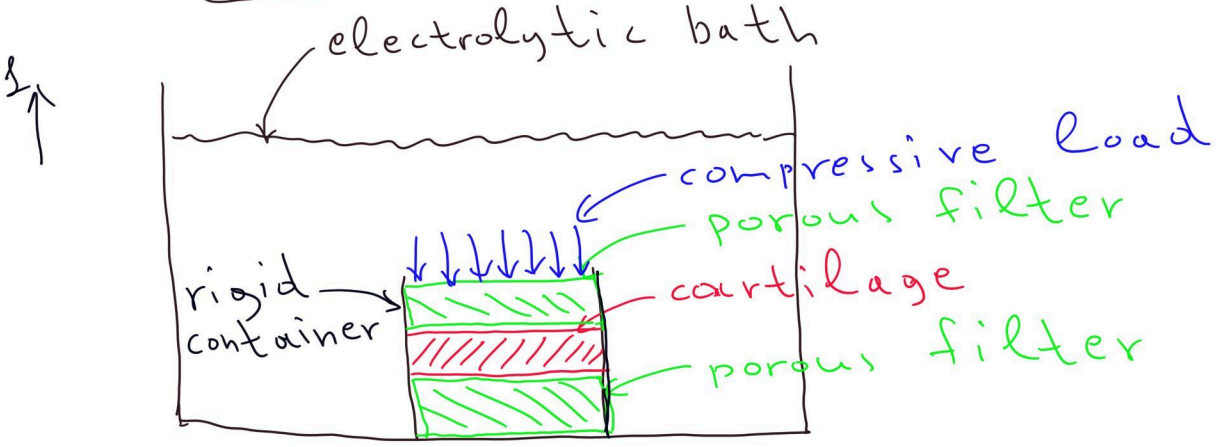
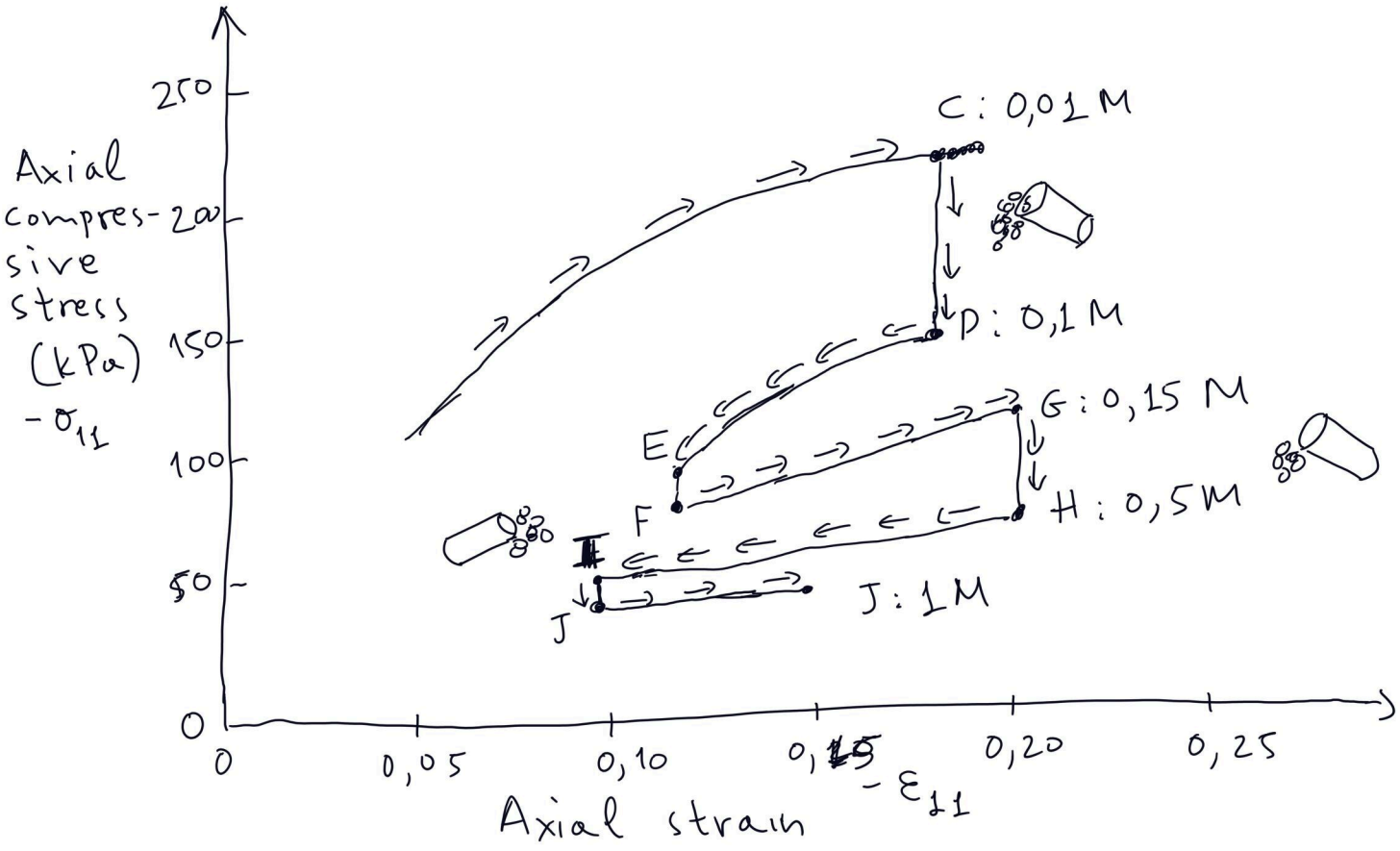
Confined compression experiment on bovive articular cartilage



