Development of LRFD Procedures for Bridge Pile Foundations in Iowa

Volume I: An Electronic Database for PIle LOad Tests (PILOT)

tech transfer summary

This summary focuses on the importance of PILOT, its structure, key parameters, and quality of data.

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RESEARCH PROJECT TITLE
Development of LRFD Procedures for Bridge Pile Foundations in Iowa Volume I: An Electronic Database for PIle LOad Tests (PILOT)

SPONSORS
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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Objectives

Research Project

- Examine current pile design and construction procedures used by the Iowa Department of Transportation (DOT).
- Recommend changes and improvements to these procedures that are consistent with available pile load test data, soils information, and bridge design practice recommended by the Load and Resistance Factor Design (LRFD) approach.

PILOT

- Develop a user-friendly electronic database consisting of pile load test information from the State of Iowa, which can be used for calibration of LRFD resistance factors as well as for other applications by the DOT, city, county, and consulting engineers within and outside of Iowa.
- Ensure the database allows for efficient performance of filtering, sorting, and querying procedures upon the amassed dataset.
- Using quality assurance procedures, input all available pile, soil, and static load test information of all historical pile load tests carried out by the Iowa DOT, as well as the 10 static load tests completed as a part of IHRB Project TR-583.

Research Problem Statement

With the goal of producing engineered designs with consistent levels of reliability, the Federal Highway Administration (FHWA) issued a policy memorandum on June 28, 2000 requiring all new bridges initiated after October 1, 2007 to be designed according to the LRFD approach. Because the foundation is a critical element of the bridge system, conservative LRFD resistance factors were recommended by the American Association of State Highway and Transportation Officials (AASHTO) for their design to ensure safe foundation design practices.

However, an unnecessarily conservative design method does not make economic sense, particularly given that foundation systems typically account for as much as 30 percent of the total bridge cost. Consequently, regionally-calibrated LRFD resistance factors were also permitted by AASHTO to improve the economy of bridge foundation elements.

Since current LRFD pile design specifications have not been written for direct application in Iowa, those recommended in the 2007 edition of the AASHTO LRFD Bridge Design Specifications are expected to be conservative in nature. Therefore, it is important to examine the proposed specifications for pile design using locally-available pile load test data, Iowa soil conditions, and locally-adopted design and construction procedures. This examination will ensure a cost-effective implementation of the LRFD specifications in Iowa.

To aid in this investigation, the locally-available pile load test data was first analyzed for reliability and quality, and then placed in a newly-designed relational database management system named PIle LOad Tests (PILOT). It is through the use of this database and the combined efforts of IHRB Projects TR-573, TR-583, and TR-584 that LRFD pile design recommendations are being developed for Iowa via a three-volume report.

PILOT Description

Historical Perspective

In response to AASHTO permitting regionally-calibrated LRFD resistance factors for the design of driven pile foundations, many states across the nation have made an effort to develop such factors to improve the economy of bridge foundation elements. More specifically, Florida, Illinois, Washington, and Wisconsin have all published studies recommending LRFD resistance factors for the design of driven pile foundations in their regions by means of static analysis methods and the construction control of driven pile foundations by means of dynamic methods.

While these studies provide valuable information, including the identification of available regional pile load test data, in almost all cases, the reported LRFD resistance factor calibrations were accomplished through the use of national databases such as the FHWA Deep Foundation Load Test Database (DFLTD). The DFLTD contains 1,500 deep foundation load test records from nearly 850 sites covering various parts of the world. Such procedures were adopted due to the absence of quality-assured regional information on geotechnical and static load test (STL) data.

With the goal of becoming a model database for an effective regional LRFD calibration process that can be refined as more data becomes available, PILOT was designed using a well-defined hierarchical classification scheme, in addition to an appealing user-friendly interface that has not yet been seen with other databases such as the DFLTD.

Furthermore, by requiring strict acceptance criteria for each of the three hierarchical pile load test dependability classifications (reliable, usable-static, and usable-dynamic), it is ensured that the resulting data available in PILOT for LRFD regional calibration is of consistent and superior quality. These aforementioned qualities delineate the importance of establishing databases such as PILOT at the state and national levels.

