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Dilatancy and compaction of saturated granular media

Pavel Pokatashkin (1), Andrey Karakin (1), Pyotr Kuharenko (2), and Yuri Kuharenko (2)

(1) Russian Research Institute of Geosystems, Moscow, Russian Federation (p.a.pokatashkin@gmail.com), (2) The Schmidt Institute of Physics of the Earth, Moscow, Russian Federation

The microstructure and properties of brittle poroelastic and poroviscous media is sufficiently well studied at low porosity. However, at the critical porosity value of approximately 30% one the theoretical methods of describing microstructures are not longer accurate. To this end, this paper proposes statistical methods based on the Feynman diagram technique. Methods of averaging three-saturated granular media suitable for research in the near-critical region are explicated in this work. These methods are suitable for both periodic and for a randomly inhomogeneous microstructure. Precise averaged nonlocal constitutive equations are obtained. Methods are constructed to calculate the effective material parameters of the granular medium in three different approximations: correlation, singular approximation and in the approximation of 'lubrication layer'. The latter approach is based on the calculation of the hydrodynamic interaction between hard particles that are closely spaced but not adjoined. Correlation approximation takes into account pair correlations of heterogeneous environments, which are calculated using the diagrammatic Feynman technique. Singular approximation is due to the replacement of the second derivative in the Green's function in the spatial variables with the delta function in accordance with Laplace equation. Each of these methods has its own possibilities and limitations. The most common and versatile method is the diagram technique, which allows to go beyond the applicability of the standard granular medium and to obtain nonlocal constitutive equations for porosity greater than the critical value. At a lower porosity of all the governing equations are local, except for the viscoelastic medium, which is nonlocal in time.

Within the boundaries of applicability of the mentioned local equations for these media the effective stress tensor and the Bio-Terzaghi parameter are calculated. Additionally, it is demonstrated that in the case of the incompressible liquid phase of the heterogeneous media in these environments, a second bulk viscosity appears in addition to shear viscosity. The value of this viscosity is calculated. The proposed approach allows to describe the porous medium with viscous and viscous elastic skeleton, suspensions and emulsions, in which the viscosity of the phases differ significantly. We consider the following microstructures of granular media. Solid and elastic spheres in a viscous fluid, described with hydrodynamic Stokes equations. Solid spheres, surrounded by a thin layer of highly viscous liquids (grease), in low viscous liquid.

The resulting research results in the supercritical region can be interpreted as the emergence of a cluster of permeability in porous media.