The experiment consists of alternate compressive loading, followed by change in the chemical composition of the bath by adding NaCl. Some time is left for the cartilage sample to find equilibium. The strain is kept constant after each addition of the salt.

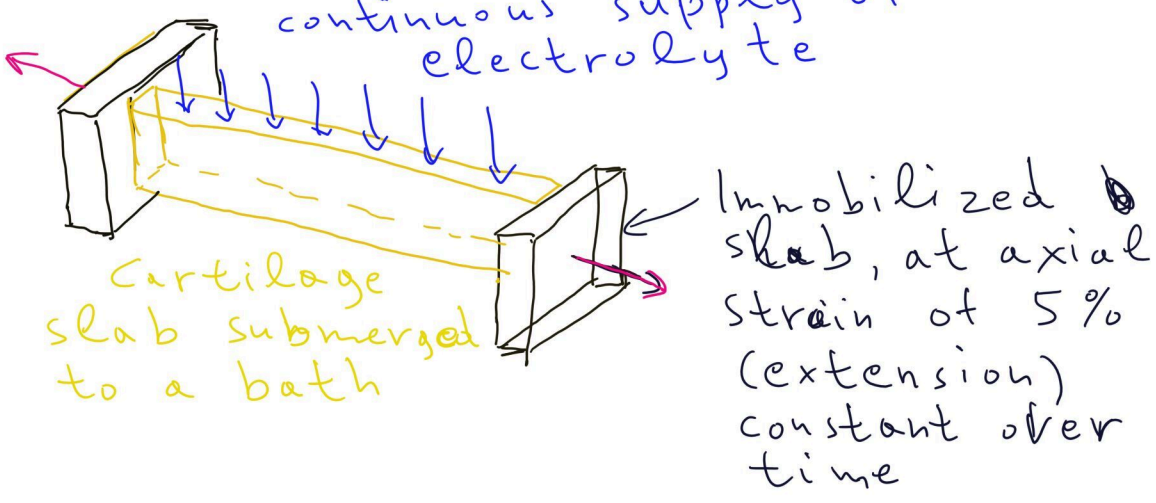


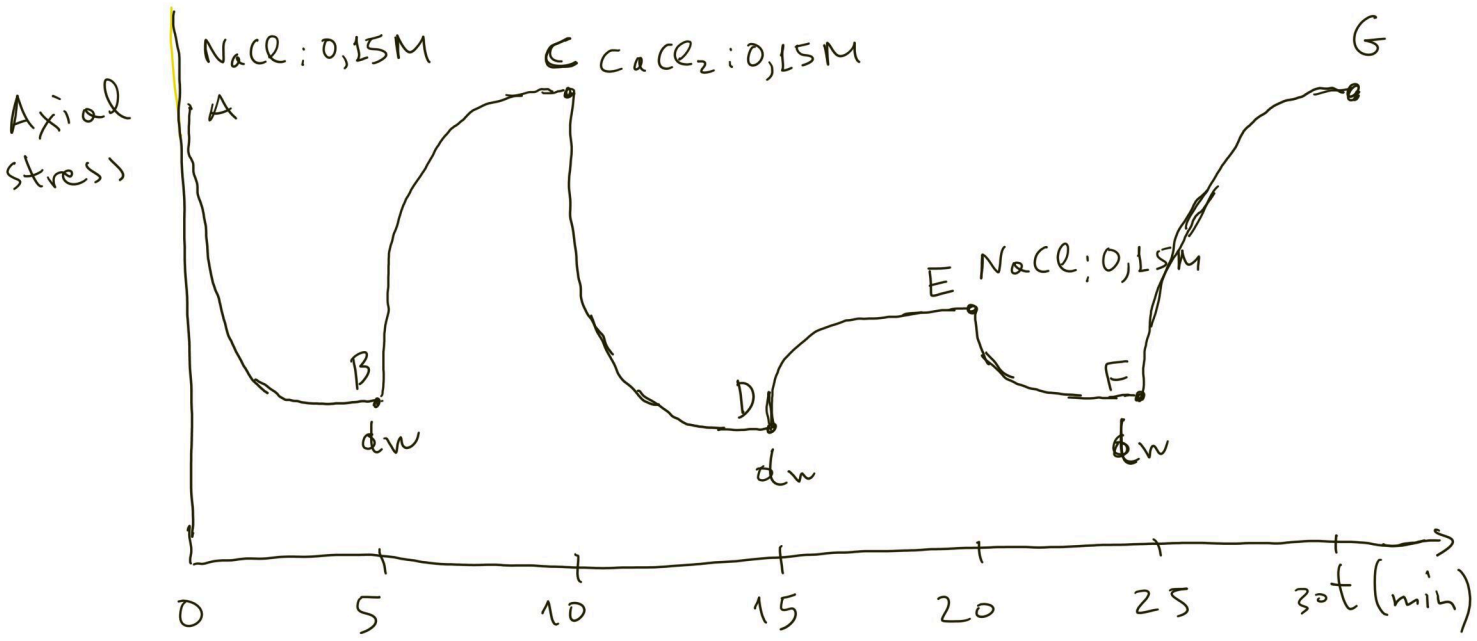
Conclusions:

1) Addition of the salt, under constant strain, leads to the reduction of the stresses (chemical loading). The positive ions that are added, reduce (shied) the repulsive forces between the negatively charged PG's.

2) The slope of the stress-strain curve is also reduced when the salt concentration is increased. The apparent moduli are lower at large salt concentrations, since the cartilage becomes more compliant.

Variation of the axial stress along a slab of cartilage subjected to constant axial strain, due to chemical loading



