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Estimation of Effective Mechanical Properties of Linear Elastic Materials with Voids Due to Volume and Surface Defects

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Abstract : The media with voids is considered and the method of the analytical estimation of the effective mechanical properties in the theory of elastic materials with voids is proposed. The variational model of the porous media is discussed, which is based on the model of the media with fields of conserved dislocations. It is shown that this model is fully consistent with the known model of the linear elastic materials with voids. In the present work, the generalized model of the porous media is proposed in which the specific surface properties are associated with the field of defects-pores in the volume of the deformed body. Unlike typical surface elasticity model, the strain energy density of the considered model includes the special part of the surface energy with the quadratic form of the free distortion tensor. In the result, the non-classical boundary conditions take modified form of the balance equations of volume and surface stresses. The analytical approach is proposed in the present work which allows to receive the simple enough engineering estimations for effective characteristics of the media with free dilatation. In particular, the effective flexural modulus and Poisson's ratio are determined for the problem of a beam pure bending. Here, the known voids elasticity solution was expanded on the generalized model with the surface effects. Received results allow us to compare the deformed state of the porous beam with the equivalent classic beam to introduce effective bending rigidity. Obtained analytical expressions for the effective properties depend on the thickness of the beam as a parameter. It is shown that the flexural modulus of the porous beam is decreased with an increasing of its thickness and the effective Poisson's ratio of the porous beams can take negative values for the certain values of the model parameters. On the other hand, the effective shear modulus is constant under variation of all values of the non-classical model parameters. Solutions received for a beam pure bending and the hydrostatic loading of the porous media are compared. It is shown that an analytical estimation for the bulk modulus of the porous material under hydrostatic compression gives an asymptotic value for the effective bulk modulus of the porous beam in the case of beam thickness increasing. Additionally, it is shown that the scale effects appear due to the surface properties of the porous media. Obtained results allow us to offer the procedure of an experimental identification of the non-classical parameters in the theory of the linear elastic materials with voids based on the bending tests for samples with different thickness. Finally, the problem of implementation of the Saint-Venant hypothesis for the transverse stresses in the porous beam are discussed. These stresses are different from zero in the solution of the voids elasticity theory, but satisfy the integral equilibrium equations. In this work, the exact value of the introduced surface parameter was found, which provides the vanishing of the transverse stresses on the free surfaces of a beam.

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