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A NUMERICAL MODEL FOR STRUCTURAL SETTLEMENTS DUE TO DEFORMATION ACCUMULATION IN GRANULAR SOILS UNDER REPEATED SMALL AMPLITUDE DYNAMIC LOADING

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ABSTRACT

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

Property owners often complain about vibration related structural damage. In practice, it is impossible to attribute existing structural damage to repeated cyclic loading because of the presence of other deterioration processes. Furthermore, threshold limit values of vibration found in norms and guidelines do not provide adequate safety against damage induced by foundation settlements in loose sandy soils susceptible to densification due to vibrations [1].

In this paper, an accumulation model is for granular soils under low amplitude cyclic loading is formulated, where 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, a constitutive model is formulated that only describes the evolution of the average permanent deformation per load cycle. This methodology, originally developed for metal fatigue, has also been adopted to compute settlements of roads and railway tracks [6] under a large number of vehicle passages.

This approach involves a double time scale. The first time scale is the short term time scale, where the dynamic response of the structure and the soil due to a single load event, e.g. a single passage of a vehicle on a nearby road, is calculated, possibly accounting for dynamic soil-structure interaction. In the second time scale, the long term behaviour of the soil and the structure is considered in a quasi-static calculation. The cyclic stress amplitude of the short time scale is used as an input parameter for the constitutive model: a larger cyclic loading amplitude results in a larger incremental permanent strain per load cycle. In this sense, the two time scales are weakly coupled. The accumulation model

is implemented in a three-dimensional non-linear finite element framework, allowing for the solution of general boundary value problems and the rigorous computation of static soil-structure interaction effects. A consistent tangent approach is used in combination with a backward Euler integration scheme, resulting in a stable and accurate integration [2, 5]. The parameters for the accumulation model are determined from cyclic triaxial tests, and account for the dependency of the accumulated strains on the stress conditions and the cyclic loading amplitude [7].

The model is applied to compute the foundation settlement of a masonry building due to repeated passages of vehicles on a nearby traffic plateau. The computation consists of two parts: first, the single load event (the passage of a truck on the road) is studied in order to assess the distribution of the cyclic load amplitude over the soil domain [3, 4]. Secondly, the accumulation model is applied for the computation of the differential settlement of the structure due to a large number of vehicle passages. As a result of the differential foundation settlement, the stress distribution in the structure is modified. During the passages of vehicles, the stresses at the bottom of the structure increase, corresponding to a global bending which may result in cosmetic damage. In the case of structures susceptible to differential foundation settlements, e.g. for a structure where static foundation loads vary, the differential foundation settlement is expected to be more important and may result in more considerable structural damage.

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