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Directors' research and development activities

The Application of Partial Floating End Bearing Sheet Piles to Mitigate Liquefaction-Induced Foundation Settlements

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Introduction

Liquefaction-induced tilting and settling of buildings founded on top of saturated sandy soils has been a major contributor to damage in many past earthquakes. These included the 2011 Tohoku Earthquake in Japan, the 2010-2011 earthquakes in New Zealand, the 2015 Nepal earthquake, and the most recent 2023 Turkey earthquakes. Geotechnical engineers have recommended the installation of sheet piles near foundations as an effective strategy to mitigate settlement induced by liquefaction as illustrated in Fig. 1. However, the cost associated with full-length sheet piles can be reduced by implementing partial floating sheet piles (PFS).

Initially, the PFS approach was conceived as a solution to counteract subsidence caused by the load of a river embankment constructed on soft clay ground within residential areas. This method involved the combination of partially floating sheet piles and end-bearing sheet piles. The partially floating sheet piles were situated in the liquefiable layer, while the end-bearing sheet piles were supported by a stable layer. Consequently, the utilization of the PFS technique allowed for a reduction in the weight of sheet piles used, cutting it approximately in half.

However, previous research investigated that sheet piles with gaps or half-lengths in liquefiable soils did not effectively mitigate liquefaction-induced shallow foundation settlements. To achieve improved performance in reducing liquefaction-induced foundation settlements, it is necessary to use full-length sheet piles that cover the entire liquefiable layer. As a result, our study involved only changing the configuration of the end-bearing portion of sheet piles to prepare the PFS.

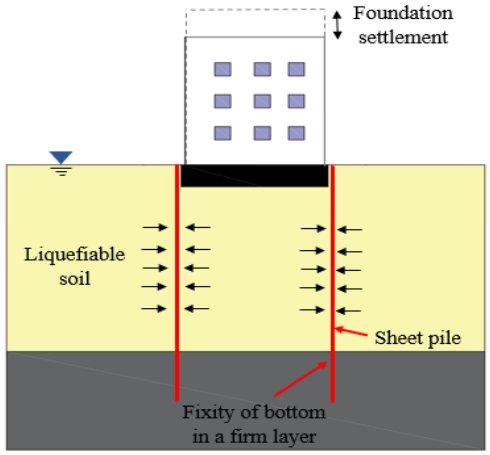

Fig. 1. Application of the sheet pile to mitigate the liquefaction-induced foundation settlement.

Experimental Program

In this study, the model ground properties were scaled down according to the similitude law, which was obtained based on a large-scale shake table test. The scaled model comprised three distinct soil layers with different relative densities: a 50% relative density top crust layer, a 30% relative density middle liquefiable layer, and an 85% relative density bottom dense layer. A shallow foundation was placed atop the crust layer, followed by the insertion of sheet piles (both full-length and PFS) at 0.625 times the foundation width from the center, utilizing the press-in technique as shown in Fig. 2(i). This study included five 1g shaking table tests. Test 1 had no mitigation measures (NM). Test 2 used full-length sheet piles (FL), while Tests 3 to 5 employed partial floating end-bearing sheet piles. For instance, "5-cut" indicates that 5 cm of the end-bearing sheet pile was removed to prepare 5 cm of PFS, as depicted in Fig. 2-ii(b).

