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MODELING OF STRAIN ACCUMULATION IN NON-COHESIVE SOILS DUE TO MULTIAXIAL DYNAMIC LOADING

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Structures in urban areas are exposed to low amplitude dynamic loads as arising from road and railway traffic or construction activities. Single events are unlikely to result in instantaneous structural damage to building components. Repeated dynamic loading of the soil in the vicinity of the foundation, however, may result in plastic deformation of the soil, causing differential foundation settlements and a considerable increase of the internal forces in the structure, resulting in structural damage.

The accumulation of deformation in granular soils under cyclic loading is studied by means of a cyclic triaxial test. A cylindrical soil sample is confined by a hydrostatic stress while an additional cyclic vertical stress is applied by a loading piston. The deformations of the sample are measured over a large number of small-amplitude load cycles.

The results of cyclic triaxial tests are used to calibrate phenomenological models for the calculation of foundation settlements. A numerical model for vibration induced foundation settlements of structures is formulated [1] that accounts for the long term constitutive behavior of the soil and the dynamic response of the soil and the structure during a single load event. It is assumed that the cyclic part of the loading is small with respect to the static part, reflecting the stress conditions in the soil underneath a structure loaded by a low amplitude incident wave field. As the permanent deformations are only observed after a large number of load events, only the average plastic deformation per load cycle is considered. The accumulation model accounts for the dependency of the deformation on the stress conditions and the cyclic loading amplitude. The stress conditions in the cyclic triaxial tests that are used to calibrate the above model, are an approximation of the complex loading paths in the soil under traffic induced vibrations, that are intrinsically multi-axial and transient signals. A methodology is proposed where multiaxial rain flow counting algorithms are used to decompose the transient loading signals into a number of equivalent sinusoidal signals.

The accumulation model is implemented in a finite element framework using a consistent tangent approach. The model is applied to compute the differential settlement of a two-story building founded on loose sandy soil under repeated passages of a truck on a nearby traffic plateau. Results demonstrate that vibrations may give rise to significant long term settlement of structures.

References

[1] S. François, C. Karg, W. Haegeman, and G. Degrande. A numerical model for foundation settlements due to deformation accumulation in granular soils under repeated small amplitude dynamic loading. International Journal for Numerical and Analytical Methods in Geomechanics, (34):273-296, 2010.