FAKULTA APLIKOVANÝCH VĚD ZÁPADOČESKÉ UNIVERZITY V PLZNI
STUDENTSKÁ VĚDECKÁ KONFERENCE 2013

Cortical bone tissue modelled as double-porous medium: Parameter study

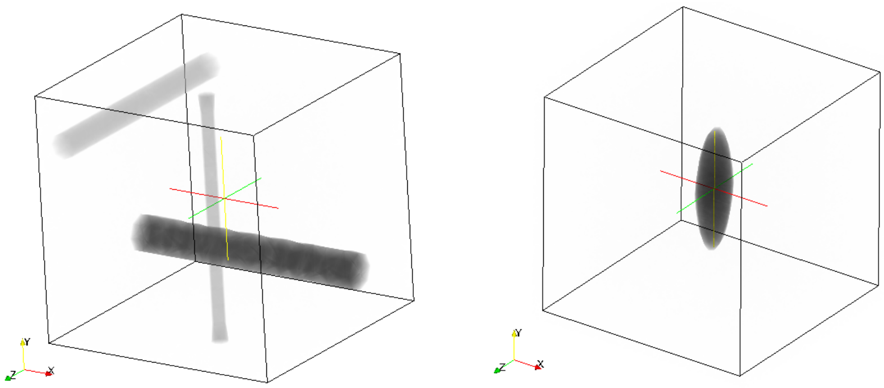
Jana Turjanicová[1], Eduard Rohan[2], Salah Naili[3], Robert Cimrman[4]

1 Inroduction

It is possible to model a cortical bone tissue as a poroelastic material with periodic structure represented at two, microscopic and mesoscopic levels. On those levels the bone matrix is perturbed by lacunar-canalicular network causing changes in mechanical properties on higher levels.

In this note, the pores on microscopic (α) level are modeled as three orthogonal channels which represent canaliculi. On mesoscopic (β) level the porosity is caused by lacunae with approximately ellipsoidal shape (Fig.1). The pores of micro- and mesoscopic scale are connected creating one system of connected network filled with compressible fluid.

We apply the method of asymptotic homogenization to upscale a microscopic problem of fluid-structure interaction. Obtained homogenized coefficients describe material properties of the poroelastic matrix fractured by fluid-filled pores whose geometry is described at the mesoscopic level. The second-level upscaling provides homogenized poroelastic coefficients relevant on the macroscopic scale, see [2].

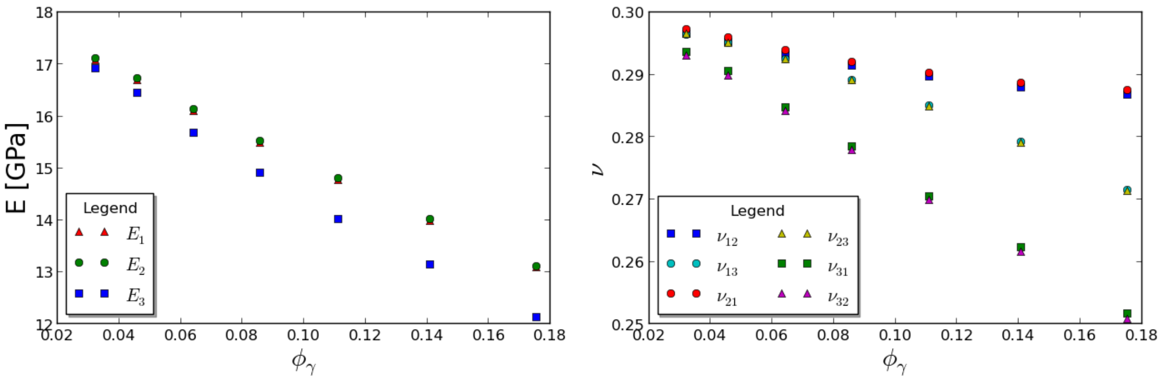


Obrázek 1: Left – geometry on α-level; Right – geometry on $\beta-$level

[1] Bc., Department of Mechanics, Faculty of Applied Sciences, University of West Bohemia, e-mail: turjani@students.zcu.cz
[2] Prof. Dr. Ing. DSc., Dept. of Mechanics, New Technologies for Information Society – the Center of Excellence, Univerzitní 8, Plzeň, e-mail: rohan@kme.zcu.cz
[3] Prof., Laboratoir modélisation et simulation multi échelle, Université Paris-est, 61 avenue du Général de Gaulle, Créteil cedex, France, e-mail: salah.naili@univ-paris-est.fr
[4] Ing. Ph.D., New Technologies Reasearch Centre, University of West Bohemia in Pilsen, Univerzitní 8, Plzeň, e-mail: cimrman3@ntc.zcu.cz

2 Parameter study

A parameter study was performed; the porosity on $\alpha-$level was changed by increasing the x-direction canaliculi diameter r_x. The y-direction and z-direction was kept constant. The structure on $\alpha-$level was oriented in x-axis direction. Logicaly, this caused a change of the poroelastic properties on the macroscopic level. The dependency of Young's modulus and Poisson ration on ϕ_γ porosity, where $\phi_\gamma = \phi_\alpha + \phi_\beta - \phi_\alpha\phi_\beta$, is shown in the Fig.2. It can bee seen that using the isotropic material considered at the microscopic level we an orthotropic material has been obtained on the macroscopic level, whose anisotropy increases with the change of porosity.



Obrázek 2: The dependency of poroelastic properties on porosity change caused by increase of r_x: Left – Young's modulus; Right – Poisson ratio

3 Conclusion

The presented homogenized model can be used for modeling cortical bone tissue. Various geometries representing fluid saturated porous structure related to microscopic and mesoscopic level were considerd. The influence of changing one of the $\alpha-$level geometric parameters on the homogenized coeficients, related to macroscopic level, was studied. This modeling approach is proposed as an advanced hierarchical description of poroelastic properties of the cortical bone tissue, but a wide range of further applications is expected.

Poděkování

The work has been elaborated with the support of project SGS-2013-026 and in part by the proejct IGA, NT-13326.

Literatura

[1] Hellmich, C. at al. Mineral-collagen Interactions in Elasticity of Bone Ultrastructure - a Continuum Micromechanic Approach. *European Journal of Mechanics and Solids*. 2004, XXIII, Nr. 5, pp. 783-810. ISSN: 0997-7538.

[2] Rohan, E. at al. Hierarchical Homogenization of Fluid Saturated Porous Solid with Multiple Porosity Scales. *C. R. Mecanique*. 2012, CCCXL, Nr. 10, pp. 688-694. ISSN: 1631-0721.

[3] Yoon, Y.J., Cowin, S. C. An Estimate of Anisotropic Poroelastic Constants of an Osteon. *Biomechan Model Mechanobiol*. 2008, VII, Nr. 1, pp. 13-26. ISSN: 1617-7959.