Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7119

THREE-DIMENSIONAL DYNAMIC ANALYSIS OF A THREE-PHASE POROELASTIC MEDIUM USING THE TIME-DOMAIN BOUNDARY ELEMENT METHOD

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ABSTRACT

The paper presents the results of numerically modeling the dynamics of a partially saturated porous medium. The mathematical model is based on using Terzhagi's principle of effective stresses and on representing the porous medium as a combination of three phases - an elastic skeleton, a liquid and a gas. The equations of motion are written in Laplace forms for five unknown functions - displacement of the skeleton, pore pressure of the liquid and pore pressure of the gas. The boundary-value problem is solved using the boundary integral equation method with a direct approach. The boundary-element methodology is implemented, based on a regularized boundary integral equation. Generalized boundary elements are used. A solution in time domain is obtained using the stepped method of the numerical inversion of Laplace transform. Dynamic responses of a poroelastic prismatic body loaded by a force in the form of Heaviside function in time domain are found.

Keywords: BEM, BIE, three-phase porous medium, dynamic behavior, time step method.

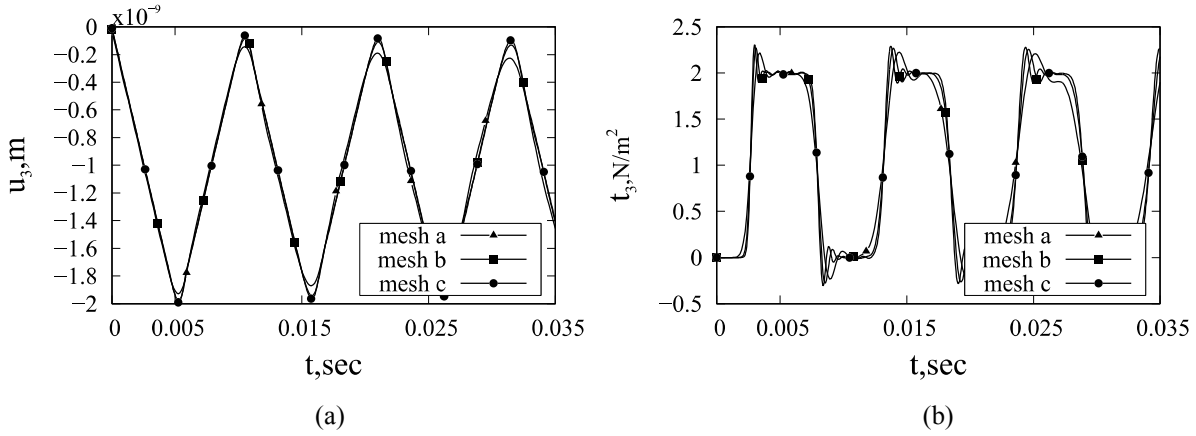
INTRODUCTION

Liquid- or gas-saturated poroelastic materials are naturally represented by soil and rock media, oil strata and biological tissues. Research results on the propagation of waves in such materials are of paramount practical importance for civil engineering and industry. Wave processes in porous media are significantly affected by the presence in the pores of one or several filling fluids, so that an elastic or viscoelastic model of the material cannot adequately evaluate the dynamic behavior of the medium. The model of a saturated poroelastic medium developed by Biot, based on the works by Terzhagi, accounts for the motion of the filling in the pores and is most often used for describing multiphase poroelastic media. In this case, the interaction of the fillings is also accounted for. In particular, when modeling a three-phase medium, the capillary pressure is additionally considered (Li, 2013). Analysis of the wave propagation in three-phase porous media using analytical methods is often possible only in certain special cases and for particular types of boundary conditions. That is why such problems are analyzed using developed numerical methods, such as the BEM (Bazhenov, 2008), (Igumnov, 2015).

RESULTS AND CONCLUSIONS

The problem of an end force acting on a 3m-long, 1m-high and 1m-wide prismatic poroelastic body, with a rigidly fixed end, is analized. Responses of displacement u_z and surface tractions t_z, caused by force $F(t)$=1 N/m^2, are observed at the loaded and the fixed ends,

respectively. The parameters of the porous material correspond to the parameters of a sandy soil. The problem was analyzed using three boundary-element grids with different degrees of spatial discretization. Two symmetry planes make it possible to analyze only a part of the grid: one quarter of grids «a», «b» and «c» consists of 14, 56 and 126 elements, respectively.



(a) (b)

Fig. 1 - Boundary-element solutions on the three different meshes for: (a) displacements; (b) tractions

The results of the analysis of the convergence for the grids used show that, with the increasing number of the elements, the boundary-element solutions for the displacement and traction acquire values close to those computed using analytical formulae (Li, 2011).

ACKNOWLEDGMENTS

This work was supported by a grant from the Government of the Russian Federation (contract No. 14.Y26.31.0031).

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