On the Efficiency of Using Helical Piles in Liquefiable Ground: a Shake Table Investigation

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Introduction

Several past studies investigated the mitigation measures to reduce the liquefaction-related consequences during strong ground motions. These methodologies resulted in less settlement of rigid shallow foundation once the liquefaction triggered, however limited cost-effective measures have been introduced to mitigate the liquefaction-induced settlement of shallow foundations supporting structures. In this study, the effect of using helical piles as a cost-effective countermeasure to alleviate the liquefaction-induced settlement of buildings has been studied. Two large-scale shake table experiments were conducted at University of California San Diego Powell Laboratory to investigate the effectiveness of using helical piles in liquefiable ground. Both experiments were conducted in similar ground conditions, ground water level, foundation dimensions, foundation contact pressure and input ground motions except the fact that in the second test helical piles have been utilized to underpin the shallow foundation situated atop the soil model.

Fig. 1. Liquefaction-Induced Settlement of a Shallow Foundation with and without Using Helical Piles

Large Scale Shake Table Test Results

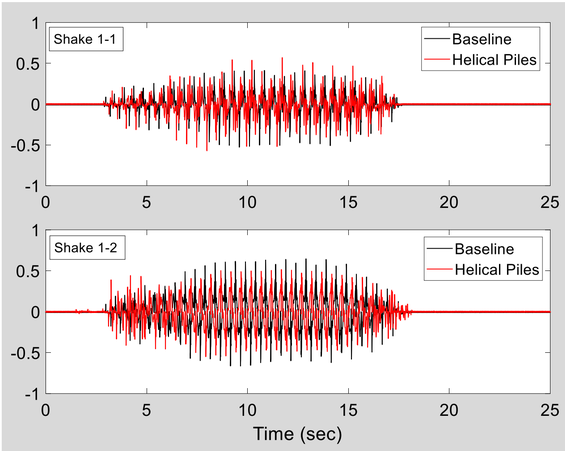

Fig. 6. Acceleration Time Histories for Baseline and Helical Pile Tests

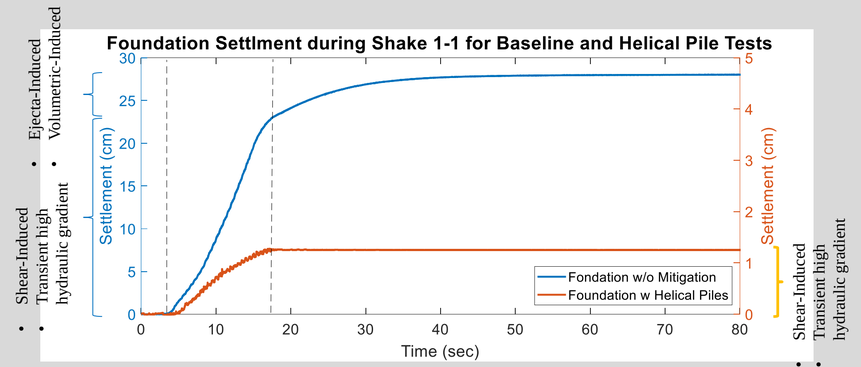

Fig. 7. Avg. Foundation Settlement for Baseline and Helical Pile Tests (Shake 1-1)

