Development of a Database for Drilled SHAft Foundation Testing (DSHAFT)

tech transfer summary

The newly-developed DSHAFT database was created to compile quality-assured drilled shaft load test information with the intent of calibrating regional resistance factors.

Problem Statement

Drilled shafts have been used in the US for more than 100 years in bridges and buildings as a deep foundation alternative. For many of these applications, the drilled shafts were designed using the Working Stress Design (WSD) approach. Even though WSD has been used successfully in the past, a move toward Load Resistance Factor Design (LRFD) for foundation applications began when the Federal Highway Administration (FHWA) issued a policy memorandum in 2000 requiring all new bridges initiated after October 1, 2007 to be designed using the LRFD approach.

The American Association of State Highway and Transportation Officials (AASHTO) recommends resistance factors based on general soil classification, which results in an overly conservative and less cost-effective drilled shaft design. Because bridge foundation systems generally account for as much as 30 percent of the entire bridge cost, a regional calibration of resistance factors is permitted by AASHTO to improve the economy of foundations and to make the drilled shaft option competitive with the driven pile foundation.

The goal of this project was to develop a quality assured, electronic Database for Drilled SHAft Foundation Testing (DSHAFT), which is intended to establish LRFD resistance factors for the design of drilled shafts in the Midwest region. To achieve this goal, available static load test information was collected, reviewed, and integrated into DSHAFT using Microsoft Office Access™. In doing so, an efficient, easy-to-use filtering and capability was provided to DSHAFT, along with easy access to original field records in an electronic format.

Background

Drilled shaft foundations are large diameter, cast-in-place piles that support axial loads though a combination of shaft and end bearing resistances. They are referred to as bored piles, caissons, cast-in-drilled-hole piles (CIDH), continuous-flight-auger piles (CFA), displacement auger-cast piles, and drilled piers. Since the 1900s several cities in the US have used caissons or shafts to support buildings and transportation structures.

Originally, the construction of shafts was done by hand, and it was not until the 1920s that machine-drilled shafts were being developed. Today's drilling techniques range from small truck-mounted equipment to modern machines capable of drilling large, deep holes suitable for drilled shafts through very hard subsurface materials.

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RESEARCH PROJECT TITLE
Development of a Database for Drilled SHAft Foundation Testing (DSHAFT)

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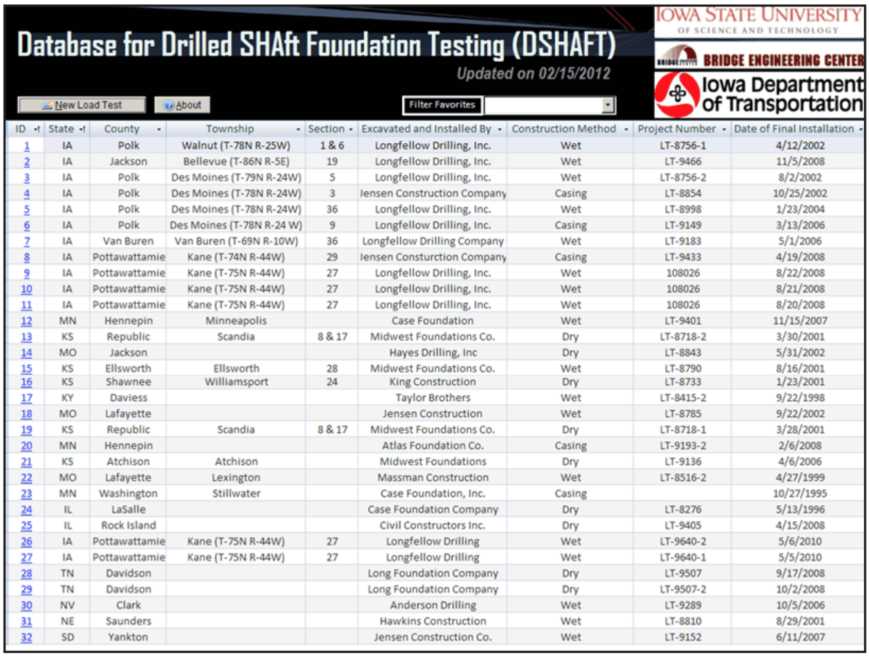
The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

