GROUND IMPROVEMENT FOR LIQUEFACTION MITIGATION AT EXISTING HIGHWAY BRIDGES

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ABSTRACT

The feasibility of using ground improvement at existing highway bridges to mitigate the risk of earthquake-induced liquefaction damage has been studied. The factors and phenomena governing the performance of the improved ground were identified and clarified. Potential analytical methods for predicting the treated ground performance were investigated and tested.

Key factors affecting improved ground performance are the type, size, and location of the treated ground. The improved ground behavior is influenced by excess pore water pressure migration, ground motion amplification, inertial force phasing, dynamic component of liquefied soil pressure, presence of a supported structure, and lateral spreading forces.

Simplified, uncoupled analytical methods were unable to predict the final performance of an improved ground zone and supported structure, but provided useful insights. Pseudostatic stability and deformation analyses can not successfully predict the final performance because of their inability to adequately account for the transient response. Equivalent-linear dynamic response analyses indicate that significant shear strains, pore water pressures and accelerations will develop in the improved ground when the treated-untreated soil system approaches resonance during shaking. Transient seepage analyses indicate that evaluating pore pressure migration into a three-dimensional improved zone using two-dimensional analyses can underestimate the pore pressures in the zone.

More comprehensive, partially-coupled analyses performed using the finite difference computer program FLAC provided better predictions of treated ground performance. These two-dimensional, dynamic analyses based on effective stresses incorporated pore pressure generation, non-linear stress-strain behavior, strength reduction, and groundwater flow. Permanent movements of structures and improved soil zones were predicted within a factor of approximately two. Predictions of ground accelerations and pore water pressures were less accurate.

Dynamic analyses were performed with FLAC for an example bridge pier and stub abutment on an approach embankment supported on shallow foundations and underlain by thick, liquefiable soils with and without improved ground zones. Ground improvement that restricted movements of the pier and stub abutment to tolerable levels included improved zones of limited size extending completely through the underlying liquefiable soils and formed through densification by compaction grouting or cementation by chemical grouting or jet grouting. A buttress fill at the abutment was unsuccessful.