Soils and Foundations 2014;54(3):296–312

The Japanese Geotechnical Society

Soils and Foundations

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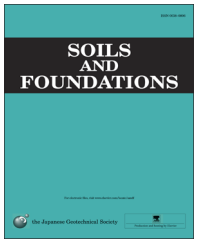

Understanding ground deformation mechanisms for multi-propped excavation in soft clay

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Received 30 June 2012; received in revised form 14 May 2013; accepted 8 April 2014
Available online 17 May 2014

Abstract

Deep excavation works are carried out to construct underground infrastructures such as deep basements, subways, and service tunnels. The execution of these deep excavation works requires the use of retaining walls and bracing systems. Inadequate support systems have always been of major concern, as excessive ground movement induced during excavation could cause damage to neighboring structures, resulting in delays, disputes, and cost overruns. To gain a better understanding of the mechanisms involved in soil excavations, centrifuge model tests of deep excavations in slightly over-consolidated soft clay have been carried out using a newly developed testing system, in which the construction sequence of a multi-propped wall for deep excavations can be simulated in flight. Deformation mechanisms are observed using Particle Image Velocimetry. Settlements of the ground surface and changes in pore water pressure are monitored during the excavation. The effects of prop stiffness, wall rigidity, and excavation geometry on the characteristics of ground deformation and soil–structure interaction are demonstrated and discussed. The use of the conservation of energy within the framework of the mobilizable strength design in calculating ground movements is validated and shown to perform satisfactorily.

Keywords: Centrifuge; Multi-propped excavation; Deformation mechanisms; Mobilizable strength design

1. Introduction

Deep excavations in soft clay are carried out for a variety of purposes, including the construction of station boxes and cut-and-cover tunnels during underground railway construction. In order to prevent the collapse of these excavations and to minimize the disruption to neighboring infrastructures due to settlements, multiple levels of props are used to support the retaining walls during construction. In order to better understand the mechanisms involved in the construction of multi-propped deep excavations in soft clay, centrifuge model tests have been carried out using a newly developed testing system, in which the construction sequence of a multi-propped deep excavation can be properly simulated (Lam et al., 2012).

2. Methodology

Small-scale centrifuge models can be used to simulate the prototype behavior of an excavation in soft soil. A

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Peer review under responsibility of The Japanese Geotechnical Society.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sandf.2014.04.005

centrifugal acceleration field of 60 g is used in a small-scale model to match the stress induced by gravity in the prototype. The principal challenge is to design a test package that can simulate the construction sequence of a propped excavation in the field, so that a cross-section can be used for the measurement of the resulting ground movements. The advantages are that the tests can be repeated with planned variations, and that the model can be observed continuously from the occurrence of small deformations up to complete collapse, which is not generally possible in the field. Similar approaches were adopted by Takemura et al. (1999) and Loh et al. (1998).

Table 1
Summary of centrifuge testing program.

Centrifuge tests	1	2	3	4	5
	Floating rigid wall with stiff props	Floating flexible wall with stiff props	Fixed-base flexible wall with base grout	Floating rigid wall with soft props	Fixed-base flexible wall in shallow clay
Objectives	Baseline test	Wall stiffness	Fixed-wall toe condition	Prop stiffness	Clay thickness
Depth of clay stratum, D (mm)	300	300	300	300	160
Prop stiffness (kN/mm)	1.66	1.66	1.66	0.55	1.66
System stiffness $EI/\gamma_w s^4$	2860	106	106	2860	106
Toe fixity	Free	Free	Fixed	Free	Free

Note: Numbers are in model scale.

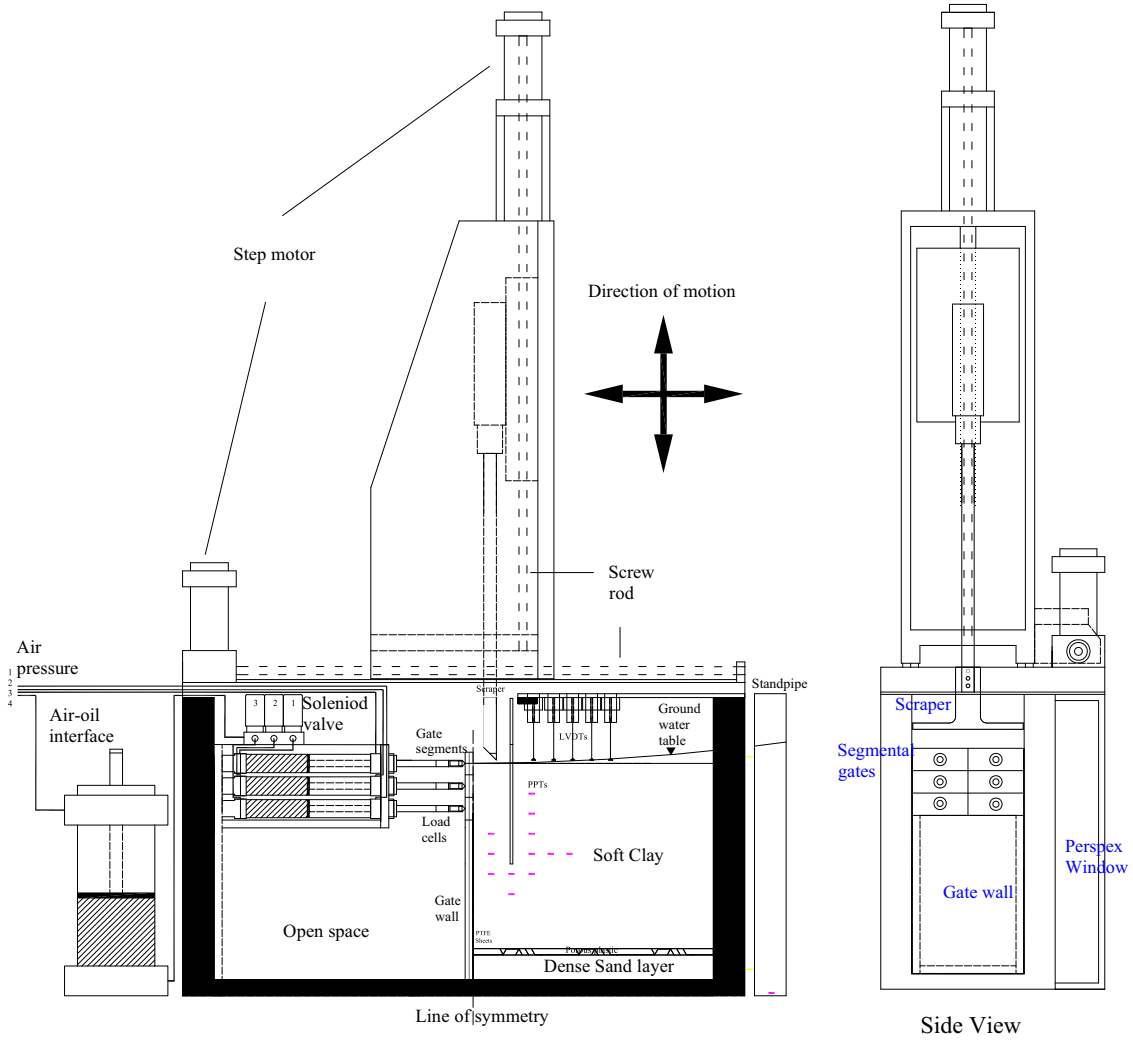

Fig. 1. Schematic diagram of experimental setup with in-flight excavator.