Structure

Resulting from the use of only two main forms, navigation within PILOT is straightforward. The first of these two forms is the PILOT Display Form shown in Figure 1. With all available records presented in a datasheet view, two quick-access buttons facilitate insertion of new pile load test records and provide access to information about PILOT.

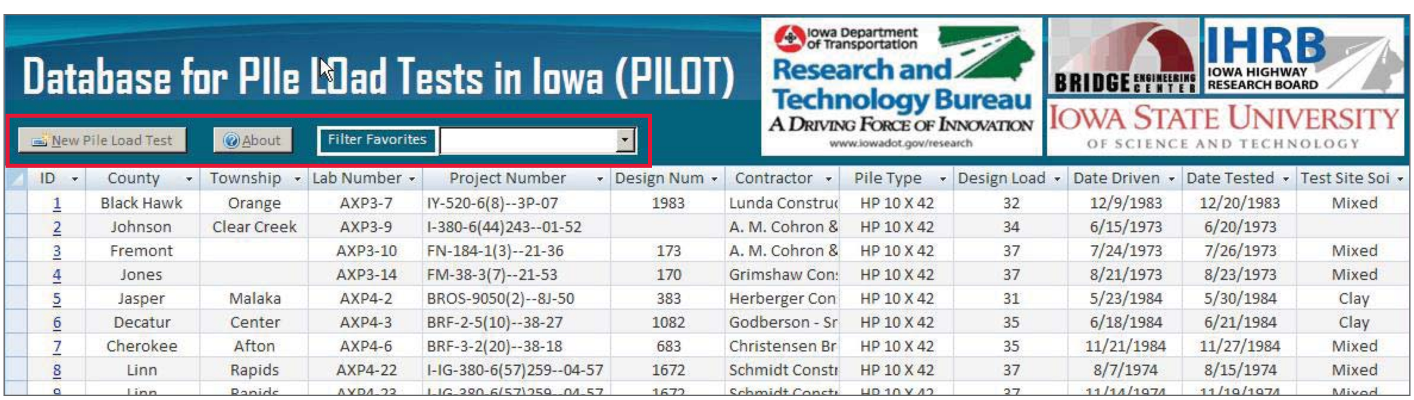
With a drop-down menu featuring a variety of filtering options, the PILOT Display Form successfully functions as a nucleus for the entire database. Via unique, hyperlinked identification numbers or the New Pile Load Test quick-access button on the PILOT Display Form, the second of the two main forms incorporated within PILOT, the Pile Load Test Record Form (PLTRF), can be accessed.

As illustrated in Figure 2, the PLTRF, which functions as a user-friendly complement to the PILOT Display Form, consists of a series of nine tabbed sub-forms located in the lower left-hand quadrant, with the remaining form space accompanied by a multitude of informative database fields.

Key Terminology → Data Quality Assurance

An estimate of a pile's capacity can be achieved through the use of static and/or dynamic methods. Employing a static method requires a detailed site investigation for the evaluation of soil parameters. For a dynamic method, driving record information and reported pile driving equipment characteristics are typically required.

Consequently, it was determined during the formulation of PILOT that a well-defined hierarchical classification scheme would be required to clearly identify those pile load tests containing sufficient information for the estimation of pile capacity by means of both static and dynamic methods. Furthermore, based on the reality that not every pile load test is dependable, an additional level in the hierarchical classification scheme



