INSIGHTS THROUGH DYNAMIC ANALYSIS OF STRUCTURES AT LIQUEFIED SITES

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Several buildings in Christchurch settled differentially and were damaged as a result of soil liquefaction during the 2010-2011 Canterbury earthquake sequence. The state-of-the practice still largely involves estimating building settlement using empirical procedures developed to calculate post-liquefaction, one-dimensional, consolidation settlement in the free-field away from buildings. Performance-based earthquake engineering requires improved procedures, because these free-field analyses cannot possibly capture shear-induced deformations in the soil beneath shallow foundations. Nonlinear effective stress fully coupled soil-structure interaction (SSI) analyses were performed using FLAC-2D with the PM4Sand constitutive model calibrated with field and laboratory testing data. The dynamic SSI analyses provide salient insights regarding the mechanisms contributing to building movements. The primary mechanisms of liquefaction-induced settlements of structures can be categorized as shear-induced, volumetric-induced, and ejecta-induced ground deformation. Shear strains in the foundation soils developed due to shaking-induced ratcheting of buildings into cyclically softened soil or due to a transient loss of bearing due to soil softening in several cases. Damaging volumetric strains in the foundation soils were largely due to liquefaction of shallow soils, if they were present at a site. The dynamic SSI analyses captured these mechanisms of nonlinear soil response. However, the influence of the loss of ground due to the development of sediment ejecta, which was another potentially important factor in some cases, was not captured with this continuum based approach. Engineers should employ simplified procedures and engineering judgment based on field case histories to assess this mechanism. Recommendations for evaluating the seismic performance of structures founded at liquefiable sites are made.