BIFURCATION CRITERIA FOR GEOMATERIALS: THEORETICAL AND NUMERICAL ANALYSIS

H.D.V. KHOA*, F. DARVE* AND F. LAOUAFA†

* Laboratoire Sols, Solides, Structures
BP 53 – 38041 Grenoble cédex 9, FRANCE
Felix.Darve@inpg.fr

† INERIS B.P. N°2
60550 Verneuil en Halatte, FRANCE

The prediction of the occurrence of slope instability in engineered and natural slopes has attracted increasing attention in recent years around the world. Various modes of failure in geomaterials, who can not be explained in the framework of plastic limit analysis, have been observed in practice. Different criteria have been proposed to analyze these failures (see [2], [6] and [7],...). The focus of the paper is on the capacity of the Hill's sufficient stability criterion [5], based on the sign of second order work, in analyzing the diffuse failure modes.

The first part is devoted to demonstrating that the Hill's criterion allows to define the material bifurcation domains in the stress space, strictly inside the plastic failure surface for plane strain conditions, in which the onset of various bifurcation modes such as localized modes and diffuse modes could occur. These studies are analytically and numerically conducted by using the incrementally piece-wise linear and non-linear constitutive relations (see [3] and [4]) for different soils (loose sand and dense sand). Furthermore the equation of the boundaries of the bifurcation domains is specially given for incrementally piece-wise linear model.

In the last part, as examples of applying the Hill's criterion to real boundary value problems, the landslide occurring on the Trévoux hillside (France) after an intense rainfall period in 1983 is simulated in plane strain by finite element computations. This modelling was undertaken by unsaturated hydro-mechanical coupling with a simple elasto-plastic model PLASOL [1] implemented in the finite element code LAGAMINE (developed at the University of Liège, Belgium). The location of the zone of negative values of the local second order work allows us to faithfully reproduce the real landslide and to clearly display the unstable material points such as the potentially unstable zones on the Trévoux hillside. Secondly, it is concluded that the interpretation of the evolution of the global second order work might be considered as a precursor to certain modes of failure of the overall massive.

References

[1] J. D. Barnichon, "Finite element modelling in structural and petroleum geology", Ph.D thesis, *University of Liège*, 1998.

[2] D. Bigoni and T. Hueckel, "Uniqueness and localization-I. Associative and nonassociative elastoplasticity", *Int. J. Solids Structures*, **28**(2), 197-213, 1991.

[3] F. Darve, "Incrementally non-linear constitutive relationships", in *Geomaterials, Constitutive Equations and Modelling*, Darve F. ed., Francis and Taylor Books publ., 213-238, 1990.

[4] F. Darve, G. Servant, F. Laouafa and H. D. V. Khoa, "Failure in geomaterials: continuous and discrete analyses", *Comput. Methods Appl. Mech. Engrg.*, **193**(27-29), 3057-3085, 2004.

[5] R. Hill, "A general theory of uniqueness and stability in elastic-plastic solids", *J. Mech. Phys. Solids*, **6**(3), 239-249, 1958.

[6] R. Nova, "Controllability of the incremental response of soil specimens subjected to arbitrary loading programmes", *J. Mech. Behav. Mater.*, **5**(2), 193-201, 1994.

[7] J. W. Rudnicki and J. R. Rice, "Conditions for the localization of deformation in pressure sentive dilatant materials", *J. Mech. Phys. Solids*, **23**(6), 371-394, 1975.

Keywords: incrementally non-linear models, bifurcation, material instability, diffuse failure, Hill's stability criterion, second order work, slope stability, landslides