Proceedings of the 10th World Congress on Civil, Structural, and Environmental Engineering (CSEE 2025)
Barcelona, Spain - April, 2025
DOI: 10.11159/icsect25.002

Seismic Retrofit of Existing Bridges on Pilegroups

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Extended Abstract

The vast majority of existing bridges were built before the 90's, without any or just basic seismic design. Pile group strengthening can be a challenging, costly, and time-consuming operation, calling for optimised solutions. The lecture will look into the behaviour of pile groups under combined Vertical, Horizontal and Moment (VHM) loading, combining 3D Finite Element (FE) analysis and centrifuge modelling. Initially, a proof-of-concept study is conducted, inspired by the recent widening of a Swiss bridge. According to conventional design, the existing pile group needs retrofit to accommodate the increased seismic loads due to widening. An unconventional "do-nothing" approach is explored (maintaining the existing foundation), exploiting nonlinear soil response. Such an approach requires improved design methods and better definition of the ultimate capacity of pile groups under combined loading. In this context, after developing a database of Swiss bridges and identifying pile group typologies encountered in practice, a fundamental yet representative 2 x 2 bored pile group is tested at the ETH Zurich (ETHZ) Geotechnical Centrifuge Centre (GCC). Four experimental setups are developed and verified for vertical, pushover, combined, and vibration testing. After determining the bearing capacity under vertical loading, pushover loading is employed to measure the moment capacity of a lightly- and a heavily-loaded (widening) pile group. In contrast to intuitive expectations, the heavily-loaded system mobilises larger M_ult. Combined loading is performed to derive experimental failure envelopes, confirming their tendency to expand with increasing vertical load. The centrifuge results are used for FE model validation. The numerical technique is upgraded to account for nonlinear soil–pile interaction, using hypoplasticity for sand and appropriate modelling of interfaces and pile response. The transition to prototype scale accounts for scale effects, and employs the Concrete Damaged Plasticity (CDP) model for proper simulation of the reinforced concrete (RC) piles. The latter is a key advancement, accounting for the axial load dependency of bending moment capacity. The problem is studied parametrically, deriving failure envelopes in function of vertical loading, confirming the increases of pile group capacity with increasing vertical load. Finally, the Limit Equilibrium method is used to derive closed-form analytical failure envelopes, providing a useful design tool for engineering practice.