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The numerical simulation of landslide dynamics in the model of pore-saturated, elastoplastic media

R. Mazova (1), L. Lobkovsky (2), and E. Kolchina (1)

(1) R.E.Alekseev Nizhny Novgorod State Technical University, Nizhny Novgorod, Russia (raissamazova@yandex.ru, 8 831 436 23 11), (2) P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences, Russia

It is well known that triggering mechanism for both subaerial and coastal landslide processes can be seismic or aseismic in nature. In landslide processes the important role belongs to excess pore pressure which, being the main triggering factor for subaerial landslides, provides also essential role for submarine ones. For subaerial landslides, important factor is weathering, especially heavy railfalls (aseismic mechanism). For coastal ones there are important balanced accretion and erosion processes due to wind, overloading of slopes because of accumulation of sediments, low tide inducing increase of pore pressure, sharp changes of atmosphere pressure and strong storm waves (aseismic mechanism). In the latter case, landslide process is a result of long-term accumulation of sediment fractions in coastal region. The slope failure in both cases may be considered as a result of liquefaction of ground because of excess pore pressure, which reduces the shear strength or causes loss of strength, depending on structure of ground and its constituents, so that liquefaction can be considered as necessary component of triggering mechanism for both subaerial and coastal landslides.

However, the evaluation of stability of slopes is usually based on engineering kinematical approach for sliding surfaces suggested in which sliding conditions take into account porous pressure but pore-saturation of ground and the possibility of its liquefaction under conditions of any dynamical action is not considered. In contrast to kinematical method the entire solution of the problem for stress-strained slope at any dynamical action gives the possibility to estimate the residual deformation distribution in the whole volume of ground with taking into account of its possible liquefaction and disconsolidation. Also it is necessary to take into account the possible dynamical action on the process since namely at dynamical action it is possible sliding of part of consolidated ground layer on forming zone of inelastic strain localization. The key factor, controlling the process of plastic strain localization and connected with it slope instability, is character of disconsolidation of surface ground layer: deformation of real grounds, after reaching of destruction point is continued at decreasing stress, i.e. it occurs the decrease of shear strength with increasing strain (at tests with drainage or no) unless stress will reach some final or residual level. In present computation of slope stability it is taken into account the important rheological effect of decrease of ground strength when reaching fluidity limit in result of dynamical action. It is demonstrated the possibility of development of long-distant slide shifts of large-block formations in upper part of slope. The program code FLAC, in contrast to finite element method, realizes the explicit finite-difference scheme of solution of 3D problem for geomechanics what permits to numerically simulate nonlinear behavior of pore-saturated grounds under conditions of plastic flow above shear strength. For calculations, the material is represented by polyhedral elements within a 3D grid to fit the shape of the object to be modeled. Each element behaves according to a prescribed linear or nonlinear stress/strain law in response to applied forces or boundary restraints. The grid is deformed and moves with the material that it represents. The parameters used are the layer density, shear modulus, bulk modulus, cohesion, maximum friction angle, and tensile strength.

In this work, the process is considered for coastal landslide triggered by any dynamical action with preliminarily liquefaction of ground masses at beach slope with water under corresponding pressure. With using of numerical code FLAC it is performed numerical simulation of stressed state in each of a few layers to which the landslide body was divided for each of which there are determined shear strains which permits to determine component of vertical displacement for each element of moving landslide mass [1]. The detailed comparison of landslide dynamics and evolution of landslide generated surface water waves during sliding is performed. The process of generation of such waves, depending on its initial location: at dry beach, at the shoreline or at underwater slope, is studied, using nonlinear shallow water equations. The new effect is obtained: because of layer-by-layer sliding of upper part of pore-saturated elastoplastic ground layer of the landslide body on the slope surface which is formed during sliding (erosive-like process), the local runup of these waves occurs at the slope with time-dependent surface.

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[1] Papadopoulos G.A., Lobkovsky L.I., Mazova R.Kh., Garagash I.A., Karastathis V., Kataeva L.Yu., Kaz'min V.G. Marine Geodesy V.30, 135-144 (2007).