IOWA STATE UNIVERSITY
Institute for Transportation

Project Objectives

- Provide a means of electronic storage for all past, present, and future Iowa Department of Transportation (DOT) drilled shaft load test data for subsequent reference and analysis
- Collect, review, and integrate data from available static load tests in Iowa and other states on drilled shafts into a quality assured, electronic database, using Microsoft Office Access™
- Make filtering, sorting, and querying procedures more efficient by using a collective dataset designed in the display form (see Figure 1)
- Be housed on a website so that the information can be shared with designers and researchers



ID	State	County	Township	Section	Excavated and Installed By	Construction Method	Project Number	Date of Final Installation
1	IA	Polk	Walnut (T-78N R-25W)	1 & 6	Longfellow Drilling, Inc.	Wet	LT-8756-1	4/12/2002
2	IA	Jackson	Bellevue (T-86N R-5E)	19	Longfellow Drilling, Inc.	Wet	LT-9466	11/5/2008
3	IA	Polk	Des Moines (T-79N R-24W)	5	Longfellow Drilling, Inc.	Wet	LT-8756-2	8/2/2002
4	IA	Polk	Des Moines (T-78N R-24W)	3	Jensen Construction Company	Casing	LT-8854	10/25/2002
5	IA	Polk	Des Moines (T-78N R-24W)	36	Longfellow Drilling, Inc.	Wet	LT-8998	1/23/2004
6	IA	Polk	Des Moines (T-78N R-24 W)	9	Longfellow Drilling, Inc.	Casing	LT-9149	3/13/2006
7	IA	Van Buren	Van Buren (T-69N R-10W)	36	Longfellow Drilling Company	Wet	LT-9183	5/1/2006
8	IA	Pottawattamie	Kane (T-74N R-44W)	29	Jensen Consturction Company	Casing	LT-9433	4/19/2008
9	IA	Pottawattamie	Kane (T-75N R-44W)	27	Longfellow Drilling, Inc.	Wet	108026	8/22/2008
10	IA	Pottawattamie	Kane (T-75N R-44W)	27	Longfellow Drilling, Inc.	Wet	108026	8/21/2008
11	IA	Pottawattamie	Kane (T-75N R-44W)	27	Longfellow Drilling, Inc.	Wet	108026	8/20/2008
12	MN	Hennepin	Minneapolis		Case Foundation	Wet	LT-9401	11/15/2007
13	KS	Republic	Scandia	8 & 17	Midwest Foundations Co.	Dry	LT-8718-2	3/30/2001
14	MO	Jackson			Hayes Drilling, Inc	Dry	LT-8843	5/31/2002
15	KS	Ellsworth	Ellsworth	28	Midwest Foundations Co.	Wet	LT-8790	8/16/2001
16	KS	Shawnee	Williamsport	24	King Construction	Dry	LT-8733	1/23/2001
17	KY	Daviess			Taylor Brothers	Wet	LT-8415-2	9/22/1998
18	MO	Lafayette			Jensen Construction	Wet	LT-8785	9/22/2002
19	KS	Republic	Scandia	8 & 17	Midwest Foundations Co.	Dry	LT-8718-1	3/28/2001
20	MN	Hennepin			Atlas Foundation Co.	Casing	LT-9193-2	2/6/2008
21	KS	Atchison	Atchison		Midwest Foundations	Dry	LT-9136	4/6/2006
22	MO	Lafayette	Lexington		Massman Construction	Wet	LT-8516-2	4/27/1999
23	MN	Washington	Stillwater		Case Foundation, Inc.	Casing		10/27/1995
24	IL	LaSalle			Case Foundation Company	Dry	LT-8276	5/13/1996
25	IL	Rock Island			Civil Constructors Inc.	Dry	LT-9405	4/15/2008
26	IA	Pottawattamie	Kane (T-75N R-44W)	27	Longfellow Drilling	Wet	LT-9640-2	5/6/2010
27	IA	Pottawattamie	Kane (T-75N R-44W)	27	Longfellow Drilling	Wet	LT-9640-1	5/5/2010
28	TN	Davidson			Long Foundation Company	Dry	LT-9507	9/17/2008
29	TN	Davidson			Long Foundation Company	Dry	LT-9507-2	10/2/2008
30	NV	Clark			Anderson Drilling	Wet	LT-9289	10/5/2006
31	NE	Saunders			Hawkins Construction	Wet	LT-8810	8/29/2001
32	SD	Yankton			Jensen Construction Co.	Wet	LT-9152	6/11/2007

