Metaplastic response and collapse of frame-foundation systems, and the concept of rocking isolation

Scope of this research is to explore the effectiveness of a new approach to foundation seismic design. Instead of the conventional foundation over-design, it is now intentionally under-designed to uplift and mobilize the strength of the supporting soil in the hope that they will thus act as a rocking?isolation mechanism, limiting the inertia transmitted to the superstructure, and guiding the plastic "hinge" into the foundation?soil interface. Idealized simple but realistic reinforced concrete (RC) moment resisting frames serve as an example to compare the two design alternatives. The thesis is structured along 5 sections: The first section presents a simplified constitutive model for analysis of the cyclic response of shallow foundations. The model is based on a simple kinematic hardening constitutive model with Von Mises failure criterion modified accordingly so as to be applicable for sand. The model is validated against centrifuge tests performed at UC Davis and large-scale 1-g experiments under the EU program TRISEE. Despite its simplicity and lack of generality and rigor, for the particular type of problem investigated herein such a constitutive model yields quite reasonable results. The second section, which forms the core of this thesis, investigates the potential effectiveness of the proposed new design by comparing the response of a fairly simple 1-bay 2-dof frame founded on a stiff clay under very strong seismic shaking (exceeding the design level). The problem is analyzed employing the finite element (FE) method, taking account of material (soil and superstructure) and geometric (uplifting and P-Δ effects) nonlinearities. The response of the two alternatives is first investigated through static pushover analysis. The seismic performance is further explored through dynamic time history analysis, using as excitation a wide range of seismic motions. It is shown that For very strong seismic shaking, the performance of the rocking-foundation system is advantageous : it survives sustaining non-negligible but repairable damage to its beams and non-structural elements (infill walls, etc.). The third section proposes a Simplified Methodology for the Foundation Design of Rocking?isolated Frames. According to this the range of optimum (or acceptable) footing widths should simultaneously meet two contradicting criteria: (i) the footing width B needs to be small enough, so that its moment capacity Mult is adequately smaller than the corresponding capacity of the column MRD and (ii) the footing width B has to be large enough, so that an adequate margin of safety against toppling is achieved. Sections 4 and 5 investigate the response of a simple frame structure subjected to valley contaminated ground motion. Emphasis was given in the proper simulation of the 2D wave propagation phenomena that take place in one typical trapezoidal alluvial basin accounting for both elastic and full non-linear soil response. It was shown that the valley presence may significantly modify the rocking response of the frame and hence producing unexpectedly high distress on its structural members.