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EFFECT OF SOIL SLOPE ON LATERAL CAPACITY OF PILES IN COHESIVE SOIILS

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ABSTRACT

Pile supported bridges are often constructed on natural or man-made slope. To assess the behavior of laterally loaded piles in/near sloping ground, full-scale laterally loaded pile tests has been carried out at Oregon State University in Summer/Fall 2009. A series of tests are being performed in cohesive soils. This paper presents the test results in the cohesive soils and the corresponding detailed information of the testing plan, such as test piles, test set-up plan and instrumentations. The test results showed that when piles were located within 4D from the slope crest, the presence of soil slope adversely affected the load carrying capacity of driven steel piles at low displacement ductility.

Introduction

Due to limited results from full-scale lateral load tests on piles near sloping ground, Current practice has no specific procedure used for the design of piles in such conditions, and often implements a purely structural system approach procedure that ignores the presence of soil, resulting in unnecessary higher costs. This study is aimed to develop a reliable and readily usable method to predict the lateral force capacity of piles with soil slope effect.

The most applicable up-to-date research to study effect of soil slope on lateral capacity of piles was conducted on small-scale centrifuge tests in cohesionless soils by Mezazigh and Levacher (1998). The test results indicated that lateral pile response depends only on the distance from the slope crest and its slope angle and is relatively insensitive to the soil relative density. In addition, results from full-scale test of two 1.2-m diameter Cast-In-Drilled-Hole piles in weakly cemented sand (Juirnarongrit and Ashford, 2001) indicated significant reduced stiffness at large displacements when compared with the pile without soil slope effect.

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A series of full-scale laterally loaded pile tests in cohesive soil has been carried out at Oregon State University (OSU) that include baseline testing, as well as experiments on piles near sloping ground. The objectives of the study are to assess the behavior of laterally loaded piles near sloping ground. The test results are meant to complement the existing database developed from previous tests in the literature and will be used to develop design recommendation for piles with soil slope effect.

Site Description

The test site was located near the western edge of the OSU campus. Figure 1 presents a typical soil profile of the test site based on the soil boring investigation (Dickenson, 2006). Stiff to very stiff, low to medium plasticity silt is located from the ground surface to a depth of 10 ft (the upper Willamette Silt). This layer is underlain by a layer of dense, poorly graded sand with silt and gravel which extends to a depth of approximately 13 ft. Below this sand layer is a stratum of medium stiff, high plasticity sandy silt that is approximately 5 ft thick (the lower Willamette Silt). Another layer of medium dense to dense, well-graded sand with silt and gravel extends to a depth of approximately 23 ft. These soils were underlained by a layer of stiff to very stiff, blue-gray, high plasticity silty clay which extends to a depth of approximately 70 ft. The water table was approximately 7 ft below the ground surface but fluctuates throughout the year.