Figure 1. DSHAFT display form (Microsoft Office Access™ 2007)

Research Description

As illustrated in Figure 2, a total of thirty-two drilled shaft load tests were performed and provided by the Iowa, Illinois, Minnesota, and Missouri DOTs and Nebraska Department of Roads (DOR). In addition, the load test performed in Tennessee was located in a report titled *Load Testing of Drilled Shaft Foundation in Limestone, Nashville, TN* (Brown 2008).

The detailed information provided in most of the reports includes location, construction details, subsurface conditions, drilled shaft geometry, load testing methods and results, and concrete quality. Because the available information was stored in several different locations and formats, the process to calibrate the LRFD resistance factors would have proved inefficient.

After the available information was implemented into the database, a preliminary calibration of LRFD resistance factors was performed to find if a sufficient amount of information is available for a regional calibration. The preliminary analysis was completed using the 13 datasets collected in Iowa. Table 1 provides a brief summary of the information used to complete this calibration.

From this analysis, it was concluded that more load tests must be included into the database for accurate calibration of suitable resistant factors. As a result, load test information was included from surrounding states.

Table 1. Summary of 13 drilled shaft datasets collected in Iowa

ID Number	Diameter (ft)	Embedded Length (ft)	Brief Soil Description		Rock Socketed	Construction Method	Load Test Method
			Shaft	Toe			
1	4	67.9	Silty G.C.	Shale	Yes	Wet	O-cell
2	3	12.7	Weathered Dolomite	Weathered Dolomite	Yes	Wet	O-cell
3	4	65.8	Silty G.C.	Clay Shale	Yes	Wet	O-cell
4	3.5	72.7	Sandy G.C. and Medium Sand	Clay Shale	Yes	Casing	O-cell
5	4	79.3	Sandy Lean Clay and Clay Shale	Clay Shale	Yes	Wet	O-cell
6	2.5	64	Silty Clay	Sandy G.C.	No	Casing	O-cell
7	3	34	Lean Clay and Limestone	Limestone	Yes	Wet	O-cell
8	5.5	105.2	Silty Clay and Sand	Limestone	Yes	Casing	O-cell
9	5	66.25	Silty Clay and Sand	Coarse Sand	No	Wet	Statnamic
10	5	55.42	Silty Clay and Find Sand	Coarse Sand	No	Wet	Statnamic
11	5	54.78	Silty Clay and Find Sand	Coarse Sand	No	Wet	Statnamic
26	5	75.17	Silty Clay and Find Sand	Fine Sand	No	Wet	O-cell
27	5	75	Silty Clay and Find Sand	Fine Sand	No	Wet	O-cell

