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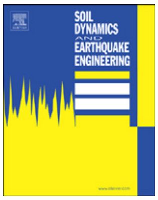

Evaluation of reliquefaction resistance using shaking table tests

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ABSTRACT

Cases of modern and prehistoric liquefaction illustrate that sand deposits can be liquefied again (or "reliquefied") by a subsequent earthquake after initially liquefying during seismic shaking. In order to test the validity of two postulates regarding reliquefaction mechanisms and to examine the role of gradational characteristics on reliquefaction resistance, 1 g shaking table tests were performed using five sands with differing gradation characteristics. The test results demonstrate that the number of cycles required to reliquefy each sand decreased significantly following the 1st liquefaction event as a result of destroying the "aged" sand fabric developed prior to the 1st shaking event via secondary compression of the initially loose sands. Reliquefaction resistance correlated reasonably well with a proxy for c_v ($\propto D_{10}^2 D_r^{2.8}$), illustrating that both the permeability and compressibility of the sand play significant roles in the post-liquefaction fabric (and hence reliquefaction resistance) formed by a sand. While the initial decrease in reliquefaction resistance supports both the Oda et al. [8] and the Olson et al. [5] reliquefaction postulates, only the Olson et al. [5] postulate reasonably explains the subsequent, large increase in reliquefaction resistance observed during the 3rd through 5th shaking events. These tests suggest that the coefficient of consolidation, $c_v = k_v/\gamma_w m_v$ (or proxy values such as $D_{10}^2 D_r^{2.8}$ or D_{10}/C_U) may be a useful tool for evaluating reliquefaction potential in forward and inverse (i.e., paleoliquefaction) analysis.

1. Introduction

Cases of modern and prehistoric liquefaction illustrate that after initially liquefying in response to cyclic or seismic loading, sand deposits can be liquefied again (or "reliquefied") by a subsequent smaller cyclic or seismic load [1–3]. As a result, understanding the liquefaction resistance of previously liquefied sites is important for both forward and inverse (i.e., paleoliquefaction) geotechnical analysis.

The process of liquefaction can be simplified into three phases: (1) destruction of pre-earthquake soil structure during undrained monotonic or cyclic loading, leading to porewater pressure increase and loss of strength and stiffness in very loose to medium dense soils; (2) post-liquefaction reconsolidation and densification; and (3) post-consolidation aging [4]. Despite the increase in density associated with post-liquefaction consolidation, Olson et al. [4] argued that this process may not lead to a post-event increase in liquefaction resistance.

At least three postulates (which are not mutually exclusive) are available to explain this phenomenon. Olson et al. [4,5] proposed one, as follows. Thomann and Hryciw [6] suggested that liquefaction causes "effectively infinite" shear straining at particle contacts. This straining completely destroys the pre-existing (aged) soil structure that had developed through mechanisms such as secondary compression, preshearing, and cementation, all of which improve interlocking at particle contacts and increase liquefaction resistance. As a result of the large shear straining associated with liquefaction, the liquefied soil essentially becomes freshly deposited following post-liquefaction reconsolidation. Thus, the post-event liquefaction resistance may be lower than the pre-event liquefaction resistance because of the loss of particle interlocking [4,5]. However, Olson et al. [4,5] also argue that after sufficiently large density changes occur as the result of shaking-induced settlement and post-liquefaction reconsolidation, post-event liquefaction resistance should increase. Based on data compiled by Mesri et al. [7] from ground improvement projects, liquefaction resistance may increase after the relative density increases on the order of 20% to 30% (from originally loose to medium dense states).

Prior to Olson et al. [4,5], Oda et al. [8] proposed that deposits undergoing liquefaction experience large shear strains (exceeding 2% to 3%), and this straining changes the soil fabric from a random

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