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Drained Triaxial Behavior of SCP-reinforced Composite Ground with Low Area Replacement Ratio

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Shear strength parameters and elastic parameters play an important role in design and analysis, especially in stability analysis and block analysis by finite element analysis. Most researchers have performed an undrained triaxial test to estimate these parameters. As sand piles installed into the ground also act as a drainage channel in the condition of a low area replacement ratio, it is more reasonable to consider that the composite ground experiences a drained shear. This study performed a series of conventional drained triaxial tests on the specimen-installed sand compaction pile to investigate the composite behavior according to the area replacement ratio and the rate of shear and confined stress. In the composite ground with a low area replacement ratio, in spite of the fact that the stress-strain behavior is similar to that of sand, variation of shear strength parameters and elastic parameters according to the area replacement ratio show some unique relations to the properties of original clay.

INTRODUCTION

The sand compaction pile (SCP) method forms a composite ground by installing a sand pile into soft ground. This has been a commonly used soil improvement method for reinforcing and strengthening soft clay deposits in many countries for over 30 years, although it has found a wider application in Japan and Korea than in any other country. It consists of well-compacted sand piles which are installed in soft ground by using a vibrating casing pipe. The SCP method can be applied to both sandy and clay grounds by using the same equipment and machines. Especially when the SCP method is applied to a clay ground, the improved result is called a composite ground.

Many researchers have investigated the mechanical behavior of composite ground reinforced by sand compaction piles (Murayama, 1962; Aboshi et al., 1979; Kimura et al., 1983). Most of the research has focused on 5 main points (Jung, 1998):

- bearing capacity
- consolidation settlement and deformation
- construction problems
- design methods
- partly penetrated SCP problems

Yet, the behavior of SCP composite ground, especially with a low area replacement ratio, has not yet been identified because the composite behavior between a sand pile and the surrounding clay is more complicated than with a high area replacement ratio.

In the design and analysis of the SCP method, estimations of shear strength parameters and elastic parameters have very important significance. Most of the research has been performed under the undrained shear condition. However, with a low area replacement ratio, as sand piles in the ground also act as a drainage channel, an assumption of drained shear behavior seems to be more reasonable. In this study, a series of conventional consolidated drained triaxial (CD) tests is performed in order to investigate the behavior of the composite sample with a low area replacement ratio. From test results, shapes of stress-strain relation according to the area replacement ratio and the strain rate are presented. In addition, the variation of peak stress, ultimate stress, effective internal friction angle, and effective cohesion of composite ground are quantified according to the area replacement ratio and properties of pure clay ground.

BASIC THEORY FOR SAND COMPACTION PILE

The ground improved by compacted sand piles is termed composite ground. When loaded, the pile deforms by bulging into the subsoil strata and distributes the stresses at the upper portion of the soil profile rather than transferring them into the deeper layers, thus causing the soil to support it. As a result, the strength and bearing capacity of the composite ground can be increased and the compressibility reduced. In addition, lesser stress concentration is developed on the sand piles. Since the component materials are granular and have higher permeability, sand piles could also accelerate the consolidation settlements and minimize the post construction settlements.

The tributary area of the soil surrounding each sand pile is closely approximated by an equivalent circular area. The equivalent circle has an effective diameter of (Bergado et al., 1996):

$$D_e = 1.05S \text{ for equilateral triangular pattern of sand piles} \quad (1)$$

$$D_e = 1.13S \text{ for regular square pattern of sand piles} \quad (2)$$

where S is the center-to-center spacing of sand piles. The equilateral triangular pattern gives the densest packing of sand piles in a given area. The resulting cylinder of composite ground with diameter D_e enclosing the tributary soil and one sand pile is known as the unit cell.

Fig. 1 illustrates the area replacement factor as well as the stress concentration in the sand pile:

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