Behavior of Weathered Soil under Combined Undrained Cyclic-Monotonic Loading

Mohammed-Aslam Abdul-Khader[1] and Sangseom Jeong, M.ASCE[2]

Abstract: Liquefied soils are considered as soils devoid of any strength or having only limited strength. Post-liquefaction shear behavior of soil before the drainage of excess pore pressure is important in predicting the immediate performance of foundation and soil structures subjected to liquefying loads. In the present study, the post-cyclic undrained behavior of weathered silty sand was examined under triaxial test conditions. The soil showed complete strength recovery after subjecting it to monotonic shearing up to large strains. The post-liquefaction shear behavior was mostly determined by the amount of excess pore pressures that developed during cyclic loading. The cyclic load amplitude and shear strain did not seem to have an effect on the post-cyclic shear behavior. Post-cyclic shearing showed that with sufficient strain the soil recovered its original strength even without dissipation of any excess pore pressure. **DOI: 10.1061/(ASCE)GM.1943-5622.0001969**.

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Introduction

Saturated soils subjected to undrained dynamic loading can fail due to liquefaction or cyclic mobility under large seismic loads. The failure is dictated by the initial density, effective stress and plasticity of the soil. Liquefaction due to the dynamic loading transforms soil from a solid to a fluid-like state. In the process, soil loses its strength and stiffness. During flow liquefaction, or liquefaction (Castro 1975), there is an increase in pore pressure that causes effective stress to drop to zero, and a sudden reduction or loss of shear strength. In the case of cyclic mobility failure, large deformation occurs with continued cyclic loading. Liquefaction occurs in loose sands with low standard penetration test N-values (SPT-N values). Flow liquefaction is triggered when the stress applied is beyond the steady-state strength of soil (Kramer 1996). The soil then loses strength and undergoes large deformations. Failure is sudden and the soil does not need additional loading for further strain accumulation. Cyclic mobility (Castro and Poulos 1977) occurs in dilative saturated sands possessing a wide range of densities, including those in loose to dense states (Zhang and Wang 2012). During cyclic mobility, there is an instantaneous point in each cycle of cyclic loading where the effective stress approaches zero and large, but limited, shear deformations occur. The first point of occurrence of zero effective stress is termed the "initial liquefaction" (Seed and Lee 1966). After initial liquefaction, the soil does not fail straightaway; but there is further strain accumulation as long as the cyclic loading continues. If there is stress reversal, then the effective stress will drop to zero or close to zero in each cycle; otherwise, the stress path will cycle along the steady-state line (Mital et al. 2017).

The initial liquefaction divides the soil behavior into pre- and post-liquefaction states. Apart from the loss of strength and stiffness due to liquefaction, a liquefied soil might also be subjected to large deformations. The post-liquefaction shear behavior of soil before the dissipation of excess pore pressure is important in predicting the immediate performance of foundation and soil structures.

Liquefaction can cause undesirable effects, such as landslide, lateral spreading, ground settlement, loss of lateral confinement, loss of end bearing, loss of skin friction, and additional loads on foundation due to lateral soil movement, among others. While many of these failure mechanism occur during dynamic loading, some of them can also occur afterward. There is ample literature available on various liquefaction-triggering mechanisms and behavior of sands under liquefying loads. But studies on the post-liquefaction characters of soil, especially silts and silty sands, are limited. For any foundation, its immediate post-cyclic strength and stiffness are also equally important. In the present study, the post-cyclic shear behavior of Korean weathered soil is examined using the framework of triaxial experimentation. The soil is subjected to undrained monotonic shearing immediately after cyclic loading without draining the pore pressure. This is expected to generate shear behavior and strength response in soil corresponding to an earthquake event.

It was seen that monotonic behavior of soil after the initial liquefaction is quite different from the normal behavior of soil (Kokusho et al. 2004; Shamoto et al. 1997; Sitharam et al. 2009; Sivathayalan 1994; Vaid and Thomas 1995). For example, Vaid and Thomas (1995) performed post-liquefaction triaxial tests on Fraser River sand over a range of relative densities and effective confining stresses. They showed how the soil lost all its stiffness after initial liquefaction, but recovered a part of its stiffness under undrained post-liquefaction loading. This behavior is contrary to the usual tendency of soil to show a stiffness reduction with increase in strain. They continued the test until around 20% axial strain was achieved and noted that the soil showed no tendency to reach a residual strength. This was also shown by a few other studies on sand (Rouholamin et al. 2017; Sitharam et al. 2009; Sivathayalan 1994). However, Kokusho et al. (2004) showed that

[1]Post-Doctoral Fellow, Dept. of Civil and Environmental Engineering, Yonsei Univ., Seoul 03722, South Korea. ORCID: https://orcid.org/0000-0001-6212-6002. Email: aslamak@yonsei.ac.kr

[2]Professor, Dept. of Civil and Environmental Engineering, Yonsei Univ., Seoul 03722, South Korea (corresponding author). Email: soj9081@yonsei.ac.kr

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