Soil–structure interaction under strong seismic moment: material and geometric nonlinearity

The study is focused on the nonlinear effects associated with the response of a shallow foundation subjected to large overturning moment. Slender structural systems are more vulnerable to develop high levels of foundation moment even during a moderate seismic shaking and evidently rocking component of motion is predominant. In the domain of large displacements, nonlinear features of such a soil-foundation system may be summarised in separation of a footing undergoing rocking oscillations from the supporting soil ('uplifting'), and mobilisation of bearing capacity type failure surface echanisms under large cyclic overturning moments ('soil failure').An introduction to study the geometrically nonlinear SSI was attempted first. Rocking behaviour of a rigid, block-type or onestorey structure supported on a rigid base was examined. In the case of a one-storey structure the flexibility of the pier was also considered. The profound nonlinear aspects of the dynamic rocking response were highlighted.The compliance of the supporting soil was implemented in the analysis of the rocking response of shallow foundations through sophisticated nonlinear finite element modeling. Monotonic response was calculated with static 'push-over' analysis to extract backbone load-displacement curves. Moreover, time-domain analysis using pulses or earthquake records as bedrock excitation was carried out to elucidate the nonlinear features of the dynamic response of the soil-foundation system. Based on theseanalyses, a macroscopic modelling of the soil–foundation system was developed, capable of representing the large-displacement domain of the response and overcoming the drawbacks of conventional Winkler-based modelling. Analytical equations for the monotonic load-displacement relationship were extracted incorporating both geometric and material nonlinearities. Interaction curves were also produced under static conditions and compared to the existing solutions of the literature. Theanalysis was extended in the time-domain by using both pulse-type time histories and earthquake records. Permanent cumulative displacements were also calculated in light of a fundamental sensitivity study. Finally, the conditions under which uplifting leads to large angles of rotation and eventually to overturning were investigated through rigorous, large displacement approach. A profoundly nonlinear rocking behaviour was revealed for both rigid and elastic soil conditions. This geometrically nonlinear response was further amplified by unfavourable sequences of long–durationpulses in the excitation.