ID	County	Township	Lab Number	Project Number	Design Num	Contractor	Pile Type	Design Load	Date Driven	Date Tested	Test Site Soi
1	Black Hawk	Orange	AXP3-7	IY-520-6(8)--3P-07	1983	Lunda Construc	HP 10 X 42	32	12/9/1983	12/20/1983	Mixed
2	Johnson	Clear Creek	AXP3-9	I-380-6(44)243--01-52		A. M. Cohron &	HP 10 X 42	34	6/15/1973	6/20/1973	
3	Fremont		AXP3-10	FN-184-1(3)--21-36	173	A. M. Cohron &	HP 10 X 42	37	7/24/1973	7/26/1973	Mixed
4	Jones		AXP3-14	FM-38-3(7)--21-53	170	Grimshaw Con:	HP 10 X 42	37	8/21/1973	8/23/1973	Mixed
5	Jasper	Malaka	AXP4-2	BROS-9050(2)--8J-50	383	Herberger Con	HP 10 X 42	31	5/23/1984	5/30/1984	Clay
6	Decatur	Center	AXP4-3	BRF-2-5(10)--38-27	1082	Godberson - Sr	HP 10 X 42	35	6/18/1984	6/21/1984	Clay
7	Cherokee	Afton	AXP4-6	BRF-3-2(20)--38-18	683	Christensen Br	HP 10 X 42	35	11/21/1984	11/27/1984	Mixed
8	Linn	Rapids	AXP4-22	I-IG-380-6(57)259--04-57	1672	Schmidt Constr	HP 10 X 42	37	8/7/1974	8/15/1974	Mixed
9	Linn	Rapids	AXP4-23	I-IG-380-6(57)259--04-57	1672	Schmidt Constr	HP 10 X 42	37	11/14/1974	11/19/1974	Mixed

Figure 1. Top of PILOT Display Form with quick-access buttons and filtering menu in the red box upper left (above the data)

