ANALYSIS OF A FINITE LENGTH OF CONSTRAINED CYLINDRICAL GRANULAR BED UNDER AXIAL LOAD

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The case of a cylindrical container filled with granular material is a basic situation where the presence of the wall boundaries induces horizontal pressure, and hence shearing forces caused by friction between the wall of the container and the granular bed in it. It can be found in various engineering applications, e.g. in caissons construction and pile driving, in the design of silos and hoppers, and in space life support systems for water processing where granular material contained in a steel cylinder is compacted by a spring. The phenomenon commonly referred to as "arching" can make vertical pressure at a certain depth of the material zero, which can lead to a column of granular material with free top and bottom surfaces that is held in vertical equilibrium by the friction forces at the cylinder wall. When an axial load is applied at one end of the bed and increased slowly, the whole granular column starts to slide at a critical load value. A method to predict this mobilization force can be used beneficially in the above mentioned practical fields, e.g. to determine the maximum shear capacity of a foundation pile or the minimum compaction force for a certain depth of granular material.

In this paper we present an analytical methodology for modeling the stress and deformation behavior of a granular column when it is pushed from one end. A finite length of the bed is considered. An axial load is applied at one end and the other end is free to move. It is assumed that length scales are sufficiently large, so that the discrete nature of granular material can be neglected, and the material and its properties such as density and constitutive relations can be assumed to be continuously distributed [1]. The analytical model incorporates the equilibrium of stresses and considers all the relevant stress and displacement/deformation boundary condition. In addition, an attempt has been made to include the "arching" effect [2, 3] which causes stress fluctuations along the column, and essentially is responsible for making the stresses zero at its lower free end. Secondly, a detail computational model of the granular bed has been developed using the finite element code ABAQUS. Simple deformable elastic solid elements are used to model the granular column, together with a generalized Coulomb's friction law, a non-associated slip rule and superposed horizontal stresses at the wall contact interface [4]. The results from analytical and the computational studies compare with each other well. Furthermore, these results also compared with the experimental results from the friction mobilizing and axial stress-deformation tests done in a series of activated alumina beds constrained in a steel cylinder [5,6]. The results match reasonably well.

References

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