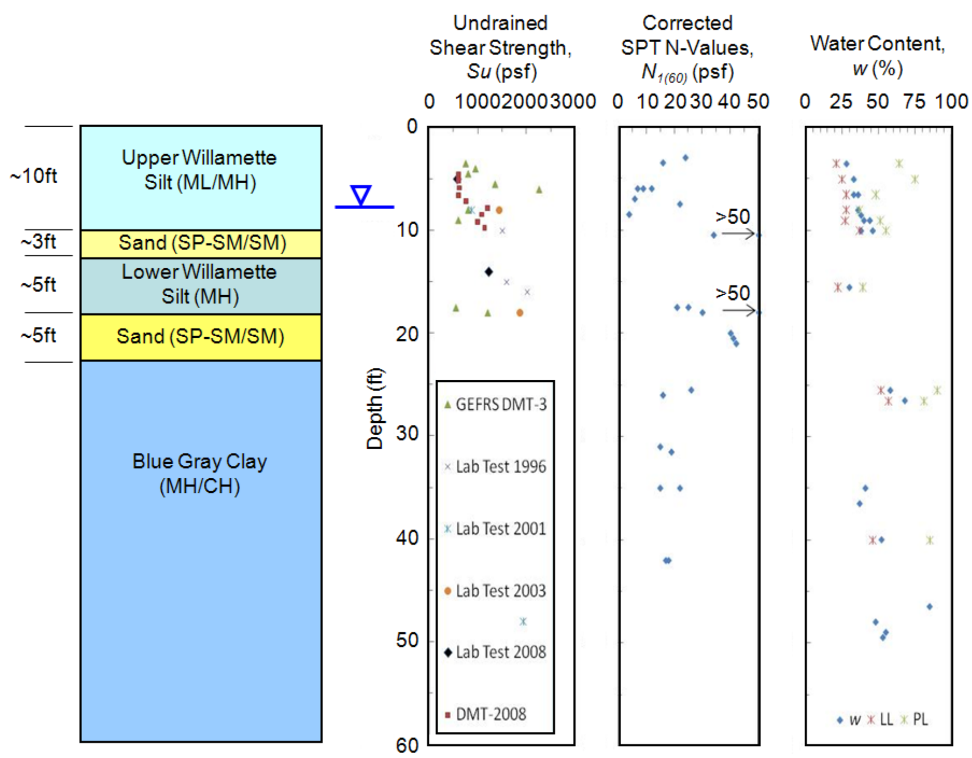

Figure 1. Typical soil profile of the test site.

Pile Properties and Instrumentation

All test piles were 1 ft in diameter with wall thickness of 0.375 in. and a nominal length of 30 ft. All steel test piles conform to ASTM specification A252 Gr 3. Several types of instrumentation (i.e., strain gauges, tiltmeters, load cells, and linear potentiometers) were installed on each test pile to measure pile responses during lateral loading. All test piles were carefully instrumented with 15 levels of strain gauges at 1-ft, 2-ft and 4-ft spacing. Steel channels C3x4.1 were welded to the steel pipe piles to protect the strain gauges installed along the piles from damage during pile installation. A series of tiltmeter were installed along the pile to monitor pile rotation. Each tiltmeter was fixed on a linear actuator that was fitted against the inner wall of the test pile. A cross-section view of the test pile and tiltmeter is shown in Figure 2. The load acting on the piles was measured by load cells in the actuator. String-activated linear potentiometers were attached to the piles to monitor pile displacements as well as load-displacement curves during the lateral load tests. The locations of all sensors for baseline testing are summarized in Figure 3.

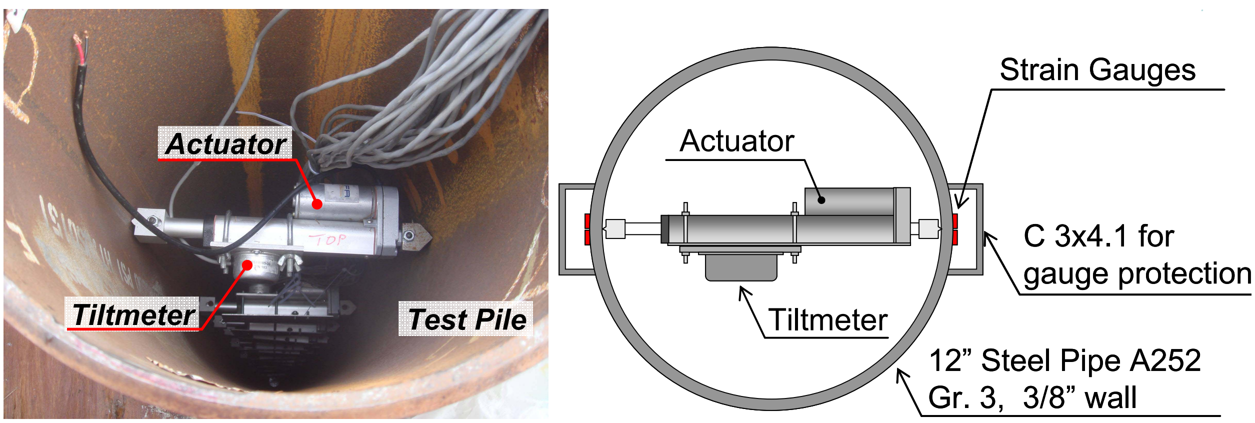

Figure 2. Cross-section view of test pile showing tiltmeter arrangement.

