Hybrid Analysis for Continua with Solid and Liquid Properties in Infinite High Tubes

M. Göttlicher*

* Faculty of Civil Engineering and Conservation/Restoration
University of Applied Sciences Erfurt
Altonaer Str. 25, 99085 Erfurt, Deutschland
e-mail: m.goettlicher@t-online.de, web page: http://www.fh-erfurt.de

ABSTRACT

Many materials like sand, soil, cement, snow and grain, perform like solids or liquids depending on loads and boundary conditions. The proposed coupled solid-liquid analysis has the potential to deal conveniently with the severe nonlinearities that are associated with single state descriptions. Linear elastic behavior characterizes the solid part. Slowly moving incompressible viscous behavior characterizes the liquid part.

Granular material in structural and geotechnical engineering generally is treated as a solid with special reference to large deformations. Transformation to a steadily moving state is not possible. If granular material is treated as a liquid with special properties, the hydrostatic pressure evolves in the static state which is not in agreement with the observed impact on structures [2]. The internally coupled solid-liquid analysis presented in this paper allows the complete transformation between static solid state and steady liquid state.

The interaction of static solid and steady incompressible liquid continua has been discussed for an infinite high tube in in 2006 [1]. In the present paper the liquid state is represented by pressure only. Dependent on loads and boundary conditions an inhomogeneous distribution of solid and liquid properties in space is determined by the relation of the first stress invariants. The velocities of the liquid state may be subject of a secondary analysis.

A functional is postulated for plane continua [3] with solid and liquid properties. An elastic solid interacts with an incompressible liquid which is represented by a pressure field. The associated hybrid principle covers the complete range from elastic static behavior to mere liquid behavior. It is restricted to applications without tension.

For resting or steadily moving hybrid material in an infinite high tube, exact analytical solutions are available. This allows an evaluation of the general performance of the numerical analysis based on the hybrid solid-liquid formulation.

The computational method presented in this paper adresses a wide range of possible applications. It is based on the simultaneous interaction of two materials in the same place at the same time. The linearity of the analysis is preserved. The unavoidable nonlinear effects are covered by obvious a priori considerations as usual in engineering. Further research is directed towards more general applications and the investigation of the usefulness of the numerical analysis that has been developed for an infinite high tube.

REFERENCES

[1] M. Göttlicher, "*Hybrid solid-liquid model for granular material*", *17th international conference on the applications of computer science and mathematics in architecture and civil engineering (IKM), Bauhaus-University,* Weimar, Germany, 2006.

[2] S. Ehmann, K. Morgen, C. Ruckenbrod, *Silos.* Beton-Kalender, Band 2, Ernst & Sohn, 2016.

[3] O.C. Zienkiewicz and R.L. Taylor, *The finite element method*, 5th Edition, Vol. 1, Butterworth-Heinemann, 2013.