21st International Conference **ENGINEERING MECHANICS 2015**
Svratka, Czech Republic, May 11 –14, 2015
Paper **#108**, **pp. 140–141**

Fresh Concrete Flow through Reinforcing Bars using Homogenization Approach

Filip Kolařík[a], Bořek Patzák[b], Jan Zeman[c]

Department of Mechanics, Faculty of Civil Engineering, CTU in Prague,
Thákurova 7, 166 27, Prague, CZ

[a]filip.kolarik@fsv.cvut.cz, [b]borek.patzak@fsv.cvut.cz, [c]zemanj@cml.fsv.cvut.cz

Keywords: flow, fresh concrete, homogenization, Variational Multiscale Method

Abstract: Mechanical performance, surface quality, and durability of concrete structures is to a significant extent influenced by the casting process. Thus, predicting the flow behavior of concrete in the formwork, and identification of critical zones, has become an important part of the design procedure of concrete mixes. The aim of the present contribution is to model the effect of reinforcing bars in the single-fluid approach by means of computational homogenization. Flow in parts of the domain without any reinforcement is governed by Stokes equations. In areas with the reinforcement, governing equation is Darcy law, which is obtained by averaging the velocity on the microscale.

Introduction

The modeling of fresh concrete casting is an important issue for construction industry but also very interesting problem from the computational point of view. One of the main issues represents the effect of reinforcement on the flow of fresh concrete. In the case of traditional reinforcement, the reinforcing bars represent obstacles to the flow of fresh concrete, see [1] for wider discussion. Direct modeling of each reinforcing bar individually is theoretically possible, but usually not affordable, as the mesh would have to be locally very fine and simulations too time-consuming. Natural way how to avoid this difficulty is to consider the reinforced area as a porous medium and employ multiscale approach. In this work, we follow procedure introduced in paper [2], where so-called variational multiscale method is combined with usual separation of scales.

Description of the problem

Fresh concrete is in our approach considered as a single homogeneous fluid with Bingham model as a constitutive relation. For the time being, we restrict ourselves to steady state flow. This can be justified by the fact that flow of the concrete is slow enough so the inertia effects are negligible. Following methods introduced in [2], we employed variational multiscale method. After formulation of the Stokes problem in the weak sense, the trial and test functions corresponding to pressure are decomposed into subscale and macroscale parts. According to that decomposition, standard weakly formulated Stokes problem splits into subscale and macroscale problem as well. The macroscale problem represents continuity equation, while the subscale remains the Stokes problem. Next step consists in introducing intrinsic averages and in decomposing the whole domain into union of non-overlapping subdomains (referred to as RVE's). Averaging applied to the macroscale problem leads to (non-linear) Darcy law, which relates macroscale effective seepage velocity field with pressure gradient in the pores. The seepage velocity is obtained by averaging velocity over the RVE, where the flow is driven by macroscopic pressure gradient. The whole problem is solved using FEM, linear approximations for both velocities and pressures have been used. Numerical scheme for both the Stokes and the Darcy problem was stabilized by Variational Multiscale Method proposed in [3] due to Babuška-Brezzi condition.

Numerical examples

The solution obtained by homogenization technique is compared with direct simulation, where the reinforcement is modeled explicitly. The results are shown in Fig. 1.

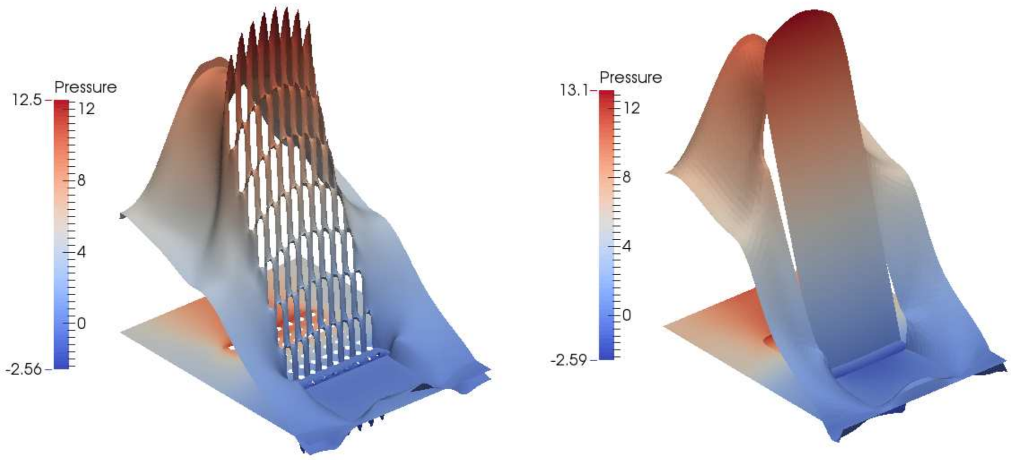

Fig. 1: Flow through the reinforced area - Comparison of fully resolved solution (on the left) and homogenized solution (on the right).

Summary

In this paper, we showed homogenization approach to modeling of the influence of reinforcement to the flow of fresh concrete. The model was validated against direct numerical simulation and results are in a very good agreement.

Acknowledgement: The research was carried out within the the project SGS15/031/OHK1/1T/11 — Advanced numerical modeling in mechanics of structures and materials and the authors gratefully acknowledge the financial contribution of the MŠMT ČR.

References

[1] N. Roussel et al., Computational modeling of concrete flow: general overview Cement and Concrete Research 37 (2007) 1298–1307.

[2] C. Sandström, Fredrik Larsson, Variationally consistent homogenization of Stokes flow in porous media Journal for Multiscale Computational Engineering 11 (2013) 117–183.

[3] T. J. R. Hughes et al., The variational multiscale method - a paradigm for computational mechanics Computer Methods in Applied Mechanics and Engineering 166 (1998) 3–24.