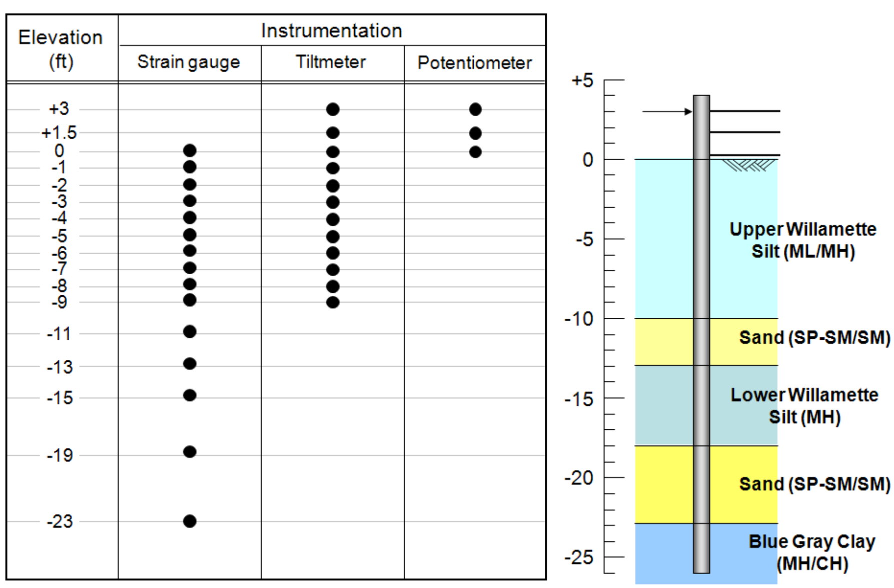

Figure 3. Summary of sensors for baseline pile test.

Test Setup

Test setup for the baseline pile test and three piles near sloping ground tests are shown in Figure 4. All test piles were driven into the ground using a diesel hammer. A total of fifteen 1-ft diameter steel pipe piles with a length of 40 ft were driven 36 ft into the ground to provide reaction for the test piles. Static load tests were performed on each test pile using a 500-kip hydraulic actuator. Each test pile was pushed against a transfer beam that was connected to a 3-in-a-row 1-ft dia. steel pipe pile arrangement. Lateral loads were applied at 3 ft from the ground surface by controlling input displacement. Figure 5 shows transversal view of test setup for baseline pile and pile near sloping ground load tests.

Figure 6 (left) shows the overall view of actual test setup for baseline pile test. After completion of lateral load test for piles in level ground (I-1), the test area was excavated along the slope crest line shown in Figure 4 to a 2:1 slope for remaining load tests for piles near sloping ground (I-2, I-3 and I-4). The completed slope excavation is shown in Figure 7. Figure 6 (right) shows overall view of actual test setup for Pile I-2 which was located at 2D from the slope crest.

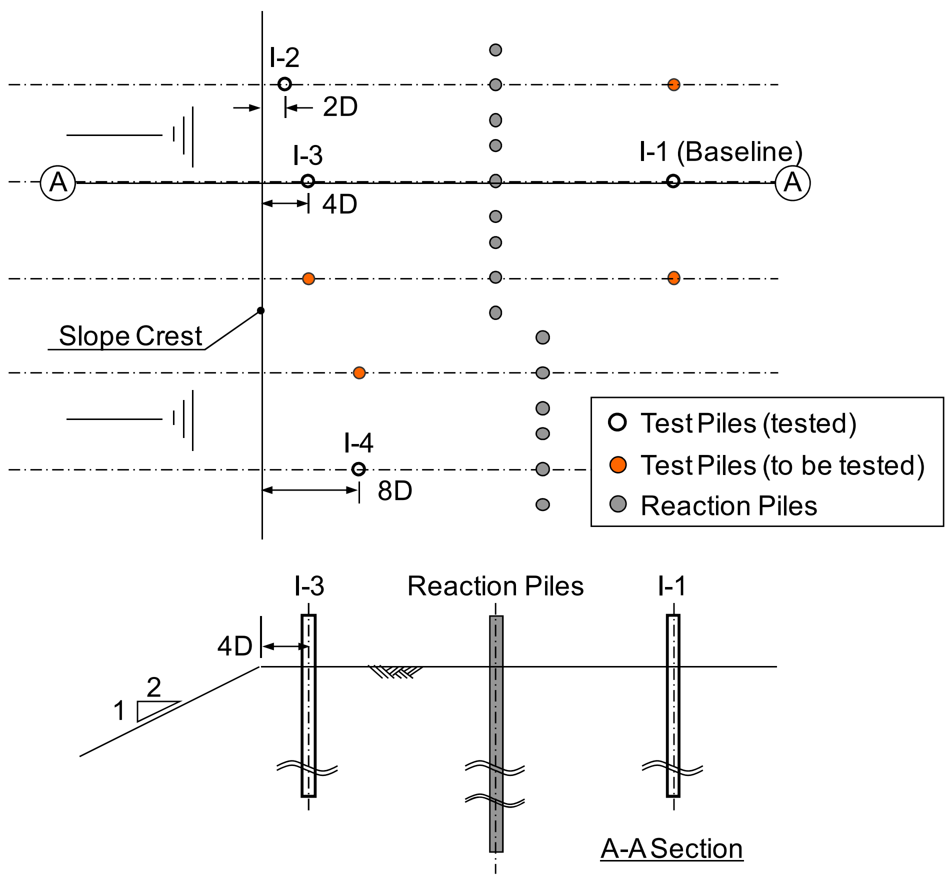

Figure 4. Test setup for baseline pile and piles near sloping ground.

