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R.W. Roos, J.M. Huyghe, F.P.T. Baaijens
Eindhoven University of Technology, Department of Biomedical Engineering

Introduction

Cartilage is a material with high water content and surprisingly high mechanical strength. It is an example of a porous ionized material. It can be described as a mixture of proteoglycan supra-molecules with a water solution, enmeshed in a resilient collagen network. An odd property of cartilage is its strong swelling propensity due to Donnan osmosis. The resulting prestress in the collagen network contributes to the shear stiffness.

Free energy function

The effective stress in a material is the derivative $\frac{\delta W}{\delta \epsilon}$ of the free energy function W to the strain (ϵ). This function depends on concentration- and a strain. On cartilage, Grodzinsky [1] measured under constant volume that shear stiffness depends on salt concentration. This implies that mixed terms in concentration and strain appear in the free energy:

$$W = W(c^+, c^-) + W(\epsilon) + W(c^+, c^-, \epsilon) \tag{1}$$

This extra term is either caused by the sensitivity of the collagen network to its osmotic environment, or to Maxwell stresses around the proteoglycan chains. In this study we want to discriminate the contribution of these two sources.

Objectives

- Quantify the extra term in an ionized porous medium without collagen: synthetic hydrogel.

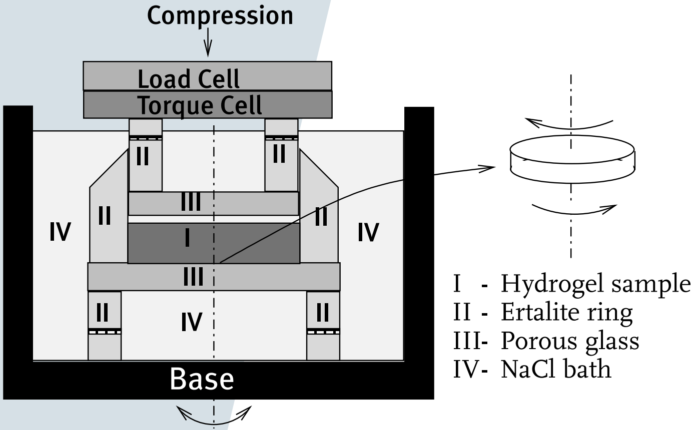

Figure 1 *A hydrogel disc is placed in the center of the Plexiglas base chamber filled with NaCl solution at constant temperature. The plastic ring and the porous glass plates prevent the disc from swelling. While the torque cell of the draw-torsion bench (MTS) applies a torque on the disc, the vertical relative angular displacement and the axial force are measured.*

Experiment

A cylindrical hydrogel disc is put inside a plastic ring, between two porous glass plates (Fig. 1), fixed between a draw-torsion bench. The sample is in equilibrium with a salt solution. For different salt concentrations of the liquid, the torque-rotation relationship is compared.

Results

Although swelling was not completely prevented, initial results of the experiments are plotted in Figure 2. This graph shows that the shear stiffness varies significantly with the external salt concentration.

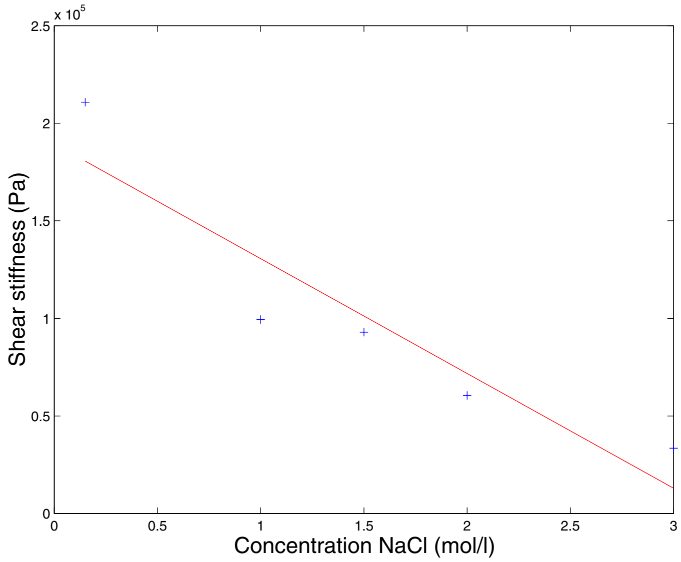

Figure 2 *At constant volume, the shear modulus of hydrogel decreases with increasing external salt concentration.*

Discussion

The results suggest that hydrogel displays chemical-mechanical interaction, indicating that Maxwell stresses might be an important source of chemical- mechanical interaction in cartilage under shear.

Acknowledgement

This research is supported by the technology foundation STW, applied science division of NWO, and the technology programs of the Ministry of Economics.

References:

[1] J. Moonsoo and A.J. Grodzinsky: Effect of Electrostatic Interactions between Glycosaminoglycans on the Shear Stiffness of Cartilage: A Molecular Model and Experiments. *Macromolecules*, 2001, 34, 8330-8339.

PO Box 513, 5600 MB Eindhoven, the Netherlands