

# Estimation of lateral pile capacity for design of soil-structure interaction experiments



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## Introduction

The accurate prediction and computational simulation of 3D multi-modal dynamic soil-pile interaction remains a significant challenge. As part of an ongoing research project to advance fundamental knowledge on this subject, dynamic soil-pile interaction experiments will be performed on single piles and pile groups, and new computational continuum models will be developed for seismic applications. To help calibrate the computational models, full-scale field tests are being planned for a single pile and a 2x2 pile group, including lateral vibration tests with small soil strains and quasi-static cyclic loading to failure.

This paper describes the estimation of the ultimate lateral capacity of the single pile and 2x2 pile group at

the selected project sites, required for designing the experiments.

## Planned Lateral Load Tests

Several series of multi-modal vibration tests will be performed using a servo-hydraulic inertial shaker and random vibration techniques. Following the vibration tests, the quasi-static lateral cyclic load tests will be performed on the single pile and 2x2 pile group at a project site in Ames, Iowa.

## *Project Site Selection, Soil and Pile Parameters*

Two sites were selected for the field tests, referred to as Sites 2 and 3. The soil profile for Site 2 was obtained from geophysical Multichannel Analysis of Surface Waves (MASW) tests performed by the authors and project team, and the soil profile for Site 3 was evaluated using data from previously conducted Cone Penetration Tests (CPTs). The resulting soil parameters are given in Table 1.

**Table 1: Soil profile parameters for Sites 2 and 3**

Soil parameters for Site 2, located at intersection of East Lincoln Way and I-35, Ames, IA						
Soil Type	Depth (ft)	$V_s$ (ft/s)	$\gamma$ (pcf)	SPT $(N_1)_{60}^a$	$c_u$ <sup>b</sup> (psi)	$\phi'$ <sup>c</sup> (°)
Clay	0	530	112	11	2.5	-
	7.9	707	112	15	7.7	-
	14.6	720	119	15	8.3	-
	30.0	737	119	12	9.0	-
	47.4	790	119	15	11.8	-
	64.4	1020	119	31	31.2	41
Sand	82.8	1419	119	82	111.4	45

Soil parameters for Site 3, located near Spangler Geotechnical Laboratory at Iowa State University, Ames, IA				
Soil Type	Depth (ft)	$\gamma$ (pcf)	$c_u$ (psi)	$\phi'$ (°)
Clay	35	130	20	-
Clay	78	135	50	-

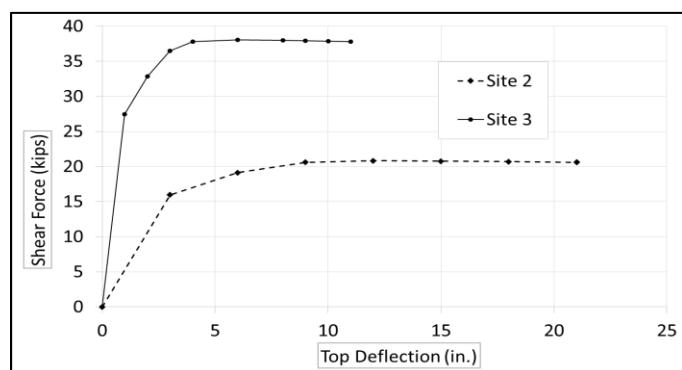
*V<sub>s</sub>: Shear Wave Velocity; γ: Unit weight; c<sub>u</sub>: undrained shear strength; φ': friction angle; a: (FHWA 2002); b: (Kulhawy & Mayne 1990); c: (Kulhawy & Chen (2007))*

**Table 2: Pile parameters for L-Pile analysis**

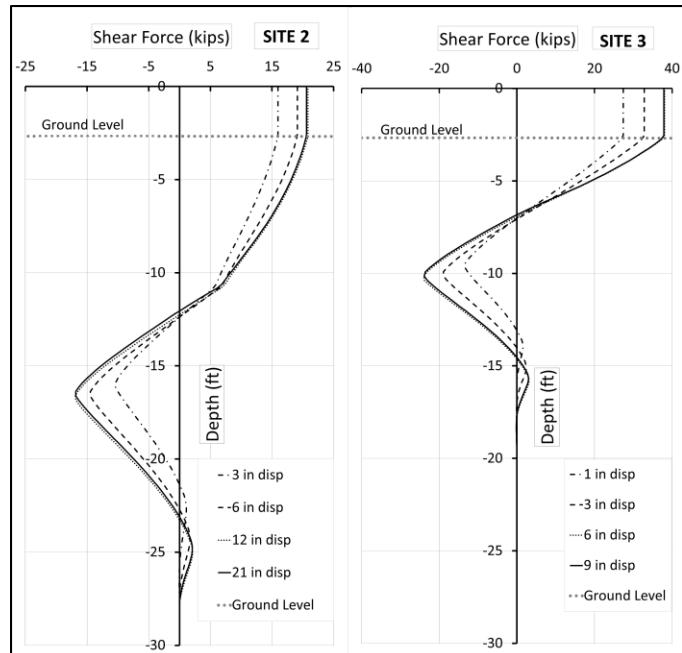
Case	1	2	3
Pile diameter (in.)	8.625	10.75	12.75
Wall thickness (in.)	0.322	0.365	0.375
Pile length (in.)		360	
Pile embedded length (ground surface to pile bottom) (in.)		300	
Pile unembedded length (ground sfc. to bottom of pile cap) (in.)		32	
Modulus of elasticity (lb/in.)		$29 \times 10^6$	
Yield stress of pile (ksi)		50	

### Lateral Pile Capacity Analysis

The lateral capacity of the single fixed-head pile for displacement-controlled field tests was determined using the L-Pile Plus (V5.0) software program. The results are detailed in Figures 1 and 2 and Table 3.



**Figure 1: Force-deflection at the bottom of pile cap for 8.625 in diameter steel pipe pile**



**Figure 2: Shear force profiles for increasing pile-head displacements for fixed head 8.625 in. diameter pipe pile**

**Table 3: Lateral Pile Analysis Results for Sites 2 and 3**

Site	Site 2			Site 3		
	Pipe Pile Diameter (in.)	8.625	10.75	12.75	8.625	10.75
Capacity of single pile <sup>1</sup> (kips)	21	28	39	38	60	80
Estimated capacity of pile group <sup>2</sup> (kips)	84	112	156	152	240	320
Top deflection at pile capacity (inches)	10.65	11.48	12.1	6.0	8.0	10
Maximum bending moment (in-kips)	1090	1930	2815	1100	1950	2800
Depth of max. moment from ground level (ft)	9	10	11	7	5.30	6.4
Maximum shear force (kips)	17	25	33	25	36	47
Depth of max. shear from ground level (ft)	14	15	17	7.4	9.3	10.5

<sup>1</sup>From L-Pile Type 3 Analysis

<sup>2</sup>Neglects pile interaction factors for conservatism

### Results and Discussion

The lateral capacities of the pile groups are given in Table 3 for all three potential pile sizes. Based on these analyses, the 8.625-inch diameter pipe piles at Site 3 were chosen to be used in the field tests. A Shore-Western hydraulic actuator having a capacity of 235 kips in compression and 175 kips in tension will be used, along with a reaction frame and piling constructed using steel HP 10x42 piles.

### References

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### Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1351828. This support is gratefully acknowledged. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.