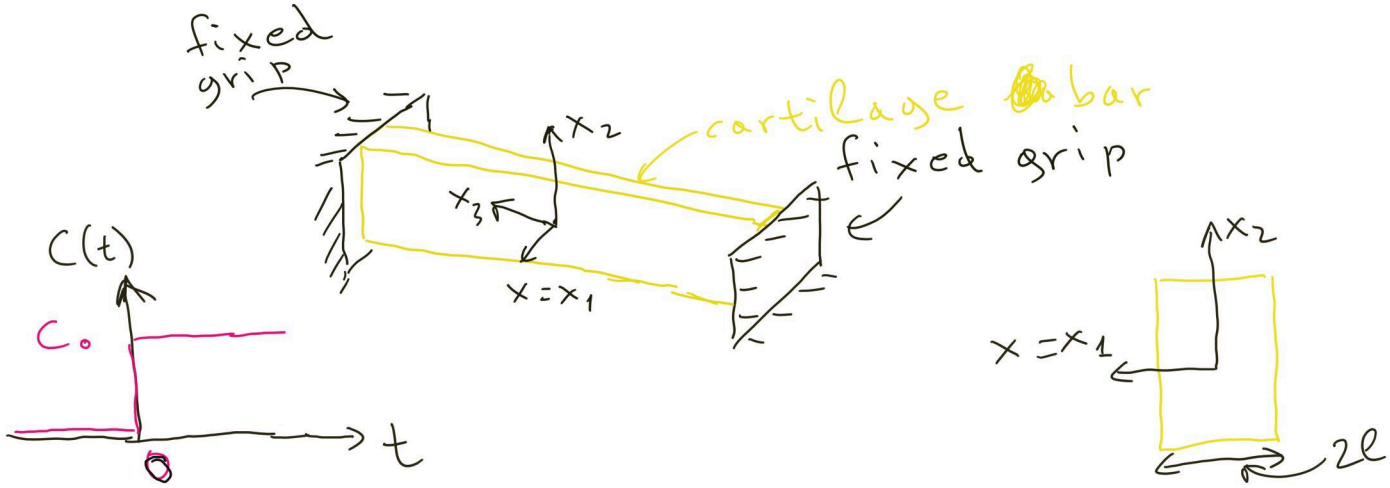


dw: distilled water

we have to add NaCl, at the last stage of chemical loading, in order to recover at point G, the initial stress at point A. This was not achieved after adding $CaCl_2$.

Changes in PH also may alter the mechanical response of cartilage.

Modeling of the mechanical response of cartilage, due to changes in the chemical composition of the bath



Essentially the only non-zero displacement is along the x_1 direction, and is denoted by $u_s(x,t)$. s stands for the solid phase. We treat the cartilage as poroelastic medium.
For points in the middle of the height along the x_2-direction, we can consider a 1-dimensional problem along the $x = x_1$ direction

Equations to be satisfied for the poroelastic cartilage with incompressible costituents:

Mass balance of the poroelastic medium: $\operatorname{div}(n^s \vec{v}_s + n^w \vec{v}_w) = 0$ (1)

n^s, n^w: volume fractions of solid s and water w, in the poroelastic medium

$\vec{v}_s, \vec{v}_w$: velocities of the solid and fluid phases

Mass balance of the chemical: $\frac{\partial C}{\partial t} + \operatorname{div} \vec{J} = 0$ (2)

C: concentration of the chemical

$\vec{J}$: is the flux of the chemical in and out of the poroelastic medium

Balance of momentum:

1) Of the solid phase:

$$\operatorname{div} \underset{\sim}{\sigma}^s + k_{sd}(\vec{v}_w - \vec{v}_s) - p_w \vec{\nabla} n^w = 0 \quad (3)$$

k_{sd}: Stokes drad constant

p_w: intrinsic fluid pressure

2) Of the fluid phase

$$\operatorname{div} \underset{\sim}{\sigma}^w - k_{sd}(\vec{v}_w - \vec{v}_s) + p_w \vec{\nabla} n^w = 0 \quad (4)$$

σ^w ; σ^s : stress tensor for the fluid and solid phases

The total stress for the poroelastic medium, is

$$\underset{\sim}{\sigma} = \underset{\sim}{\sigma}' + \underset{\sim}{\sigma}^w \quad (5)$$

where

$$\underset{\sim}{\sigma}^w = -n^w p_w \underset{\sim}{I} \quad (6)$$

with $\underset{\sim}{I}$ being the unit 2nd order tensor

Relation between the flux $\vec{J}$ of the chemical and the concentration C of the chemical :

$$\vec{J} = -D \vec{\nabla} C \quad (7) \quad \text{(Fick's law)}$$

D : coefficient of molecular diffusion

It is also known that

$$\vec{J} = C(\vec{v}_c - \vec{v}_w) \quad (8)$$

where

$\vec{v}_c$: is the velocity of the chemical

From (7) and (8), we write the decoupled equation of mass balance of the chemical

$$\frac{\partial C}{\partial t} - D \frac{\partial^2 C}{\partial x^2} = 0 \quad (9)$$