SOIL – STRUCTURE INTERACTION FOR LOW DAMAGE SEISMIC ROCKING SYSTEMS

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ABSTRACT

In earthquake prone areas, stakeholders now ask for low damage systems that can be easily repaired, following even earthquakes of catastrophic potential. Seismic protection of structures by means of rocking isolation is becoming increasingly popular, since allowing uplift is an inexpensive way to reduce the damage demand placed in structures. However, understanding the role of soil–structure interaction in the response of rocking systems remains a challenge. The goal of this thesis is to offer new knowledge on this field by assessing experimentally and computationally the response of rocking structures and the soil they are founded in.

For the first time, structural and foundation rocking are unified under a common experimental campaign. Two building models, designed to rock above or below their foundation level so that they can reproduce structural and foundation rocking respectively, were tested side by side in a centrifuge. The models were placed on a dry sand bed and subjected to a sequence of earthquake motions. Dense and then medium dense (loose) sand were used.

The range of rocking amplitude that is required for base isolation was quantified. Overall, it is shown that the relative density of sand does not influence structural rocking, while for foundation rocking, the change from dense to loose sand can affect the time-frequency response significantly and lead to more predictable load demands. Results also demonstrate that the rocking motion of the buildings is evident in the soil response beneath the structures, and foundation rocking causes larger dynamic differential settlements than structural rocking for a given rocking amplitude.

Within OpenSees, foundation and structural rocking were modelled using a Beam-on-a-Nonlinear-Winkler-Foundation model (BNWF). The modelling incorporated flat-slider elements for footing-soil and superstructure-footing interactions, respectively. A modified BNWF model (mBNWF) was presented that involved an uplift-dependent stiffness and viscosity transmission for both vertical and horizontal directions, and a friction-vertical force coupling. In general, the proposed modelling approach, without calibration, adequately captured the experimental response observed in centrifuge experiments. Due to its inherent dependency on initial conditions, foundation rocking was found more sensitive than structural rocking to the type of soil model and the soil properties. Finally, selecting appropriate modal damping ratios can further improve the response profile and based on these parameters a calibration scheme was proposed.