Seismic Responses of Mono-Pile Foundation in Liquefiable Sandy Soil

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ABSTRACT

A series of centrifuge shaking table tests of mono-pile embedded in the liquefiable sand deposit and dry sand deposit was conducted at an acceleration of 80-g. Two natural frequencies were identified by means of the Fourier spectrum of acceleration measured at the tip mass attached at different elevations in the pre-shaking. The maximum bending moment of pile in dry sand appeared at the depth of 4 m (z/L=0.2) and the maximum bending moment of pile in saturated liquefiable sand appeared at the depth of 8-9 m (z/L= 0.39-0.43). The earthquake induced bending moments and the pile displacements became larger if the tip mass fixed at the higher elevation of the mono-pile. The occurrence of liquefaction would lead to the loss of confinement from the surrounding sand.

KEY WORDS: Mono-pile; liquefaction of sand; Bending moment; centrifuge shaking table test.

INTRODUCTION

The use of green energy generated from renewable sources such as wind energy and solar energy dramatically increased to reduce the impact of and protection of global environment in the recent years. The wind energy resource in western Taiwan is very abundant and the offshore wind power industry has been developing in the coming decade. The area of Western Taiwan coastline is classified to a high earthquake activity zone and the most of sea bed is deposited with very loose sandy soils that liquefy very likely during big earthquakes. Mono-piles are widely used as foundations of wind turbines at onshore as well as offshore locations. The mono-pile foundation is planning to be used as the foundation of wind turbine that is located at Western Taiwan. However the current design codes of wind turbine foundation does not give the detailed earthquake resistant design requirements for the support foundation that embedded in the liquefiable sand deposit in engineering practices.

The mono-pile must be designed for resisting cyclic lateral loads both due to wind and wave acting on the turbine tower and the blades and due to inertial forces resulting from earthquake shaking as well. The external loadings on the foundation of offshore wind turbine are quite different from those on the foundation of the civil structures like traditional buildings or bridges. The foundation for an offshore wind turbine is subjected to large moments and small vertical loads at the seabed level. The situation would become more critical once the part of surrounding soil turning into liquefying during big earthquakes. No detailed research on this topic is reported. In the paper a series of centrifuge shaking table model mono-pile tests was conducted to investigate the seismic responses of mono-pile embedded in liquefiable sandy soil.

TESTING SETUP AND TESTING PROCEDURES

Testing Equipment

This experimental work was undertaken in the geotechnical Centrifuge at the National Central University (NCU). The NCU Geotechnical Centrifuge has a nominal radius of 3 m and equips a 1-D servo-hydraulically controlled shaker integrated into a swing basket. The shaker has maximum nominal shaking force 53.4 kN with maximum table displacement of ±6.4 mm and operates at up to 80 g centrifugal acceleration. The nominal operating frequency range is 0 - 250 Hz. A laminar container with inside dimensions of 711 mm x 356 mm x 353 mm (L×W×H) is constructed from 38 light-weight aluminum alloy rings arranged in a stack. The laminar container is designed for dry or saturated soil models. The boundary effects of the laminar container used in the study is minimal; hence the container permits development of stresses and strains associated with one dimensional shear wave propagation (Lee et al., 2012). Fig. 1 shows the laminar container resting on the NCU Geotechnical Centrifuge Shaker.

Fig. 1 Laminar container resting on the NCU geotechnical centrifuge shaker