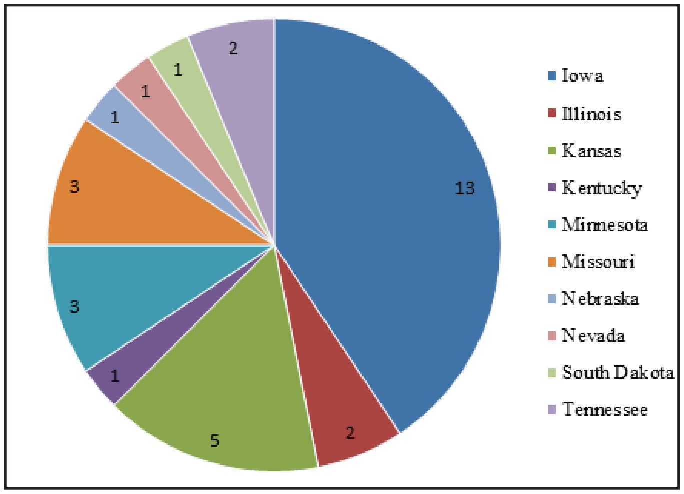


Figure 2. Distribution of drilled shaft load tests reported in DSHAFT by location as of February 2012

Key Features of DSHAFT

- Because the resistance factors will be calibrated using the information included in the database, it is vital to have a strict acceptance criteria for reports being entered into DSHAFT to make the LRFD regional calibration of superior quality and consistency.
- Not all load test reports found and input into the database contain complete information. This data was included even though some of the information was missing, such as a detailed bore log. The rationale is that each one has the potential to be qualified once the information has been made available. To notify the user when this occurs, the usable data sets are identified by a yes/no category titled usable data.
- Only two axial load test methods, the Osterberg (Figure 3) and Statnamic, are included in the database because, they are not only the most prevalent load tests in the region, but they are also preferred by most DOTs.
- The distinctions between Osterberg and Statnamic load tests are critical because the data contained in each of the reports is different. The data from either report can be used to determine the capacity of the drilled shaft by using a different technique.
- A major aspect when analyzing the results of axial load tests on drilled shafts is the soil profile classification, as each category behaves differently and affects the capacity of the drilled shaft accordingly. The soil profile classification system devised for DSHAFT is a series of guidelines to be used on soil information provided in the load test report.
- The performance of a drilled shaft dramatically changes when a portion of the shaft is embedded into rock, known as a rock socket. In DSHAFT, rock sockets are identified by a Rock Socketed? yes/no category to account for the potential increase in end bearing and shaft resistance.
- A quality control measure incorporated into the DSHAFT database is to include the Cross-Hole Sonic Logging (CSL) report, when available.

