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Investigation into Effect of Liquefaction on Behavior of Retaining Walls

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ABSTRACT

Retaining walls constructed adjacent to underground water are the structures which may be influenced by liquefaction. The design of these structures under vibration involves determining their displacements and forces caused by earthquake and liquefaction phenomena. In this study, it is attempted to assess the effect of liquefaction on the behavior of retaining walls using finite element method (FEM). The OPENSEES software is used for this purpose, which can simulate the behavior of saturated porous media using the u-P correlation formulation. Moreover, the Dafalias-Manzari critical state two-surface plasticity behavioral model is applied to simulate the behavior of sand, which can model a variety of behaviors of saturated sand in various uniaxial and cyclic loadings under drained and undrained conditions for different relative densities. The results of this study suggest that the OPENSEES software and Dafalias-Manzar behavioral model possess essential capabilities for numerical modeling of behavior of retaining walls under liquefaction conditions. The presence of retaining walls also changes the pattern of development of excess pore water pressure, particularly at middle depths of the wall.

Key words: Retaining wall, Liquefaction, Saturated sand, Critical state.

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1. INTRODUCTION

Soil liquefaction is one of the most important and complicated issues in seismic geotechnics, which occurs due to undrained behavior of saturated loose sandy soils under cyclic loads and has caused widespread damage to bridges, piers, deep foundations and crucial arterial roads. The development of pore water pressure under undrained conditions is the common symptom of all liquefaction processes. When saturated loose sandy soil is exposed to rapid loading under undrained conditions, its tendency to compaction increases the pore water pressure and reduces the effective stresses. An assessment of areas with liquefied soil suggested that liquefaction often reoccurs in areas where the soil has liquefied previously and the ground conditions have not been changed yet. In other words, previously liquefied soils are prone to liquefaction in earthquakes (1). It was previously believed that the liquefaction phenomenon happens only in sandy soils. Later, it was observed that non-plastic and non-cohesive coarse-grained silt is extremely susceptible to liquefaction; liquefaction has been observed even in gravel soils under undrained conditions (1). In the San Fernando earthquake in 1906, many buildings, bridges, roads and, most importantly, main arterials were damaged due to liquefaction phenomenon. In this earthquake, main water supply pipes were halted in San Francisco city center due to lateral spreading, which slowed down firefighting operations in the city center after the earthquake and caused heavy casualties and financial losses in the city (2, 3). In the Alaska earthquake in 1964, the lateral spreading phenomenon devastated a great number of bridges, buildings, roads and arterials between cities such as Anchorage, Kodiak, Valdez, Sward, Portage and Whittier. In this earthquake, the lateral spreading phenomenon caused damage by approximately $80 million and 266 bridges were destroyed entirely (4). Given the investigation into various data on lateral spreading recorded in different earthquakes, it was concluded that liquefaction-induced lateral ground movement is highly probable to occur during earthquake in the slopes terminating a canal, river or excavated area; in this case, more displacement usually occurs compared to when there is no pit or canal down the slope (4). Many coastal structures, particularly gravity quay walls, have been intensively damaged by soil liquefaction in their surroundings over the past 50 years. Hence it is so important to assess the potential of liquefaction and application of suitable techniques