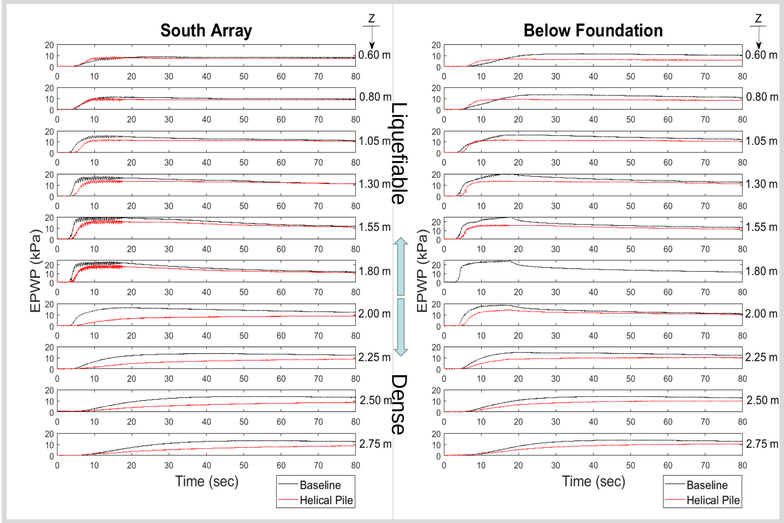

Fig. 8. Excess Pore Water Pressure Comparison for Baseline and Helical Pile Tests along Depth

Fig. 11. Observed Ejecta

Fig. 9. Before Shake 1-1

Fig. 10. After Shake 1-1

Experimental Procedure

Soil Properties, Testing Program and Helical Piles Instrumentation:

- Ottawa F-65 Sand (SP).
- Two shaking sequence with varying peak accelerations.
- Extensive instrumentation.
- 4 helical piles used as liquefaction-induced settlement Countermeasure.
- 7 pairs of strain gauges on each helical pile.

Fig.2. Helical piles, Bracket and Instrumentation

Fig.3. Helical Piles Instrumentation Sequence

Shake #	Target peak acceleration (g)	Achieved peak acceleration (g)
1-1	0.15	0.53
1-2	0.30	0.66

Type	#
Accelerometer	14
High Speed Accelerometer	24
Pore Pressure Transducer	33
String Pot	18
Linear Pot	4
Strain Gauge	56
Total	149

Property	Value
G_S	2.65
e_{max}	0.853
e_{min}	0.503
C_c	0.96
C_u	1.61
ρ_{max} (kg/m^3)	1759
ρ_{min}, (kg/m^3)	1446
k_{loose} (cm/s)	0.022
k_{dense} (cm/s)	0.016

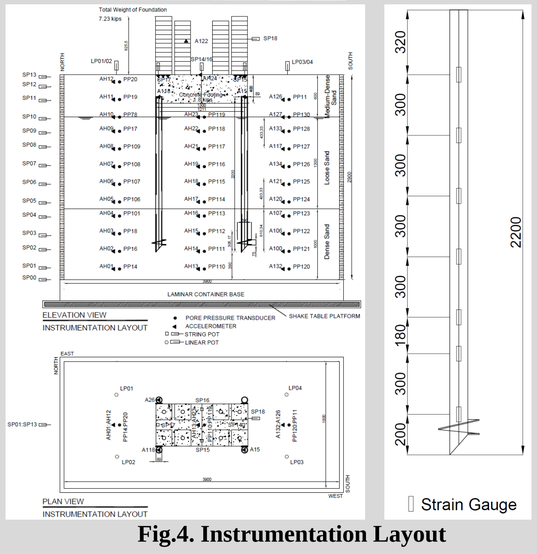

Fig.4. Instrumentation Layout

Fig. 5. Model Prior to Shake

Conclusion

- Results from these two experiments highlighted a highly improved performance of shallow foundation supported with helical piles.
- Reduced EPWP generation below the foundation array in helical pile test due to the densification of soil around helical piles.
- The maximum bending moment along depth of helical piles observed at the interface of loose and dense layer.
- The first experiment (Baseline) resulted in 28 cm average settlement of the foundation due to liquefaction. On the other hand, the helical pile experiment led to 1.2 cm average settlement of the foundation in the same liquefiable ground conditions.
- These large-scale shaking table experiments demonstrated the usefulness of using helical piles as a cost-effective countermeasure to mitigate the liquefaction-induced building settlement in high seismic areas.

Acknowledgement

This work was supported by funding through PEER (Pacific Earthquake Engineering Research) and Ram Jack. Their support is gratefully acknowledged. Furthermore, the staff at the UC San Diego Powell laboratory and a group of undergraduate students is highly appreciated for their assistance.

This project was made possible with support from:

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