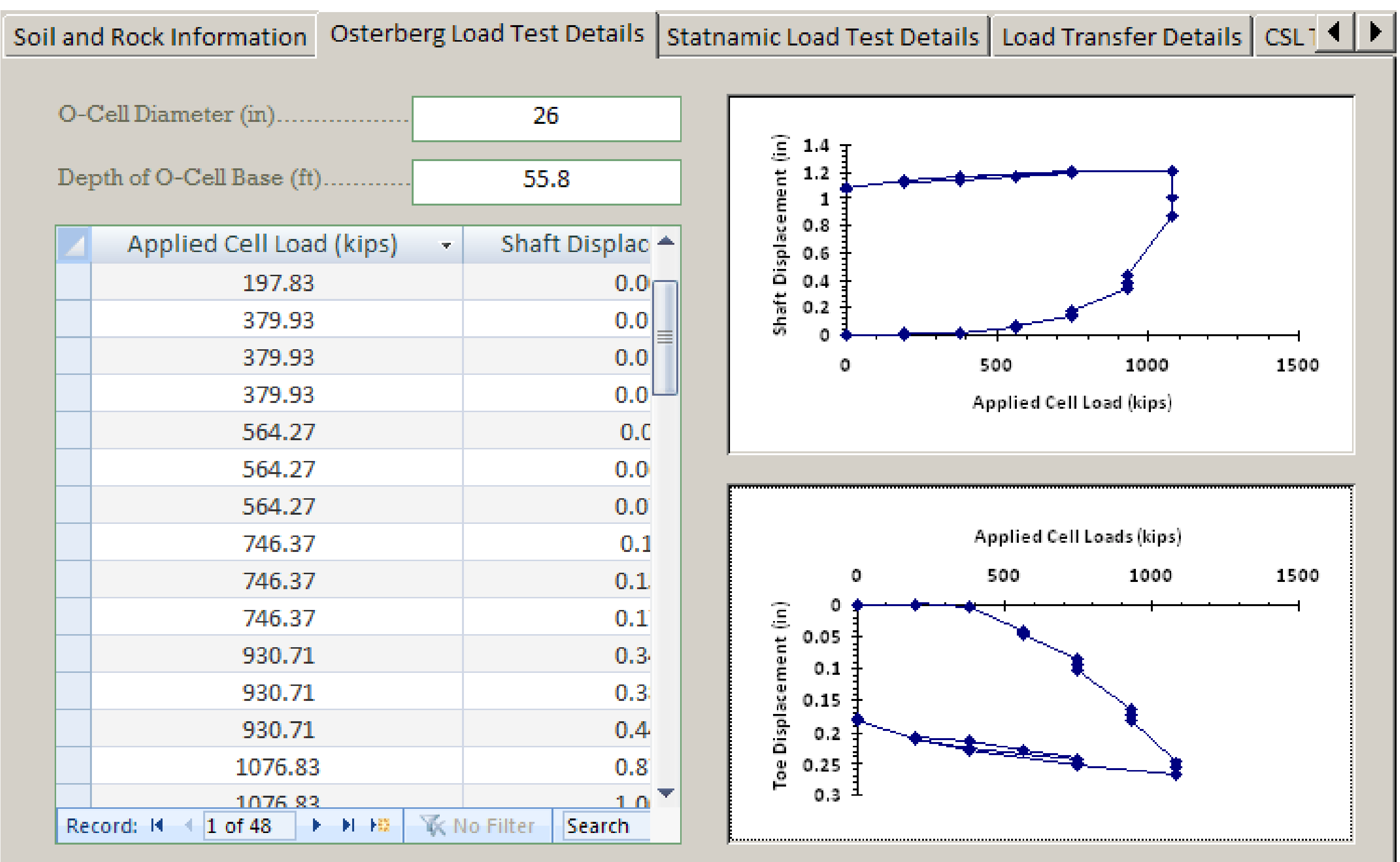


Figure 3. Osterberg Load Test Details tab of Drilled Shaft Load Test record form

Implementation Readiness

The construction method and quality control of construction still have a large impact on the drilled shaft and should be taken into consideration when calibrating the regional resistance factors. A set of acceptable guidelines for tolerances during construction should be included with the new resistance factors.

Additional load tests, along with detailed analyses, are needed to provide an accurate statistical calibration of the resistance factors for the final calibration.

Implementation Benefits

- DSHAFT embodies a model for effective, regional LRFD calibration procedures consistent with the PIle LOad Test (PILOT) database available at http://srg.cce.iastate.edu/lrfd/, which currently contains driven pile load tests accumulated from the state of Iowa.
- DSHAFT allows for collecting, reviewing, and integrating data from available static load tests on drilled shafts into an electronic database. In doing so, efficient, easy-to-use filtering and storage capabilities are available to provide a basis for analytical procedures on the datasets.
- DSHAFT is housed on a website (Figure 4) so that the information can be easily shared with designers and researchers. The value of DSHAFT comes with the use of this website by Iowa State University and can be found at http://srg.cce.iastate.edu/dshaft.
- The easy-to-query interface for DSHAFT allows researchers and designers to further filter the data to fit their needs.
- To ensure the superior quality of DSHAFT, strict acceptance criteria for the available test information was used. The quality assurance of the data is the driving factor when adding each new dataset to the database.

