Centrifuge Modeling of Base Load - Displacement Response of Piles in Sand under Static Vertical Load

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ABSTRACT.

This paper presents results of a series of centrifuge model tests to study the base load – settlement response of piles in a medium sand. The experiments were designed to investigate the effects of relative density of sand and pile type on a pile’s base response during static loading. The tests revealed that soil stresses at the pile base reached 18 - 20 MPa. Sand particle breakage was significant beneath the pile base. No slip plane was observed along the pile. The failure pattern at the base of the pile in sand was a type of punch shear failure. The soil at the base moved basically downward. The base resistance was associated with the compression of the sand within a zone of 4.3 D in depth and 3D in width beneath the pile base. Stiff response of pile occurred in dense sand and greater base resistance occurred with cone shape pile end. The base resistance at a pile base displacement of 0.1D of the cone end pile is 21.2% greater than that of the flat end pile.

KEY WORDS: Pile, medium sand, relative density, pile type, base load-displacement response.

NOMENCLATURE

Optional, but do not use unless it is absolutely necessary. If used, place in alphabetical order, followed by any Greek symbols.

INTRODUCTION

Our understanding of the behavior of pile foundation is improving but there is still great uncertainty attached to the process of pile installation, and to the detail of the pile-soil interaction (Randolph et al. 1994). For many years pile foundation design involves great empiricism (Randolph 2003). Among these empirical approaches, the cone penetration tests (CPT) based methods enjoy preference (Randolph 2003). It has been established that the deformation beneath the base of a loaded pile looks like the expansion of a spherical cavity in an infinite medium (e.g. Vesic 1972, Randolph et al. 1994, Yasufuku and Hyde 1995)

The base load – displacement response of piles can be evaluated by physical, analytical and numerical methods. Physical modeling plays a fundamental role in the development of geotechnical understanding (Zhang JH et al. 2007, Zhang JM et al. 2009). There is obvious disadvantage of full scale modeling, as it is usually expensive, time-consuming, and sometimes may not be possible. Smaller scale modeling, such as centrifuge modeling, often leads to much more rapid results purely because of smaller size. The great advantage of the centrifuge modeling is that a full control over all the details of the model is possible. It permits more tests to be performed and more variables to be explored. The relevant scaling law of the centrifuge is well established (Taylor 1995).

This paper is based on a centrifuge study on piles under static vertical loading in medium sand. The purpose of the study is to examine the deformation behavior and particle breakage of the sand beneath the pile base. The effects of relative density of sand and pile type on a pile’s base load-displacement response were also investigated.

CENTRIFUGE MODEL DEVELOPMENT

Model Pile

Fig. 1 shows the model piles used in centrifuge tests. The pile was made of stainless steel. A half solid pile, as shown in Fig. 1a, will be installed in the sand adjacent to a transparent window fixed at one side of the strong box, from which deformation of the ground is visible. Two close ended piles made of hollowed aluminum tubes were used to investigate the total and base response of pile, as shown in Figs. 1b and 1c. Their pile end is different, one is with flat pile end and the other one is with cone shape pile end. All the piles have identical pile length of 250 mm.

In order to measure the base load of the pile, a force transmission rod was screwed up with the cone shape pile end, leaving the pile cap unscrewed, as shown in Fig. 1c. By doing so, the vertical static load can be directly applied on the pile base. A base load – displacement response can be obtained. Alternatively, if the rod was screwed up with the pile cap, then all parts, i.e. the cap, pile shaft, rod and pile base, will be integrated. In this case, the vertical static load was a sum of the base load and shaft friction resistance. A total load – displacement response can be obtained. As the pile was fairly rigid, so the displacement of the pile head may be considered identical with that of the pile base.