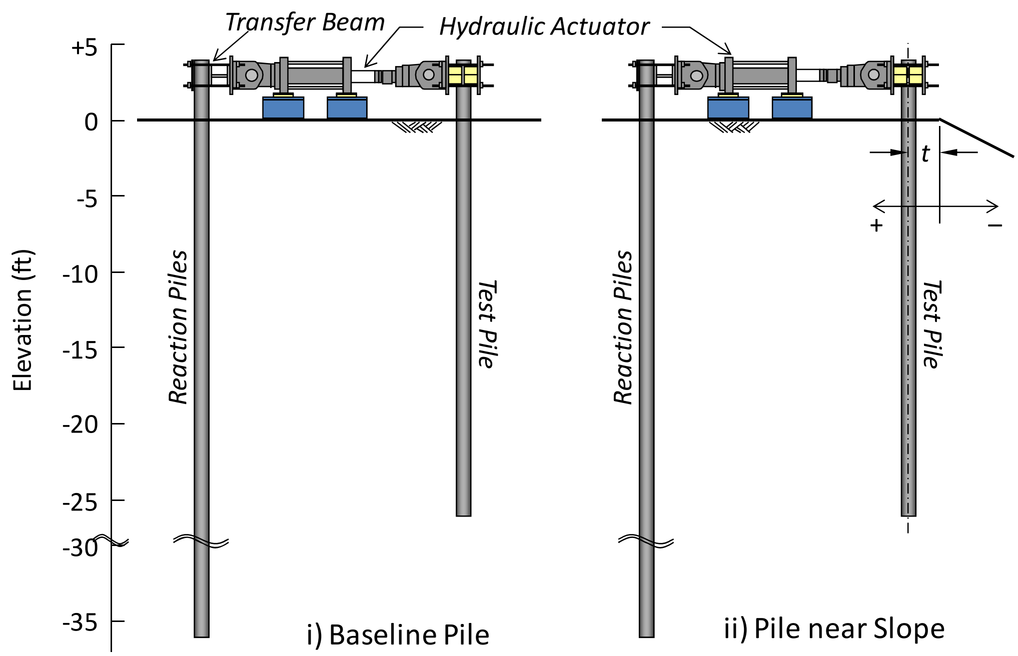

Figure 5. Transversal view of test setups.

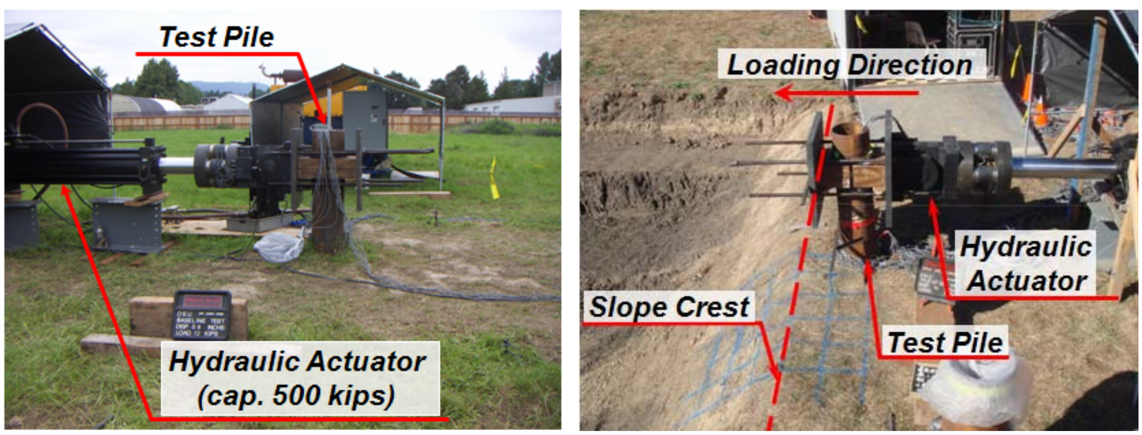

Figure 6. Actual test setup – Baseline pile test (left) and Pile I-2 located at 2D from the slope crest (right).