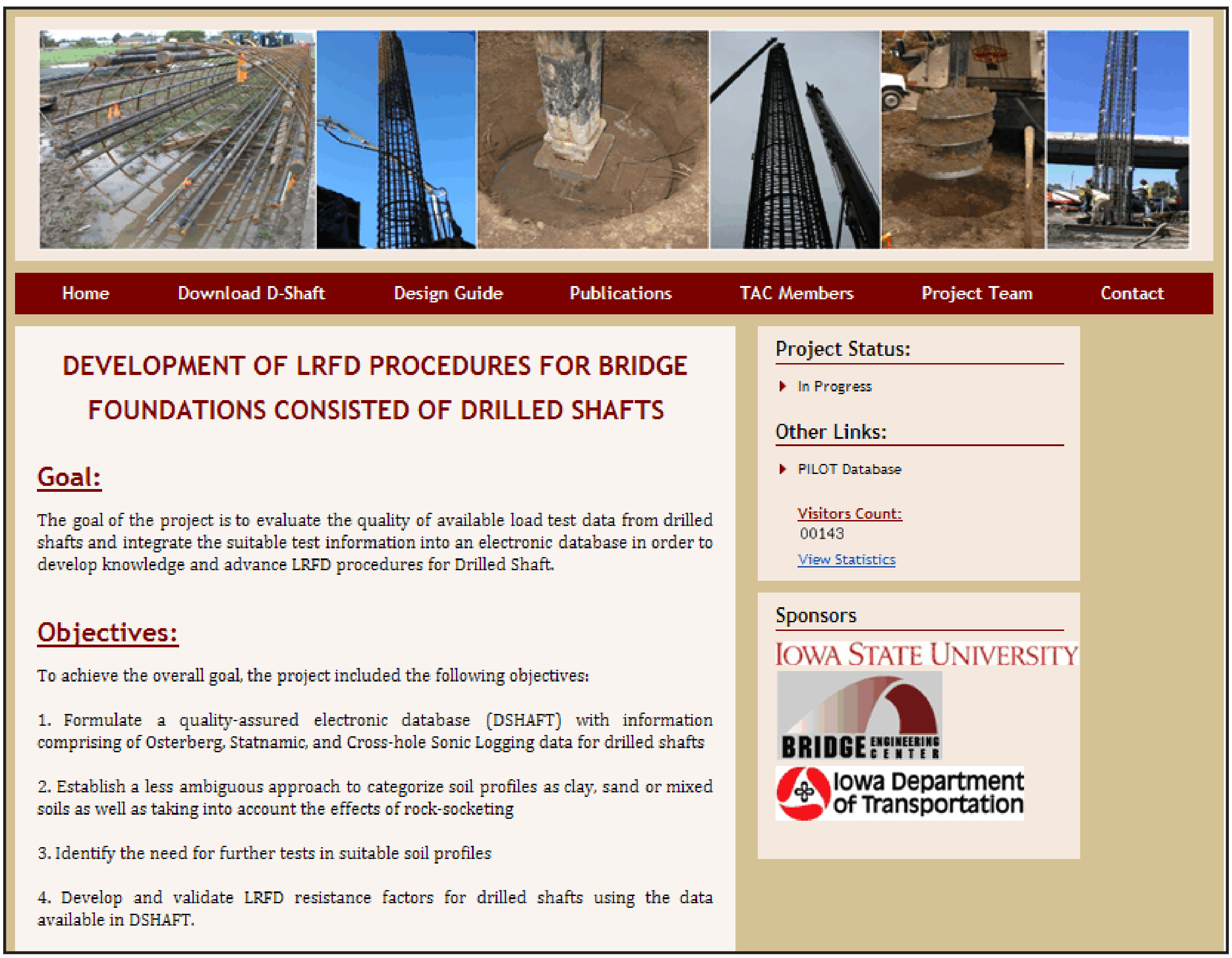


Figure 4. DSHAFT website (http://srg.cce.iastate.edu/dshaft/)