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Residual Liquefaction under Standing Waves

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ABSTRACT

This paper summarizes the results of an experimental study which deals with the residual liquefaction of seabed under standing waves. It is shown that the seabed liquefaction under standing waves, although qualitatively similar, exhibits features different from that caused by progressive waves. The experimental results show that the buildup of pore-water pressure and the resulting liquefaction first starts at the nodal section and spreads towards the antinodal section. The number of waves to cause liquefaction at the nodal section appears to be equal to that experienced in progressive waves for the same wave height. Recommendations are made as to how to assess liquefaction potential in standing waves.

KEY WORDS: Residual liquefaction; marine soils; sand; silt; standing waves.

INTRODUCTION

Under wave action, the seabed may undergo a process called residual liquefaction, where the cyclic shear deformations rearrange the soil grains at the expense of pore volume and resulting buildup of pore water pressure exceeds the effective stresses between soil grains.

A great many works have been devoted to residual liquefaction under progressive wave action; a detailed account of the topic can be found in Sumer and Fredsøe (2002) and most recently in Sumer et al. (2011 and 2012).

Liquefaction is also a concern in standing-wave situations, e.g., in front of breakwaters, seawalls, and large caisson structures. To the authors' knowledge, there have been very few investigations of seabed liquefaction under standing waves, Sekiguchi et al. (1995) and Sassa and Sekiguchi (1999 and 2001), in which the so-called centrifuge wave testing was used to obtain data.

The purpose of the present investigation is to study the residual liquefaction under standing waves in a systematic manner in a physical model investigation, using a standard wave-flume facility. It turns out that the seabed liquefaction under standing waves, although qualitatively similar, exhibits features different from that caused by progressive waves.

EXPERIMENTAL SETUP

Wave Flume and Instrumentation

The experiments were conducted in a wave flume (26.5 m in length and 0.6 m in width), specially manufactured for liquefaction tests and equipped with a piston-type wavemaker, the same flume as that used in Sumer et al. (2011 and 2012). The water depth within the flume was h = 30 cm throughout the study.

The soil was placed in a 0.40 m deep, 0.60 m wide and 0.78 m long pit (Fig. 1) located 14 m from the wave generator as a rigidly fixed part of the flume. In the tests, the pit was filled with the soil such that the surface of the soil was flush with the bottom of the flume.

The standing waves were obtained by a fully reflecting, vertical, plywood plate, Plate P, in the flume (2 cm thick, 80 cm high and 60 cm wide) placed at the onshore end of the soil pit (Fig. 1a). The plate was sealed at the edges to ensure the full reflection. The standing wave experiments were designed such that the length of the soil pit is equal to one half of the wave length ($L/2$), being 78 cm. With this arrangement the nodal section coincided with the centre of the soil pit while the antinodal sections coincided with the two (offshore and onshore) ends of the soil pit (Fig. 1a). In this way, the soil in the pit was exposed to the standing wave fully. The dispersion relation for linear water waves dictates a wave period of T=1.09 s to satisfy this wave length (L=156 cm) when h=30 cm.

In addition to liquefaction tests with standing waves some tests with progressive waves were also conducted, for comparison. In this case, the reflecting plate was removed and a wave absorber was placed at the end of the flume to handle reflections.

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