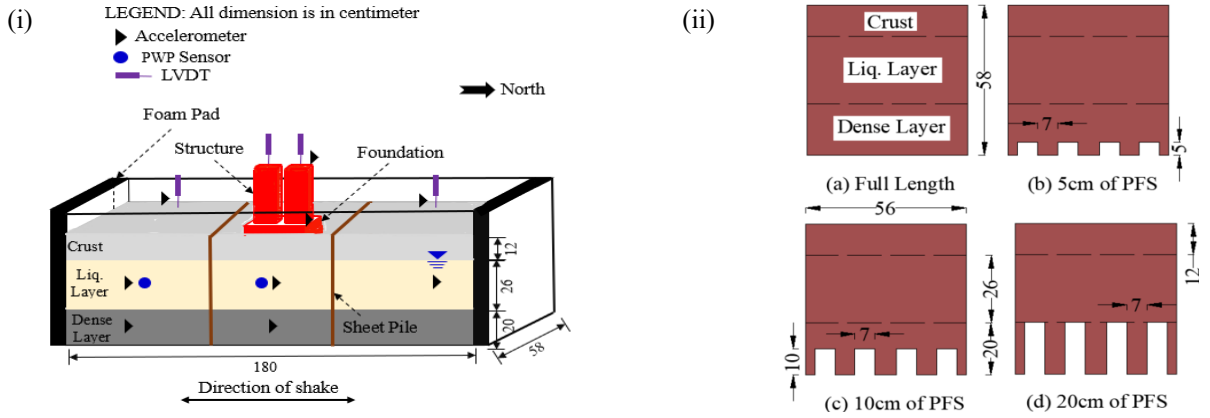

Fig. 2. (i) Schematic view of the model ground, sheet pile, foundation, and structure, (ii) Sheet pile types utilized in this study

Performance of PFS against Liquefaction-Induced Foundation Settlements

In this study, the settlement of the shallow foundation is represented in the form of settlement time histories as depicted in Fig. 3a. The maximum foundation settlement was determined from the recorded settlement-time histories in Fig. 3a and then plotted against the corresponding experiment number in Fig. 3b. In Fig. 3b, the installation of sheet piles resulted in a decrease in foundation settlement. For 'FL', '5-cut', and '10-cut' of PFS configurations, the sheet pile achieved sufficient fixity of bottom into the dense layer when compared to the '20-cut' of PFS. As a result, an increase in PFS led to a higher maximum foundation settlement.

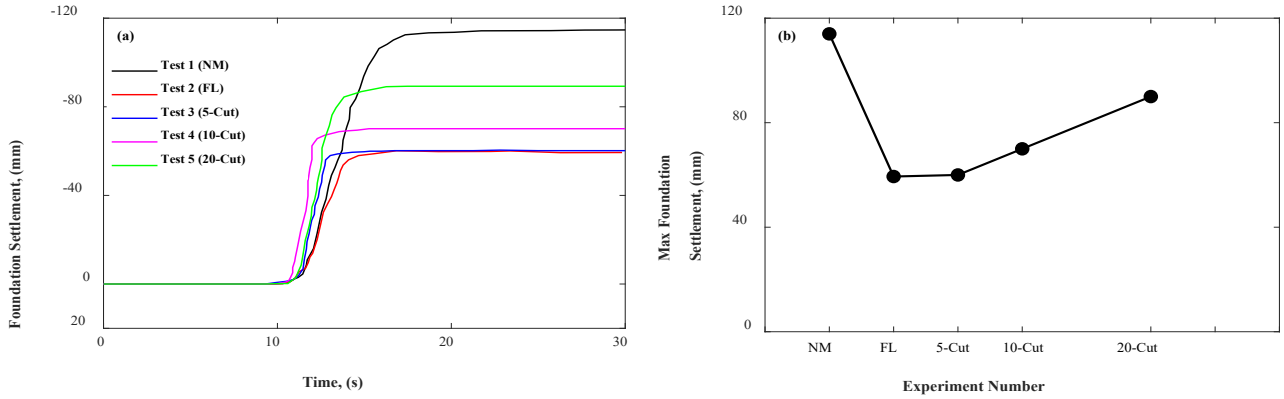

Fig. 3. (a) Foundation settlement-time histories, (b) The variation of maximum foundation settlement with the experimental number.

Conclusions

The objective of this investigation was a comparative analysis of partial floating end-bearing sheet piles within a model ground, aiming to mitigate liquefaction-induced foundation settlement using a series of scaled 1-g shaking table tests. The experimental outcomes demonstrated that the foundation settlement measured by installing 25% (5-cut) and 50% (10-cut) of PFS closely approximated the settlement observed with full-length sheet piles. please note our comprehensive research paper will be presented at the Third International Conference on Press-in Engineering in 2024, hosted in Singapore.