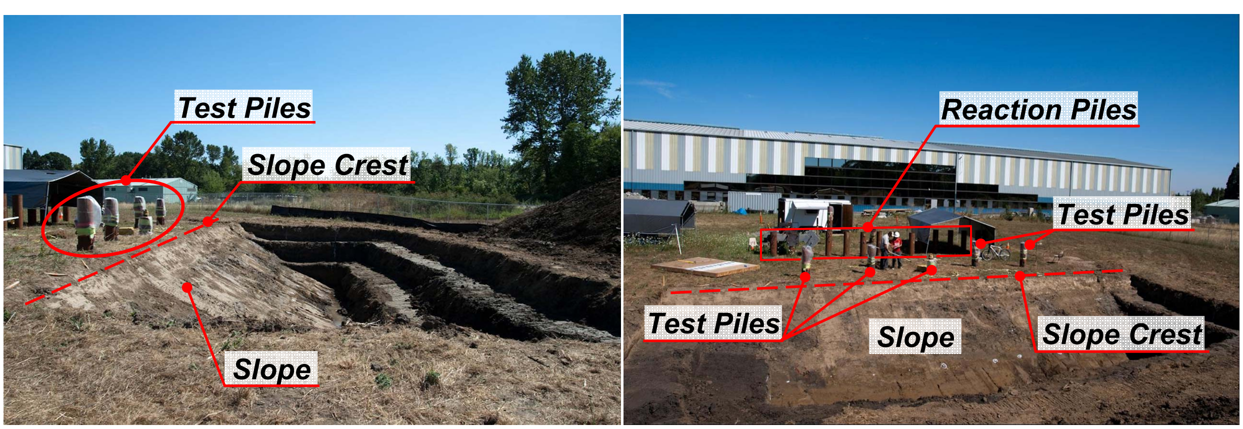

Figure 7. Overall view of the completed slope excavation.

Load Protocol

Static load test were performed to obtain the load-displacement information under lateral loading so as to develop p-y curves for the test pile. Each test pile was loaded monotonically until the displacement reached a target level as shown in Figure 8. Then, the displacement was maintained for 10 minutes depending on the displacement level to allow the pile displacement to stabilize. Afterward, the next displacement increment was applied and the same procedure was repeated. Within elastic range, the specimen were loaded to 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% of the predicted yield displacement. The estimation of yielding displacement was based on available geotechnical parameters obtained from site investigation and available *p-y* curves in LPILE. The loading was stopped once it was determined that the maximum load carrying capacity of each test pile was reached.

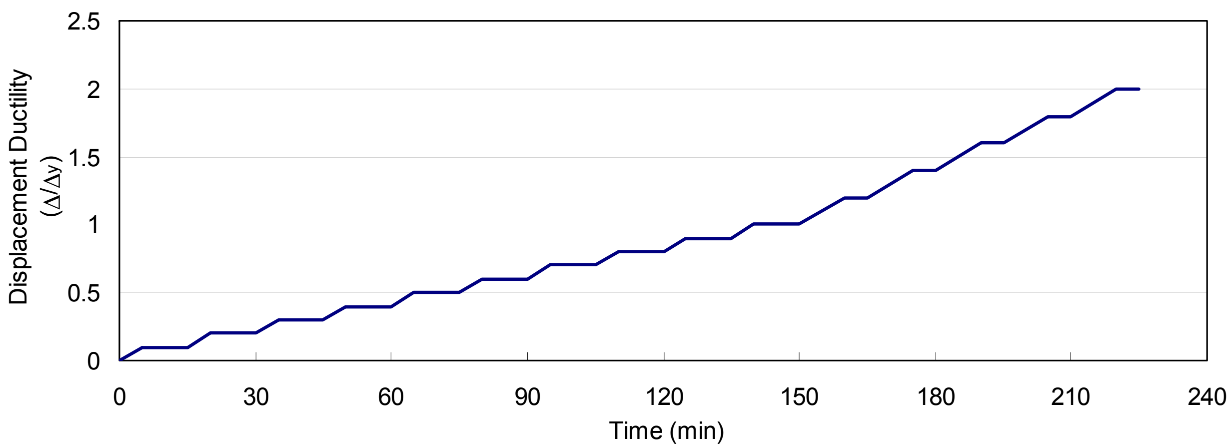

Figure 8. Load protocol.

