Effects of Over-Consolidation on Steady State Line and Liquefaction Resistance of a Marine Sand

Yao-Chung Chen
National Taiwan University of Science and Technology
Taipei, Taiwan, China

ABSTRACT

This research performed triaxial tests on remolded specimens of a marine silty sand by a lubricated-end-platen triaxial test apparatus. The influences of stress path, over-consolidation ratio, and fines content on the steady state lines are studied. Cyclic triaxial tests were also performed to study the effects of mean confining pressure, over-consolidation ratio, and relative density on the liquefaction resistance. Based on test results, the relationships between state parameter and liquefaction resistance were established. According to the test results, liquefaction resistance will increase with increasing relative density and over-consolidation ratio, and will slightly decrease with increasing confining pressure. The state parameter can be correlated with the liquefaction resistance. The liquefaction resistance will decrease with increasing state parameter. To obtain a unique relationship between liquefaction resistance and state parameter, the liquefaction resistance should be normalized by the square root of overconsolidation ratio.

KEY WORDS: Liquefaction resistance, state parameter, overconsolidation, silty sand

INTRODUCTION

Liquefaction resistance generally refers to the following definitions. Initial liquefaction indicates a condition where, during the course of cyclic stress applications, the residual pore water pressure on completion of any full stress cycle becomes equal to the applied confining pressure. Cyclic mobility represents a condition in which cyclic stress applications develop a peak cyclic pore pressure ratio of 100% and subsequent cyclic stress applications cause limited strains to develop because the soil dilates during the deformation. In this paper, liquefaction resistance is defined as the cyclic stress ratio required to cause soil to reach initial liquefaction at a certain number of cyclic loading.

The liquefaction of a site can be determined by the following approaches. The first approach is to assume that the factors of stress history and density, which control liquefaction resistance, also affect penetration resistance. The blow count obtained by the standard penetration test or the cone tip resistance is related to the liquefaction resistance of the deposit by means of empirical equations based on penetrometer measurements at sites that did (or did not) liquefy, supplemented by the results of large-scale liquefaction tests. Such correlation obviously depends on the general applicability of penetration data obtained at relatively few sites. This method is generally believed to be conservative.

The second approach is to recover undisturbed, from the problem deposit, specimens that could be subjected to actual liquefaction tests. However, conventional sampling techniques will produce significant disturbance of clean sand specimens and the true liquefaction resistance will be considerably underestimated in laboratory tests.

Another approach is to correlate the state of laboratory specimens with in-situ soil characteristics using some appropriate index property. The state parameter seems to be a good index. It is found that the state parameter is closely correlated with many mechanical properties of sand, including liquefaction resistance.

Behavior of sand is controlled by its density and confining stress. Relative density is the commonly used index to describe the state of sand. However, it is well known that relative density cannot fully describe the mechanical behavior of sand. Therefore a parameter, which can incorporate the density and stress state of soil, is needed to reflect the engineering behavior of sand. To establish a rational engineering approach to constructing structures on hydraulic sand fill, Been and Jeffries (1985) developed a state parameter concept to characterize the sand behavior. They found that significant engineering design parameters are dependent on the state parameter. Recently, quite a few hydraulic sand fill islands are or will be constructed on the west coast of Taiwan to be used as industrial parks. Therefore, it would be economic and safe to apply the state parameter concept in designing these islands.

Been and Jeffries (1985) propose to use the steady state line (SSL) on the c-log p plane as the reference line. State parameter, \( \Psi \), is defined as the difference between initial void ratio and the corresponding void ratio at the same stress level on the steady state line. State parameter combines the influence of density and stress so that it can reasonably characterize many important engineering behaviors of sand, as well as liquefaction resistance.

Previous researches mostly concentrated on normally consolidated samples, very few studies were conducted on over-consolidated samples. Hydraulic-filled sand layers are usually in loose condition and