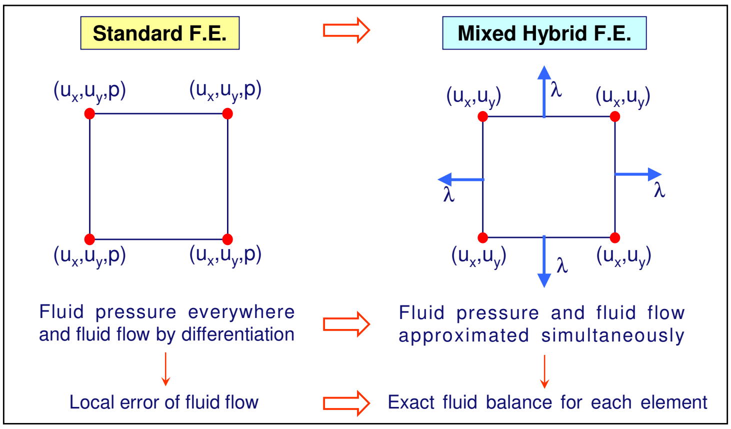
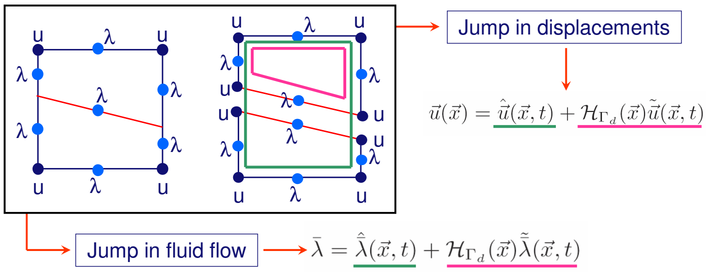


Figure 3: differences between standard and mixed hybrid FEM.

The mixed hybrid formulation is implemented with the Partition of Unity method. Using this method the cracks can be placed anywhere in the model and can propagate in any arbitrary direction without remeshing [1,3].



$$\vec{u}(\vec{x}) = \hat{\vec{u}}(\vec{x},t) + \mathcal{H}_{\Gamma_d}(\vec{x})\tilde{\vec{u}}(\vec{x},t)$$

$$\vec{\lambda} = \hat{\vec{\lambda}}(\vec{x},t) + \mathcal{H}_{\Gamma_d}(\vec{x})\tilde{\vec{\lambda}}(\vec{x},t)$$

Figure 4: discretization with the Partition of Unity method (PUM)

Results

We develop a mixed hybrid formulation with discontinuity for 2D poroelasticity with discontinuity. Implementing this formulation in C++ we will be able to understand the role of the fluid during crack propagation in porous materials.

References

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