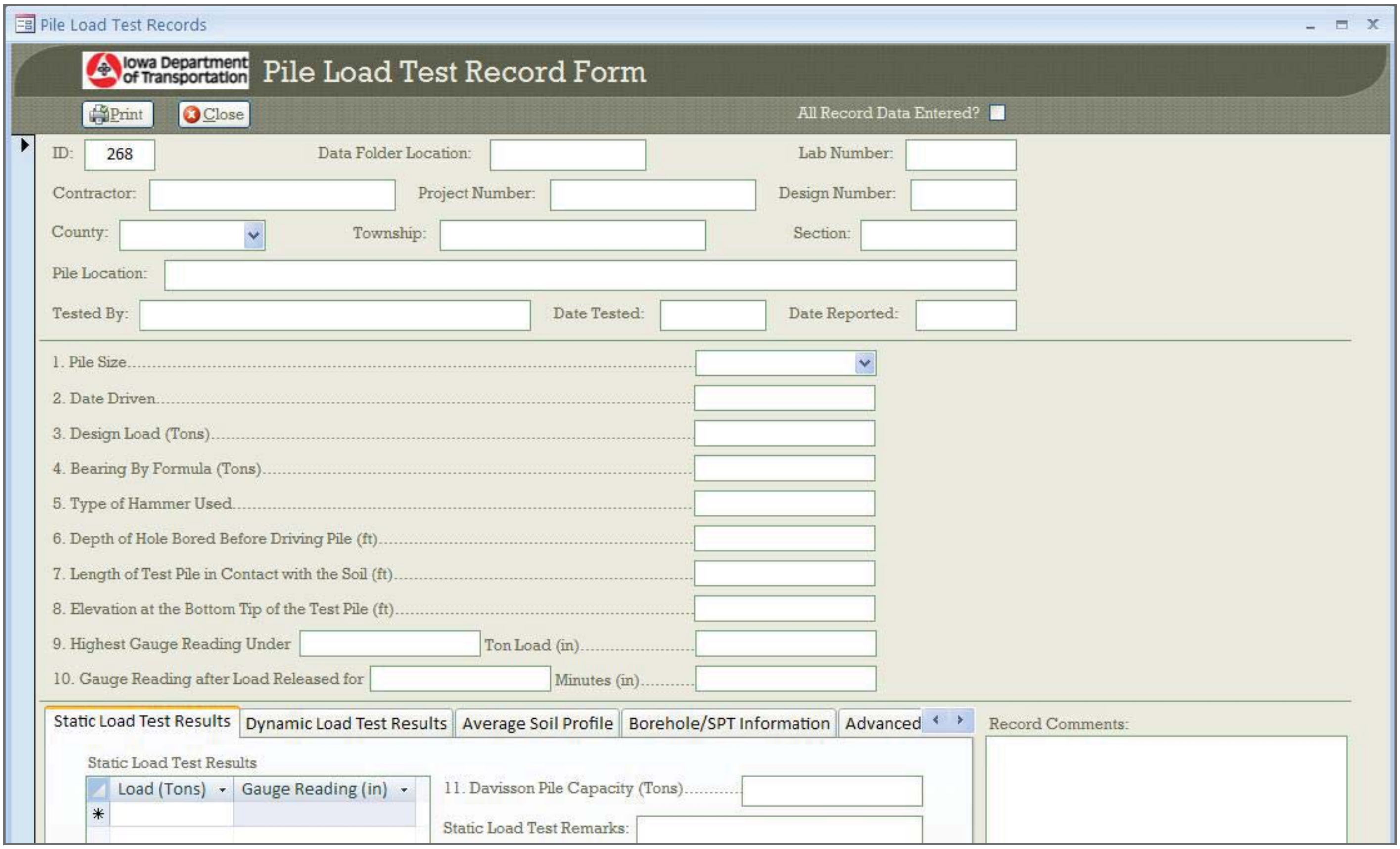


Figure 2. Top of PILOT Pile Load Test Record Form (PLTRF)

was deemed necessary for initial separation of the reliable pile load tests from the entirety of the PILOT database.

The unique classification system developed for PILOT is as follows:

- Reliable Pile SLT: A pile load test that has achieved the displacement-based criteria for pile capacity, as defined by Davisson (1972), prior to the pull-out of any anchor piles.
- Usable-Static Pile SLT: A reliable pile load test that has soil boring information and SPT data within 100 feet of the test pile.
- Usable-Dynamic Pile SLT: A usable-static pile load test that has complete driving records and information concerning characteristics of the pile driving equipment for the test pile under consideration.

As a final means of ensuring data quality and consistency within PILOT, distinct classification rules were established for generalization of the soil profile located along the test pile embedded length. In other words, a test pile is classified as being embedded in a sand soil profile when at least 70 percent of the soil located along the shaft of the pile is classified as a sand or non-cohesive material according to the Unified Soil Classification System (USCS).

Likewise, a test pile is classified as being embedded in a clay soil profile when at least 70 percent of the soil located along the shaft of the pile is classified as a clay or cohesive material according to the USCS. When neither of the aforementioned classifications is achieved, the test pile is classified as being embedded in a mixed soil profile. In the absence of a well-defined soil profile classification in the literature, the adopted definition was established by examining the sensitivity of the new soil profile classification on the outcome of the LRFD resistance factors (AbdelSalam et al. 2011).

Data Summary

Between 1966 and 1989, information concerning 264 pile SLTs conducted in Iowa on steel H-shaped, timber, pipe, Monotube, and concrete piles was collected by the Iowa DOT (Figure 3). During this time period, the entirety of the aforementioned pile test information, although not always wholly available, included details concerning the site location, subsurface conditions, pile type, hammer characteristics, blow count at the end of driving (EOD), and static load test results. The soil profile and usability breakdowns for each pile type are provided in Table 1.