Test Results

A comparison of the measured lateral load-pile head displacement curves of the different tests is shown in Figure 9. At low displacement, the stiffness of Pile I-2, I-3, I-4 and the baseline pile were similar. After approximately 1.5 inch of displacement, the load carrying capacity for Pile I-2 was lower than that of the baseline pile and pile I-4 for the same applied displacement. For pile I-3, the load carrying capacity was lower than that of the baseline pile and pile I-4 after approximately 2 inches of displacement. At maximum target displacement of 9 inches, the maximum load for pile I-2 was lower than pile I-3. Based on these observations, it can be concluded that when piles were located within 4D from the slope crest, the presence of the soil slope adversely affected the ultimate load carrying capacity of driven steel piles at low displacement ductility. The effect of soil slope is greater if the pile is located closer to the slope crest. These observations complement the findings by Mezazigh and Levacher (1998) from their centrifuge tests for piles in cohesionless soils. It should be noted that the effect of slope was negligible for pile I-4 which were located at 8D from the slope crest even at two times the displacement ductility.

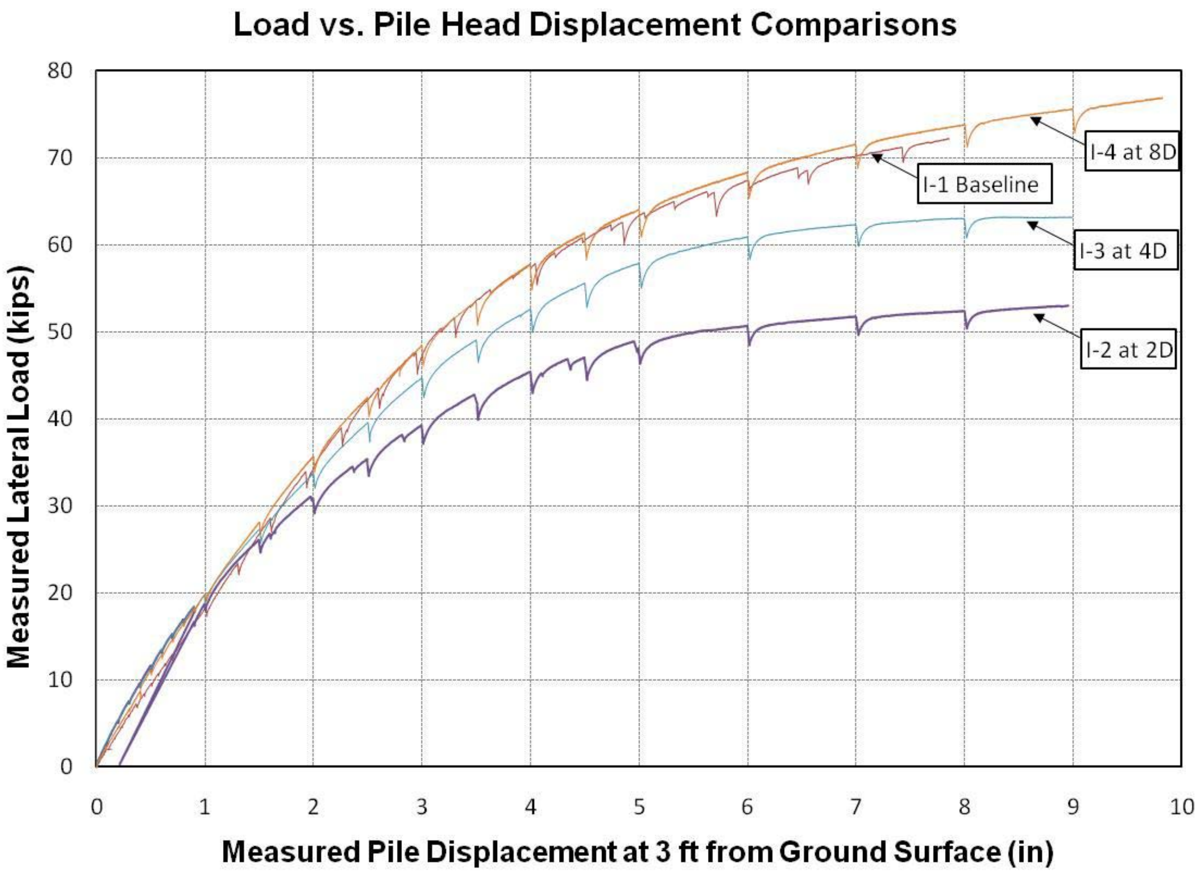

Figure 9. Measured load and pile head displacements curves.

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