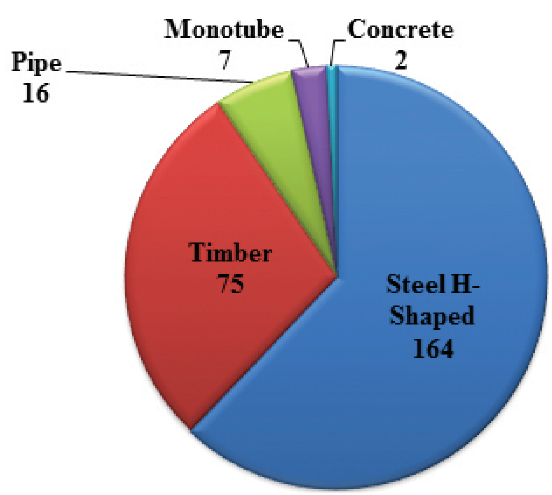


Figure 3. Distribution of historical pile SLTs

Table 1. PILOT historical data summary

Pile Type	Soil Type: Sand	Clay	Mixed	Unavailable	Total	Reliable	Usable-Static	Usable-Dynamic
Steel H-Shaped	50	46	58	10	164	141	82	34
Timber	7	43	12	13	75	47	24	9
Pipe	6	3	6	1	16	15	14	2
Monotube	3	0	2	2	7	5	3	3
Concrete	0	0	1	1	2	1	0	0
Totals	66	96	81	27	264	209	123	48

With the predominant pile type used within Iowa being the steel H-shaped pile, an additional 10 static pile load tests were carried out as a part of IHRB Project TR-583 on steel H-piles driven in locales spanning the five geological soil regions of Iowa (Ng et al. 2011). In addition to simply driving and load testing the piles to failure, most were instrumented with strain gauges and monitored dynamically during driving and restrikes using the Pile Driving Analyzer (PDA).

Moreover, the subsurface conditions at each test pile location were characterized using various laboratory tests (moisture content, grain-size distribution, Atterberg limits, and consolidation tests) and in situ tests (SPT, CPT, and BST) (Figure 4).

In some cases, ground instrumentation (i.e., push-in pressure cells) was used to capture horizontal soil stress and pore water pressure data near the test pile during driving, restrikes, and static load testing. The extensive set of high-quality data gathered from these test piles is also included in PILOT.

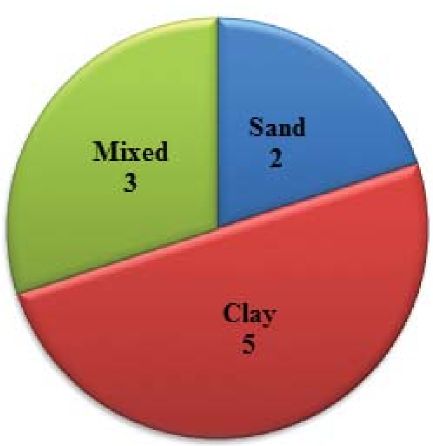


Figure 4. Soil type distribution summary for TR-583 test piles

Summary and Key Findings

- PILOT uses a well-defined hierarchical classification scheme in addition to employing an appealing user-friendly interface. These features are unique to PILOT and have not been seen for any other pile load test databases.
- Imposition of a strict acceptance criterion for each of the three hierarchical pile load test dependability classifications (reliable, usable-static, and usable-dynamic) ensures that the resulting data available in PILOT for LRFD regional calibration is of superior quality.
- The ultimate pile capacities for the historical dataset were previously determined using inconsistent and subjective methods (e.g., the ultimate pile capacity can be equated to the applied load at which "excessive penetration" is observed). To overcome this inconsistency and minimize subjectivity, the ultimate pile capacity for each of the records in PILOT was defined according to the Davisson's displacement-based approach.
- Due to the limits of the load testing setups for some of the historical pile load tests, the Davisson's displacement-based approach was never achieved. Using an extrapolation technique recommended by the FHWA and reassessing the extrapolated results for validity, the ultimate pile capacities for some of these PILOT records were determined.
- The soil profile classification scheme adopted by PILOT is the first of its kind and it allows for a concrete or quantifiable distinction between the all-too-subjective sand and clay site soil classification delineation.
- Of the 164 historical steel H-pile records contained within PILOT, 80 are usable for investigations dealing with static analysis methods, while 32 are usable for investigations dealing with dynamic methods.
- Likewise, of the 75 PILOT timber pile records, 24 were classified as usable for investigations dealing with static analysis methods, while nine were considered usable for investigations dealing with dynamic methods.
- PILOT serves as a model database for the archiving of pile load test information for the continuous improvement of pile foundation design practices at the regional and national levels. A copy of PILOT can be downloaded free of charge from http://srg.cce.iastate.edu/lrfd/database%20downloads.html.

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